ANALYSIS OF CLIMATE SENSITIVITY IN OUTDOOR SPACE: EVALUATING URBAN PATTERNS IN DIFFERENT CLIMATES

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ABSTRACT

ANALYSIS OF CLIMATE SENSITIVITY IN OUTDOOR SPACE: EVALUATING URBAN PATTERNS IN DIFFERENT CLIMATES

Many urban design projects we produce today underestimate the design strategies as utilizing the same design criteria for every urban environment regardless their different localities. This problem leads to increasing demands for active heating, cooling and lighting systems, rising energy consumption, declining quality of urban living, environmental deterioration, and expensive and hardly maintained built-up areas.

The intention of this study, on one hand, is to present a method of how to examine the climatic factors in an urban area, and on the other hand, is to reconsider urban patterns of Konak Square in Izmir and Kızılay Square in Ankara, from climate sensitive design view point. The overall aim here is to find to what extend designs of the built environment are sensitive to the climate. Specifically, the present study investigates if those urban patterns take the advantage of their particular climate while eliminating the inconveniences.

In this framework, the case study was conducted in the summer period, comprising two steps; site surveying and climatic measurements. The findings were processed through the comparison of field measurements with the meteorological data, and the evaluation of the spatial structure in relation to the given comparisons.

The study found that Konak Square is more sensitive to the climate comparing to Kızılay Square. The results show that urban pattern of Konak Square takes the advantage of the existing wind conditions, accelerating it throughout the site and decreases air temperature in many locations through its design.

ÖZET

DIŞ MEKANIN İKLİME DUYARLILIĞININ ANALİZİ: FARKLI İKLİMLERDEKİ KENTSEL DOKULARIN DEĞERLENDİRİLMESİ

Günümüzde üretilen birçok kentsel tasarım projesi, ortaya koyduğu standart tasarım kriterleri ile mekanın yerel verilerini dikkate almadan her kentsel mekan için tek düze bir yapılaşma önermektedir. İklim verilerinin tasarımda gözardı edilmesi, kentlerdeki aktif iklimlendirme ve aydınlatma sistemlerine olan ihtiyacın artmasına, enerjinin fazlaca tüketilmesine, yaşam kalitesinin düşmesine, çevresel bozulmaya ve maliyetli yapılı çevrelerin oluşmasına neden olmaktadır.

Bu tezin amacı, bir taraftan, kentsel tasarıma girdi oluşturması adına iklim verilerinin kentsel mekanda nasıl tespit edilmesi gerektiğine dair bir yöntem sunmak, diğer taraftan, İzmir Konak Meydanı ve Ankara Kızılay Meydanı'ndaki kentsel örüntüleri, iklime duyarlılık açısından değerlendirmektir. Bu çalışmanın temel çıkış noktası, yapılı çevrenin ne ölçüde iklime duyarlı olduğunu araştırmaktır. Bu araştırmayı, iki önemli kent meydanındaki mevcut kentsel örüntülerin, yapılaşma ile bulundukları farklı iklimlerin avatajlarını nasıl kullandığı ve bu iklimlerde ortaya çıkan zorlukların ne ölçüde üstesinden geldiğinin tespiti ile gerçekleştirmektedir.

Bu araştırma çerçevesinde, yaz dönemi içerisinde her iki kentsel alanda, keşif ve iklimsel ölçümleri içeren bir arazi çalışması gerçekleştirilmiştir. Arazi çalışmasından elde edilen veriler, alanda yapılmış iklimsel ölçümlerle gerçek hava koşullarının karşılaştırılması ve bu karşılaştırmadan çıkan sonuçların her iki kentsel örüntünün mekansal özellikleri bağlamında değerlendirmesi aşamalarına göre yorumlanmıştır..

Çalışma sonucunda, Konak Meydanı'ndaki fiziki çevrenin, Kızılay Meydanı'na kıyasla, iklime daha duyarlı olduğu bulunmuştur. Araştırmada, Konak Meydanı'ndaki mevcut yapılaşmanın, yaz aylarındaki yüksek sıcaklığı alan üzerindeki birçok noktada azalttığı, mevcut hakim rüzgarın alanın tümünde daha etkili bir biçimde görülmesini sağladığı görülmüştür.

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CHAPTER 1

INTRODUCTION

1.1. Problem Definition

Climate considerations are one of the key aspects to be taken into account in urban design process. However design issues over urban climate have being neglected for the last decades. Majority of the urban design projects underestimate the design strategies as utilizing the same design criteria for the cities in different climate regions, regardless their different localities.

> "Often the urban planning regulations used in hot dry countries, most of which are in the developing world, are imported from temperate climates and are thus poorly adapted to the local climate. Additionally, they may be very inflexible and thereby restrict the possibility of climate-conscious urban design. As a consequence, urban areas often become unnecessarily uncomfortable." (Johansson 2006, 1327)

The emergence of uncomfortable urban living as a result of disregarding the local climate is being widely stated by the scholars (e.g. Oktay 2001; Johansson 2006; Yılmaz 2007; Manioğlu and Yılmaz 2008). On the contrary to the traditional settlements where climatic factors are taken into account to a large extent, the spatial practice of today mostly neglects climate considerations. In the modern era, majority of urban design practices ignore the localities of urban spaces. On the one hand, this harms the quality of urban life and on the other hand, destroys the nature while resulting in excessive consumption of world's resources.

Increasing demands for active heating, cooling and lighting systems in built environment brings about high energy consumption, especially in the places which are not adapted to the existing climate. In many developed countries, especially in the industrialized world, buildings are reported accounting directly for over 50% of total energy consumption (Rosenlund 2000). For instance, nearly 60% of electrical energy use in Hong Kong is for indoor space conditioning during summer months (Giridharan, et al. 2004). This is highly due to insufficient account of climate considerations in the urban environment. More recently, the active methods in heating or cooling systems, ventilation, evaporative cooling, and solar heat storage have being used in urban area (Golany 1996). For instance, the design in such extreme climates as in hot-dry, hot-humid and cold climate regions, is generally not determined by climate imperatives yet, instead, they rely on the technology. In contrast to the traditional settlements which all are well adapted to the climate, today's active space conditioning techniques we pursue is leading to excessive energy consumption, carbon emission and high cost of urban living, while deteriorating the nature.

The interventions and modifications through the later phase of a project to adapt it to the climate are reported not being cost effective and highly limited as a consequence of the existing construction pattern. The additional costs are relatively low in the projects which are well adapted to the climate and where the layout plan, the density, the orientation of the buildings, the size of the windows, the details of shading devices and the vegetation are taken into account.

The current situation in our country, concerning the subject of this study, is portrayed by the increasing developments. Yet, research and design projects dealing with climate sensitivity are limited to building scale in Turkey. There are only a small number of published research projects that focus on outdoor space (e.g. Oktay 2001; Manioğlu and Yılmaz 2008; Yılmaz 2007). For design projects, Turkey is less experienced on climate sensitive design practice at urban scale, current climate sensitive developments are mostly seen in building scale. Even though there are a few on-going climate sensitive urban design projects in Turkey, the need for climate sensitive developments at urban scale, is still excessively reported (e.g. Oktay 2001; Manioğlu and Yılmaz 2008; Yılmaz 2007).

There is an increasing need to overcome those deficits with taking the climate essentials into consideration and providing particular climate sensitive design criteria based on those essentials in urban design. The scholars highlight the necessity of interpretation of the available climate knowledge on design guidelines to cope with the climate (see. Golany 1996; Pressman 1996; Mills 1999, Scherer, et al. 1999). There is a need to generate guidelines specific to the climate characteristics of an urban area rather than providing general and usually average criteria adapted by all kinds of localities all over the world.

Climate sensitive design is a useful tool to maximize outdoor space comfort, to reduce the consumption of world's resources and also to minimize of the costs of urban projects. It provides climate sensitive design criteria in order to adapt the urban space to its particular climatic conditions. Adaptation of an urban environment to its climate has not only a positive effect on outdoor space but also on indoor space conditions, which results in lower energy consumption, easier indoor space conditioning as well as reduction of the costs in a single unit.

1.2. Aim and Scope of the Study

This study underlines the need for climate sensitive design, focusing on the relationship between the built-up area and climate. The intention of this study is to evaluate the existing urban patterns in terms of climate sensitivity.

The main question that this study aims to answer is to what extend designs of the built environment are sensitive to the climate. Specifically, the present study intends to examine if the urban patterns take the advantage of their particular climate while eliminating the inconveniences.

Initially, the study defines the concepts of climate sensitive design and thermal comfort including design criteria, researches and projects on the subject of climate. Following, two different urban patterns with similar use in different climate regions of Turkey are analyzed in terms of thermal comfort and user thermal comfort perception. The findings through the evaluation and comparison of the urban patterns are anticipated to make a contribution for further urban design projects to achieve climate sensitivity.

1.3. Methodology

The thesis is specifically seeking an answer to its research question; to what extend existing urban patterns take the advantage of their particular climate while eliminating the inconveniences, through a case study. The case study analyzes urban patterns of two city centers in terms of their spatial structure and the taken climatic measurements. Then, it evaluates and compares those urban patterns, concerning the particular periods of a summer day. Before, the following sub-questions have been answered with a library and online research through the review of literature;

- What is climate sensitive design? What are the objectives of climate sensitive design? What type of climate regions are seen in the world? What kind of design principles does climate sensitive approach provide us for different climate regions?
- What kind of factors should we consider in that kind of research? How can we measure environmental parameters on the site? What type of measurement instruments can we use in this research?

I. Literature Review

Library research: The libraries of Izmir Institute of Technology and Izmir Dokuz Eylul University have been used to access related literature as the books, theses and magazines as well as the research papers in the recent publications.

Online research: For the e-journals, reports, recent research and design projects; the digital library of University of Amsterdam and Izmir Institute of Technology as well as the standard and academic search tools have been utilized to reach the literature concerning the subjects similar to the content of this study. The following keywords have been typed throughout the online research; climate sensitive /responsive /conscious /balanced design + principles /projects, design with nature /climate, urban climatology, thermal comfort + urban design /planning, climatic design + urban, design principles + climate, climate classifications /regions /types, sustainable projects /site plan, ecologic projects /site plan, eco-city, eco-village, vernacular projects, green urbanism /architecture /projects, energy efficient planning /urban design /projects, zero-carbon cities /planning, environmental friendly planning /urban design /projects, solar energy projects /cities. Additionally the recent theses completed within last 20 years in Turkey have been searched on the web archive of National Thesis Center of Council of Higher Education. The search has been limited to the related fields to urban design as city planning and architecture.

The research with the review of previous studies has led us specifically to gain the knowledge of the factors as well as of how to investigate them, which should be taken into account in a research coping with climate issues as well as in climate sensitive design. Hence, the case study has been based on the investigation of those factors. In addition, given climate sensitive principles for different climate regions have illustrated the correlation between those factors while presenting the ways how to deal with different types of climates in urban design. The review has also helped us with defining the problems in relation to the subject of this study.

II. Case Study

Selection of the case areas: The research of this thesis could be carried out with different research design alternatives based on different case selections as follows;

- The comparison of the climate sensitive urban design project with a standard project which is not climate sensitive.
- The comparison of different urban patterns in the same climate region. Those different urban patterns may chosen regarding their particular physical characteristics such as; density, location or orientation.
- The comparison of similar urban patterns such as social housing, campus area in different localities.

However, the overall aim, which is to examine urban patterns in different climates, has initially led us to select the coastal and central regions of Turkey, where temperate and semi-arid climate show considerably different climatic characteristics. Izmir and Ankara have been chosen in those climate regions as the cities, since they demonstrate typical climate characteristics of their own region and have relatively equivalent regional development level. Specifically, the selection criteria of urban patterns within those cities have been based on the consideration of their similar functions as serving for public use and greater place in collective memory as a landmark. Therefore, Konak Square in the city of Izmir and Kızılay Square in the city of Ankara have been chosen as the case study areas.

Field study-Data collection: The field study has been conducted in late of August 2009 covering the following typical summer days for each site as 20th, 21th and 23rd of August in Konak Square/Izmir; 27th, 28th, 29th and 30th of August in Kızılay Square/Ankara. Data collection consists of three major stages; site monitoring, meteorological data and field measurements.

➢ **Site surveying:** In terms of site analysis the following items have been investigated;

- General characteristics
  - Location of the site
  - General climate characteristics of the region
- Spatial characteristics:
  - Urban texture: field characteristics, existing building structure. Urban texture has been examined considering not only two dimensions as a layout but also the third dimension including building configuration.

- Surface characteristics: building and ground surface materials and color, pavement details. Ground and building surface characteristics have been explored in terms of the materials and colors, concerning the possible heat gain and the heat and sun reflection on the site.
- Use of air conditioning: installation of the active heating and cooling devices on the buildings and particularly at street level. The use of air conditioning has been investigated to explore how urban living is adapted to the current climatic conditions in terms of active heating and cooling system needs in the buildings.
- Shadow maps: concerning morning period (08:00-08:59), midday period (12:00-12:59), afternoon period (16:00-16:59) and evening period (20:00-21:59), as well as shading devices and trees. Shadow maps on one hand, illustrate the changes of the shaded areas and the areas exposure to the sun in different periods during the daylight hours which are resulted from the buildings and on the other hand, show the shading elements on the site, such as shading devices and trees.

The details of the analysis will be given in Chapter 4. The findings are illustrated with the maps and supported by the photographs taken on the site to make a better interpretation. The maps are prepared using the computer aided programs AutoCAD 2008 and Google Sketchup 6.

➢ **Meteorological data:** Meteorological data is the first set of climatic data of this study. It has been requested from the online database of Turkish State Meteorological Service – TUMAS, concerning the same day of the field measurements has been taken. The environmental parameters that meteorological data contains are hourly average air temperature (ºC), wind speed (m/s) and relative humidity (%). Only certain hours' average data has been utilized and grouped concerning the same four periods with the field measurements. The details of the data retrieved from the meteorological station are given in Appendix C and Appendix D.

➢ **Field measurements:** Field measurements represent the second set of climatic data of this study. It has been carried out after the completion of site monitoring. Field measurements have been carried out periodically for 40 points on each site. The duration of each period varies due to the site characteristics. The measurements have been taken on particular locations of the case areas. Thus, the measurement points for field measurements have been determined for certain locations regarding the primarily results of site analysis. The locations represent fairly the differences in spatial organization of the site. The climatic conditions of the points vary due to the sun path during the day, since the measurements have been taken at the same point for each period. The 1.min.-long measurements have been carried out for each selected locations at pedestrian level throughout four periods as morning period (08:00-09:59), midday period (12:00-13:59), afternoon period (16:00-17:59) and evening period (20:00-21:59). The given letter "g" coming after the point number refers to that measurement of that point has been taken in the shade. The environmental parameters collected on the site are average air temperature (ºC) and wind speed (m/s). Those parameters have been measured using Testo410-1. The findings are illustrated with tables and charts to make a better interpretation. The details of the data of field measurements are given in Appendix A and Appendix B.

Analysis of the field survey findings: The findings have been processed to analyze climate sensitivity in Konak Square and Kızılay Square, which are located in different climates. The evaluation and comparison process has been realized regarding those urban patterns' spatial structure and the taken climatic measurements (Figure 1). Taking into consideration urban patterns of each case area, the study specifically presents;

- Comparison of site air temperature measured periodically at each point (field measurements) with actual air temperature retrieved from the meteorological station (meteorological data) and comparison of site wind speed measured periodically at each point (field measurements) with actual wind speed retrieved from the meteorological station (meteorological data).
- Evaluation of the spatial structure in relation to the given comparisons. The evaluation is realized around four categories; urban texture, surface characteristics, use of air conditioning and shading.

This will lead us if, how and to what extend existing urban patterns take the advantage of their particular climate while eliminating the inconveniences. In addition, present study illustrates the ways of collecting the climatic data on the site as an initial step to link the climatic issues into urban design practice.

1.4. Structure of the Study

After a brief introduction in chapter one, the concept of climate sensitive design including its particular objectives is given in the second chapter. In addition, the factors that need to be taken into account in climate sensitive design as well as in a research dealing with climate issues are described. Following, climate regions seen in the world and specific climate sensitive design principles for those regions are introduced systematically.

In the third chapter, recent research and design projects in the world and particularly in Turkey are reviewed. Research projects are examined with regard to their subjects while design projects are in terms of their scales.

The fourth chapter aims at analyzing Konak Square and Kızılay Square separately in terms of spatial structure and climatic measurements. The given analyses are realized illustrating the maps, photographs and graphs. Following, the chapter evaluates and compares those urban patterns considering in terms of climate sensitivity.

In conclusion, after reviewing all findings derived from the study, the importance of climate sensitivity is underlined. General recommendations to bridge the gap between the current urban design practice and climate are given in the last chapter.

CHAPTER 2

CLIMATE SENSITIVE DESIGN

This chapter presents an overview of climate sensitive urban design and focuses on the factors that need to be taken into account in climate sensitive design. In addition, it gives the climate regions seen in the world and specifically in Turkey, and reviews the climate sensitive design principles specific to those different climate types.

2.1. Definition and Objectives of Climate Sensitive Design

In the late of the 1960s as the problems of standardization of the urban life and the concerns over the environmental issues came onto urban design agenda, new approaches such as sustainability, ecology, energy efficiency as well as green architecture and urbanism have gained considerable importance. Climate sensitive urban design, indicating many aspects from those approaches, is a useful tool to provide natural-based objectives specific to different types of climate to achieve pleasant urban environment through less consumption of world's resources and less destroying the nature as well as reducing the cost of energy consumption. It provides fundamental principles in design specific to different climates, since the requirements of each climate are different with respect to their particular needs. Climate sensitive design approach aims at addressing positive and negative aspects of the climate so that the design itself take advantage of free energy from the sun in terms of both heating and lighting, existing wind conditions and directions regarding natural ventilation (Oktay 2001).

The built-up area and design related variables directly influence the micro climate in urban environment (Eliasson and Svensson 2002; Giridharan, et al. 2004-2005; Gomez, et al. 2004; Johansson 2006; Eliasson 1996; Johansson and Emmanuel 2006). In other words, the changes of environmental parameters such as air temperature, wind or humidity in urban area are mostly generated by the urban landscape and this highly influences the comfort and health of the users, the energy consumption and overall urban quality. "The urban climate is thus, to a large extent, a result of human modification of the local climate in situ." (Eliasson 2002, 33) Regarding, the climate on the site is mostly dependent on the physical factors such as urban fabric, landscape elements and building configuration. Therefore, the environmental factors such as air temperature, solar radiation and wind, in urban area including both outdoor and indoor spaces, can be adjusted by climate sensitive design criteria. Such criteria may include the provision of shading elements, adequate materials and colors of the surroundings for the climate, the details of green surfaces, setting of green roof treatments, installing wind breaks, in particular urban areas enabling the places open to wind or sun and so forth.

"Reducing energy consumption, using natural resources and providing comfortable, healthier and sustainable living spaces are the aims of a climatically responsive sustainable design." (Manioğlu and Yılmaz 2008, 1301) Specifically, the objectives of climate sensitive design briefly can be summarized as follows regarding the review of the previous studies;

- Maximizing the site's natural potential through the selection of location, orientation, H/W ratio and density
- Maximum efficiency from daylight; reducing the reliance on artificial lighting
- Maximum efficiency from the sun; passive solar heating
- Responding to the sun-path
- Maximum efficiency from the wind; natural ventilation
- Advancing water efficiency; re-using all rainwater and wastewater
- Reducing the amount of unpleasant wind blow and solar radiation
- Aiming to sustainable approach to landscape and nature
- Utilizing a variation of plantings throughout the physical properties; vegetated roof, green walls, vertical gardens and vegetation-covered surfaces, sky courts
- Enabling recyclable and renewable building materials, advancing thermal insulation

2.2. Factors to be Considered in Climate Sensitive Design

The studies focusing on the climate issues in urban area are generally carried out by the climatologists, city planners, urban designers and the architects, which aim at achieving pleasant urban living in harmony with climate that satisfies the majority of people in urban space. Those studies examine the various variables through both quantitative and qualitative approaches (see Chapter 3 for the details). Quantitative approach mainly utilizes the four parameters: temperature, radiation, humidity, wind speed while qualitative approach explores people's subjective perception of the thermal environment through the use of questionnaires, interviews and observation (e.g. Nikolopoulou and Lykoudis 2006; Johansson and Emmanuel 2006). The factors that those qualitative and quantitative studies dealing with are given as followed in order to be considered in urban design projects with the intention of responding to climate and meeting people's expectations accurately.

Investigation of the climatic conditions on the site is considerably complex subject. While coping with it, a range of factors need to be taken into account. In this study, general focus has been given to the factors used in the quantitative approaches. It indicates physical parameters (e.g. urban form and location width to height ratio, building properties) and environmental parameters (e.g. air temperature, wind speed, humidity). Apart from those parameters, the urban temperature itself which is called urban heat island phenomenon in the literature has a significant effect on the climate in the cities. Specifically, the factors need to be considered in climate sensitive design will be highlighted in following sections.

2.2.1. Physical Parameters

Many scholars (Golany 1996; Johanssons 2006; Bosselmann and Arens 2005) highlight the correlation between physical and environmental parameters in terms of thermal performance of the built environment. Golany (1996) stresses three distinct urban forms which can be appropriate for different climates; compact, dispersed, and clustered forms, from the thermal performance point of view. He finds out that the thermal performance of each distinctive urban form performs in a different way in terms of the climate type. "Thus, the form can, to some extent, modify the micro-climate of the site and offer an improvement of the ambient temperature and therefore increase human comfort." (Golany 1996, 455) In addition, Johanssons (2006) states that urban geometry; the average building height, distance between buildings, H/W ratio and building configuration as well, affects the weather conditions on the site. Similarly, Bosselmann and Arens (2005) examine the effects of buildings on wind conditions at street level, and of sun and wind conditions on pedestrian comfort. Their study clearly shows a strong relationship between urban form and climate. The dimensions of streets and the position of buildings affect city climate. (Bosselmann and Arens 2005) The following physical parameters obtained from the previous studies are grouped in three categories as follows;

- **Urban configuration:** location, urban pattern, urban density, street width and orientation, nature of ground surface.
- **Landscape elements:** pavement materials and colors, planting and green spaces, pools, fountains, fixed or operable shadings and other design elements.
- **Building configuration:** distance between the buildings, average building height, H/W ratio, surface materials, façade characteristics and other design settings as well as the installations on the buildings.

Design interventions which aim to accomplish climate sensitive design and also the studies dealing with the climate in relation to the urban environment consider that wide range of physical factors above-mentioned. All of the existing physical features and any additional design interventions made in either building or urban scale make a considerable change in the site climate as influencing people's behaviors and usage of outdoor spaces.

2.2.2. Environmental Parameters

The great majority of the scholars necessarily investigate environmental parameters in their studies concentrating on the built-up area. (see, Giridharan, et al. 2004, 2005; Johansson 2006; Bosselmann and Arens 2005; Nikolopoulou, et al. 2001; Nikolopoulou and Lykoudis 2006; Walton, et al. 2007; Gomez, et al. 2004; Johansson and Emmanuel 2006; Thorsson, et al. 2007; Manioğlu and Yılmaz 2008; Yılmaz 2007). The following environmental parameters are the most common factors used in those studies;

- Ta - **Air temperature** (°C-Celsius, °F-Fahrenheit, °K-Kelvin)
- RH - **Relative humidity** (%)
- W - **Wind speed** (m/s, km/h, knots and mph)
- SRD - **Solar radiation** (MJ/m2)

2.2.3. Urban Heat Island Phenomenon (UHI)

According to Givoni (1998), on the average the day time (diurnal) temperature in a densely built urban area is warmer comparing to the surrounding rural areas. Besides, the largest elevations of the urban temperatures occur during the nights (nocturnal). Regarding the temperature differences between a densely urban area and its surrounding open areas, temperature elevations of about 3-5°C are common, yet the elevations of about 8-10°C can be observed. This nocturnal temperature difference between the urban area and the surroundings rural areas is described as urban heat island and the maximum urban-rural difference is defined as the heat island intensity (Givoni 1998). UHI is affected by two types of factors. First, they are correlated with environmental factors such as, wind speed and humidity. Second, physical factors such as the size of the cities, the density of the built-up areas can have strong effect on the magnitude of the urban heat island (Rosenlund 2000).

The subjects indicating the investigation of urban heat island effect have been a point of the focus of various fields in recent years (e.g. Eliasson and Svensson 2002; Giridharan, et al. 2004, 2005; Eliasson 1996). The built-up area within the city creates an air dome above and around the city, similar to a canopy shape, filtering specific air temperature and humidity conditions, may occur and solar radiation is absorbed, down to the street level The main factors generating the heat island are as follows;

- Lower heat radiation loss during the night, due to the geometry of the city
- Heat storage in the building mass
- Heat generating activities (transportation, industry etc.)
- Lower evaporation due to less vegetation and different surface structures
- Active energy systems such as the energy consumed by air conditioning and eventually released to the environment elevates the urban temperature and the degree of urban heat island effect (Rosenlund 2000).

The phenomenon of the urban heat island increases urban air temperatures in densely built-up areas comparing to its surroundings. The relative role of the factors causing the heat island effect is greatly influenced by the climate, season, and the type of the activities in the city.

2.3. Climate Regions

Koppen world climate classification, which is one of the most widely used climate classification systems in the literature, combines average annual and monthly temperatures and precipitation, and the seasonality of precipitation (Figure 2.1). It divides the climates into five main groups and several types and subtypes as in the following. Each climate type is designated by a capital letter. The third letter can be included to indicate temperature. Originally, h signified low latitude climate (average annual temperature above 18°C) while k signified middle latitude climate (average annual temperature below 18°C).

1. Tropical/mega thermal climates (Group A) are for constant high temperature and large amount of year round rain. All twelve months of the year have average temperatures of 18 °C or higher.

- Tropical rainforest climate (Af)
- Tropical monsoon climate (Am)
- Tropical wet and dry or savanna climate (Aw)

2. Dry (arid and semiarid) climates (Group B) are characterized by little rain and a huge daily temperature range.

- Semiarid or steppe climate (BS)
- Arid or desert climate (BW)

3. Temperate/mesothermal climates (Group C) have an average temperature above 10°C in their warmest months, and a coldest month average between −3°C and 18°C.

- Mediterranean climates (Csa, Csb)
- Humid subtropical climates (Cfa, Cwa)
- Maritime Temperate climates or Oceanic climates (Cfb, Cwb, Cfc)

4. Continental/microthermal climates (Group D) can be found in the interior regions of large land masses. Total precipitation is not very high and seasonal temperatures vary widely.

- Hot Summer Continental climates (Dfa, Dwa, Dsa)
- Warm Summer Continental or Hemiboreal climates (Dfb, Dwb, Dsb)
- Continental Subarctic or Boreal (taiga) climates (Dfc, Dwc, Dsc)
- Continental Subarctic climates with extremely severe winters (Dfd, Dwd)

5. Polar climates (Group E) are characterized by average temperatures below 10 °C in all twelve months of the year

- Tundra climate (ET)
- Ice Cap climate (EF) (Kottek, et al. 2006)

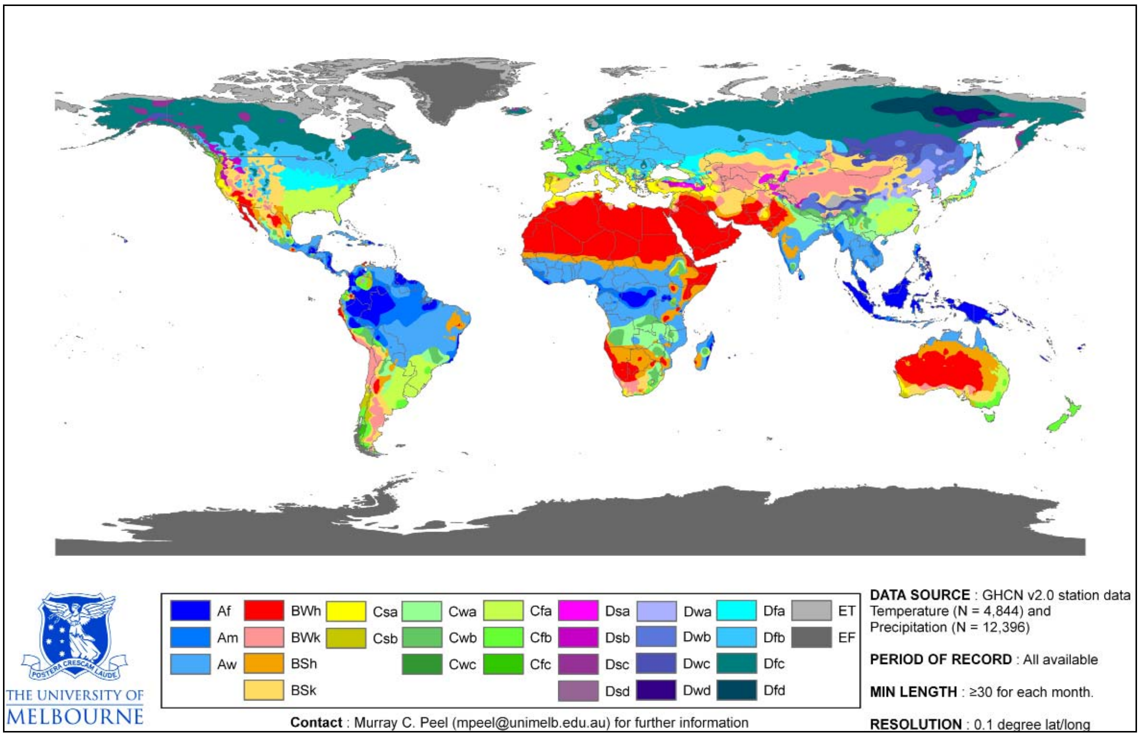

Figure 2.1. World map of Köppen-Geiger climate classification
(Source: WEB_1)

Regarding the main groups in the Koppen world climate classification, Turkey has Dry (arid and semiarid), Temperate and Continental climate regions (Kottek, et al. 2006). Semi-humid Marmara, Black Sea and Mediterranean Climates correspond to the subgroups of Temperate Climate one of the main group of Koppen world climate classification. In this study, Turkey climate types have been assumed to be divided into three main groups; Semi-arid, Temperate and Continental Climate regions. Regarding the geographical regions of Turkey; Central Anatolian and South-eastern Anatolian Regions have Semi-arid Climate, Blacksea, Marmara, Aegean and Mediterranean Regions have Temperate Climate and Eastern Anatolian Region has Continental Climate.

On the other hand, Turkey climate classification which is prepared by Ministry of Environment and Forestry has been divided into seven groups related to geographical regions of Turkey (Figure 2.2). The major climate types with subgroups in Turkey are as follows;

1. The Mediterranean Climate: Dominant in the coastal zones of the Aegean and Mediterranean Regions. It is hot and dry in the summer, and mild and rainy in the winter.

- The humid Mediterranean Climate: Rare snow and frost events in the coastal area, with an average annual precipitation of 1000 mm pouring in the winter.
- The semi-humid Mediterranean Climate: The average annual precipitation is around 600-800 mm. Precipitation occurs usually in the winter.

2. The Black Sea Climate: The average annual precipitation is more than 1000 mm occurring mostly in the fall and winter .The average annual temperature is around 8-12 ºC.

3. The Semi-humid Marmara Climate: The temperature is not as high as the Mediterranean climate in the summer, and is lower in the winter.

4. The semi-arid (steppe) Climate: Extends throughout the Central Anatolian Region, including Central-West and the Lakes Region, as well as the western part of Eastern and South-Eastern Anatolian Regions. The terrestrial influence leads to large scale differences in temperatures between seasons.

- The Semi-arid Central Anatolian Climate: Cold in the winter, with decreasing temperatures in the east. The maximum precipitation occurs in the spring and the minimum in the summer at a rate of %10 in the summer.
- The Semi-arid South-eastern Anatolian Climate: Hot in the summer with a terrestrial and tropical desert influence affecting the annual temperature regime. The average annual precipitation is less than 500 mm, and the rate of evaporation is highest in Turkey.

5. The Continental Eastern Anatolian Climate: Severe terrestrial conditions prevail as long and cold winters. Precipitation is higher than the precipitation of the Central Anatolian Region and mainly occurs as snowfall in the winter (Ministry of Environment and Forestry Publication 2006).

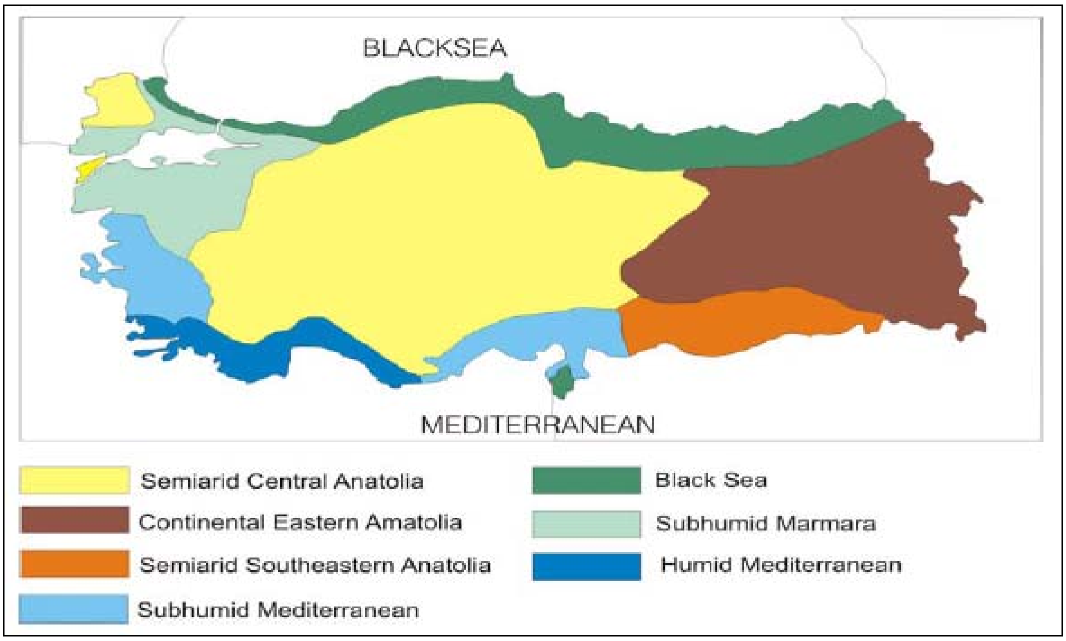

Figure 2.2. Turkey climate classification
(Source: Ministry of Environment and Forestry Publication 2006)

2.4. Climate Sensitive Design Principles

Climate sensitive design provides urban designers with several principles specific to different climate regions through the passive design objectives. The aim of the following sections is to illustrate the use of those design related variables in the design of the built environment in different climates, which are mentioned as physical parameters in previous sections. The principles have been realized through climate sensitive design projects reviewed in the literature and also related publications (Pressmen 1996; Golany 1996; Givoni 1998; Hyde 2000; Roselund 2000).

The climate sensitive principles presented in both building and urban scales, have been adapted to the most stressful climate regions that covering the great majority part of the world; hot-dry, hot-humid and cold regions, which also seen in many regions of Turkey (Table 2.1).

Table 2.1. Design principles for different climate regions
(Source: Pressmen 1996; Golany 1996; Givoni 1998; Hyde 2000; Roselund 2000)

	General Characteristics	**Design at Urban Scale**		**Design in Building Scale**
Hot-dry Climate Region	• Warm to hot summers and cool to cold winters. • Air temperature difference between day and night, summer and winter seasons. • High heat stress on summer days. • High ambient air temperature. • Extreme solar radiation. • High glare from direct and reflected sunlight.	• Selecting a site where lower summer air temperatures and good ventilation conditions exist. • Compact urban form with optimum density (not too-high). • Close-by urban functions, nearby neighborhoods and facilities. • Protected and small-dispersed public open spaces, natural vegetation. • Considerations on setback regulations. Short distance between buildings in the east-west direction about 1-5 of their height.	• Avoidance of the north-south orientation of the streets. • Narrow and deep land lots when the streets along the north-south direction. • Shading by special details of the buildings or by trees. • Avoidance of the buildings oriantation perpendicular to the wind direction. • Row houses or town houses, rather than the individual, detached houses. • Grid layout in diagonal orientation, northeast-southwest and northwest-southeast. • Fountains and little garden pools.	• White roofs. • Use of the materials such as bricks, stone, wood, concrete and of lighter construction. • Reasonable distance between the blocks for natural ventilation. • Overhanging roofs or the colonnades. • Small and north-facing windows. • Avoidance of the windows by eastern or western side. • Enabling vegetation around the buildings.
Hot-humid Climate Region	• Hot to humid summers and chilly to mild winters. • Excessive heat stress. • High humidity. • Significant amounts of rainfall. • Flood-risk.	• Selecting a site on windward slopes, rather than leeward slopes. • Proximity to the seashore and large lakeshore. • Interconnected valley systems. • Open-ends, dispersed urban form. • Spreaded high rise buildings into the city. • Avoidance of high, long buildings, of the same height, perpendicular to the wind. • Urban reservoirs such as mini-lakes. Parallel streets to the direction of the prevailing wind.	• Wide main boulevards oriented at about 30 degrees angle to the prevailing wind. • Combination of varied building heights. • Avoidance of the orientation of the buildings obstructing the wind. • Trees along sidewalks and the special details of the buildings for shading. • Adequate drainage system in the streets. • Permeable pavement, such as open-grated concrete blocks or special bricks.	• Enabling cross ventilation, the windows opposite to each other. • High ceilings in living areas, long, narrow floor-plan in sleeping zones. • Enabling long axis of the houses by east-west direction. • Outdoor living areas. • Shutters, verandahs, canopies and fixed overhangs. • Pale colors for the walls and roofs. • Use of the materials such as timber and fibro.

(cont. on next page)

Table 2.1. (cont.)

Cold Climate Region	• The average temperatures during the winters below zero and cool to comfortable summers. • Stressful and strong winter conditions. • Excessive low temperature. • Dryness and strong winds	• Selecting a site on the southern slopes. • Avoidance settling where a hill in the south of the given site. • Selecting the areas naturally sheltered by hills on the north side. • Compact and homogeneous urban form. • Protected urban edges. • High density in the residential and commercial built-up area. • Complementary urban functions. • Small, dispersed and protected public spaces. • U-shaped belts of high evergreen vegetation. Wide urban arteries at 90 degree angle to the wind direction.	• Continuous positioning of high buildings. • Snaky or angled street layout rather than straight. • Covered and glazed street configuration. • Enabling passages providing glazed roof in the streets. • Underground highways. • Enclosed residential courtyards. • Configurations of the urban blocks along east-west axis. • Windscreens, snow fences and shelterbelts.	• Curved convex and U-shape, long urban blocks by east-west axis. • High and multi-storey buildings, orienting in the winter wind direction. • Large distances between adjacent buildings in the north-south direction. • Long two-three storey town houses oriented toward the south. • Enabling direct solar heating through the windows. • East-facing windows for sunlight during the cooler months. • Outer doors opening to the small entry halls. • Sun-porch, glasshouse or conservatory within buildings.

2.4.1. Climate Sensitive Design in Hot-dry Regions

Hot-dry climate regions are characterized by the summers warm to hot and the winters cool to cold. There is a considerable air temperature difference between day and night as well as between summer and winter seasons. Major issues in the hot-dry climate are high heat stress on summer days, resulting from high ambient air temperature, extreme solar radiation and high glare from direct and reflected sunlight. In general, design details in hot-dry regions should aim at providing good shading opportunities over the sidewalks, playing grounds, and other public areas, securing adequate ventilation, preventing dust, reducing glare and minimizing heat stress of people.

Design Principles at Urban Scale:

The town or neighborhood preferably should be located in the places where lower summer air temperatures and good ventilation take place, essentially during the evenings when the breeze has cooling effect. The variations in altitude and in the locations within the region make a change in temperature and wind conditions. “Locations can be found in close proximity but at different elevations with daytime temperatures around 35°C (95°F) at higher elevations and 40°C (104°F) and more at lower elevations." (Givoni 1998) Compact urban form within optimum density assists in adequate shading without slowing the ventilation speed. It should be taken into consideration that too-high density of the built-up area may bring about poor ventilation and cause thermally stressful environments. Similarly, it is advantageous for hot-dry climate to ensure close-by basic services for the people, since nearby neighborhoods and facilities may shorten the walk distance. On the other hand, protected and small-dispersed public open spaces should be designed, concerning the need of shaded resting areas for the users. In addition, appropriate landscape or/and maintaining the existing natural vegetation in the un-built areas help filtering dust, since unplanned urban lands in the hot-dry regions often cause dust problem.

Design considerations for the spaces between the buildings should be maximizing the shading opportunities for pedestrians and minimizing the solar exposure of the buildings along the streets. In this regard, setback regulations in the development plans should regard the possibilities of minimizing solar heating of buildings and shading of pedestrians walking between buildings, while ensuring the potential for natural ventilation. There is a special importance in hot-dry regions should given to the distance between buildings in the east-west direction. In the east-west direction, the streets and the walls would benefit from the natural shading provided by the walls of the buildings. However, while short distances between the streets providing opportunities in summer, this may cause inadequate solar access in winter seasons. Thus, a distance of 1.5-2 times the height of the buildings would be needed to prevent unnecessary mutual shading of the walls in winter seasons. On the other hand, the north-south orientation of a street may result in the east-west orientation of the long façade of the buildings and this causes unfavorable solar exposure for these buildings. In case of where streets running north to south, subdivisions into narrow and deep land lots enable locating the long buildings perpendicular to the streets, while facing north and south. From good ventilation view point, while the narrow streets provide better shading opportunities for pedestrians on the sidewalks than the wide streets, they may cause inadequate ventilation. Within optimum density, in case where the wide streets are needed for good ventilation, sidewalks can be shaded by special details of the buildings or by trees.

Similarly, distances between the building blocks should be ensured, and long buildings should not serve as a barrier perpendicular to the wind direction. In addition, any design interventions to reduce the distances between the buildings, in the east-west direction about one to fifth of their height, assists in protected spaces. In this respect shaded ground area and the walls of the buildings can achieve natural shading by the walls. Likewise, these distances can be eliminated with the help of designing row houses or town houses, rather than the individual, detached houses. In street level, grid layout in diagonal orientation, northeast-southwest and northwest-southeast, is a useful pattern, regarding the solar exposure aspect. It provides more shading opportunities in summer and more sun exposure in winter seasons. Humidity, in dry climate, is welcomed from thermal comfort viewpoint. Therefore, existing landscape and/or planting in the space between the buildings can be useful to increases the evaporation rate instead of raising the temperature, since solar absorption of leaves is rather high. Finally, design elements such as the fountains and little garden pools are preferable in hot-dry regions, if water supply is sufficient.

Design Principles in Building Scale:

As the long wave radiant loss noticeably exceeds the absorbed solar radiation, the average temperature of the roof surfaces becomes lower than the average regional air temperature. It thus sinks downward to the street, since cool air is heavier than warm air. In this respect, land surface covered by the white roofs may result in considerable lowering of the urban temperatures in the hot-dry regions. Besides, white colored walls decrease the heat charge of the building, while increasing outdoor glare. This conflict can be resolved by the horizontal overhangs projecting from the walls. The overhangs cover on the section of the wall below as providing shade in the street. On the other hand, for adequate ventilation of the buildings especially during the evenings, the special details of the building configuration should be considered with the intention of keeping reasonable distance between the building blocks. The wind should be able to penetrate the buildings for natural ventilation. Protection against sun for pedestrians on the sidewalks is highly desirable in hot-dry regions. Thus, the overhanging roofs, or the colonnades should be provided in the case where ground floor is set back from the edge of the road, and also extended upper storey exist. In building design, small and north-facing windows are required, rather than the windows by eastern or western side of the building with respect to stressful characteristics of the climate. In addition, heat-storage capacity should be enhanced in living areas to keep daytime temperatures down, using the materials such as bricks, stone, wood, concrete and the lighter construction, which cool quickly at nights. Finally, vegetation around the buildings is desirable in order to filter dust from the air.

2.4.2. Climate Sensitive Design in Hot-humid Regions

Hot-humid climate regions are characterized by hot, humid summers and chilly to mild winters. Major issues in the hot-dry climate are excessive heat, high humidity and significant amounts of rainfall. The design details in hot-humid regions should aim at rapid disposal of excess rainwater, providing rain protection and shading for outdoor activities and enabling good natural ventilation of the urban space. When shading and ventilation opportunities are conflicting, the ventilation aspects should be the primary concern in hot-humid climate.

Design Principles at Urban Scale:

The town or neighborhood preferably should be located on the windward slopes, rather than leeward slopes to facilitate good ventilation. Similarly, open-ends within dispersed urban form assist in effective ventilation for the city. In addition, the town or neighborhood located at the seashore and large lakeshore areas can benefit from the daytime sea breeze which usually reaches its maximum speed in the afternoon, when the temperature difference between the cooler sea and the warmer land is the largest. These kinds of locations present more comfortable places with higher velocity and lower temperatures when compared to more sheltered ones. On the other hand, spreading the high rise buildings into the city facilitates good ventilation. The urban configuration which consists of high, long buildings, with same height, and perpendicular to the prevailing wind direction should be avoided in design.

Regarding the design considerations at urban scale related to the flood risk and the need for adequate drainage, existing land use such as interconnected valley systems should be preserved to prevent flood-risk and facilitate natural drainage. Similarly, the urban reservoirs such as mini-lakes avoid flood risk. These reservoirs can also function as urban parks or open public spaces in the development plans. The design response to flood risk can later save costs and reduce property damage resulting from the hazards.

In order to enable the best ventilation for the spaces between the buildings, the streets should be parallel to the direction of the prevailing winds throughout the afternoon hours, since the urban temperature reaches its maximum. Yet, as streets are parallel to the wind direction, ventilation potential of the buildings along the streets is compromised, because all the walls of the buildings locate in suction zones. For effectual indoor cross-ventilation, at least one of the windows should be in pressure zone. Appropriate street layout, from the urban ventilation viewpoint in this climate, is as wide boulevards are oriented at about 30 degrees angle to the prevailing winds. This can still facilitate diffusion of the wind into the town and provide effective natural ventilation for both the buildings and the streets. On the other hand, the combination of varied building heights and the long facades of the tower-like building regulate existing wind direction and enhance ventilation conditions for the lower floors, as well as for the pedestrians in the streets and the open spaces between the buildings. Besides ventilation, adequate shading and drainage in the streets should be taken into consideration in hot-humid climate regions. In this regard, the trees along sidewalks and the special details of the buildings can create extensive shadowing in the street. Also, urban surface should be covered with permeable pavement, such as open-grated concrete blocks or special bricks with regard to drainage in the street level.

Design Principles in Building Scale:

Regarding thermal comfort, cross ventilation through the building itself has considerable importance in hot-humid climate. In addition to the principles mentioned above at urban scale, for successful indoor cross-ventilation, the windows should be placed opposite to each other. Similarly, high ceilings in living areas and long, narrow plan in sleeping zones enable maximization of air movement. Building heat gain can be minimized by orienting the long axis of the house in east-west direction and keeping the windows on this direction in minimum. In terms of shading needs, the outdoor living areas, such as verandah, should be designed within the single house. The walls and windows can be shaded by the shutters, verandahs, canopies and fixed overhangs. The use of pale colors for walls and roofs helps to reflect the heat of sun. Finally, the materials such as timber and fibro should be utilized, since they cool quicker at night when compared to the other materials.

2.4.3. Climate Sensitive Design in Cold Regions

Cold climate regions are characterized by the average temperatures during winter season below zero and cool to comfortable summers. Major issues in the cold regions are stressful and strong winter conditions, excessive low temperature associated with dryness and strong winds. The design details in cold regions should aim at grouping the services for the city, easing the mobility and shortening the distance between the facilities, reducing heat loss, minimizing stressful northern wind, maximizing passive solar gain and enabling special features for snow and ice activities.

Design Principles at Urban Scale:

The town or neighborhood should preferably be located on the southern slopes that provide more protected and sunny environment than the other slopes, since the areas sloping to north are windier and may lack adequate sun exposure. In addition, it should be taken into account that a hill located in the south of the given site may cut sun exposure in winter seasons. Such locations should be avoided as much as possible. Cold climate necessitates compact and homogeneous urban form with protected urban edges. In this regard, high density in the residential and commercial built-up areas should be rendered, which entails more intensive use of the land. High density of the complementary urban functions should be grouped. This, on one hand, enables people to work and shop where various urban functions exist and on the other hand, reduces the walking and driving distances. In cold regions, the main objectives in designing public park areas should be enabling sun and protecting from wind. Thus, public open spaces, which are designed small, dispersed and protected, are suitable for cold climates.

The location of urban parks and the planting details are crucial in cold climate. Locating urban parks in the areas naturally sheltered by hills or high and dense borders of evergreen trees on the north side can enable wind protection without blocking the winter sun. U-shaped belts of vegetation around benches, those are open to south, provide seating places year-round in cold regions.

On the subject of design of spaces between the buildings, wide urban arteries should be preferably at 90 degree angle to the wind direction, since stressful winter winds are not acceptable. Similarly, continuous positioning of high buildings along such streets assists in lowering wind speed. Snaky or angled street layout helps lessening wind speed when compared to the straight streets with same orientation. This design consideration is beneficial in the case of where narrow streets are parallel to the wind in general orientation. On the other hand, covered and glazed street configuration is highly preferable in cold climate, since the overall aim is to enhance thermal comfort through minimizing the stressful wind and snow, and maximizing the solar exposure. In this respect, the passages which provide glazed roof covering the streets in the commercial areas, enable protection from wind and snow for a large volume of pedestrians, and considerably improve comfort of the customers in winter period. However, the buildings crossing over the street may increase the velocity underneath, while reducing the overall wind speed in the street. Likewise, underground highways can provide snow-free traffic across the city. The enclosed residential courtyards enable a more pleasant micro-climate where wind turbulence and velocity significantly low. The open areas between the lower buildings can be protected from the winter winds by the configurations of high urban blocks by east-west axis. The use of the spatial design of windscreens, snow fences and shelterbelts helps achieving to a flourishing micro-climate.

Design Principles in Building Scale:

Regarding the objectives for wind protection, curved convex and U-shape, long urban blocks with east-west axis provides a sheltered area to its south while breaking the northern wind. Similarly, high and multi-storey buildings, orienting to specific directions with respect to the winter wind characteristics, protect the lower buildings behind. Sufficient solar access requires a design objective keeping adequate distances between adjacent buildings in the north-south direction. In this respect, long two-three storey town houses-so-called row houses which are oriented toward the south provide direct solar heating through the windows. Enabling east-facing windows, with external shading to restrict summer sun, provides morning sunlight during the cooler months. In addition, outer doors opening to the small entry halls, locks the air between inside and outside space. Similarly, the sun-porch, glasshouse or conservatory within buildings catches more sun for indoor heating. Regarding snow disposal, pitched roofs are needed where snow falls occur.

2.5. Evaluation

This chapter presents the issues of climate sensitive design through its given objectives and particular principles for the three main climate regions covering the great part of the world. Besides, the chapter provides us the factors that need to be taken into consideration in climate sensitive design.

Initially, the given objectives of climate sensitive design emphasize that the passive techniques provided by climate sensitive design aim at taking advantage of the climate while eliminating the negative aspects. Following, environmental parameters and physical parameters are highlighted as a base of the present research, since climatic conditions on the site can be adjusted through the design of built-up environment. As the relationship between physical and environmental parameters is considered as a focal point to analyze climate sensitivity and to evaluate urban patterns, a part of the research of this study has been realized regarding those parameters. The analysis of the spatial characteristics of the site has been investigated in accordance to physical parameters, while the data to be measured in the field measurements and retrieved from the meteorological station have been selected regarding environmental parameters. Moreover, climate sensitive principles have been realized to draw attention to that correlation between the physical parameters and environmental parameters. In addition, given principles help with presenting the ways to deal with different types of climates in design of the urban environment. Specifically, the principles have shown us how the climatic conditions of outdoor space are being manipulated through design, regarding the physical parameters.

CHAPTER 3

RECENT RESEARCH AND DESIGN PROJECTS: HOW TO COPE WITH CLIMATE ISSUES

This chapter briefly reviews the studies including recent research and design projects from all around the world. It specifically stresses the ways to deal with climate issues in urban area, and demonstrates the use of climate sensitive principles, illustrating the objectives of different design projects at urban scale and in building scale.

3.1. Recent Research Projects

The research projects are conducted mostly by the climatologists and more recently by the engineers, architects, planners, urban designers as well as the sociologists, since climatology is a shared field by various actors. They have been carried out by different research institutions including the municipalities, associated departments of different universities as well as the private companies. The research projects presented here mostly deal with climate issues in urban area. This section presents some of the research projects from all around the world concentrating on the relationship between the urban environment and thermal comfort (e.g. Eliasson and Svensson 2002; Giridharan, et al. 2004-2005; Gomez, et al. 2004; Johansson 2006; Eliasson 1996; Johansson and Emmanuel 2006) and the relationship between outdoor thermal comfort and usage of the space (e.g. Bosselmann and Arens 2005; Nikolopoulou, et al. 2001; Nikolopoulou and Lykoudis 2006; Walton, et al. 2007; Thorsson, et al. 2007; Eliasson and Lim 2007). It also shows recent studies specifically from Turkey that generally focus on thermal performance of the buildings in different climates (Yılmaz 2007) as well as the differences between traditional and modern architecture with respect to thermal comfort (e.g. Oktay 2001; Manioglu and Yılmaz 2008; Valsson and Bharat 2008).

3.1.1. Research Projects in the World

The recent research projects primarily focuses on the influences of built-up area and design related variables on outdoor climatic conditions and thermal comfort in particular (e.g. Eliasson and Svensson 2002; Giridharan, et al. 2004-2005; Gomez, et al. 2004) (Table 3.1).

Eliasson and Svensson (2002) examined the effect of three different types of urban built-up areas on air temperature. Three built-up land-use categories examined in the research are urban dense, multi-family and single houses. Hourly air temperature data was collected throughout an 18-month period from 1998 to 1999, using the measurement loggers at 18 locations randomly chosen in the city of Gothenburg, Sweden. The study evaluated and compared the sites regarding the distinctions between day and night periods, in different seasons and considering the weather conditions in each land-use category. It proved that the concentration of the buildings affects the temperature pattern, energy consumption and overall thermal comfort while the wind does not affect the correlation between urban temperature and land use to a large extend. Besides, densely built-up areas were found warmer than the other two categories at night. In the study, the consequences of air temperature variations on human comfort and energy consumption were highlighted, measuring human comfort through physiological equivalent temperature (PET) which is an index that represents thermal stress on people (Eliasson and Svensson 2002).

Giridharan, et al. (2004 and 2005) investigated the impact of design-related variables on outdoor micro level daytime heat island effect (2004) and on nocturnal heat island effect (2005) as well as nocturnal urban heat island's significance in relation to daytime UHI in the case study areas (2005). The study was conducted in the residential developments of Hong Kong city. The Belchers is a new generation housing development while Wah Fu 1 and Wah Fu 2 are the high-rise developments of the 1960s. The study is based on multiple regression models as urban heat island is a dependent variable. Independent variables are glass to surface area, total height to floor area ratio, surface albedo, local green area, width to height ratio, proximity to heat sink, sky view factor, surrounding built area ratio, altitude of the site, wind velocity and solar radiation. The measurements were carried out between 15:00-18:00h for daytime urban heat island and 18:00-20:00h for nocturnal urban heat island. The researchers spent three days on each site and took the measurements more than 6 measurement points depending on the site. They found that how the changes in each independent variable affects urban heat island correspondingly. In their study, they emphasized on that the changes in surface albedo, height-to-floor area ratio, sky view factor and altitude have more effect on nocturnal urban heat island comparing to daytime urban heat island (Giridharan, et al. 2004-2005).

Gomez, et al. (2004) explored the influence of green areas on urban thermal comfort in the city of Valencia as a sample for Mediterranean cities. Eight different districts of the city of Valencia were selected. Two of them were the most densely populated ones and those with urban and environmental patterns are the ones located on the outskirts and rural areas of the city surroundings. The others were the ones in the market garden and seafront. Four environmental parameters; solar radiation, air temperature, ambient temperature and wind speed were measured. An average of 18 sampling points for each site was chosen and measurements took place each district during 10.00-14.30h. In addition, an analysis of human perception was assessed at the same hours. The study concluded that different sampling points showing considerable differences between cold, comfortable and hot locations are related to soft and hard spaces. The vegetation has a major role in the energy control of the city and highly affects the amount of solar radiation (Gomez, et al. 2004).

Besides, some other research projects specifically concentrate on the influence of urban/street geometry in terms of different H/W ratio and orientation (e.g. Johansson 2006; Eliasson 1996; Johansson and Emmanuel 2006) (Table 3.1).

Johansson (2006) investigated the influence of urban geometry on microclimate and thermal comfort at street level in a hot dry climate. He compared urban street canyons of two distinctive neighborhoods; a compact and a dispersed urban form, in Fez, Morocco, during the summer and winter seasons. The field study was carried out in both neighborhoods throughout 2-6 February 2000 and 26-30 June 2000, also on each site individually 19-20 July 1998, 4-5 December 1998 (compact), 17-18 July 1998, 6-7 December 1998 (dispersed). The measurements of air and surface temperatures, humidity and wind speed were taken for three times per day; prior to sunrise, in the afternoon (14:00–15:00 h), and in the evening after sunset. In addition, thermal comfort was assessed by calculating the physiologically equivalent temperature (PET). It was found that compact urban form provides a good shelter during the summer season whereas dispersed urban form causes a thermally uncomfortable environment in the summer. Yet, it was concluded that there is still an inconvenience with compact urban form in the winter season (Johansson 2006).

Eliasson (1996) analyzed nocturnal air temperature distribution in relation to differences in street geometry and land use in Goteborg, Sweden. In this regard, two weather stations were set up in the central city area; one in a street canyon oriented along the northwest-southeast direction, and the other in a large open area; nearly 400m away from the canyon. The measurements of air temperature and wind speed were taken during a 3-year period at the stations. It was found that urban geometry has a minor effect on the air temperature pattern, particularly in the city centre. The air temperature difference between the large park and the city centre (4°C avr.) was monitored likewise the average urban-rural air temperature difference (3.5-6°C) (Eliasson 1996).

Johansson and Emmanuel (2006) examined the influence of street canyon geometry on outdoor thermal comfort in Colombo, Sri Lanka. Five different neighborhoods representing different H/W ratio of street canyons, orientation, surface material properties, vegetation, and proximity to the coast were chosen to examine. Environmental parameters; air temperature, humidity, wind speed, and solar radiation, were measured, and thermal comfort was estimated by the physiologically equivalent temperature (PET). The measurements were taken between April 30 and May 12 2003. It was proved that the worst conditions are experienced in the wide streets where low-rise buildings and no shade trees exist. On the contrary, the most comfortable conditions were seen in the narrow streets with tall buildings and shade trees, as well as in the areas close by the coast where the sea breeze effects perceived climatic conditions positively (Johansson and Emmanuel 2006).

Secondly, the research projects deals with the effects of climate related variables on outdoor thermal comfort and the consequences of the variables on usage of the space (e.g. Bosselmann and Arens 2005; Nikolopoulou, et al. 2001; Nikolopoulou and Lykoudis 2006; Walton, et al. 2007; Thorsson, et al. 2007; Eliasson and Lim 2007) (Table 3.1).

Bosselmann and Arens (2005) illustrated the effects of buildings on wind conditions at street level and the combined effects of the sun and wind conditions on pedestrian comfort in three distinctive areas with different characteristics in Toronto, Canada. The special method used in the research was including the modeling of existing and potential development for wind tunnel experiments, and mathematical modeling of the human body's thermoregulatory system. Four environmental parameters; air temperature, air velocity, solar radiation, humidity and two human parameters concerning users' thermal perception; metabolic rate and clothing, were investigated. Hourly data was taken for each location. Then, they tested the study areas with the redesigned future buildings in the wind tunnel and repeated the modeling of human comfort conditions; afterward they mapped the new results and compared the changes between existing conditions and each of the two alternative futures. This technique led them to see all comfort variables more closely, and to determine which variables influence the comfort level the most (Bosselmann and Arens 2005).

Nikolopoulou, et al. (2001) explored how microclimatic characteristics in outdoor urban spaces and comfort implications influence people's behavior and usage of outdoor spaces. Four case study areas were chosen in the city-centre of Cambridge, United Kingdom, which purposely serving for public. The research was carried out in the spring, summer and winter seasons. Three weekdays and the weekend as a sample of a week, was spent at each site during two hours at lunchtime in each season. Environmental parameters; air temperature, solar radiation, wind and humidity have been monitored. A portable mini-meteorology station was placed near the interviewee to compare the actual environmental parameters with the perceived ones. In this regard, a total of 1431 people have been interviewed. The measured parameters were compared with subjective behavior and responses, including observations, in order to evaluate the thermal comfort conditions which people experience. It was given in the final report of the research that thermal environment influences people's use of the space, but psychological adaptation is also of great importance (Nikolopoulou, et al. 2001).

Nikolopoulou and Lykoudis (2006) evaluated the results of the microclimatic and human monitoring, in relation to the thermal environment and comfort conditions in the open spaces within 14 different case study site across 5 countries in Europe. The research was conducted between July 2001 and September 2002. The environmental parameters are air temperature, solar radiation, wind speed and humidity were measured with a portable mini-weather station, while people were being surveyed through the interviews at the same time. The periods of the monitoring are morning period (10:00-11:59), midday period (12:00-14:59), afternoon (15:00-17:59) and evening period (18:00-20:59). The evaluation of the study regarding user perception and comfort conditions were carried out through the results of human monitoring. Also environmental parameters were compared to the results of human monitoring. Then, it was found that there is a correlation between microclimatic and comfort conditions that air temperature and solar radiation are important determinants for user comfort, yet one parameter oneself is not sufficient for assessing thermal comfort conditions. The votes such as “very hot” and “very cold” were considerably connected to increased levels of discomfort (Nikolopoulou and Lykoudis 2006).

Walton, et al. (2007) studied the relative influence of wind, sunlight and temperature on user comfort in urban outdoor spaces. In this regard, different inner city locations; two urban parks and one open mall in Wellington, New Zealand were chosen to collect data over 13 days of sampling. Mean radiant temperature, air temperature, wind speed, and humidity were monitored during a 9-month period. The main weather station was placed where exposure to wind and sunlight was the most on the site. This has been combined with human monitoring and the questionnaire that surveyed 649 people between 11am and 3pm. The surveys were handed out to the participants seated on the site during those hours. The measures of user adaptation to the site were clothing, exposure of seating location, and length of exposure. In this respect, the surveyors were asked to note what type of material they were seated on e.g. concrete, grass, wood, etc. as well as how they were seated in terms of their positions in the wind and sun e.g. facing, turned against, sheltered/ shaded etc. The study put forward that people adapt to conditions to maintain comfort with variation in the microclimatic conditions of outdoor spaces (Walton, et al. 2007).

Thorsson, et al. (2007) examined the usage and levels of activity in two different urban areas; a park and a square in Tokyo, Japan. The field surveys were conducted on March 12 through 24, 2004 (winter/spring) and May 16 through 26, 2005 (spring/summer). Air temperature, surface temperature, relative humidity, wind speed and solar radiation were monitored. Monitoring of environmental parameters and human perception were carried out between 11 a.m. and 3 p.m. on weekdays. People’s thermal perception, climatic and aesthetic preferences, and emotional state were also investigated through structured interviews. A total of 1,142 people were surveyed (469 in March 2004 and 673 in May 2005) of which 541 were interviewed in the park and 601 were interviewed in the square. It was found that the park is generally cooler than the square. Thermal conditions have relatively a low influence on the use of the space. In general, there is a loose relation between the thermal environment and the use of those two places regarding the total crowd (Thorsson, et al. 2007).

Table 3.1. Research projects in the world

Author / Year	**Subject of the Study**	**Case Study**	
		Content	Measured
Eliasson, I. & Svensson, M.K. (2002)	The effect of built-up land use areas on air temperature.	Urban Dense, Multi-family and Single Houses. (Gothenburg, Sweden)	Hourly temperature data.
1)Giridharan R., Ganesan S. & Lau, S.S.Y. (2004) 2) Giridharan R., Ganesan S. & Lau, S.S.Y. (2005)	1)The impact of design-related variables on outdoor micro level daytime heat island effect 2) on nocturnal UHI and its significance in relation to daytime UHI in the case study areas.	Three different housing developments. (Hong Kong, China)	The specific variables concerning UHI, altitude of the site, wind velocity and solar radiation.
Johansson, E. (2006)	The influence of urban geometry on microclimate and thermal comfort at street level.	Urban street canyons in two neighborhoods; compact and dispersed. (Fez, Morocco)	Air and surface temperatures, air humidity and wind speed.
Bosselmann, P. & Arens, E. (2005)	1) The effects of buildings on wind conditions at street level, 2) The combined effects of sun and wind conditions on pedestrian comfort.	Three areas with different characteristics. (Toronto, Canada)	Air temperature, air velocity, solar radiation, and humidity. Users' thermal perception regarding metabolic rate and clothing.
Nikolopoulou, M., Baker, N. & Steemers, K. (2001)	Microclimatic characteristics in outdoor urban spaces and the comfort implications influence people's behavior and usage of outdoor spaces.	Four case study sites (squares and streets) in the city-centre. (Cambridge, United Kingdom)	Air temperature, solar radiation, wind and humidity. A total of 1431 interviewees.
Eliasson, I. (1996)	Analysis of nocturnal temperature distribution in relation to differences in street geometry and land use.	The street canyon which is oriented along northwest-southeast and large open area about 400m away from the canyon. (Göteborg, Sweden)	Temperature, H/W ratio.
Nikolopoulou, M. & Lykoudis, S. (2006)	The results of the microclimatic and human monitoring, in relation to the thermal environment and comfort conditions in open spaces.	14 different case study sites. (Five countries in Europe)	Air temperature, solar radiation, wind speed and humidity. Human monitoring and 10,000 questionnaires.
Walton, D., Dravitzki, V. & Donn, M. (2007)	The relative influence of wind, sunlight and temperature on user comfort in urban outdoor spaces.	Three different inner city locations; Two urban parks and one open mall. (Wellington, New Zealand)	Mean radiant temperature, air temperature, wind speed, and humidity. Human monitoring and questionnaire.
Gomez, F., Gil, L. & Jabaloyes, J. (2004)	The influence of green areas on the urban comfort.	Eight different districts; 2 densely populated areas, 2 outskirts, 3 rural areas, 1 seafront (Valencia, Spain)	Solar radiation, air temperature (dry and humid), ambient temperature and wind speed. An analysis of human perception (performed at the same hours)
Johansson, E. & Emmanuel, R. (2006)	The influence of street canyon geometry on outdoor thermal comfort.	Five different neighborhoods which are characterized by differences in the H/W ratio of street canyons, orientation, surface material properties, vegetation, and proximity to the coast. (Colombo, Sri Lanka)	Air temperature, humidity, wind speed, and solar radiation.
Thorsson, S., Honjo, T., Lindberg, F., Eliasson, I.& Lim, E. (2007)	Examining the usage and levels of activity in two different urban areas.	A park and a square. (Tokyo, Japan)	Air temperature, surface temperature, relative humidity, wind speed, solar radiation. A total of 1,142 interviewees

3.1.2. Research Projects in Turkey

Recent research projects carried out in Turkey mainly concentrate on the vernacular architecture versus the new developments regarding their thermal performances in different climate regions. Besides, some of them specifically deal with traditional and modern architecture in the same climate region with respect to climate sensitivity (e.g. Oktay 2001; Manioglu and Yılmaz 2008), while the others only focus on vernacular architecture and traditional settlements (e.g. Valsson and Bharat 2008). Apart, some others concentrate on thermal performance of the buildings in different climates (Yılmaz 2007) (Table 3.2).

Oktay (2001) evaluated the vernacular and new architectural patterns in Northern Cyprus in terms climate sensitivity. In this context, the courtyards and various design elements of the built-up area in a hot climatic region were examined. It was found that in the case of vernacular settlements, similar regional solutions to the problems of urban living have been generated in terms of climate adaptation. The houses are grouped together as shading mutually to maximize the protection from the midday sun. Also, the ratio of building height to street width provides a compact and protected space. On the other hand, new housing developments were found insensitive to the climatic conditions regarding their orientation, formation and arrangement (Oktay 2001).

Manioglu and Yılmaz (2008) intended to show the similarities and differences of traditional housing design principles in terms of climate sensitivity. Their research took place in Mardin, a town situated in the hot-dry area of the south-eastern part of Turkey. The study, on the one hand, put forward the basic principles examining the selection of the area, distance between buildings, orientation, building envelope and building form, and on the other hand, evaluated and compared the traditional housing with the contemporary housing using the data derived from the measurements and questionnaires. The measurements were carried out for 100 buildings and the questionnaire with 100 occupants in the selected modern and traditional buildings at the same time. It was highlighted that the heat storage capacity of the building envelope has been neglected and the same design strategies have been proposed regardless the context of the building envelope and the climate. The modern buildings in South-eastern Anatolia which are constructed according to standards of Turkey do not correspond to the climate of the region. This has also been confirmed by the results of the measurements and the users' perception in questionnaires (Manioglu and Yılmaz 2008).

Yılmaz (2007) evaluated the thermal performance of two different buildings constructed according to the TS 825 in Mardin and Istanbul cities. The study presents the differences in climatic effects of two regions on building energy performance and the importance of thermal mass of building envelope in hot-dry climate. The study underlines the important role of traditional construction technology in energy conscious design. Also, it emphasizes on neglected energy standards for different climate regions (Yılmaz, 2007).

Valsson and Bharat (2008) explored the climatic considerations in the ancient town planning by analyzing the planning thoughts at different periods. They examined the old houses of Diyarbakir and the scattered settlement in the Eastern Black Sea region in Turkey. The findings of the research are mainly based on the inferences from traditional architecture, underlying the several principles monitored at urban scale as well as in building scale.

Table 3.2. Research projects in Turkey

Author / Year	**Subject of the Study**	**Case Study**	
		Content	Measured
Oktay, D. (2001)	Evaluation of the housing settlements (vernacular and new developments)	Author's survey-based study in different cities, (Northern Cyprus)	The courtyards and various design elements of the built-up area in a hot climatic region.
Manioglu, G. & Yılmaz, Z. (2008)	Evaluation of modern and traditional housing South-eastern Anatolia .	100 buildings. (Mardin)	Design variables; site selection, distance between buildings, orientation, building envelope and building form. Window temperature, indoor air temperature, internal surface temperature. The users' satisfaction degree.
Yılmaz, Z. (2007)	Evaluation of the thermal performance of two buildings in temperate and hot-dry climate to show the difference in climatic effects.	Comparison of the buildings in different climate regions. (Istanbul and Mardin)	Architectural design variables (in building scale) Window temperature, indoor air temperature, internal surface temperature
Valsson, S. & Bharat, A. (2008)	The climatic considerations in the ancient town planning and evaluation of vernacular architecture.	Hot-dry and warm-humid regions (Eastern Blacksea and South-eastern of Turkey)	Design variables (building and urban scales)

3.2. Recent Design Projects

The following sections present some recent design projects from all around the world of which all are not fully climate sensitive but to some extent take the climate essentials into account. It reviews specifically the projects where the climate sensitive design criteria exist. The projects from the world are seen as eco-towns, eco-resorts, campuses or mixed-use developments at urban scale and mostly as green buildings or eco-towers in building scale. Contrary to the wide-ranging projects in the world, design projects at urban scale are mostly mixed-use housing developments in Turkey. Similarly, the current projects in building scale are generally portrayed by the concepts such as solar housing and green-buildings. Regarding the vision, goals and strategies of the presented design projects from all over the world, design projects constitute not only a climate sensitive framework but also sustainable and ecologic.

3.2.1. Design Projects in the World

All of the design projects in the world reviewed in this section have many environmental features that aim to achieve climate sensitivity that associate with naturally derived solutions in design. In this respect, they mainly focus on two objectives; site selection and street orientation with regard to the climate. Specifically, they intend to boost the use of passive design such as maximizing solar use in terms of energy efficiency, optimizing daylight contribution to reduce artificial lighting, re-using of the rainwater or wastewater and enabling natural ventilation to eliminate the need for air conditioning.

In the following, particular design intentions of the recent design projects from the world at urban scale (Table 3.3) will be reviewed in details;

University of the Sunshine Coast, Queensland/Australia is a leading climate sensitive design project constructed in Temperate (Humid-subtropical) climate, covering the entire campus development which aims at being responsive to the climate (Figure 3.1). Environmentally sustainable design of the campus has already been implemented, but partly under-construction. The strengths of the project are as followed (WEB_2 2009);

- Fully climate sensitive development
- Use of passive design, including natural ventilation, lightening, adequate glazing choice, shading and insulation
- Landscape properties; minimizing water-use and energy consumption, enhancing biodiversity

Januburu Six Seasons, Broom/Australia is a sustainable housing development located in Dry (Continental and semi-arid) climate (Figure 3.2). The project has already been completed. The potentials of the project are as followed (WEB_3 2009);

- Use of passive thermal design increasing overall thermal performance
- Enabling natural cross-flow ventilation
- Enabling the openings to cooling breezes
- Considering solar orientation
- Aiming at low energy use
- Use of suitable material

Figure 3.1. University of the Sunshine Coast
(Source: WEB_2 2009)

Figure 3.2. Januburu Six Seasons
(Source: WEB_3 2009)

BedZED, Zero-fossil Energy Development, Sutton, London/UK is known as UK's first large-scale zero carbon community. It is a mixed-use, carbon neutral housing development located in Temperate (Oceanic sub-group) climate (Figure 3.3). The project has been implemented and was awarded in 2004. The climate sensitive intentions of the project are as followed (Thomas and Fordham 2003);

- Reducing the annual running cost
- Enabling equitable solar access through sky gardens
- Maximizing wind speed for power generation and ventilation

Parkmount Housing, Belfast, Northern Ireland/UK is a sustainable and low-energy housing development which was awarded in 2003 (Figure 3.4). It is located in Temperate (Oceanic sub-group) climate. Distinctive potentials of the project in terms of climate sensitivity are as followed (Thomas and Fordham 2003);

- The effective use of solar energy, maximizing solar potential in design
- Design of a series of buildings of ascending height according to the sun path
- Enabling good orientation for sunlight

Figure 3.3. BedZED
(Source: WEB_4 2009)

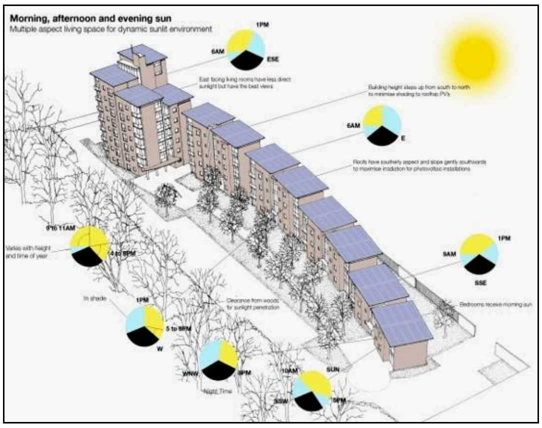

Figure 3.4. Parkmount
(Source: WEB_5 2009)

Nieuwland, Amersfoort, Utrecht/the Netherlands is an eco-town comprising of 5.000 homes and 70 ha. area for industrial purposes (Figure 3.5). It is located in Temperate (Oceanic sub-group) climate. This solar suburb covers five different sustainable projects, under-construction, depending on solar energy. The project mostly deals with energy efficiency and environmental responsibility. Also, affordability is another objective of the project (Wheeler and Beatley 2004).

Ecolonia, Alphen aan den Rijn/the Netherlands is a sustainable housing unit which has been founded by EU as a low energy housing demonstration project (Figure 3.6). It is located in Temperate (Oceanic sub-group) climate. The units have been already constructed. The climate sensitive intentions of the project are as followed (WEB_6 2009);

- Use of passive and active solar energy
- Orientation of the building for maximizing solar collection
- Use of rainwater
- Reduction in water consumption

▪ Rainwater runoff and disposal management
▪ Utilizing recyclable building materials
▪ Enabling organic architecture, healthy building materials

Figure 3.5. Nieuwland
(Source: WEB_7 2009)

Figure 3.6. Ecolonia
(Source: WEB_6 2009)

Lloyd Crossing, Portland, Oregon/USA is a mixed-use, sustainable urban design project located Temperate (Oceanic sub-group) climate (Figure 3.7). It was awarded in 2005 due to its overall carbon-neutral strategy. The portion of 95% of the project is a new construction whereas its 5% is renovation. The strengths of the project are as followed (WEB_8 2009);

▪ Enabling environmentally low-impact unit
▪ Aiming at ecological sensitivity in the city centre
▪ Reducing potable water consumption by 62 %
▪ Rainwater harvesting and wastewater reuse

Masdar City, Abu Dhabi/United Arab Emirates is a sustainable zero-carbon, zero-waste city planned in Dry (arid and semiarid) climate (Figure 3.8). The potentials of the project in terms of climate sensitivity are as followed (WEB_9 2009 and WEB_10 2009);

▪ 100 % of energy supplied by renewable energy using solar and wind power
▪ Recycling, composting, waste to energy (using 50% less water than a typical city)
▪ Zero carbon emissions from transport
▪ Reducing the emissions related to construction

Figure 3.7. Lloyd Crossing
(WEB_8 2009)

Figure 3.8. Masdar City
(Source: WEB_9 2009)

Table 3.3. Design projects from the world at urban scale

Project	Project Type	Status	Climate
University of the Sunshine Coast, Queensland, Australia	Environmentally sustainable campus design	Completed	Temperate (Humid-subtropical)
Januburu Six Seasons, Broom, Australia	Sustainable housing development	Completed	Dry (Continental and semi-arid climate
BedZED, Zero-fossil Energy Development, Sutton, London, UK	Mixed-use, Carbon neutral housing development	Completed	Temperate (Oceanic climates)
Parkmount Housing, Belfast, Belfast, Northern Ireland, UK	Sustainable and low-energy housing development	Completed	Temperate (Oceanic climates)
Nieuwland, Amersfoort, Utrecht, The Netherlands	Eco-town, solar suburb	Under-construction	Temperate (Oceanic climates)
Ecolonia, Alphen aan den Rijn, The Netherlands	Sustainable housing units	Completed	Temperate (Oceanic climates)
Lloyd Crossing, Portland, Oregon, USA	Sustainable Urban Design project (mixed-use)	Planned	Temperate (Oceanic climates)
Masdar City, Abu Dhabi, United Arab Emirates	Sustainable zero-carbon, zero-waste city	Planned	Dry (arid and semiarid)

Similarly, special design objectives of the recent design projects in building scale (Table 3.4) will be reviewed in details as follows;

Swiss Re Tower, London/U.K. is named an ecological high-rise in Temperate (Oceanic sub-group) climate (Figure 3.9). The building has a form reducing the amount of wind deflected to the ground. It also features an innovative use of windows on the light wells that helps in passive ventilation supply systems to be switched off for forty-percent of the year. There is a high-performance coating over the wells to reduce solar radiation. The climate sensitive intentions of the project are as followed (WEB_11 2009);

- Aiming at 40% reduced energy consumption through natural ventilation and passive solar heating
- Enabling innovative use of the light wells
- Reducing the reliance on artificial lighting

Commerzbank Headquarters, Frankfurt/Germany is known as a green-tower which is located in Temperate (Oceanic sub-group) climate (Figure 3.10). The tower has an atrium forming large sky gardens opening up at different levels. These open areas allow more natural light in the building, reducing the need for artificial lighting. The climate sensitive intentions of the project are as followed (Wheeler and Beatley 2004);

- Maximum efficiency from daylight,
- Enabling natural ventilation
- Use of the plantings throughout the building
- Consuming 25-30% less energy

Figure 3.9. Swiss Re Tower
(Source: WEB_11 2009)

Figure 3.10. Commerzbank Headquarters
(Source: WEB_12 2009)

Bank of America Tower at One Bryant Park, New York/USA is an environmentally-responsive high-rise office building which is currently under-construction (Figure 3.11). It has been designed to achieve U.S. Green Building Council's Leadership in Energy & Environmental Design Platinum designation. The project will be located in Continental (with hot humid summers and cold dry winters) climate. The potentials of the project are as followed (WEB_13 2009);

- Enabling higher ceilings and extremely transparent low iron, low insulating glass; maximum daylight in interior spaces, optimal views and energy efficiency
- Use of recyclable and renewable building materials
- 50 % Water efficiency; re-using all rainwater and wastewater

Beijing Int. Terminal Building, Beijing/China is one of the world's most sustainable terminal buildings (Figure 3.12). It has been designed considering Continental (with hot humid summers and cold dry winters) climate. The terminal building incorporating a range of passive environmental design concepts such as the south-east orientated skylights, maximized heat gain from the early morning sun. It also enables environment-control system that minimizing energy consumption (Web_10 2009).

Figure 3.11. Bank of America Tower (Source: WEB_13 2009)

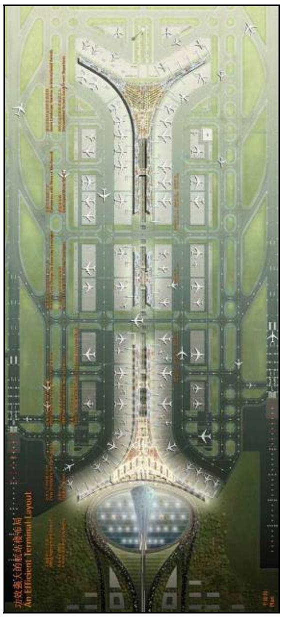

Figure 3.12. Beijing Int. Terminal Building (Source: Web_10 2009)

Bahrain World Trade Centre/Bahrain is a sustainable tower designed as a two sail-shaped towers to accelerate the wind velocity through the wind tribunes installed in between the towers (Figure 3.13). The three wind tribunes deliver approximately 11-15% of the energy needs of the entire building. It is located in Dry (arid and semiarid) climate. The strengths of the project in terms of climate sensitivity are as followed (WEB_14 2009);

- Enabling thermal glass with a low solar gain
- Use of thermal insulation, reflection pools for evaporative cooling,

- Aiming at environmentally responsive in reducing carbon emissions

Tel Aviv University, Tel Aviv/Israel is another example of full climate sensitive design (Figure 3.14). The ongoing project of the university building will be a green-building located in Mediterranean climate. Distinctive potentials of the project in terms of climate sensitivity are as followed (WEB_15 2009);

- Aiming at ultra energy efficiency; 25% less energy than the standards
- Towards carbon zero: additional 50% in CO2 reductions
- Aiming at sustainable approach to landscape
- Use of ultra low carbon in construction
- Reducing the dependency on artificial lighting

Figure 3.13. Bahrain World Trade Centre (Source: WEB_14 2009)

Figure 3.14. Tel Aviv University Building (Source: WEB_15 2009)

Table 3.4. Design Projects from the world in building scale

Project	Project Type	Status	Climate
Swiss Re Tower, London, U.K.	Ecological tall building	Completed	Temperate (Oceanic climates)
Commerzbank Headquarters, Frankfurt, Germany	Green-tower	Completed	Temperate (Oceanic climates)
Bank of America Tower at One Bryant Park, New York, USA	Environmentally-responsive high-rise office building	Under-construction	Continental (hot humid summers and cold dry winters)
Beijing Int. Terminal Building, Beijing, Beijing, China	Sustainable building	Completed	Continental (hot humid summers and cold dry winters)
Bahrain World Trade Centre, Bahrain	Sustainable tower	Completed	Dry (arid and semiarid)
Tel Aviv University, Isreal	Green-building	Under-construction	Temperate (Mediterranean)

3.2.2. Design Projects in Turkey

Design projects from Turkey reviewed in this section have some fundamental design features that aim at utilizing passive design techniques to be responsive to climate. The projects at urban scale which are mostly in still design process mainly endeavor to maximize the energy efficiency through the use of renewable energy sources; solar energy and wind power. Regarding the content of the projects in Turkey, they show similarities with the ones in the world in terms of passive design attributes such as enabling natural lightening and ventilation, advanced recycling system for the waste, using sustainable materials in the constructions and installing roof treatments or particular vegetation techniques in terms of greening.

In the following, particular design intentions of the recent projects from the world at urban scale (Table 3.5) will be reviewed in details;

Zorlu Eco-city, Istanbul is known as an environmental friendly green city which is still in the progress (Figure 3.15). It will be designed regarding Temperate (Humid-subtropical) climate. The strengths of the project in terms of climate sensitivity are as followed (WEB_16 2009; WEB_17 2009);

- Enabling sky courts responding to the specific sun-path diagram
- Use of passive ventilation strategy through wind turbines
- Aiming at green architecture; vegetated roofs, green walls, vertical gardens and vegetation-covered ramp;
- Providing rainwater storage

Atasehir Mixed Use Development, Istanbul is consisting of green-high rises serving for mixed-use (Figure 3.16). The design of the project is still in progress. It is expected to be responding the needs of Temperate (Humid-subtropical) climate. It has been designed to achieve U.S. Green Building Council's Leadership in Energy & Environmental Design. The potentials of the project are as followed (WEB_18 2009);

- Maximizing the site's natural potential; building orientation and landscaping
- Minimizing solar heat gain of the building facades
- Enabling rainwater collection sites
- Reducing energy consumption through wind turbine technology and cooling water pools

Figure 3.15. Zorlu Eco-city
Source: WEB_17 2009)

Figure 3.16. Ataşehir Green Development
Source: WEB_18 2009)

Cigli Housing Development Project, Izmir is an energy-efficient housing designing for Mediterranean climate (Figure 3.17). It has been generated to achieve U.S. Green Building Council's Leadership in Energy & Environmental Design but yet in design process. In terms of climate sensitivity, it utilizes passive heating systems through sun panels and enables natural lightening and ventilation in the design. (WEB_19 2009; WEB_20 2009)

Shopping Square Meydan, Istanbul is an ecologic bazaar located in Temperate (Humid-subtropical) climate (Figure 3.18). The project has been implemented due to energy and water efficiency. The project aims at using advanced recycling and passive cooling systems (WEB_21 2009).

Figure 3.17. Çiğli Housing Development
(Source: WEB_20 2009)

Figure 3.18. Shopping Square Meydan
(Source: WEB_21 2009)

Table 3.5. Design projects from Turkey at urban scale

Project	Project Type	Status	Climate
Zorlu Eco-city, Istanbul	Eco friendly city	Planned	Temperate (Humid-subtropical)
Atasehir Mixed Use Development, Istanbul	Green mixed use development	Planned	Temperate (Humid-subtropical)
Çiğli Housing Development Project, Izmir	Energy-efficient Housing	Planned	Mediterranean
Shopping Square Meydan, Istanbul	Eco-Bazaar	Completed	Temperate (Humid-subtropical)

Similarly, special design objectives of the recent design projects in building scale (Table 3.6) will be reviewed in details as follows;

Siemens Complex, Gebze Industrial Zone, Kocaeli is a green-building which has been designed to achieve U.S. Green Building Council's Leadership in Energy & Environmental Design Gold designation (Figure 3.19). It is still under-construction. The green features of the project are as followed (WEB_21 2009; WEB_22 2009);

- Reducing heat-island effect
- Maximizing water and energy efficiency, and
- Maximizing solar collection through reflective panels
- Managing rainwater runoff and disposal

METU-Matpum, Research Center Building, Ankara is an energy efficient building located Middle East Technical University Campus in Dry (Continental and semi-arid) climate (Figure 3.20). It has been designed with extendable features such as sun light collectors and wind turbines. The climate sensitive potentials of the building are as followed (WEB_23 2009);

- Enabling energy efficient orientation
- Use of passive heating-cooling systems
- Maximizing the use of day light

Figure 3.19. Siemens Complex
(Source: WEB_21 2009)

Figure 3.20. METU-Matpum
(Source: WEB_23 2009)

METU-Solar House, Ankara is the first sustainable architecture as a solar housing in Turkey. It is located Middle East Technical University Campus in Dry (Continental and semi-arid) climate (Figure 3.21). The building has insulated walls and roof in terms of passive heating. It functions with the roof built-in sun collectors. It is designed as 50-70% self-sufficient (WEB_24 2009).

Diyarbakır Solar House, Diyarbakır is the first solar house implementation in Turkey. It is located in the south-east part of Turkey where Dry (Continental and semi-arid) climate exist (Figure 3.22). The house has passive heating lighting and cooling systems provided by solar energy which is being converted into electric and hydrogen energy. (WEB_25 2009)

Figure 3.21. METU-Solar House
(Source: WEB_24 2009)

Figure 3.22. Diyarbakır Solar House
(Source: WEB_25 2009)

Istanbul Sapphire, Istanbul is the first green tower in Turkey, which is currently under-construction (Figure 3.23). The design of the tower is realized to respond Temperate (Humid-subtropical) type of climate. The potentials of the project are as followed (WEB_24 2009);

- Enabling natural ventilation
- Noise proofed design (Buffer zones)
- Maximum efficiency from day light
- Providing vertical gardens
- Reducing energy consumption and sun glare

Figure 3.23. Istanbul Sapphire Green Tower
(Source: WEB_24 2009)

Table 3.6. Design projects from Turkey in building scale

Project	Project Type	Status	Climate
Siemens Complex, Gebze Industrial Zone, Kocaeli	Green-building	Under-construction	Temperate (Humid-subtropical)
METÜ-Matpum, Research Center Building, Ankara	Energy efficient building	Completed	Dry (Continental and semi-arid climate)
METU-Solar House, Ankara	Solar house	Completed	Dry (Continental and semi-arid climate)
Diyarbakır Solar House, Diyarbakır	Solar house	Completed	Dry (Continental and semi-arid climate)
İstanbul Sapphire	Green-tower	Under-construction	Temperate (Humid-subtropical)

3.3. Evaluation

The reviewed research projects in the world are mostly found at urban scale and focus more on outdoor space and use of the space, comparing to the ones in Turkey. Regarding their methodologies, recent research projects in the world give more attention to urban design variables such as height to width ratio or street orientation. They also deal with different urban parts within one city or in the cities within different climate regions. Conversely, the research projects in Turkey rather deal with indoor space and generally underline how the architectural design variables manipulate indoor climatic conditions. In addition, they emphasize the differences between vernacular and modern architecture in terms of their thermal performance. Besides, the general focus of the research projects in Turkey is limited to the building scale.

The methodologies of recent research projects in the world consist of the investigation of environmental parameters; air temperature, wind speed, humidity and solar radiation, and the physical parameters; urban design variables as well as the design variables in building scale. The measurements of environmental parameters depend on the context of the study in terms of its required research design; however, the recent research projects generally operate sampling points with different physical characteristics on the site in numerous periods of a day, season or a year. Plus, in the majority of the research projects, the findings of the measurements on the site are justified by the questionnaires aiming at investigation of the users' comfort concerning outdoor space. The research projects in Turkey consist of the authors' survey based research on different sorts of housing developments in one city and as well as in different climate regions. As the other research project examples in the world, the environmental and physical parameters have been investigated as well in Turkey. Besides, some of the research projects in Turkey also give attention to indoor space so that they examine additional variables concerning indoor space.

Recent design projects reviewed in this chapter illustrate a real concern and consciousness in designing with the climate through taking advantage of clean energy and protecting from unpleasant climatic conditions. Concerning the design projects at urban scale, Australia, the Netherlands and United Kingdom have been found the most experienced countries in terms of climate sensitive developments with regard to the numbers of the projects reviewed in the literature. However, European countries in general have been seen more proficient on building scale regarding many world-wide known green high-rises in Europe. Similarly, Turkey has not as much of experience on climate sensitive design practice at urban scale, since the current projects in Turkey are mostly in building scale. Yet, recently there are some on-going design projects in Turkey.

The review of the recent research and design projects, on one hand, presents the knowledge of how to investigate the factors that need to be considered in climate sensitive design and illustrates the use of the principles mentioned in Chapter 2 through highlighting the objectives of the design projects. On the other hand, the review portrays the current situation in the world in terms of recent developments on the climate subject. This provides us some hints for defining the need for this research on the subject of climate and how to carry out those research projects specific to urban patterns and climate conditions of Turkey. Research and design projects have provided particular ways to conduct this research, in terms of the techniques to collect the data and determination of the methodology of this study. In addition, design projects constitute a deep knowledge in terms of the use of the climate sensitive principles in practice. This has led us investigating the related properties on the site.

CHAPTER 4

CASE STUDY: CLIMATE SENSITIVITY INVESTIGATION IN URBAN PATTERNS OF KONAK SQUARE AND KIZILAY SQUARE

This chapter investigates urban patterns of Konak Square/Izmir and Kızılay Square/Ankara in terms of climate sensitivity, through the analysis of spatial structure and climatic measurements on the site. The chapter starts with the analysis of spatial structure based around 4 categories; urban texture, surface characteristics on the site, use of air conditioning on the buildings and shadow maps for each area. Then, it presents the analysis of the climatic measurements based on two set of climatic data which have been collected through field measurements and retrieved from the closest meteorological station to the site. Following, those analyses are evaluated and compared for each case study in terms of climate sensitivity.

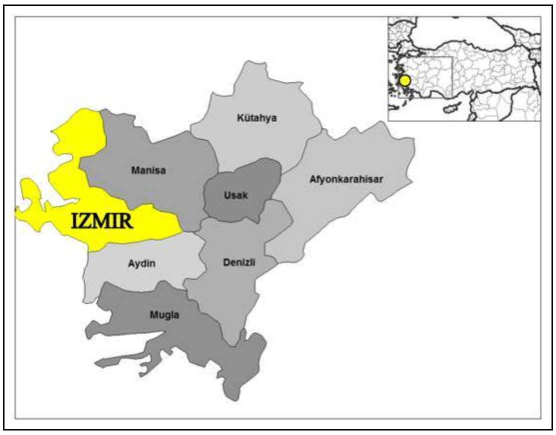

Figure 4.1. Izmir in the Aegean Region

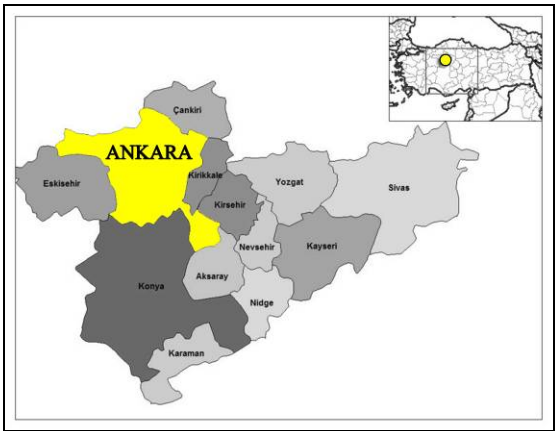

Figure 4.2. Ankara in the Central Anatolia Region

Konak Square and Kızılay Square are the main city centers of Izmir and Ankara, locating in different climate regions of Turkey. Having a population of 3.2 million the city of Izmir is third biggest city of Turkey. It is located on the west coast of the country by the Aegean Sea (Figure 4.1). The city of Ankara, the capital of Turkey, is an inland

and is located in the center of the country (Figure 4.2). It is the country's second city with the population of 4.751.360. (State Institute of Statistics 2009).

In terms of the cities' climates, Izmir has a typical Mediterranean climate which corresponds one of the sub-groups of temperate climate defined in Koppen climate classification whereas Ankara has a typical semi-arid (steppe) climate as one of the sub-groups of dry climate. (Kottek, et al. 2006) The weather of Izmir is characterized by long, hot and dry summers and mild to cool, rainy winters. The total precipitation for Izmir falls mainly during November through March. There is almost no rainfall during the months of June, July and August. The average maximum temperatures during the winter months vary between 12 and 14°C. Although it's rare, snow can fall in Izmir in December, January and February staying for a period of hours. The summer months, from May to October, usually brings average daytime temperatures of 30°C or higher (Turkish State Meteorological Service 2009) (Table 4.1).

Table 4.1. Izmir long-term monthly air temperature, 1975-2008
(Source: Adapted from Turkish State Meteorological Service 2009)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avr. Air Temp. (°C)	8.9	9.1	11.7	15.9	20.8	25.7	28.1	27.4	23.6	18.9	13.7	10.3
Max. Air Temp. (°C)	12.6	13.2	16.4	20.9	26.0	31.0	33.3	32.7	29.2	24.2	18.2	13.8
Min. Air Temp. (°C)	5.9	5.8	7.7	11.4	15.6	20.1	22.7	22.4	18.7	14.7	10.4	7.5

The weather of Ankara is characterized by the summers warm to hot and the winters cool to cold. There is a significant air temperature difference between day and night as well as between summer and winter seasons. Due to Ankara's high altitude and dry climate, nightly temperatures in the summer months are cool. The warmest months are June, July and August where temperature is measured above 20°C. Precipitation levels are low, but can be observed throughout the year. The peaks of precipitation are seen mostly during the spring and autumn. The average maximum temperatures during the winter months are below 10°C. The summer months, from June to August, usually brings average daytime temperatures above 20°C (Turkish State Meteorological Service 2009) (Table 4.2).

Table 4.2. Ankara long-term monthly air temperature, 1975-2008
(Source: Adapted from Turkish State Meteorological Service 2009)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Avr. Air Temp. (°C)	0.4	1.9	6.0	11.2	15.9	19.9	23.4	22.9	18.5	12.9	6.6	2.3
Max. Air Temp. (°C)	4.3	6.5	11.6	17.0	22.0	26.3	30.0	29.8	25.9	19.7	12.3	6.1
Min. Air Temp. (°C)	-2.9	-2.2	0.8	5.7	9.6	12.9	16.0	15.8	11.7	7.3	2.2	-0.8

4.1. Konak Square, Izmir, TURKEY

The first study area that is named as Konak Square in this work, is defined by the City Hall on the north end, the Mustafa Kemal Sahil Boulevard on the west end, Halil Rifat Pasa Street on the south end, and Milli Kutuphane Street on the east end (Figure 4.3). The area is situated in the historical downtown of Izmir between the traditional bazaar area (Kemeralti), business district and Izmir Gulf. It is an important transportation node with metro stations, ferry port and bus stops. Besides, the study area is bordered by vehicle traffic. There is no vehicle access through the square. The last design of Konak Square was realized by the year 2002. The implemented design does not propose a massive change in terms of the new building structure. Rather, it deals with the improvement of the landscape and townscape elements as well as with the new allocations of the bus stops and metro exits.

Figure 4.3. Location of Konak Square in the city of Izmir
(Source: Adapted from the image from Google Earth)

4.1.1. Analysis of Spatial Structure of the Site

The area is the combination of green open spaces, relatively new and tall building developments, and compact historical buildings. The spatial analysis has been carried out on the site 20th, 21st and 22nd August 2009.

4.1.1.1. Urban Texture

The form of the study area is in rectangular shape. It is open to the sea on the west end and is placed on a flat topography but surrounded by the hills on the east and south-east ends. The area consists of three different types of structures; detached rectangular formed buildings on the north end, open spaces in the center and by the coastline on the west end, and attached building blocks along the east end (Figure 4.4). The surrounding buildings in the open space, the ones facing the square on the east end in particular, are parallel to the coast.

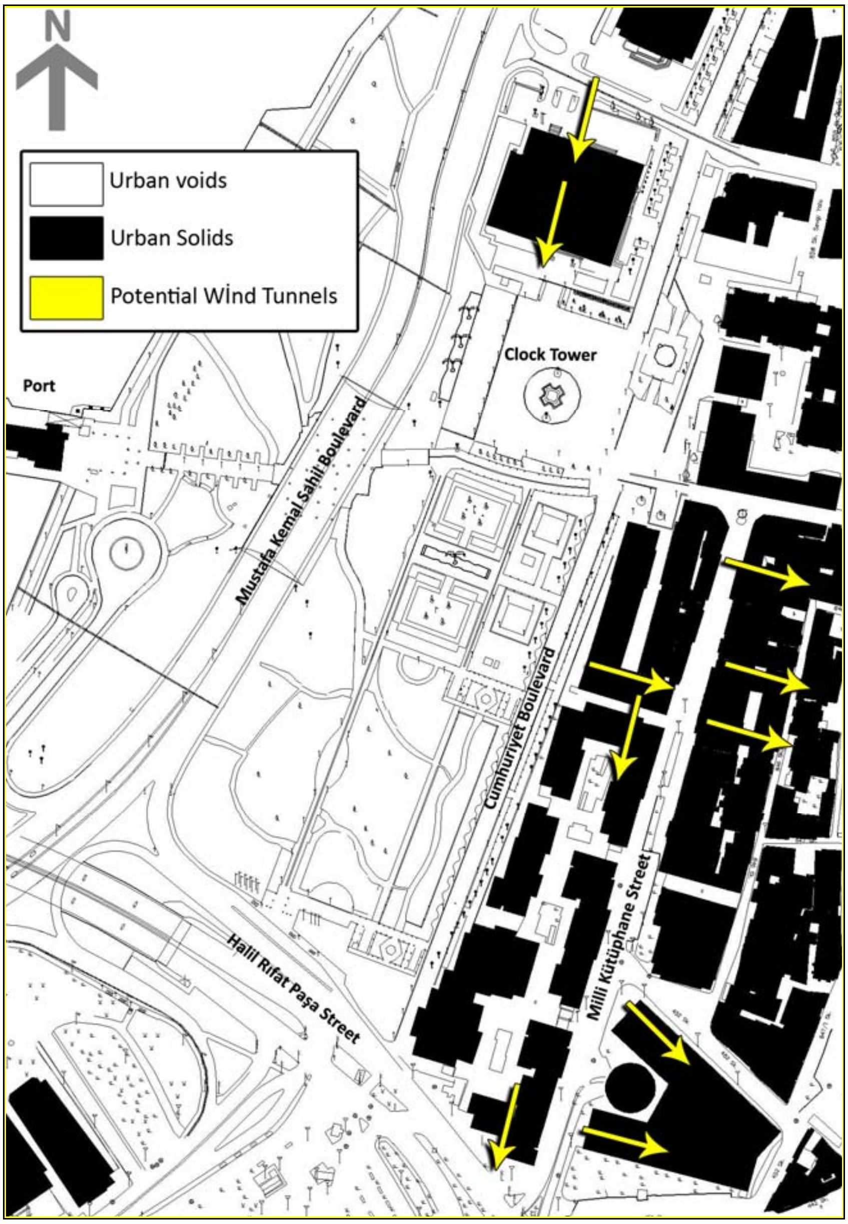

Figure 4.4. Urban Texture of Konak Square

Figure 4.5. A view from the ground floor of the building

Figure 4.6. A view from the ground floor of the building

Milli Kutuphane Street along the north-south direction on the east end has a dense building group without any vacant area in between on the right side, a clustered formed building group with courtyards on the left side. On the other hand, potential wind tunnels have been experienced due to the structure of the buildings which were built with a corridor through two sides of the building at the ground floor. Regarding, the openings of the buildings at the ground floor cause potential wind tunnels at pedestrian level. Those openings are the major characteristics of the structures generally seen in the entire study area (Figure 4.5 and Figure 4.6). Height of the buildings in the study area ranges from 9m. to 51m. The area is dominated by the building height around 6-8 storey (Figure 4.7). Especially clustered building group on the south-east end and Milli Kutuphane Street are characterized by high-rise constructions up to 8-9 storey. At these locations height to width ratio is small due to the width of the streets. Apart from the north part of the area, there is not a huge height difference between adjacent buildings (Figure 4.7).

4.1.1.2. Surface Characteristics

In terms of the materials used on the surfaces of the buildings, standard materials are quite common comparing to the heat and sun reflective surface materials such as aluminum. Standard materials are seen in the ratio of 15%. They are generally found on the surfaces of the building groups in clustered area. The dominant color of the study area is relatively darker colors e.g. grey (Figure 4.7).

Figure 4.7. Building height and building surface

In terms of the ground surface of the site, Konak Square is surrounded by an asphalt paved road; however, the study area is dominated by stone paved pedestrian ways. The color and material of the stones remain same on the pavements. On the other hand, around %40 of the field is covered by green open spaces. (Figure 4.8) Furthermore, History Park and Open Exhibition Area locating in the center and the area on the way to the pier on the west end are emphasized utilizing a special lighter colored ground pavement (Figure 4.9). The Cactus Garden on the south end and in paths cutting through the garden are intended to be left natural, and as such are covered by soil (Figure 4.10).

4.1.1.3. Use of Air Conditioning

The use of air conditioning is excessive on the site. Nearly %80 of the buildings utilizes active heating and cooling systems (Figure 4.11). Specifically, the clustered area consisting of dense and high rise building group on the south-east end has high use of air conditioning (Figure 4.12). Also, air conditioning installations at street level are mostly seen in that area (Figure 4.13). They are placed on the walls facing the courtyards that people pass through or rest during the day.

Figure 4.8. Ground surface

Figure 4.9. A view from Open Exhibition Area

Figure 4.10. A view from Cactus Garden

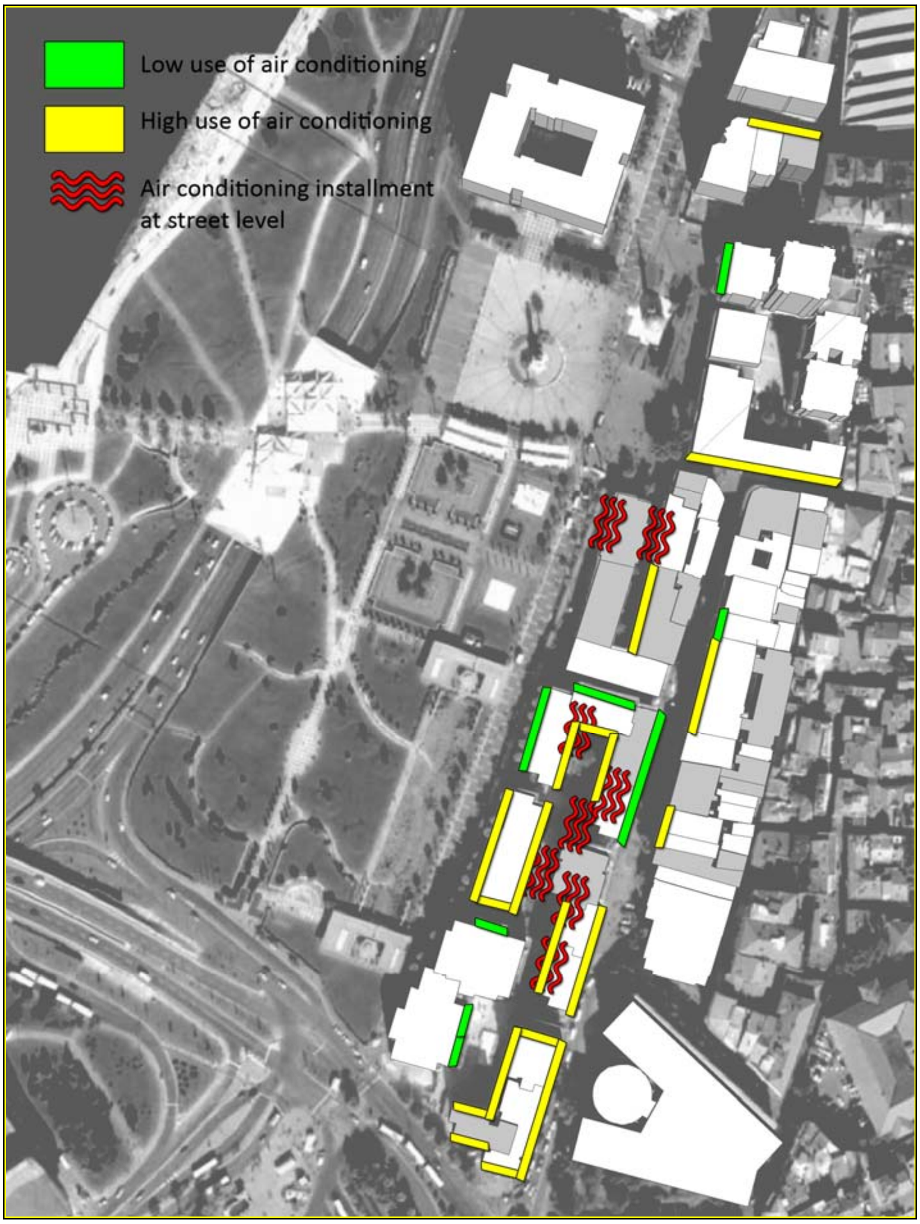

Figure 4.11. Use of air conditioning

Figure 4.12. A view from high use of air conditioning

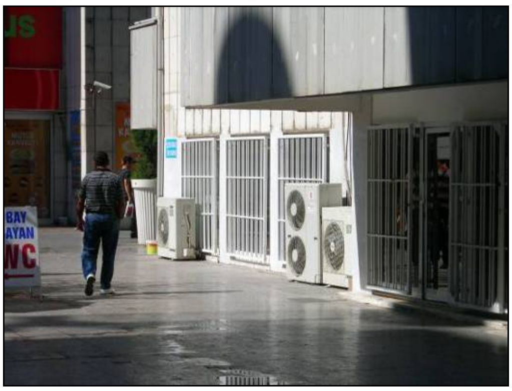

Figure 4.13. A view from an air cond. installment at street level

4.1.1.4. Shading

The investigation of the building shadows has been conducted on 21st August 2009. Three different periods and the observations due to the sun path at those periods are as follows;

- **Morning period (08.00h):** In this period, the major pedestrian axes are fully shaded (Figure 4.14). Especially, Cumhuriyet Boulevard (Figure 4.15) and Milli Kutuphane Street (Figure 4.16) can benefit from the shades of the buildings. Also, the courtyards in clustered area on the south-east end can benefit from the mutual shading of the surrounding building groups. The area around the Municipality Building on the north end is partially shaded. The lengths of the shadings in that area are longer comparing to the others on the site. On the other hand, the whole green open space as well as special design areas such as History Park and Open Exhibition Area cannot benefit from the shadings of their surroundings.
- **Midday period (12.00h):** In this period, the most of the study area is in the sun (Figure 4.17). Around the Clock Tower, particularly the places without any shading elements, has been monitored being exposure to the excessive sun (Figure 4.18). The two major pedestrian ways are half shaded (Figure 4.19). The courtyards in the south-east end are partly in the sun.
- **Afternoon period (16.00h):** In this period, again the large part of the study area is in the sun (Figure 4.20). The open green spaces, all of the special design areas and the areas around the Clock Tower are exposure to the sun. They can partly be protected from the sun by the trees which are indeed inadequate for shading (Figure 4.21). The courtyards in clustered area and the other major pedestrian way Milli Kutuphane Street are fully in the shade (Figure 4.22).

The second map showing the shading elements are realized concerning the trees and shadings devices in the study area (Figure 4.23). Shading devices can particularly be seen along the major pedestrian ways, above the platform on way to the port on the west end and over the metro exits. They can also be seen as canopies placed in front of the existing buildings (Figure 4.24). Similarly, the majority of the types of the trees can be seen along the pedestrian ways and close by the seating niches (Figure 4.25).

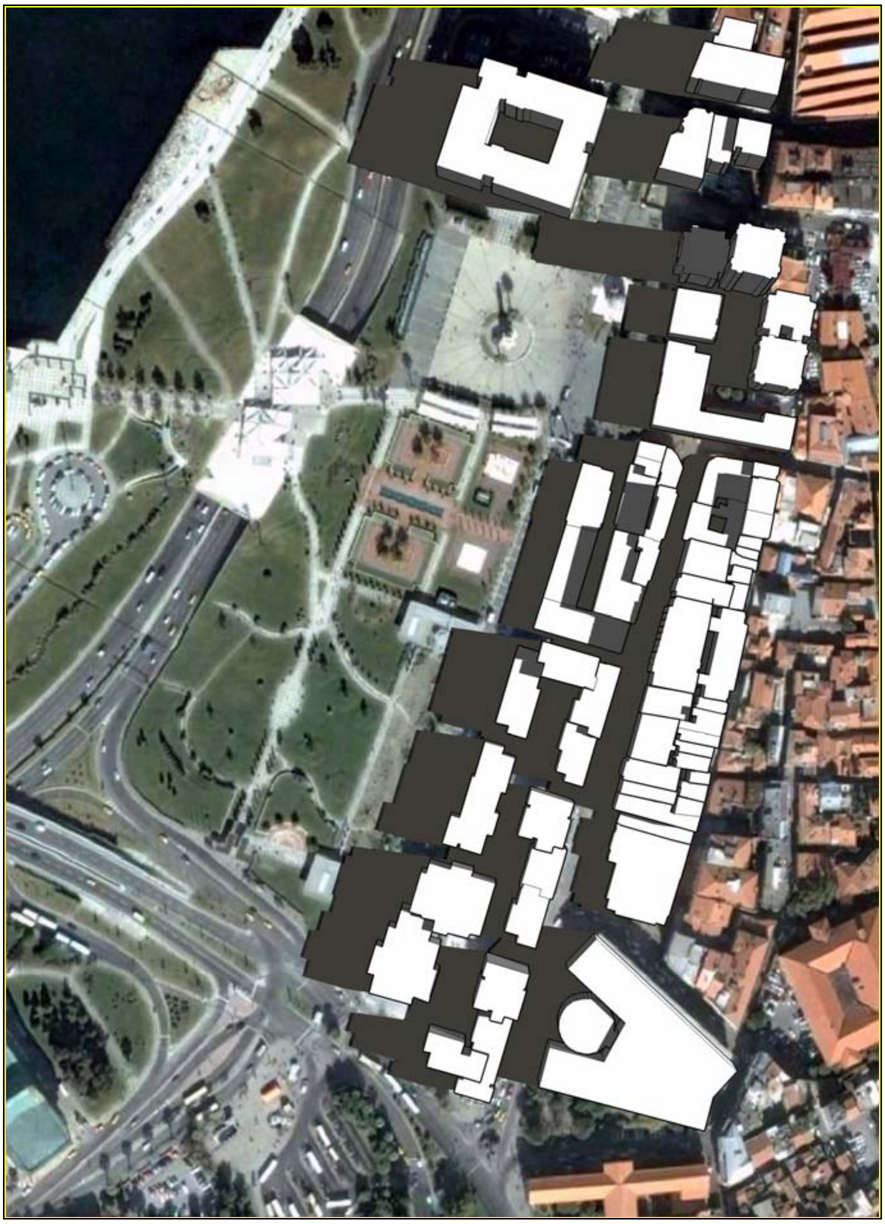

Figure 4.14. Building shadow map of morning period

Figure 4.15. A view from morning period

Figure 4.16. A view from morning period

Figure 4.17. Building shadow map of midday period

Figure 4.18. A view from midday period

Figure 4.19. A view from midday period

Figure 4.20. Building shadow map of afternoon period

Figure 4.21. A view from afternoon period

Figure 4.22. A view from afternoon period

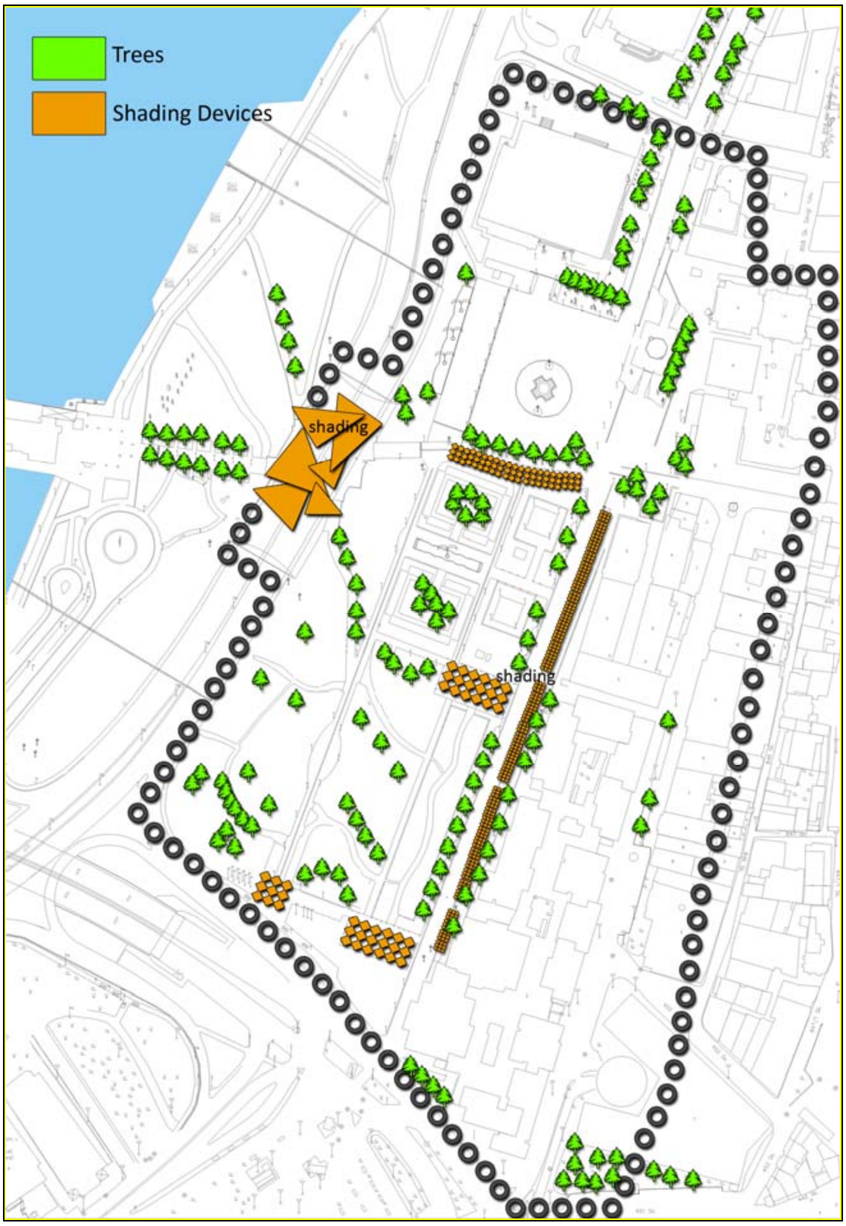

Figure 4.23. Shading elements

Figure 4.24. A view from the canopies

Figure 4.25. A view from the trees

4.1.2. Analysis of Climatic Measurements on the Site

Two climatic data set of Konak Square, are analyzed in the following two sections. The first set of climatic data, meteorological data of the August 23, has been requested from Turkish State Meteorological Service. The second set has been collected through the field measurements which have been carried out periodically around Konak Square on 23rd August 2009.

4.1.2.1. Meteorological Data

Specific data concerning the day when the field measurements were taken has been requested from TUMAS (Online Turkish State Meteorological Service). The meteorological station where the data recorded is located in Guzelyali which is situated within Konak district. The weather station is placed on a hill approximately 100m far away from the built-up area. The meteorological data concerning each environmental parameter has been grouped around four periods as follows; (Figure 4.26, Figure 4.27 and Figure 4.28)

- Average air temperature on the site shows a sudden increase in midday period while illustrating a linear decrease in afternoon and evening period. Air temperature recorded by the meteorological station gives nearly the same results in morning and afternoon periods (Figure 4.26).

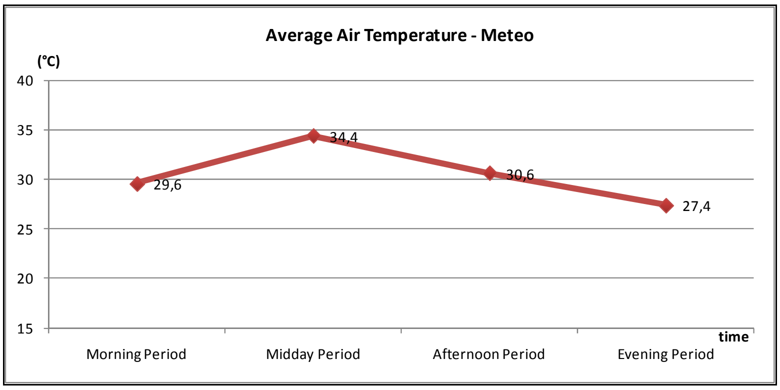

Figure 4.26. Average air temperature recorded by weather station
(Adapted by the Author, Source: Turkish State Meteorological Service-TUMAS)

▪ Average wind speed fluctuates between 2m/s and 3m/s in day periods while increasing significantly from 2m/s to 6m/s in evening period (Figure 4.27).

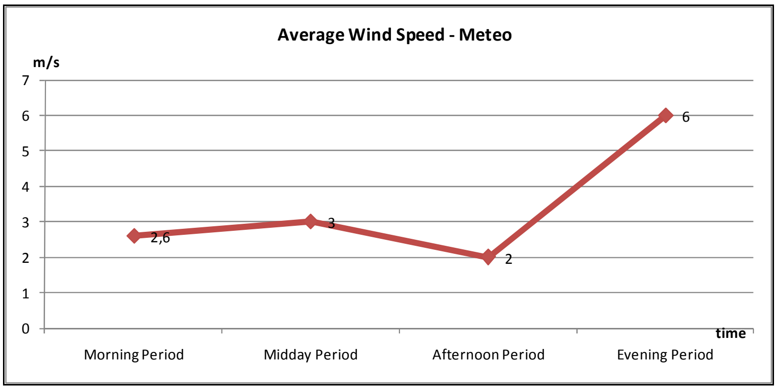

Figure 4.27. Average wind speed recorded by weather station
(Adapted by the Author, Source: Turkish State Meteorological Service-TUMAS)

▪ Average relative humidity is characterized by a sudden fall and rise in midday period. Yet, it shows similarities in other three periods (Figure 4.28).

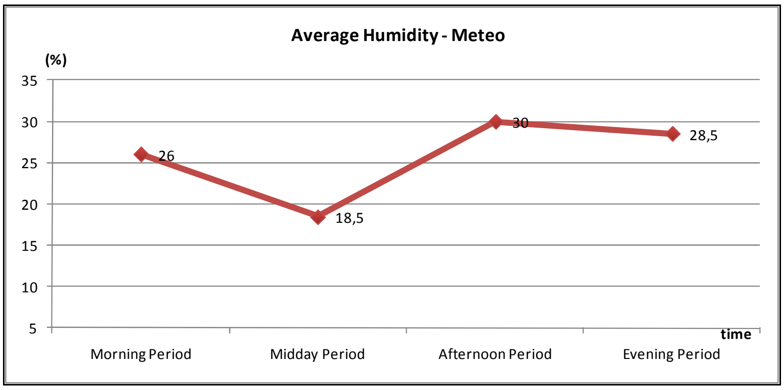

Figure 4.28. Average humidity recorded by weather station
(Adapted by the Author, Source: Turkish State Meteorological Service-TUMAS)

4.1.2.2. Field Measurements

Field measurements have been carried out periodically on 40 points around Konak Square (Figure 4.29). Air temperature and wind speed have been measured for 1.min. at each selected points throughout four periods as follows;

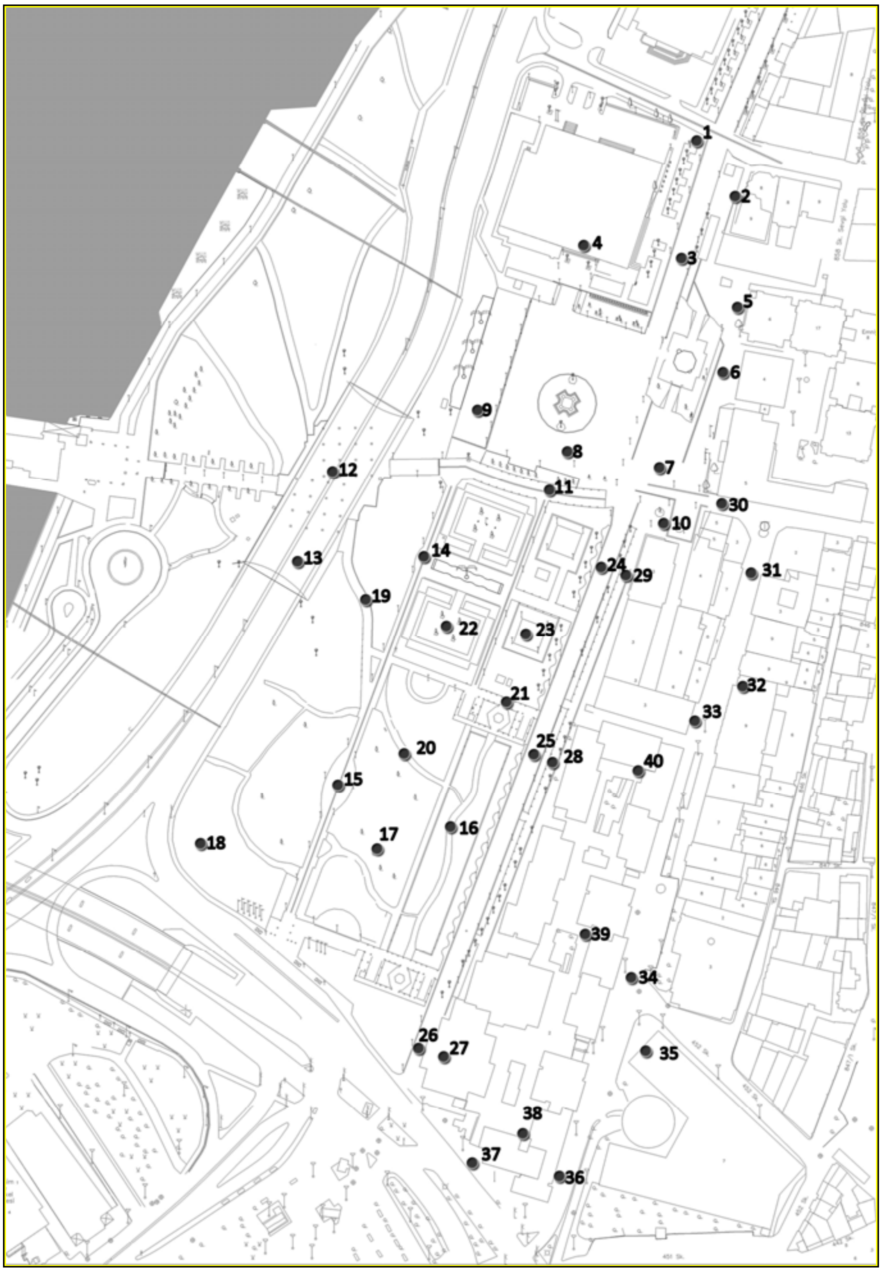

Figure 4.29. Measurement points in Konak Square

➢ **<u>Air temperature (ºC):</u>**

- **Morning period (07.50h-10.05):** The period is characterized by steady air temperature increase (Figure 4.30). However, there is a sudden jump in certain points such as 11, 15, 16, 30, and 23.
- **Midday period (12.00h-13.50h):** The period is characterized by sharp drops and increases in air temperature between 30ºC and 38ºC. However, air temperature is steady between certain points such as 26-29, 35-40 (Figure 4.30).

- **Afternoon period (16.00h-17.45h):** As it is shown in the graph that afternoon period is portrayed by different trends (Figure 4.30). Especially, the points are in the shade and in the sun significantly vary in terms of air temperature. There is an almost 6ºC air temperature difference between certain points as 1, 4 in the shade and 13 in the sun. However, the same air temperature has been measured in some locations identified with the points as 2-3-5 in the sun, 1-4 and 31-32-33-34-35-36 in the shade.
- **Evening period (20.00h-21.45h):** The period is characterized by steady air temperature fall, except some points as 28-29 and 39-40 locating within the built-up (Figure 4.30).

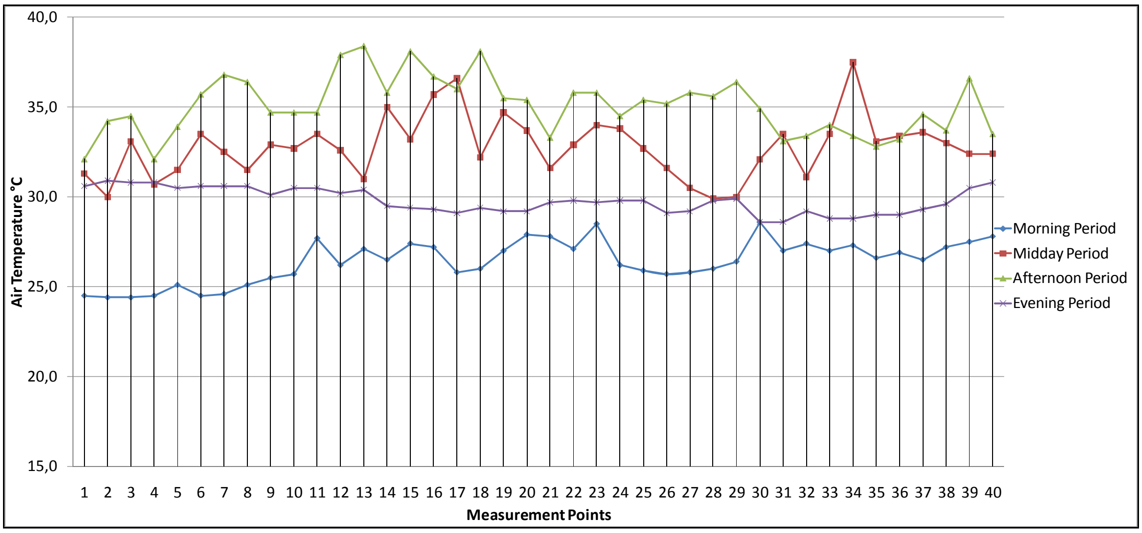

Figure 4.30. Air Temperature measured periodically in Konak Square

➢ <u>**Wind speed (m/s):**</u>

- **Morning period (07.50h-10.05):** As can be seen from the graph that the period is characterized by different air velocity regimes in different points (Figure 4.31). However, in some locations such as the ones with the following points; 2-3, 15-16-17-18, the same wind speed was measured. This is more obvious in certain locations identified by the points; 19-20-21-22-23. Besides, the measurement points; 1, 12, 26, 31, and 40 make peaks where the highest wind speed measured in the entire study area. On the other hand, there is a sudden fall in the points; 2, 5, 14, 24 and 30.
- **Midday period (12.00h-13.50h):** As can be seen from the graph that the period is characterized by sudden falls and rises (Figure 4.31). Different locations show different characteristics in terms of wind conditions. However, some points; 1, 2, 5, 7, 12, 14, 16, 20 and 28 in particular, have been measured illustrating the same wind speed.

Furthermore, wind speed has been calculated around 3m/s in the points; 13, 18 and 37, similar to what is recorded in the weather station.

- **Afternoon period (16.00h-17.45h):** As shown in the graph that the wind regime has been monitored on the site less than 2m/s of the wind speed (Figure 4.31). The point 4 illustrates relatively different wind conditions comparing to the other points.
- **Evening period (20.00h-21.45h):** As can be seen from the graph that the period is characterized by an air velocity regime with between 0m/s and 2m/s wind speed. The measurement points; 15, 18, 31 and 36 make peaks where the highest wind speed measured in the entire study area. On the other hand, there is a sudden fall nearly to 0m/s in the point 39 (Figure 4.31).

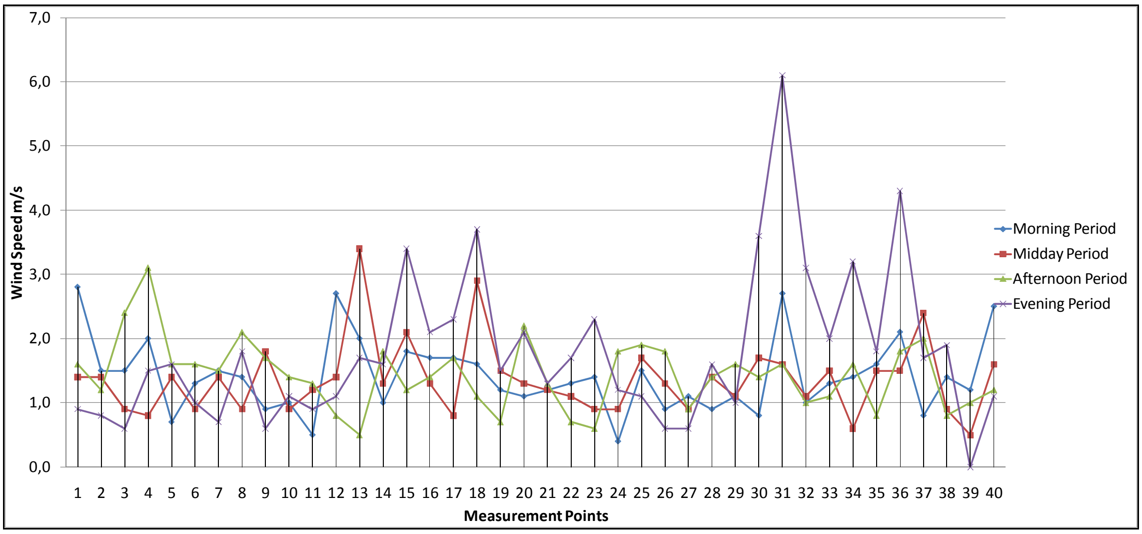

Figure 4.31. Wind speed measured periodically in Konak Square

4.2. Kızılay Square, Ankara, TURKEY

Kızılay district was planned to be serve for commercial and leisure functions. It is now appeared as the second business district of Ankara in 1980s. Kızılay Square is situated at the intersection of Ziya Gokalp Street on the east end (Kolej, Kurtulus side), Gazi Mustafa Kemal Boulevard on the west end (Demirtepe, Maltepe, Tandogan) and Ataturk Boulevard on the north-south end (Sihhiye, Ulus, Bakanliklar Kavaklidere). The study area, which is named as Kızılay Square in this work, is defined as an area bordered by Tuna Street on the north, Selanik Street on the north-east, Karanfil Street on the south-east, Meşrutiyet Street on the south and by Milli Mudafa Street on the west

(Figure 4.32). The area is surrounded by the transportation nodes; metro stations and bus stops. It is dominated mostly by governmental buildings and the shopping area. Financial institutions and high-rise office blocks are also seen along Ataturk Boulevard. There is no vehicle access in certain locations such as, Selanik and Karanfil Streets. Also, Sakarya Street on the east end perpendicular to the boulevard is only used by the pedestrians. Thus, Kızılay Square is highly accessible for everyone regarding the transportation nodes, the intersection of the major roads and the pedestrian ways.

Figure 4.32. Location of Kızılay Square in the city of Ankara
(Source: Adapted from the image from Google Earth)

4.2.1. Analysis of Spatial Structure of the Site, Kızılay Square

Kızılay Square with its surroundings is the combination of a large urban park, modern and tall building developments, and broad streets. In terms of the form of the square, the road network constitutes an important reference point in the study area. The spatial analysis has been carried out on the site 27th, 28th and 30th August 2009.

4.2.1.1. Urban Texture

The study area displays a newly planned and developed identity for Ankara as the capital of Turkey after the foundation of the republic. It is identified by the characteristics of the intersecting major roads in the center of Ankara. It is located in an area with relatively lower elevation. The high-rise building channel along the Ataturk Boulevard and lays along the south end identifies the business center characteristics of Kızılay while Guven park as a central urban park shows its leisure characteristics. The study area with its surroundings appears in the form of orthogonal parcel building blocks and the roads going between them, signifying an orthogonal grid-iron texture which is the most widespread urban texture used for territorial structuring. Other than the dominant texture on the site, different developments with low densely characteristics, which are named as Bakanlıklar, identifies the south-east part of the Square. In addition, heavy building blocks without any vacant area in between them can be seen along the north end and in the center (Figure 4.33). Height of the surrounding buildings in the study area ranges from 9m. to 69m. The area is dominated by the building height around 10-11 storey (Figure 4.36). Especially the building channel along Ataturk Boulevard is characterized by high-rise developments up to 12 storey. In contrast, the areas around Selanik Street on the north-east end, Karanfil Street on the south-east end, building heights are falling to 15-20m.

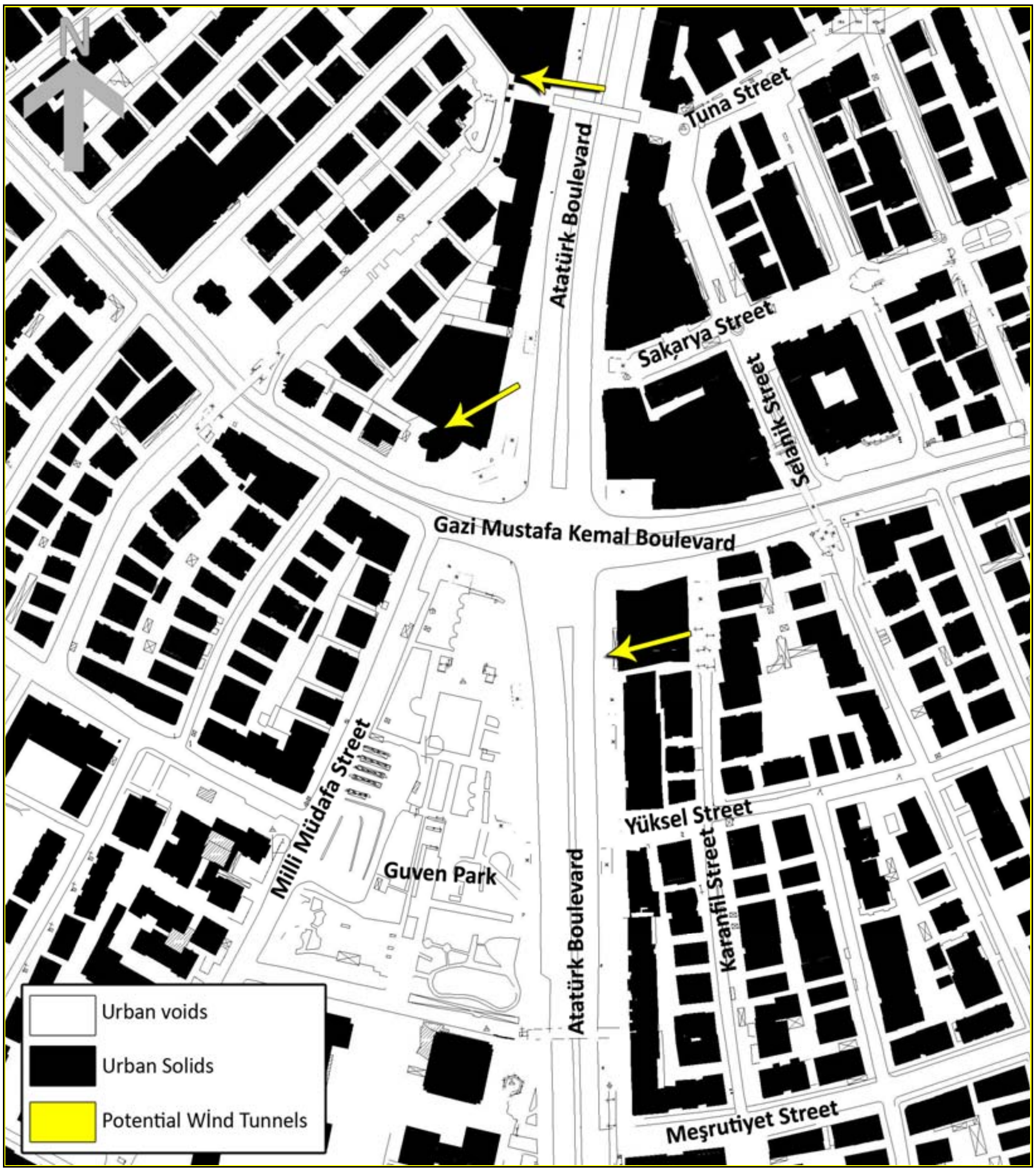

Figure 4.33. Urban texture of Kızılay Square

Figure 4.34. A view from the ground floor of the building

Figure 4.35. A view from a lot adjacent to the high-rise

Furthermore, two high-rise developments, one on the south-west corner and the other on the north-east corner of the main intersection, reinforce the business district identity of Kızılay, regarding to their heights up to 23 storey. In short, the study area is characterized by high-rises along the major roads and the average of 6-7 storey developments on the minor axis. Potential wind tunnels can be seen through the openings of the buildings at ground floor (Figure 4.34), around high-rise developments (Figure 4.35) as well as around the overpasses.

4.2.1.2. Surface Characteristics

In terms of the materials used on the surfaces of the buildings, standard materials are seen in the ratio of 65% whereas heat and sun reflective surface materials are found in the ratio of %35 on the site (Figure 4.36). Apart, nearly all of the building façades along the major roads are covered with advertisement boards which are made of highly reflective aluminum materials. The dominant color of the surrounding buildings in the study area is relatively darker colors e.g. grey. Yet, lighter colors are also seen in large number on the site.

Figure 4.36. Building height and building surface

In terms of the ground surface of the site, Kızılay Square is located at the intersection of the asphalt paved roads (Figure 4.37). The area on the west end adjacent to the park is dominated by an asphalt pavement and has been experienced as a stressful place in terms of comfort (Figure 4.38). However, the study area is dominated by stone paved minor paths, especially on the pedestrian ways on the east side of the study area. On the other hand, around 20% of the field is covered by Guven Park which is characterized by massive greening including plantings and thick trees. In addition, the pools as a waterscape can be seen along Ataturk Boulevard and in Guven Park (Figure 4.39). The sun and heat reflective lighter colored pavements are not common on the site but seen in a few locations where the excessive heat has been observed.

4.2.1.3. Use of Air Conditioning

The use of air conditioning is relatively low on the site. Nearly 40% of the buildings, specifically the buildings on the north-east end, utilize active heating and cooling systems, whereas nearly none of the buildings needs air conditioning on the north-west end (Figure 4.40). In addition, air conditioning installations at street level are mostly in dense building group on the east end. They are placed on the walls facing the pedestrian axis; Selanik Street and Karanfil Street parallel to the boulevard on the east.

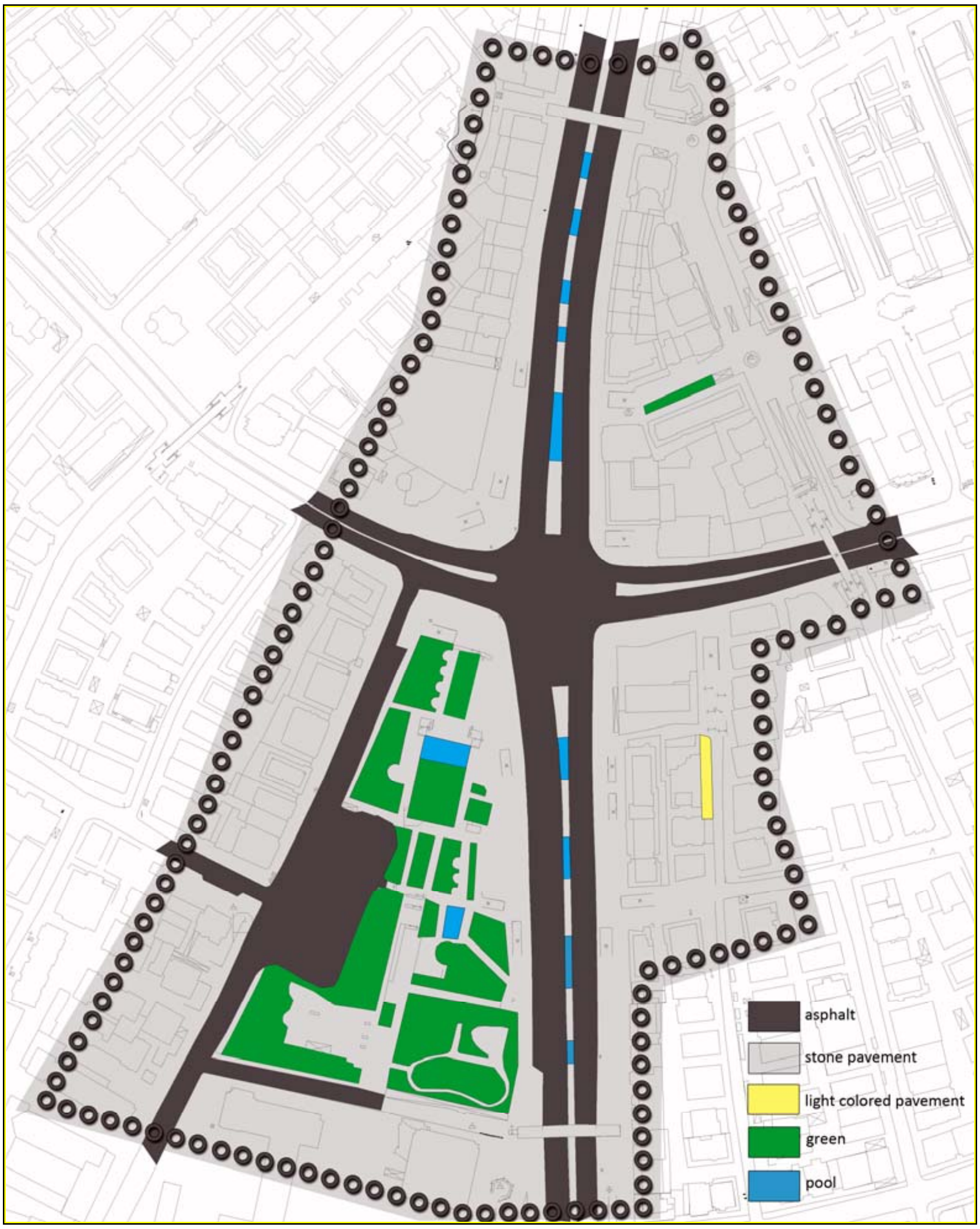

Figure 4.37. Ground surface

Figure 4.38. A view from an asphalt pavement

Figure 4.39. A view from the pools

Figure 4.40. Use of air conditioning

Figure 4.41. A view from high use of air conditioning

Figure 4.42. A view from low use of air conditioning

4.2.1.4. Shading

The investigation of the building shadows has been conducted on 28st August 2009. Three different periods and the observations due to the sun path at those periods are as follows;

- **Morning period (08.00h):** In this period, the major pedestrian axes on the east and Ataturk Boulevard leading along the north to south direction are fully in the shade (Figure 4.43). The lengths of the shadings in those areas are long enough to providing good protection from the sun over the pedestrian ways (Figure 4.44). Besides, Ziya Gokalp Street comes from the east and lead through the west is partly shaded, especially the sidewalks on the south part of the street (Figure 4.45). On the other hand, the entire urban park on the south-west cannot benefit from the shadings of its surroundings but rather from the trees planted fairly all over the place.
- **Midday period (12.00h):** In this period, the most of the study area is in the sun (Figure 4.46). At the intersection, particularly the places without any shading elements, has been observed stressful in terms of comfort (Figure 4.47). Major pedestrian axis parallel to Ataturk Boulevard on the east, cannot benefit from the mutual shading of the surrounding building walls in this period (Figure 4.48). However, Yuksel Street and the southern sidewalk of Ziya Gokalp Street are fully, Milli Mudafa Street and Ataturk Boulevard are partly in the shade due to the thick trees along.
- **Afternoon period (16.00h):** In this period, Ziya Gokalp Street fully and Ataturk Boulevard partly are in the sun (Figure 4.49). Despite Guven Park cannot benefit from the shadings of the surroundings, it is well covered by suitable types of trees (Figure 4.50). Similarly, Sakarya Street and Yuksel Streets are in the sun (Figure 4.51). Though, the trees along Yuksel Street can protect from the stressful afternoon sun.

The second map showing the shading elements are realized concerning the trees and shadings devices in the study area (Figure 4.52). No shading device has been observed in the field. On the other hand, the trees along Ataturk Boulevard (Figure 4.53) and Yuksel Street, as well as in Guven Park are monitored providing good shading opportunities. In addition, the types of the trees are suitable for shading both in the park and along the pedestrian ways (Figure 4.54). Yet, it has been observed on the site that the shadings in many important locations, as transportation nodes in particular, is lacking.

Figure 4.43. Building shadow map of morning period

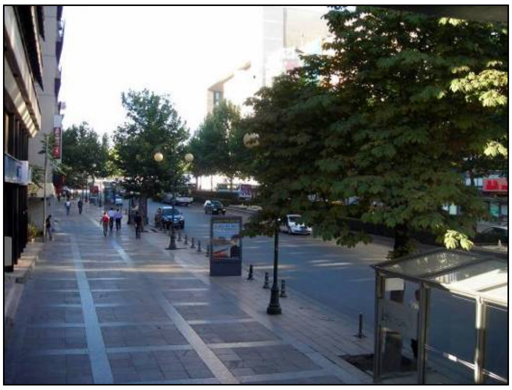

Figure 4.44. A view from Ataturk Boulevard

Figure 4.45. A view from Ziya Gokalp Street

Figure 4.46. Building shadow map of midday period

Figure 4.47. A view from the square

Figure 4.48. A view from Yuksel Street

Figure 4.49. Building shadow map of afternoon period

Figure 4.50. A view from Guven Park

Figure 4.51. A view from Sakarya Street

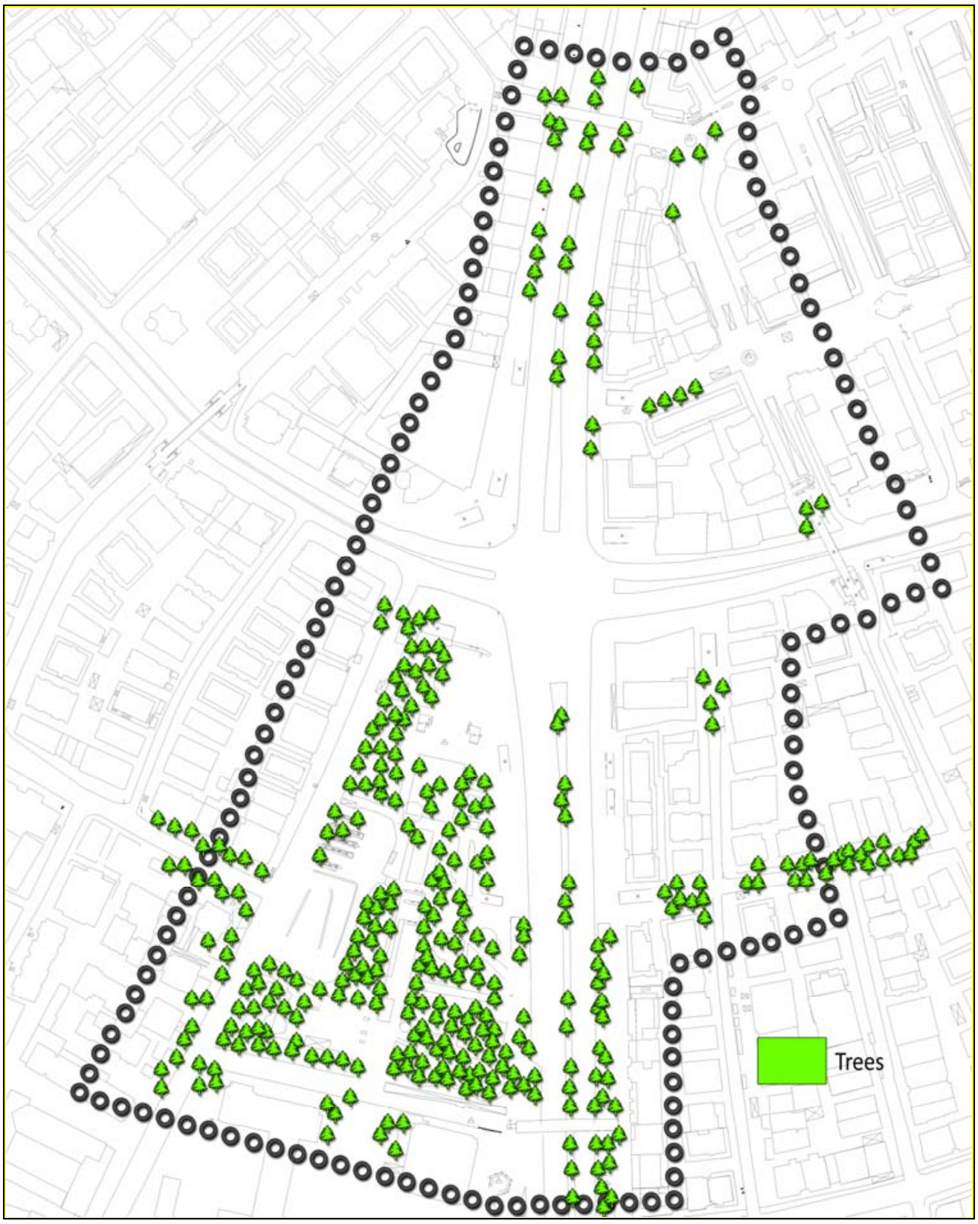

Figure 4.52. Shading elements

Figure 4.53. A view along Ataturk Boulevard

Figure 4.54. A view from Yuksel Street

4.2.2. Analysis of Climatic Characteristics on the Site

Two climatic data set of Kızılay Square will be analyzed in following two sections. The first set of climatic data, meteorological data of the August 29, has been requested from Turkish State Meteorological Service. The second set has been collected through the field measurements which have been carried out periodically around Konak Square on 29th August 2009.

4.2.2.1. Meteorological Data

Specific data concerning the day when the field measurements were taken has been requested from TUMAS (Online Turkish State Meteorological Service). The meteorological station where the data recorded is located in Kecioren District 7km. away from Kızılay Square. The weather station is placed in the campus of Turkish State Meteorological Service. The meteorological data concerning each environmental parameter has been grouped around four periods as follows; (Figure 4.55, Figure 4.56 and Figure 4.57)

- Average air temperature shows a slight increase in midday period whereas illustrating a linear decrease in evening period. As can be seen from the graph that air temperature is considerably lower at nights comparing to the day time (Figure 4.55).

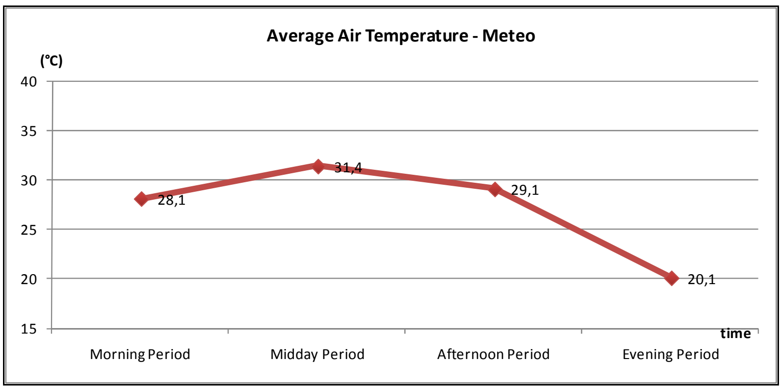

Figure 4.55. Average air temperature recorded by weather station
(Adapted by the Author, Source: Turkish State Meteorological Service – TUMAS)

▪ As shown in the graph, average wind speed gives nearly the same result in morning and midday periods. However, it drops dramatically from 2,2m/s to 1,2m/s in afternoon period and rises from 1,2m/s to 2,6m/s in afternoon period (Figure 4.56).

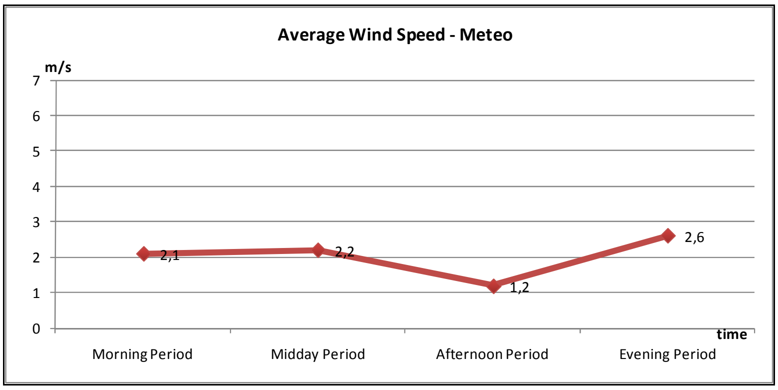

Figure 4.56. Average wind speed in recorded by weather station
(Adapted by the Author, Source: Turkish State Meteorological Service - TUMAS)

▪ Average relative humidity slightly falls in midday period while dramatically rises in evening period. It shows the same results in morning and afternoon periods (Figure 4.57).

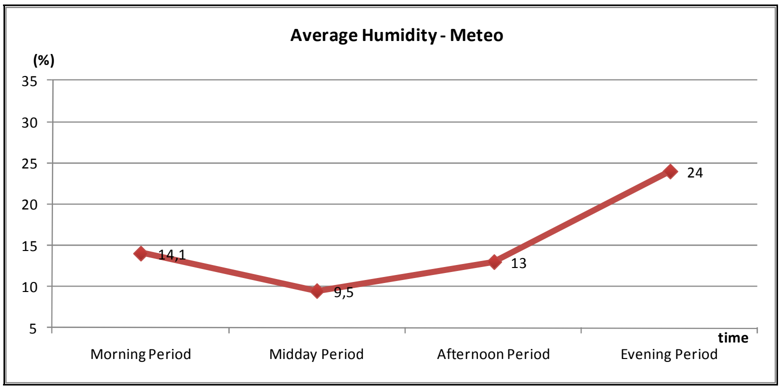

Figure 4.57. Average humidity in recorded by weather station
(Adapted by the Author, Source: Turkish State Meteorological Service - TUMAS)

4.2.2.2. Field Measurements

Field measurements, concerning air temperature and wind speed, have been carried out periodically on 40 points around Kızılay Square (Figure 4.58). The points 10, 22 and 32 refer to three different types of overpasses in the study area. Air temperature and wind speed have been measured for 1.min. at each selected points throughout four periods as follows;

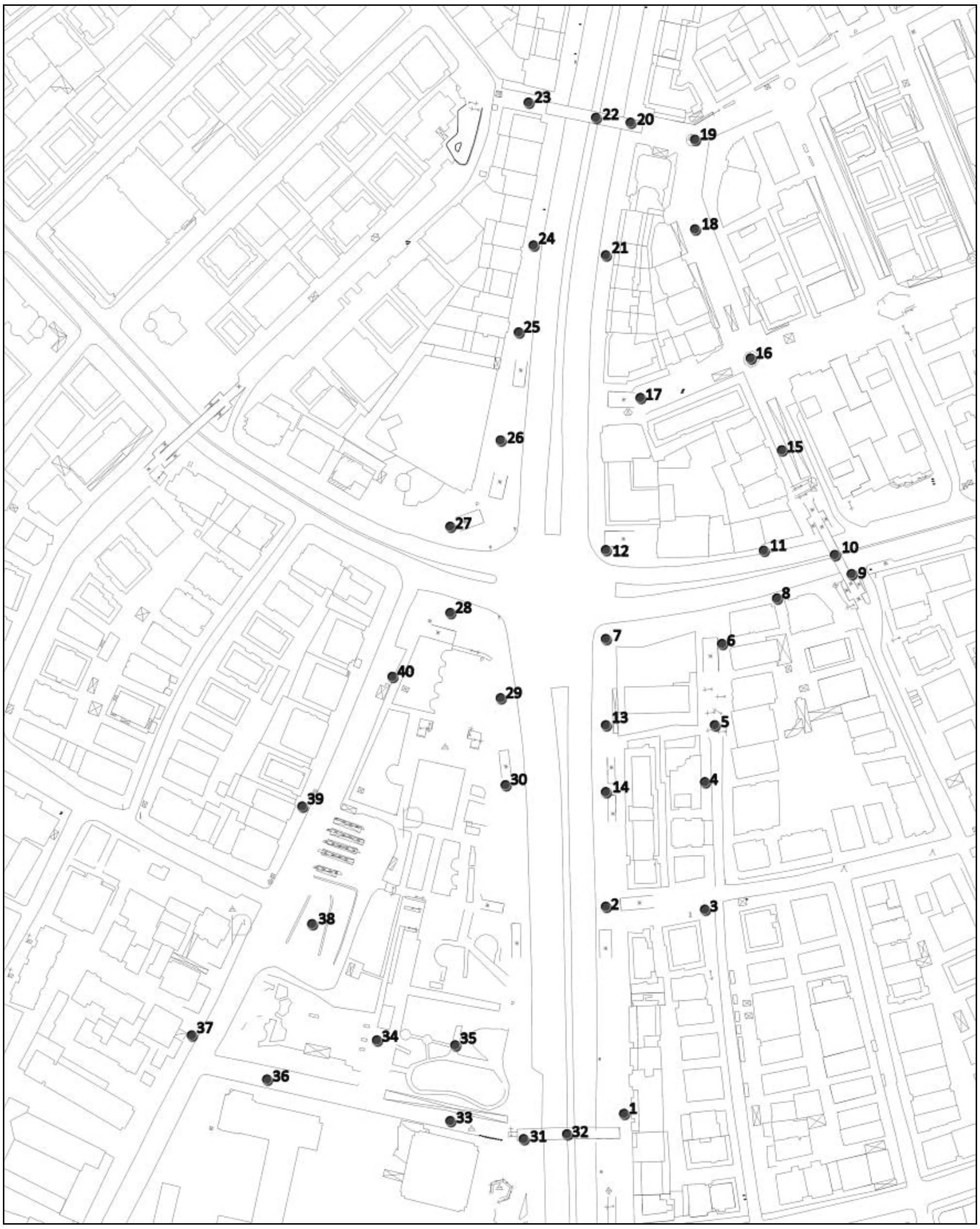

Figure 4.58. Measurement points in Kızılay Square

- **Air temperature (ºC):**

- **Morning period (07.45h-09.40):** The period is characterized by steady air temperature increase (Figure 4.59). However, there is a sudden jump at certain points such as 11-12 and 26-27-28-30-32.

- **Midday period (12.00h-13.40h):** The period is characterized by a fluctuation in air temperature between 30ºC and 35ºC (Figure 4.59). However, air temperature is steady between certain points such as 7-8-9, 19-20-21-22-23 and 35-36-37-38-39-40
- **Afternoon period (16.00h-17.35h):** As it is shown in the graph that afternoon period is portrayed by different trends again ranging between 30ºC and 35ºC (Figure 4.59). Even different points are in the shade, they show nearly 5ºC air temperature differences. Yet, the same air temperature has been measured in some locations identified with the points as 11-12 in the sun and 37-38-39-40 in the shade.
- **Evening period (20.00h-21.35h):** The period is characterized by air temperature fall but not steady (Figure 4.59). The measurement points following each other give different temperature results ranging up to 2 ºC. Air temperature is stable between certain points representing the same locations which are 8-9, 11-12, 15-16, 23-24-25, 26-27-28 and 37-38-39-40.

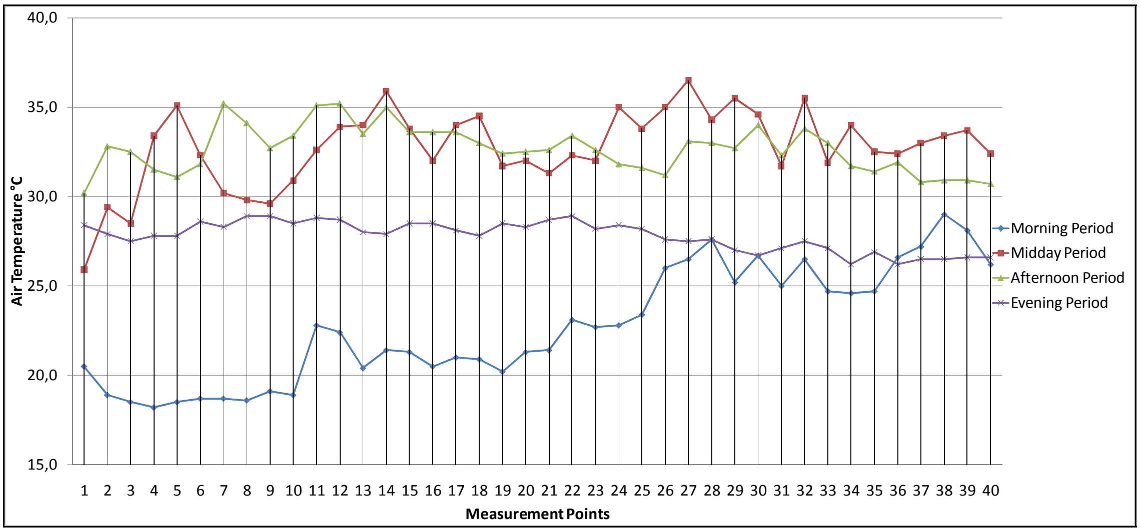

Figure 4.59. Air Temperature measured periodically in Kızılay Square

➢ <u>**Wind speed (m/s):**</u>

- **Morning period (07.45h-09.40):** As can be seen from the graph that the period is characterized by different air velocity regimes in different points (Figure 4.60). However, the same wind speed was measured in some locations such as the ones with the following points; 4-6-15-26-34, 3-21-33 and 14-16-23-30. This is more obvious in certain locations identified by the points; 8-12. Besides, the measurement points; 8, 10, 11 and 27 make peaks where the highest wind speed measured in the entire study area. On the other hand, there is a sudden fall in the points; 1, 3, 5, 7, 22, 32 and 38.

▪ **Midday period (12.00h-13.40h):** As can be seen from the graph that the period is characterized by sudden falls and rises (Figure 4.60). Each point has its own velocity characteristics in terms of wind conditions. The measurement points; 13, 25 and 30 make peaks where the highest wind speed measured in the entire study area. In certain locations characterized by the points; 5, 22 and 32, the wind speed reaches 0m/s.

▪ **Afternoon period (16.00h-17.35h):** As shown in the graph (Figure 4.60) that this period has considerably different wind conditions for different points. In certain locations characterized by the points; 6, 22 and 32, the wind speed again reaches 0m/s.

▪ **Evening period (20.00h-21.35h):** As can be seen from the graph that the period is characterized by a low air velocity regime with between 0m/s and 1,2m/s wind speed (Figure 4.60). Some points such as; 2-5-8-12, 17-19 and 25-27 have been monitored representing different locations yet they show similar characteristics in terms of wind conditions.

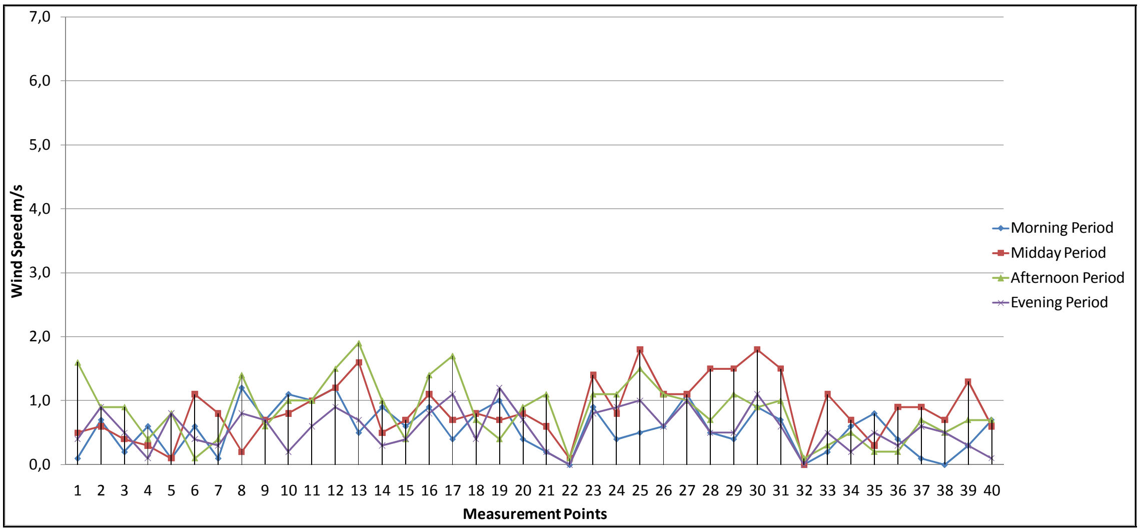

Figure 4.60. Wind speed measured periodically in Kızılay Square

4.3. Evaluation and Comparison

In this section, urban patterns of two case areas, Konak Square and Kızılay Square, will be evaluated and compared in terms of their climate sensitivity, considering their spatial characteristics and the taken climatic measurements. This will help us to see the problems and opportunities with the existing urban patterns, in a typical summer period. The evaluation and comparison will include;

- Comparison of the site air temperature measured periodically at each point (field measurements) with actual air temperature retrieved from the meteorological station (meteorological data) and comparison of site wind speed measured periodically at each point (field measurements) with actual wind speed retrieved from the meteorological station (meteorological data).
- Evaluation of the spatial structure in relation to the given comparisons. The evaluation for each case area amalgamates the results from the comparison with the synthesis of the given analyses in previous sections; urban texture, surface characteristics, use of air conditioning and shading.

4.3.1. Field Measurements versus Meteorological Data

In this section, climatic data that was collected for 40 measurement points on each site through the field measurements around four periods of a day has been compared with the data retrieved from the meteorological station, concerning two environmental parameters; air temperature and wind speed. The comparison has been explained in details around four periods and then presented in the tables (Table 4.3 and Table 4.4). Since each measurement point represents a different sort of spatial organization on the site, the location and spatial characteristics of each measurement point are given in the tables to justify the reasons of why those environmental parameters differ on the site, comparing to the meteorological records. Following, the results have been compared in terms of certain climate sensitive objectives for the summer season.

Konak Square-Izmir:

- **Morning period:** All measurement points perform below the average air temperature, 29.6ºC, of that period recorded by the weather station. Yet, the sudden jumps measured in certain points such as 11, 15, 16, 23, and 30. Specifically, the point 11 refers to an area which is half-shaded by a transparent shading device. The points 15 and 16 refer to the same location in the open green area without any shading elements and where none of the buildings provide shading. The point 16, particularly, is located in the area of where the ground pavement is soil. This location has been experienced considerably dry and hot. Especially, the point 23 is exposure to the direct sun light, since the ground surface of the area which it refers to is covered by a highly sun and heat reflective material. In addition, the point 30 cannot benefit from the mutual shadings of the surroundings in this period and situated in a densely location.

%92 of the measurement points performs below the average wind speed, 2.6m/s, of that period recorded by the weather station. Measured wind speed on the points; 1g, 12g and 31g, are above the average wind speed recorded by the weather station. Specifically, the point 1g and 31g are located in the areas which are open to the prevailing wind. The tall buildings surrounding the point 1g and the characteristics of the street canyon of the point 31g have an accelerating effect on the wind speed coming from the sea.

- **Midday period:** %87 of the measurement points performs below the average air temperature, 34.4ºC, of that period recorded by the weather station. The points; 14, 16, 17, 19 and 34 shows warmer climate characteristics comparing to the meteorological data due to their physical characteristics. Specifically, the points; 14, 16, 17 and 19 are located in the open green area which is lacking of adequate shading. This is also due to the fact that open areas can get warmer or cooler quicker comparing to the built-up areas. Also, the area which they partly represent cannot benefit from the building shadow seen in this period. The point 34 refers to an area which is nearby the asphalt paved road and also has no shading devices or trees to shade in this period when the building shadow has no effect on the site.

%97 of the measurement points performs below the average wind speed, 3m/s, of that period recorded by the weather station. Only at the point 13 has been monitored showing the wind speed above the average, since this location is open to prevailing wind as being on a relatively elevated platform over the major road. It has been seen monitored that elevated places catch more wind comparing to their surroundings. The point refers to an area which is not being affected by the built-up area in the square in terms of the wind conditions.

- **Afternoon period:** All measurement points perform above the average air temperature, 30.6ºC, of that period recorded by the weather station. The air temperature differs enormously among the points in this period, since there are limited shading opportunities on the site. In general, building shadows are not effective on shading the entire site but only on the certain points due to the direction of the sun in this period. In particular, regarding the enormous air temperature difference between those points 1, 4 in the shade and 13 in the sun; the points 1g and 4g can benefit from the building shadow while there is no shading around the point 13 refers to. Moreover, the area which the point 13 refers to is characterized by a bare place that is fully exposure to the sun as well as is largely paved by the sun and heat reflective materials.

%87 of the measurement points performs below the average wind speed, 2m/s, of that period recorded by the weather station. The points have been recorded above the average are; 3, 4g, 8, 20 and 37g. Even though they mainly refer to the areas with different physical settings, those points are open to the prevailing wind blowing from the sea to the coast in this period. Yet, the point 4 represents the area locating nearby the possible wind tunnel caused by the municipality building's structure

- **Evening period:** All measurement points perform far above the average air temperature, 27.4ºC, of that period recorded by the weather station. Especially, the points 28, 29 and 39, 40 locating in the area which is characterized by the massive building groups show relatively higher air temperature comparing to the other points on the site. This is because built-up area starts to release the heat, which is absorbed throughout the day period, to the air in evening period. Moreover, the use of air conditioning is high and their installations are excessively seen at street level in this area that those points refer to.

%97 of the measurement points performs below the average wind speed, 6m/s, of that period recorded by the weather station. The measurement points; 15, 18, 31 and 36 make peaks where the highest wind speed measured in the entire study area. While the points 15 and 18 refer to an open green area where no built-up element can block the wind, the points 31 and 36 represent the area which characterized by a street canyon that helps with accelerating the wind speed. Besides, the point 39 where is a sudden fall to nearly 0m/s has been measured refers to the area that is characterized by a massive buildings which block the wind.

Kızılay Square-Ankara:

- **Morning period:** %95 of the measurement points performs below the average air temperature, 28.1ºC, of that period recorded by the weather station. Air temperature has been measured above the average at following points; 38 and 39. Those points represent the same location which cannot benefit from the mutual shading provided by the buildings. Moreover, that location is situated nearby the asphalt paved road and the area used as bus station. Even though the location is close to Guven Park, it cannot benefit from the cooling effect of the trees or landscape either. Besides, the sudden jumps measured in certain points such as 11, 12, 26, 27, 28, 30 and 32. All of those points are in the sun. Specifically, the points 11 and 12 refer to the sidewalk which is exposure to the sun. Comparing to the other sidewalk along the same road, those particular locations cannot benefit from the building shadow. Similarly, the points 26, 27, 28, and 30 represent a bare area where has no shading devices and trees to protect from the sun. In addition, they are located nearby the asphalt paved major road. The point 32 refers to an overpass which is covered by plastic windows where the most stressful thermal conditions have been observed.

All of the measurement points perform below the average wind speed, 2.1m/s, of that period recorded by the weather station. The highest wind speed measured in the entire study area has been recorded at the points; 8, 12 and 27. Those points represent the major road cutting through the site along the west-east orientation. This channel-like road with detached tall buildings on each side of accelerates the wind speed.

- **Midday period:** %80 of the measurement points performs above the average air temperature, 31.4ºC, of that period recorded by the weather station. The points recorded below the average are 1g, 2, 3g, 7g, 8g, 9g, 10 and 21. They show cooler climate characteristics comparing to the meteorological data due to their physical characteristics. Those points can benefit from the building shadow. The layout of the site helps the buildings with providing shading to certain extend even in the midday period. It has been found that the layout of the site, grid-like layout in diagonal orientation, helps the buildings with providing shading even in the midday period.

All of the measurement points perform below the average wind speed, 2.2m/s, of that period recorded by the weather station. The highest wind speed measured in the entire study area has been recorded at the points; 13, 25 and 30. Those points are located close to the possible wind tunnels monitored on the site. The points 13 and 30 are situated nearby the 69m. tall high-rise while the point 30 is in front of the vacant lot near the tall building. Thus, tall buildings can accelerate wind speed to a large extend. Moreover, in certain locations characterized by the points; 5, 22 and 32, the wind speed reaches 0m/s. The location which the point 5 represents is characterized by relatively low elevation where the wind speed has been monitored slowing down. Similarly, the overpasses which the points 22 and 32 refer to are always lacking of air circulation, since they are closed.

- **Afternoon period:** All measurement points perform above the average air temperature, 29.1ºC, of that period recorded by the weather station. The air temperature differs enormously among the points; 11-12 in the sun and 37g, 38g, 39g-and 40g in the shade. Those points in the sun refer to the sidewalk along the asphalt paved major road.

There is no planting or shading along that sidewalk. In addition, it cannot benefit from the building shade due to the layout. Besides, the points 37g, 38g, 39g-and 40g represent the location close to Guven Park where is a vast of trees provides relatively cooler environment. However, this location benefits from the building shadow on the west end rather than the trees on the east end due to the sun direction in this period. Also, the shading of the buildings dominates the negative effect of the asphalt pavement along the road.

%82 of the measurement points performs below the average wind speed, 1.2m/s, of that period recorded by the weather station. The points; 1g, 8, 12, 13, 16, 17 and 25g have been recorded performing above the average. The points 1g-13, 8-12 and 16-17 represent the locations on the wide linear axes along the east-west and north-south orientations. Again, in certain locations characterized by the points; 6, 22 and 32, the wind speed reaches 0m/s.

- **Evening period:** All measurement points perform far above the average air temperature, 20.1ºC, of that period recorded by the weather station. Almost the same air temperature has been recorded the same locations which are identified by the points; 8-9, 11-12, 15-16, 23-24-25, 26-27-28 and 37-38-39-40. The points; 8, 9, 11 and 12 are along the asphalt paved road which is surrounded by channel-like building groups. The points; 15 and 16 refer to the street canyon where there is a massive air conditioning installation at street level. Also, the points; 23, 24 and 25 refers to the location nearby the building while 26, 27, and 28 represent the location adjacent to Guven Park along the same boulevard. In addition, the points 37, 38, 39 and 40 is located on the asphalt paved street bordering the green area and covered by the thick trees along.

All of the measurement points perform below the average wind speed, 2,6m/s, of that period recorded by the weather station. The points; 17 and 19 give the same wind speed even though they represent different locations. However, the both are located along the axes with the west-east direction. Again, the same wind speed has been recorded at the points; 8 and 12, representing different location but with the same direction. The points; 25 and 27 also give the same wind speed results since they both are located nearby the building which has a huge opening at the ground floor that causes wind tunnel at the street level.

Table 4.3. Field measurements versus meteorological data in Konak Square / Izmir

Measurement Points	Location and spatial characteristics of the Points		Wind Speed (m/s)				Air Temperature (°C)			
			Morning	Midday	Afternoon	Evening	Morning	Midday	Afternoon	Evening
			Meteo: 2,6	Meteo: 3	Meteo: 2	Meteo: 6	Meteo: 29,6	Meteo: 34,4	Meteo: 30,6	Meteo: 27,4
			On-site	On-site	On-site	On-site	On-site	On-site	On-site	On-site
1	Along the same axis but different sides of the street	Open to the prevailing wind, in the intersection with the other street	2,8	1,4	1,6	0,9	24,5	31,3	32,1	30,6
2		Nearby the tall building group	1,5	1,4	1,2	0,8	24,4	30,0	34,2	30,9
3		In front of a vacant lot	1,5	0,9	2,4	0,6	24,4	33,1	34,5	30,8
4	On the ground floor of the city hall, open along the north-south orientation		2,0	0,8	3,1	1,5	24,5	30,7	32,1	30,8
5	Along the same direction, nearby the same building group	Open to the coast	0,7	1,4	1,6	1,6	25,1	31,5	33,9	30,5
6		Blocked by a group of tree on the west	1,3	0,9	1,6	1,0	24,5	33,5	35,7	30,6
7	Along the same west-east direction, open to the prevailing wind, no shading devices	More close to the buildings	1,5	1,4	1,5	0,7	24,6	32,5	36,8	30,6
8		In the middle of the bare square	1,4	0,9	2,1	1,8	25,1	31,5	36,4	30,6
9		Nearby the pool	0,9	1,8	1,7	0,6	25,5	32,9	34,7	30,1
10	Under a big grown tree, close by the buildings		1,0	0,9	1,4	1,1	25,7	32,7	34,7	30,5
11	Half-shaded by a transparent shading device, paved by stone		0,5	1,2	1,3	0,9	27,7	33,5	34,7	30,5
12	Open to prevailing wind, on a relatively elevated platform paved by the sun and heat reflective materials, away from the buildings	Shaded by a sail type of shading devices	2,7	1,4	0,8	1,1	26,2	32,6	37,9	30,2
13		A bare place exposure to the direct sun light	2,0	3,4	0,5	1,7	27,1	31,0	38,4	30,4
14	Blocked by the trees parallel to the coast, by the pool, without any shading, paved by stone		1,0	1,3	1,8	1,6	26,5	35,0	35,8	29,5

(cont. on next page)

Table 4.3. (cont.)

15	An open green area without any shading elements, away from the buildings	Ground pavement is stone	1,8	2,1	1,2	3,4	27,4	33,2	38,1	29,4
16		Ground pavement is soil, with a specially designed area consisting of cactuses	1,7	1,3	1,4	2,1	27,2	35,7	36,7	29,3
17		Ground pavement is green-grass	1,7	0,8	1,7	2,3	25,8	36,6	36,0	29,1
18		Located on relatively higher elevation	1,6	2,9	1,1	3,7	26,0	32,2	38,1	29,4
19		Along the north-west direction, ground pavement is soil	1,2	1,5	0,7	1,5	27,0	34,7	35,5	29,2
20		Along the north-west direction, ground pavement is stone	1,1	1,3	2,2	2,1	27,9	33,7	35,4	29,2
21	With totally different settings in the same location	Along the west-east axis, under a shading device, paved by stone material	1,2	1,2	1,3	1,3	27,8	31,6	33,3	29,7
22		Under a massive group of tree, paved by stone material	1,3	1,1	0,7	1,7	27,1	32,9	35,8	29,8
23		Paved by a highly sun and heat reflective material, no shading	1,4	0,9	0,6	2,3	28,5	34,0	35,8	29,7
24	Along the north-south orientation, paved by stone material, the area between the green open space and buildings	Along the same direction, the following points, no shading	0,4	0,9	1,8	1,2	26,2	33,8	34,5	29,8
25			1,5	1,7	1,9	1,1	25,9	32,7	35,4	29,8
26			0,9	1,3	1,8	0,6	25,7	31,6	35,2	29,1
27		Along the same direction, the following points, closer to the building groups, under the shading devices	1,1	0,9	0,9	0,6	25,8	30,5	35,8	29,2
28			0,9	1,4	1,4	1,6	26,0	29,9	35,6	29,8
29			1,1	1,1	1,6	1,0	26,4	30,0	36,4	29,9
30	Densely location, open to the prevailing wind, street canyon, lower height to width ratio		0,8	1,7	1,4	3,6	28,6	32,1	34,9	28,6

(cont. on next page)

Table 4.3. (cont.)

31	Along the north-south orientation, paved by stone material, the area between two attached and tall building groups, no shading, low height to width ratio, blocked by a building row parallel to the coast	Starting point of the street canyon	2,7	1,6	1,6	6,1	27,0	33,5	33,1	28,6
32		In front of the corridor through the ground floor of the building	1,0	1,1	1,0	3,1	27,4	31,1	33,4	29,2
33		In front of the corridor through the ground floor of the building opens to the coast	1,3	1,5	1,1	2,0	27,0	33,5	34,0	28,8
34		Nearby the asphalt paved road, intersection	1,4	0,6	1,6	3,2	27,3	37,5	33,4	28,8
35		In front of the corridor through the ground floor of the building	1,6	1,5	0,8	1,8	26,6	33,1	32,8	29,0
36		Ending point of the street canyon, near by a tall building	2,1	1,5	1,8	4,3	26,9	33,4	33,2	29,0
37	Nearby the major asphalt paved road, half-shaded by the trees, along the southwest-northeast direction		0,8	2,4	2,0	1,7	26,5	33,6	34,6	29,3
38	Characterized by many massive building groups, high use of air conditioning in the buildings	In front of the corridor through the ground floor of the building	1,4	0,9	0,8	1,9	27,2	33,0	33,7	29,6
39		Air cond. Installations are excessively seen at street level	1,2	0,5	1,0	0.5	27,5	32,4	36,6	30,5
40		In front of the corridor through the ground floor of the building	2,5	1,6	1,2	1,1	27,8	32,4	33,5	30,8

Table 4.4. Field measurements versus meteorological data in Kızılay Square / Ankara

Measurement Points	Location and spatial characteristics of the Points		Wind Speed (m/s)				Air Temperature (°C)			
			Morning	Midday	Afternoon	Evening	Morning	Midday	Afternoon	Evening
			Meteo: 2,1	Meteo: 2,2	Meteo: 1,2	Meteo: 2,6	Meteo: 28,1	Meteo: 31,4	Meteo: 29,1	Meteo: 30,1
			On-site	On-site	On-site	On-site	On-site	On-site	On-site	On-site
1	Along the north-south orientation, near by a major boulevard paved by asphalt material	Under a large group of tree, in front of the tall attached building group	0,1	0,5	1,6	0,4	20,5	25,9	30,2	28,4
2		In the intersection with the minor axis along the west-east direction, starting point of the street canyon, no shading	0,7	0,6	0,9	0,9	18,9	29,4	32,8	27,9
3	Along the north-south oriented street parallel to the major axis	In the intersection with the minor axes along the west-east and north-south direction, under the grown trees	0,2	0,4	0,9	0,5	18,5	28,5	32,5	27,5
4		Paved by the sun and heat reflective materials, no shading	0,6	0,3	0,4	0,1	18,2	33,4	31,5	27,8
5		By relatively low elevation, half-shaded by the trees	0,1	0,1	0,8	0,8	18,5	35,1	31,1	27,8
6		In front of the vacant lot in between the tall buildings, no shading	0,6	1,1	0,1	0,4	18,7	32,3	31,8	28,6
7	Along the asphalt paved road cutting through the site along the west-east orientation, surrounded by channel-like building groups, no shading	In the intersection with the other crossing major axis (south side)	0,1	0,8	0,4	0,3	18,7	30,2	35,2	28,3
8		In front of the tall building group (south side)	1,2	0,2	1,4	0,8	18,6	29,8	34,1	28,9
9		Under the overpass, by the east to west oriented road	0,7	0,7	0,6	0,7	19,1	29,6	32,7	28,9

(cont. on next page)

Table 4.4. (cont.)

10	Along the asphalt paved road cutting through the site along the west-east orientation, surrounded by channel-like building groups, no shading	Upon the overpass which is open	1,1	0,8	1,0	0,2	18,9	30,9	33,4	28,5
11		In front of the tall building group (north side)	1,0	1,0	1,0	0,6	22,8	32,6	35,1	28,8
12		In the intersection with the other crossing major axis (north side)	1,2	1,2	1,5	0,9	22,4	33,9	35,2	28,7
13	Along the north-south orientation, near by a major boulevard paved by asphalt material, no shading	In front of the 69m. Tall high-rise, ground surface is stone	0,5	1,6	1,9	0,7	20,4	34,0	33,5	28,0
14		In front of the tall building group	0,9	0,5	1,0	1,0	21,4	35,9	35,0	27,9
15	Along the orthogonal axis with northwest-southeast orientation	In the street canyon where there is a massive air conditioning installation at street level	0,6	0,7	0,4	0,4	21,3	33,8	33,6	28,5
16		In the intersection with the minor axes along the northwest-southeast and northeast-southwest directions, a bare location, no shading	0,9	1,1	1,4	0,8	20,5	32,0	33,6	28,5
17	Street canyon, surrounded by row building groups with 5-6 storey, no shading		0,4	0,7	1,7	1,1	21,0	34,0	33,6	28,1
18	Along the orthogonal axis with northwest-southeast orientation, no shading, surrounded by the tall building groups		0,8	0,8	0,7	0,4	20,9	34,5	33,0	27,8
19	In the intersection of the three axes with the north-south, northwest-southeast and northeast-southwest directions, no shading, ground pavement is stone		1,0	0,7	0,4	1,2	20,2	31,7	32,4	28,5
20	Along the north-south orientation, near by a major boulevard paved by asphalt material	Under the overpass, by the road	0,4	0,8	0,9	0,7	21,3	32,0	32,5	28,3

(cont. on next page)

Table 4.4. (cont.)

21	Along the north-south orientation, near by a major boulevard paved by asphalt material	In front of the attached tall building group, no shading, ground surface is stone	0,2	0,6	1,1	0,2	21,4	31,3	32,6	28,7
22	In the overpass designed as a closed space with the plastic material, no air circulation		0,0	0,1	0,1	0,0	23,1	32,3	33,4	28,9
23	Street canyon, low height to width ratio, open to the wind along the east-west orientation		0,9	1,4	1,1	0,8	22,7	32,0	32,6	28,2
24	A bare area where has no shading devices or trees, nearby the asphalt paved major road along the north-south orientation	In front of the attached tall building group	0,4	0,8	1,1	0,9	22,8	35,0	31,8	28,4
25		In front of the vacant lot in between the tall buildings	0,5	1,8	1,5	1,0	23,4	33,8	31,6	28,2
26		In front of a massive building with huge opening at the ground floor	0,6	1,1	1,1	0,6	26,0	35,0	31,2	27,6
27			1,1	1,1	1,0	1,0	26,5	36,5	33,1	27,5
28		The location adjacent to Guven Park, ground pavement is stone	0,5	1,5	0,7	0,5	27,6	34,3	33,0	27,6
29			0,4	1,5	1,1	0,5	25,2	35,5	32,7	27,0
30		Those points are located close to the possible wind tunnels monitored on the site, 69m. Tall high-rise	0,9	1,8	0,9	1,1	26,7	34,6	34,0	26,7
31	Under the overpass, by the north to south oriented road		0,7	1,5	1,0	0,6	25,0	31,7	32,3	27,1
32	In the overpass designed as a closed space with the plastic material, no air circulation		0,0	0,0	0,1	0,0	26,5	35,5	33,8	27,5
33	In between the building and park, no shading, paved by stone material		0,2	1,1	0,3	0,5	24,7	31,9	33,0	27,1
34	In Guven Park, away from the buildings, thick trees around	Paved by stone material, no shading	0,6	0,7	0,5	0,2	24,6	34,0	31,7	26,2
35		In the playground, under a large group of tree	0,8	0,3	0,2	0,5	24,7	32,5	31,4	26,9

(cont. on next page)

Table 4.4. (cont.)

36	In a narrow street used as a small parking area by minibuses, covered by asphalt, no shading		0,4	0,9	0,2	0,3	26,6	32,4	31,9	26,2
37	By the northeast-southwest oriented street parallel to the major axis covered by asphalt, the tall building group on the east side, Guven Park on the other side, no shading	Ground pavement is stone, in front of the tall building group, facing the minor axis along the northwest-southeast orientation	0,1	0,9	0,7	0,6	27,2	33,0	30,8	26,5
38		Ground pavement is asphalt, in the area used as a bus stop	0,0	0,7	0,5	0,5	29,0	33,4	30,9	26,5
39		Ground pavement is stone, in front of the tall building group, facing the minor axis along the northwest-southeast orientation	0,3	1,3	0,7	0,3	28,1	33,7	30,9	26,6
40		Ground pavement is stone, adjacent to Guven Park	0,7	0,6	0,7	0,1	26,2	32,4	30,7	26,6

Comparison of Konak Square and Kızılay Square:

Concerning the summer season investigation, two major design objectives needed to provide more sensitive urban environment; enabling adequate ventilation and minimizing heat stress of people through design (Pressmen 1996; Golany 1996; Givoni 1998; Hyde 2000; Roselund 2000) have been taken into account in the following comparison. In this respect, relatively lower air temperature and higher wind speed has been accepted welcoming. Thus, the percentage of the measurement points where air temperature measured below (Figure 4.61) and wind speed above (Figure 4.62) the average recorded by the weather station have been compared for each case area;

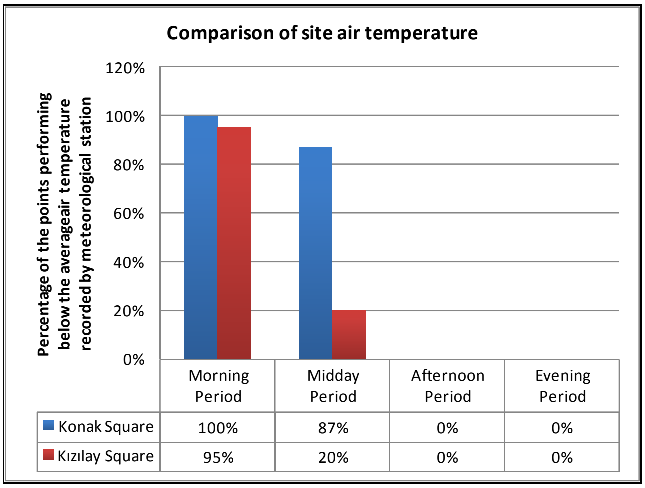

Figure 4.61. Comparison of air temperature measured at the points performing below the average air temperature recorded by meteorological station

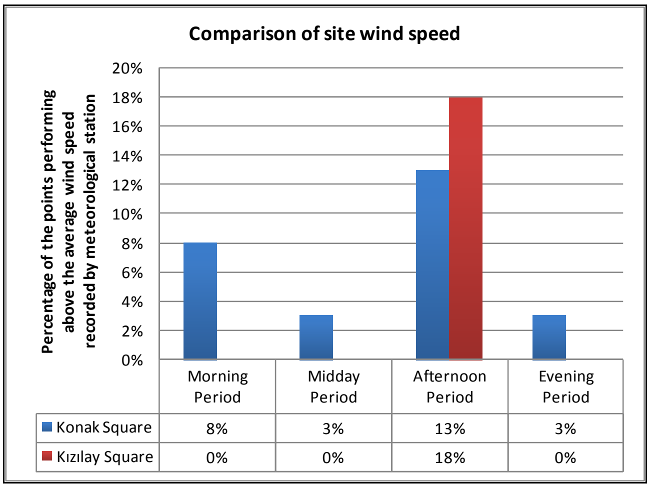

Figure 4.62. Comparison of wind speed measured at the points performing above the average wind speed recorded by meteorological station

4.3.2. Evaluation of the Spatial Structure

This section evaluates the spatial structure of each urban pattern in terms of urban texture, surface characteristics, use of air conditioning and shading, regarding the given comparisons in previous parts of this section. The results show that;

Urban Texture:

Kızılay Square has a distinctive urban texture, which is orthogonal grid-iron with the southeast and northwest direction, contributing to the shading throughout the day. Especially in midday period, relatively lower air temperatures have been measured in the areas benefit from that sort of urban texture. Similarly, at least one of the sidewalks along the major axes has been monitored in the shade. Moreover, the areas where grid-iron pattern is more obvious have been found catching more wind, along the east-west direction in particular. On the contrary, Konak Square is dominated by the large open spaces so that most of the area do not benefit from the mutual shadings of the buildings. Referring to the urban texture map, there are seen more urban voids in Konak Square. Nevertheless, those open spaces help with catching more wind in Konak Square, since they are open to prevailing wind.

The attached and row building groups along the major pedestrian axes in Konak Square provide good shading opportunities over the sidewalks for each period, especially in the morning period. Narrow streets and linear axes, especially the ones with the low height to width ration, help with the wind speed acceleration. On the other hand, massive building groups like the one seen in the clustered area have been monitored lowering the wind speed during the day and increasing the heat gain of the built-up area throughout day. Contrary, the detached buildings in Kızılay Square cause partially sunny places. Also, it has been observed that those detached buildings do not facilitate the wind penetration through the study area. This is due to the site location of Kızılay Square at considerably lower elevations. It has been seen that lower elevations reduce the wind speed. Those detached buildings, specifically the ones with a vacant lot adjacent, cause wind tunnel over the sidewalks. Relatively higher wind speeds have been measured at particular locations near by those vacant lots. The reasons for causing the wind tunnels are rather different in Konak Square. The sudden jumps in wind speed have been monitored in Konak Square, not because of the vacant lots but the structure of the buildings which were built with a corridor at the ground floor. On the other hand, the area around the channel-like building groups in both cases area have been measured that those building groups accelerate the wind speed at the street level. This provides a pleasant environment especially during the hot summer day. It has also been experienced that the heterogeneous building heights in certain locations around Konak Square more contributes to acceleration of the wind speed, comparing to the homogeneous building groups in Kızılay Square. Despite the fact that low density and detached buildings would help with penetrating the wind through the site, there is still a lack of wind in Kızılay Square. Konak Square has been monitored windier in this regard, since the specific site location of Konak Square by the coastal area is open to the prevailing wind. It has been seen that the site location that is open to the coast catches more wind.

Surface Characteristics:

The colors of the building surfaces are dominated by relatively darker colors (e.g. gray) in both cases. Besides, the use of the heat and sun reflective materials on the building surfaces is higher in Kızılay Square with the ratio of 35% comparing to Konak Square with the ratio of 15%. Regarding, the use of reflective materials has been monitored causing extremely unpleasant environments for outdoor spaces. It increases the amount of the heat and glare released to the outdoor space. On the other hand, the color of the surfaces has been found not having a major effect on air temperature. Rather, it may affect only sun glare and general comfort in outdoor space.

Kızılay Square is situated at the intersection of the heavy asphalt roads. Relatively higher air temperatures have been recorded in the areas around that intersection and along the asphalt roads. It has been seen that asphalt ground surface increases air temperature at street level. In contrast, Konak Square has been monitored not being affected by the major asphalt road cutting through the west end to a large extend. Regarding, no considerable air temperature differences have been observed in Konak Square. In terms of the natural ground surface, 20% of Kızılay Square and 40% of Konak Square is covered by the green areas. Concerning, wind speed has been experienced very much calm in the large green areas in Kızılay Square contrary to Konak Square where relatively higher wind speed has been recorded in the open green areas, comparing to the other locations. In addition, the weather has been experienced calm because of the large green areas consisting of thick tress that block the wind in Kızılay Square. The use of the pools for a cooling effect is more common in the design of Kızılay Square, comparing to Konak Square. Regarding, it has not been monitored any considerable differences in the weather conditions around the locations nearby the pools, comparing to the other locations in Kızılay Square. However, it has been experienced that the pools or any water elements effect overall thermal perception, especially in hot summer days.

Use of Air Conditioning:

There has been observed in Konak Square that the use of air conditioning is higher than Kızılay Square with the ratio of 80%. In addition, the façades of the buildings have more air conditioning installations on in Konak Square. All of those features might be contributing to the additional heat gain of the building itself. Because, recorded air temperature differences between day and evening periods is higher around the areas with those features. On the other hand, it has been rarely seen air conditioning device installations at street level in Kızılay Square, whereas there are many of them at pedestrian levels in certain locations in Konak Square. In those locations with air conditioning device installations at street level, air temperature has been recorded higher than the other locations, especially after evening period when heat loss of the buildings reaches its maximum.

Shading:

The major problem observed in Kızılay Square in terms of the shading elements, is because the lack of shading devices. The bare open spaces with no planting or shading devices have been recorded warmer than the other locations in midday period. Similarly, some pedestrian ways in Kızılay Square are excessively exposure to the sun in midday period. However, they are in the shade in morning and afternoon periods, since the surrounding buildings provide adequate shading. In addition, there are also sufficient plantings along the major pedestrian ways in Kızılay Square which protect the people resting underneath from the sun during the day. The shading devices in Konak Square have been observed not enough in numbers nor suitable for shading in general. Similarly, the plantings on the entire site are not convenient for shading.

Open spaces have been monitored quite comfortable with a few exceptions in Kızılay Square. Even though the major open space, Guven Park, cannot benefit from the mutual shading of its surroundings, the trees with suitable types for shading protect the users from the sun throughout the day. Guven Park has found providing more comfortable environment especially after the sunset. In contrast, the recreation areas have inadequate planting and trees in Konak Square. Those places have been experienced unpleasant during the entire day. There have been only a few trees providing the protection from the sun in the whole area. In both cases, there are some bare open spaces, such as the one around the intersection in Kızılay Square and the one around Clock Tower in Konak Square, which have neither shading devices nor planting, have been monitored considerably uncomfortable, since air temperature is fairly higher than the other locations in the sun but with the shading devices. Since Kızılay Square is a node for the city, bus stops and metro exits carry a considerable importance for the users. Yet, those places have been monitored partly in the shade during morning and evening periods but fully in the sun during midday period. Again, this is highly due to the lack of shading devices. The reason for them being partly in the shade in only two periods is because the shadings provided by the surrounding buildings and trees. In contrast, there has not been monitored such a problem in Konak Square. Rather, there are good shading devices over the metro exits, which protect the places where people wait underneath throughout the day.

CHAPTER 5

CONCLUSION

This study has concentrated on the relationship between the built-up area and climate. With the aim to understand to what extent design of the built environment is sensitive to the climate, it attempted to specifically investigate to what extend existing urban patterns take the advantage of their particular climate while eliminating the inconveniences. This research question was answered through a case study for a typical summer day. The case study was conducted in Konak Square/Izmir and Kızılay Square/Ankara with respect to their particular locations in the coastal and central regions of Turkey, where temperate ands-arid climates show different climatic characteristics. The intention of this study, on one hand, was to present a method of how to investigate and examine the climatic factors in an urban area, and on the other hand, was to reconsider two existing urban patterns of Turkey from the climate sensitive design view point. The overall aim through evaluating urban patterns was here to illustrate how different spatial structures influence climatic conditions on the site.

Contrary to the traditional settlements where people used to build their urban environment with climate consciousness, today's urban design practice takes small notice of the climatic concerns. Many urban design projects provide usually average criteria for the cities through their design strategies, regardless the cities' different localities. This problem leads to increasing demands for active heating, cooling and lighting systems, rising energy consumption, declining quality of urban living, environmental deterioration, and expensive and hardly maintained built-up areas.

Climate sensitive design is a useful tool to link the climate considerations into urban design. We need to merge climate sensitive design with today's urban design practice in order to provide particular principles specific to different types of climate. Those principles can be exemplified as providing good shading opportunities, enabling adequate ventilation, preventing dust, reducing glare and minimizing heat stress of people in hot-dry regions; rapid disposal of excess rainwater, providing rain protection and shading, and enabling good natural ventilation in hot-humid regions; easing mobility, shortening the proximity between the facilities, reducing heat loss, minimizing stressful northern wind, maximizing passive solar gain and enabling special features for snow and ice activities in cold regions. Besides coping with the climatic issues with the use of naturally-derived objectives, climate sensitive design is also a need for creating more comfortable urban living through less consumption of world's resources and less destroying the nature.

Environmental parameters and physical parameters given as the factors to be considered in climate sensitive design became a focal point in this work to analyze climate sensitivity and evaluate urban patterns; hence, a part of the research of this study were realized with regard to those parameters. The analysis of the spatial characteristics of the site was investigated concerning physical parameters, while the climatic data to be collected on the site was selected regarding environmental parameters. Furthermore, the given climate sensitive principles were realized to draw attention to the relationship between the physical parameters and environmental parameters. Specifically, the principles showed us how the climatic conditions of outdoor space can be manipulated through design.

A total of 15 research (11 in the world, 4 in Turkey) and of 24 design projects (15 in the world, 9 in Turkey) were reviewed in this study. Research projects in the world were found focusing mainly on 1) the influences of built-up area and design related variables on outdoor climate and thermal comfort, 2) the influence of urban/street geometry in terms of different H/W ratio and orientation, 3) the effects of climate related variables on outdoor thermal comfort and the consequences of the variables on usage of the space, whereas in Turkey they were rather seen concentrating on the comparison of 1) the traditional and modern architecture in the same climate region with respect to thermal comfort, 2) thermal performance of vernacular architecture and traditional settlements, 3) Thermal performance of the buildings in different climates. The reviewed research projects in the world were mostly found dealing with outdoor space comfort and urban design variables, whereas in Turkey they were rather found investigating indoor space comfort and architectural design variables. On the other hand, the reviewed design projects from all over the world were seen presenting a real concern and consciousness in designing with climate, both by taking advantage of clean energy and protecting from the unpleasant climatic conditions. Concerning the design projects, Australia, the Netherlands and United Kingdom were found the most experienced countries in terms of climate sensitive developments at urban scale. Whereas, European countries in general were seen more practiced in providing the projects in building scale, regarding many recent world-wide known green high-rise developments. Similarly, Turkey was found less experienced on climate sensitive design projects at urban scale, since the recent developments were mostly in building scale.

The review of the recent research and design projects gave us the knowledge of how to investigate the factors that need to be considered in climate sensitive design and provided the use of the principles in practice highlighting the objectives of the design projects. This guided us to find out particular ways to conduct this research, in terms of the techniques to collect the data and determination of the methodology of this study. Also, the review specific to Turkey provided us some clues to define the problem for this research on the subject of climate.

To analyze climate sensitivity in each case area, a field study was conducted throughout August 2009, comprising two steps; site surveying and field measurements. Site survey illustrated general and spatial characteristics of the site on the maps and supported by the photographs taken on the site. Field measurements, including the first set of climatic data, were carried out at 40 different points that refer to the certain locations on each site. The measuring instrument Testo410-1 was utilized to measure air temperature (ºC) and wind speed (m/s) at each point for 1.min.-long. Humidity could not be measured since the available instrument's capability was limited only to measure air temperature and wind speed. The measurements were performed throughout four periods; morning period morning period, midday period, afternoon period and evening period. Following, the second set of climatic data, meteorological data, was requested from the online database of Turkish State Meteorological Service – TUMAS upon the same day of the field measurements were taken. The requested data for each site indicated air temperature (ºC), wind speed (m/s) and relative humidity (%). It was grouped concerning the same four periods with the field measurements. Following the analyses of each site, the findings were processed around two steps; 1) Comparison of field measurements with the meteorological data and 2) Evaluation of the spatial structure in relation to the given comparisons.

Regarding the evaluation and comparison of urban patterns, even though none of the case area that was examined here is a climate sensitive design project, it was found that the built environment in Konak Square is more sensitive to the climate, regarding the summer period. The results derived from the field studies show that urban pattern of Konak Square lowers the temperature and accelerates the wind on the site, in comparison to the meteorological station’s records taken for the whole district. In other words, it takes the advantage of the existing wind conditions, accelerating it throughout the site and decreases air temperature in many locations through its design. In particular, %100 of the measurement points in morning period and %87 in midday period perform below the average air temperature recorded by meteorological station. In addition, %8 of the measurement points in morning period, %3 in midday and evening periods, and %13 in afternoon period perform above the average wind speed recorded by meteorological station. For Kızılay Square; %85 of the measurement points in morning period and %20 in midday period perform below the average air temperature recorded by meteorological station. Moreover, only %18 in afternoon period performs above the average wind speed recorded by meteorological station.

Since the environmental factors in the urban space is mostly dependent on the physical factors, urban design should take action to adapt the built-up area to its own climatic conditions in order to provide pleasant and less costly urban living. We should integrate the climatic essentials into urban design and provide specific climate sensitive design criteria based on those essentials in design process, rather than average criteria adapted by all kinds of localities all over the world. With the help of climate sensitive design, we can be able to address the positive and negative aspects of the climate and then take the advantage of those positive aspects while eliminating the negative ones. This will also provide us a more sustainable future as we less consume the world’s resources and less destroy the nature with the help of the naturally-derived solutions to cope with the climate.

The further studies might focus on the comparison of climate sensitive design projects with the standard projects which are not climate sensitive, in terms of the existence of the certain criteria. In this regard, this study can be considered as an initial investigation for the review of the climate sensitive design principles for certain climates and it presents the recent design projects to be focused on in the further studies. The comparison might also be associated with the field measurements. Regarding, the methodology of the present study might be modified in terms of the factors to be investigated and the duration. The environmental parameters in the further studies might be broadened as enabling solar radiation and humidity involved in the field measurements. The field study might be conducted on a yearly basis. Besides, in the process of evaluating the data from the site, different computer aided programs or statistical tools might be utilized.

REFERENCES

Ali-Toudert, F. and Mayer, H. 2006. Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate. *Building and Environment*, 41, pp.94-108.

Bal, U. 2007. *Utilization of urban design principles in designing the urban space-case studies on the Netherlands and Turkey*. Master's Thesis, Izmir Institute of Technology.

Bank of America Tower at One Bryant Park, Updated Project Fact Sheet. 2007. http://newsroom.bankofamerica.com/...bankofamerica/.../OBP+Project+Fact+Sheet_040507.pdf (accessed July 12, 2009)

Bosselmann, P. and Arens, E. 2005. Urban form and climate: case study, Toronto. *Journal of the American Planning Association*, Vol.61, No.2, pp.226-240.

Capeluto, I.G., Yezioro, A. and Shaviv, E. 2003. "Climatic aspects in urban design-a case study." *Building and Environment*, 38, pp.827-835.

City of Adelaide SA, Your Home Technical Manual, Case Studies, Medium Density Chapter 9. http://www.yourhome.gov.au/technical/pubs (accessed June 10, 2009)

Climate Booklet for Urban Development, Ministry of Economy Baden-Wuerttemberg (Wirtschaftsministerium) Theodor-Heuss-Straße 4, 70174 Stuttgart.

Çağrı, Ç. 2006. *Assesing thermal comfort conditions-a cese study on the METU faculty of architecture building*. Master's Thesis, Middle East Technical University.

Devedas, D. M. & Rose, L. A. 2008. An Overview of Urbanization and Climate. *The SPA Journal of Planning and Architecture*, Vol.13, No.1, pp.87-96

Eliasson, I. 1996. Urban nocturnal temperatures, street geometry and land use. *Atmospheric Environment*, Vol.30, No.3, pp.379-392.

Eliasson, I. 2002. The use of climate knowledge in urban planning. *Landscape and Urban Planning*, 48, pp.31-44.

Eliasson, I. and Svensson, M.K. 2002. Diurnal air temperatures in built-up areas in relation to urban planning. *Landscape and Urban Planning*, 61, pp.37-54.

Esiyok, U. 2006. *Energy consumption and thermal performance of typical residential buildings in Turkey*. Doctoral Dissertation. University of Dortmund

Evans, J.M. & Schiller, S. 1996. Application of microclimate studies in town planning: a new capital city, an existıng urban district and urban river front development. *Atmospheric Environment*, Vol.30, No.3, pp.361-364.

Farr, D. 2007. *Sustainable Urbanism: Urban Design with Nature*, John Wiley & Sons.

Giridharan R., Ganesan S. and Lau, S.S.Y. 2004. "Daytime urban heat island effect in high-rise and high-density residential developments in Hong Kong." *Energy and Buildings*, 36, pp.525-534.

Giridharan R., Ganesan S. & Lau, S.S.Y. (2005). "Nocturnal heat island effect in urban residential developments of Hong Kong." *Energy and Buildings*, 37, pp.964-971.

Givoni, B. 1998. *Climate Considerations in Building and Urban Design*, Wiley, USA.

Givoni, B., Noguchi, M., Saaroni, H., Pochter, O., Yaacov, Y., Feller, N. and Becker, S. 2003. Outdoor comfort research issues. *Energy and Buildings*, 35, pp.77-86.

Golany, G.S. 1996. Urban design morphology and thermal performance. *Atmospheric Environment*, Vol.30, No.3, pp.45-65.

Gomez, F., Gil, L. & Jabaloyes, J. 2004. Experimental investigation on the thermal comfort in the city: relationship with the green areas, interaction with the urban microclimate. *Building and Environment*, 39, pp.1077-1086.

Gökçen, Ş. 1996. Ecologically sensitive settlement design-case study in Alaçatı. Master's Thesis, Dokuz Eylül University.

Hyde, R. 2000. *Climate Responsive Design: A Study of Buildings in Moderate and Hot Humid Climates*, Taylor & Francis.

Januburu Six seasons Design Guidelines, published by Landcorp, Western Australian Government. http://www.landcorp.com.au (accessed June 10, 2009)

Johansson, E. 2006. Influence of urban geometry on outdoor thermal comfort in a hot dry climate: A study in Fez, Morocco. *Building and Environment*, 41, pp.1326-1338.

Johansson, E. and Emmanuel, R. 2006. The influence of urban design on outdoor thermal comfort in the hot, humid city of Colombo, Sri Lanka. *Int. J. Biometeorol* , 51, pp.119-133

Kottek, M., Grieser, J., Beck, C., Rudolf, B. and Rubel, F. 2006. World Map of the Köppen-Geiger climate classification updated. *Meteorologische Zeitschrift*, Vol. 15, No.3, pp. 259-263.

L. Glicksman and J. Lin (eds), *Sustainable Urban Housing in China*, Chapter 3, Springer Netherlands, 2000, 24-43

Lloyd Crossing Sustainable Urban Design Plan and Catalyst Project, Portland, Oregon, Mithun Architects + Designers + Planners and the Portland Development Commission Publications, 2004. http://www.pdc.us/pubs/inv_detail.asp?id=332&ty=17 (accessed May 18, 2009)

Manioğlu, G. and Yılmaz, Z. 2008. Energy efficient design strategies in the hot dry area of Turkey. *Building and Environment*, 43, pp.1301-1309.

Mills, G. 2006. "Progress toward sustainable settlements: a role for urban climatology." *Theor. Appl. Climatol*., 84, pp.69-7

Nikolopoulou, M., Baker, N. and Steemers, K. (2001. Thermal comfort ın outdoor urban spaces: understanding the human parameter. *Solar Energy*, Vol.70, No.3, pp.227-235.

Nikolopoulou,M. and Lykoudis, S. 2006. Thermal comfort in outdoor urban spaces: Analysis across different European countries. *Building and Environment*, 41, pp.1455-1470.

Nikolopoulou, M. and Steemers, K. 2003. "Thermal comfort and psychological adaptation as a guide for designing urban spaces." *Energy and Buildings*, 35, pp.95-101.

Oktay, D. 2001. Design with the climate in housing environments: an analysis in Northern Cyprus. *Building and Environment*, 37, pp.1003-1012.

Olgyay, V. 1963/1992. *Design with Climate: Bioclimatic Approach to Architectural Regionalism*, New York.

Passive Design Toolkit - Best Practices, City of Vancouver Publications, 2008. http://www.vancouver.ca/sustainability/documents (accessed June 21, 2009)

Passive Design, Your Home Technical Manual, Passive Design, Chapter 4. http://www.yourhome.gov.au/technical/pubs (accessed June 25, 2009)

Pressmen, N.E.P. 1996. Sustainable winter cities: future directions for planning, policy and design.*Atmospheric Environment*, Vol.30, No.3, pp.521-529.

Rosenlund, H. 2000. Climatic Design of Buildings using Passive Techniques. *Building Issues*, Vol.10, No.1, pp.2-26

Scherer, D., Fehrenbach, D., Beha, U. and Parlow, E. 1999. Improved concepts and methods in analysis and evaluation of the urban climate for optimizing urban planning processes. *Atmospheric Environment*, 33, pp.4185-4193.

Shaw, R., Colley, M., and Connell, R. 2007. *Climate change adaptation by design: a guide for sustainable communities*, TCPA, London

Thomas, R. and Fordham, M. 2003. *Sustainable Urban Design: An Environmental Approach*, Taylor & Francis.

Thorsson, S., Honjo, T., Lindberg, F., Eliasson, I. and Lim, E. 2007. Thermal comfort and outdoor activity in Japanese urban public places. *Environment and Behavior*, Vol.39, No.5, pp.660-684.

Urban Systems, 2000. *Winter City Guidelines*, Fort St. John Energetic City.

Valsson, S. & Bharat, A. 2008. Climatic considerations in planning: inferences from past. *Architecture-Time Space & People*, pp.42-48.

Walton, D., Dravitzki, V. and Donn, M. 2007. The relative influence of wind, sunlight and temperature on user comfort in urban outdoor spaces. *Building and Environment*, 42, pp.3166-3175.

Wheeler, S. M. & Beatley, T. 2004. *The Sustainable Urban Development Reader*, Routledge.

Yılmaz, Z. 2007. Evaluation of energy efficient design strategies for different climatic zones: Comparison of thermal performance of buildings in temperate-humid and hot-dry climate. *Energy and Buildings*, 39, pp.306-316.

Yaman, C. 2009. Siemens Gebze tesisleri yeşil bina. *IX. Ulusal Tesisat Mühendisliği Kongresi*, pp.1091-1101

Yannas, S. 2001. Towards more sustainable cities. *Solar Energy*, Vol.70, No.3, pp.281-294.

Zengel R. and Sayer Y. 2005. Evaluation of Squares in Non-Western Countries: The Case Study of Konak Square, İzmir, Turkey. *GBER*, Vol. 4, No.2, pp. 44-60.

WEB_1, 2009, Wikipedia, 15/09/2009,
http://en.wikipedia.org/wiki/K%C3%B6ppen_climate_classification

WEB_2, 2009, University of the Sunshine Coast, Queensland, Australia, 10/07/2009,
http://www.usc.edu.au/

WEB_3, 2009, Landcorp, 10/07/2009,
http://www.landcorp.com.au/

WEB_4, 2009, Bedzed House, 12/07/2009,
http://www.bedzedhouse.co.uk/

WEB_5, 2009, Richards Partington Architects, 12/07/2009,
http:// www.rparchitects.co.uk

WEB_6, 2009, Urban Design Compendium, 15/07/2009,
http://www.urbandesigncompendium.co.uk/

WEB_7, 2009, The Case Study Library for Sustainable Communities, 25/07/2009, http://showcase.hcaacademy.co.uk

WEB_8, 2009, Building Green, 02/08/2009, http://www.buildinggreen.com

WEB_9, 2009, Masdar City Official Website, 02/08/2009, http://www.masdarcity.ae

WEB_10, 2009, Foster +Partner Architecture, 02/08/2009, http://www.fosterandpartners.com

WEB_11, 2009, Collage of Art and Architecture, 12/08/2009, http://www.caa.uidaho.edu

WEB_12, 2009, MIT Architecture, 15/08/2009, http://architecture.mit.edu

WEB_13, 2009, Bank of America, 15/08/2009, http://www.newsroom.bankofamerica.com

WEB_14, 2009, Bahrain World Trade Centre, 19/08/2009, http://www.bahrainwtc.com

WEB_15, 2009, Battle McCarthy Engineering, 19/08/2009, http://www.battlemccarthy.com

WEB_16, 2009, Miar Mimarlık Araştırma Merkezi, 20/08/2009, http://www.adnankazmaoglu.com

WEB_17, 2009, Ecofriend: Green Living, 20/08/2009, http://www.ecofriend.org

WEB_18, 2009, Varyap Gayrimenkul, 21/08/2009, http://www.varyap.com.tr

WEB_19, 2009, Arkitera Mimarlık Yayını, 21/08/2009, http://www.arkitera.com

WEB_20, 2009, Cemal Mutlu Mimari Çalışmaları, 21/08/2009,
http://www.cemalmutlu.com

WEB_21, 2009, Yapı, 21/08/2009,
http://www.yapi.com.tr

WEB_22, 2009, Siemens Gebze Tesisleri, 21/08/2009,
http://www.siemens.com.tr/i/Assets/Gebze/kasifyildirim.pdf

WEB_23, 2009, Yapı Endüstri Merkezi, 21/08/2009,
http://www.yemodul.com

WEB_24, 2009, Mimarlık ve Tasarım Yayın Platformu, 23/08/2009,
http://www.mimarizm.com

WEB_25, 2009, Diyarbakır Güneş Evi, 23/08/2009,
http://www.gunesevi.org

APPENDIX A

THE DATA OF KONAK SQUARE/IZMIR FIELD MEASUREMENTS

Table A.1. The data of field measurements, Morning Period, Konak Square/Izmir

23.08.2009	MORNING PERIOD					
Measurement Points	Wind Speed (m/s)			Air Temperature (°C)		
	Min.	Avr.	Max.	Min.	Avr.	Max.
1g	1,5	2,8	4,5	24,4	24,5	25,2
2g	0,7	1,5	2,2	24,4	24,4	24,8
3g	0,0	1,5	2,6	24,4	24,4	24,8
4g	0,0	2,0	3,2	24,4	24,5	24,6
5g	0,0	0,7	1,3	24,9	25,1	25,3
6g	0,0	1,3	2,2	24,5	24,5	24,7
7g	0,0	1,5	2,6	24,5	24,6	24,7
8	0,0	1,4	2,2	24,8	25,1	25,6
9	0,0	0,9	1,4	25,2	25,5	26,2
10g	0,0	1,0	1,7	25,6	25,7	26,1
11	0,0	0,5	1,2	26,8	27,7	28,4
12g	0,0	2,7	3,4	26,2	26,2	26,2
13	0,0	2,0	2,8	25,8	27,1	27,0
14	0,0	1,0	2,1	26,3	26,5	27,7
15	0,0	1,8	3,1	27,0	27,4	27,8
16	1,0	1,7	2,7	26,5	27,2	27,7
17	0,0	1,7	2,5	25,4	25,8	26,8
18	0,0	1,6	2,6	25,4	26,0	26,8
19g	0,0	1,2	2,3	26,7	27,0	28,3
20	0,0	1,1	2,3	27,6	27,9	28,4
21g	0,0	1,2	1,7	27,2	27,8	29,6
22	0,0	1,3	2,8	26,8	27,1	27,6
23	0,0	1,4	3,2	27,7	28,5	29,9
24g	0,0	0,4	2,0	25,8	26,2	26,7
25g	0,0	1,5	2,2	25,6	25,9	26,1
26g	0,0	0,9	2,6	25,0	25,7	25,9
27g	0,0	1,1	2,1	25,5	25,8	26,0
28g	0,0	0,9	1,5	25,6	26,0	26,2
29g	0,0	1,1	1,6	26,2	26,4	26,9
30	0,0	0,8	1,4	27,6	28,6	29,3
31g	0,6	2,7	4,9	27,0	27,0	27,3
32g	0,0	1,0	1,5	27,3	27,4	27,5
33g	0,0	1,3	1,9	27,0	27,0	27,2
34g	0,0	1,4	3,4	26,2	27,3	27,5
35g	0,0	1,6	3,6	26,4	26,6	27,0
36g	0,0	2,1	3,0	26,7	26,9	27,2
37g	0,0	0,8	1,3	26,4	26,5	26,8
38g	0,0	1,4	4,0	27,1	27,2	27,5
39g	0,0	1,2	2,5	27,4	27,5	27,8
40g	0,7	2,5	4,4	27,3	27,8	28,6

Table A.2. The data of field measurements, Midday Period, Konak Square/Izmir

23.08.2009	MIDDAY PERIOD					
Measurement	Wind Speed (m/s)			Air Temperature (°C)		
Points	Min.	Avr.	Max.	Min.	Avr.	Max.
1	0,0	1,4	2,4	29,9	31,3	32,5
2g	0,0	1,4	2,8	29,6	30,0	31,2
3	0,0	0,9	1,6	31,5	33,1	34,4
4g	0,0	0,8	1,3	30,7	30,7	30,9
5g	0,0	1,4	2,1	30,6	31,5	33,3
6	0,0	0,9	1,9	31,0	33,5	35,0
7	0,0	1,4	2,6	30,9	32,5	33,9
8	0,0	0,9	3,0	30,7	31,5	34,1
9	0,0	1,8	2,4	30,7	32,9	35,0
10g	0,0	0,9	1,6	32,2	32,7	33,4
11g	0,0	1,2	1,8	32,4	33,5	34,9
12g	0,0	1,4	2,9	31,9	32,6	33,3
13	0,0	3,4	4,7	30,4	31,0	31,7
14	0,0	1,3	2,4	34,3	35,0	36,2
15	0,0	2,1	3,4	32,4	33,2	35,2
16	0,0	1,3	2,2	34,9	35,7	37,4
17	0,0	0,8	1,3	35,9	36,6	37,2
18	0,0	2,9	4,4	31,6	32,2	33,5
19	0,0	1,5	4,0	32,9	34,7	35,4
20	0,0	1,3	2,2	33,1	33,7	36,0
21g	0,0	1,2	2,0	31,1	31,6	32,4
22g	0,0	1,1	1,6	32,6	32,9	33,2
23	0,0	0,9	1,8	32,7	34,0	34,9
24	0,0	0,9	1,8	32,2	33,8	35,4
25	0,0	1,7	3,2	32,0	32,7	35,4
26g	0,0	1,3	2,2	31,3	31,6	32,0
27g	0,0	0,9	1,5	30,3	30,5	31,0
28g	0,0	1,4	2,1	29,6	29,9	30,4
29g	0,0	1,1	1,8	29,8	30,0	30,1
30	0,0	1,7	3,7	31,3	32,1	32,8
31	0,0	1,6	2,2	32,9	33,5	35,1
32g	0,0	1,1	1,5	30,8	31,1	31,8
33	0,0	1,5	2,2	31,1	33,5	35,1
34	0,0	0,6	1,4	34,5	37,5	38,9
35g	1,1	1,5	2,1	32,7	33,1	35,8
36g	0,0	1,5	1,9	32,8	33,4	35,1
37	0,0	2,4	3,0	33,2	33,6	34,8
38g	0,0	0,9	1,4	32,4	33,0	33,4
39g	0,0	0,5	2,4	32,2	32,4	33,4
40g	0,0	1,6	3,3	31,2	32,4	34,1

Table A.3. The data of field measurements, Afternoon Period, Konak Square/Izmir

23.08.2009	AFTERNOON PERIOD					
Measurement	Wind Speed (m/s)			Air Temperature (°C)		
Points	Min.	Avr.	Max.	Min.	Avr.	Max.
1g	0,0	1,6	3,6	32,0	32,1	33,7
2	0,0	1,2	2,3	33,1	34,2	36,3
3	0,0	2,4	3,5	33,3	34,5	35,8
4g	0,0	3,1	4,9	31,4	32,1	33,5
5	0,0	1,6	2,4	32,3	33,9	34,8
6	0,0	1,6	2,2	34,6	35,7	37,1
7	0,0	1,5	2,4	35,9	36,8	38,2
8	1,3	2,1	4,2	35,8	36,4	37,3
9	0,0	1,7	3,4	34,4	34,7	36,0
10g	0,0	1,4	2,1	34,3	34,7	35,1
11g	0,0	1,3	2,1	34,5	34,7	35,4
12g	0,0	0,8	1,9	35,3	37,9	37,4
13	0,0	0,5	1,1	36,1	38,4	39,6
14	0,0	1,8	3,1	34,6	35,8	36,8
15	0,0	1,2	1,6	37,2	38,1	38,7
16	0,0	1,4	2,2	36,0	36,7	37,2
17	1,3	1,7	2,1	35,3	36,0	37,2
18	0,0	1,1	2,0	37,2	38,1	39,2
19g	0,0	0,7	1,5	34,6	35,5	35,7
20	0,0	2,2	4,5	34,5	35,4	37,4
21g	0,0	1,3	1,6	33,2	33,3	33,9
22g	0,0	0,7	1,7	35,6	35,8	36,1
23	0,0	0,6	1,2	33,8	35,8	38,3
24	0,0	1,8	3,5	33,8	34,5	35,6
25	0,0	1,9	3,4	34,3	35,4	36,2
26	0,0	1,8	3,5	34,4	35,2	37,0
27g	0,0	0,9	1,8	35,7	35,8	36,2
28	0,0	1,4	3,2	34,7	35,6	36,6
29	0,0	1,6	2,7	35,7	36,4	37,1
30g	0,0	1,4	2,1	34,5	34,9	35,7
31g	0,0	1,6	2,9	32,5	33,1	34,0
32g	0,0	1,0	1,8	32,9	33,4	33,7
33g	0,0	1,1	1,4	34,0	34,0	34,4
34g	0,0	1,6	2,1	33,3	33,4	33,6
35g	0,0	0,8	1,9	32,0	32,8	33,3
36g	0,0	1,8	3,8	32,7	33,2	33,5
37g	0,0	2,0	2,6	34,5	34,6	34,8
38g	0,0	0,8	1,2	33,4	33,7	34,0
39	0,0	1,0	2,1	33,8	36,6	38,0
40g	0,0	1,2	2,3	33,2	33,5	34,2

Table A.4. The data of field measurements, Evening Period, Konak Square/Izmir

23.08.2009	EVENING PERIOD					
Measurement Points	Wind Speed (m/s)			Air Temperature (°C)		
	Min.	Avr.	Max.	Min.	Avr.	Max.
1	0,0	0,9	2,0	30,6	30,6	30,8
2	0,0	0,8	1,1	30,7	30,9	31,0
3	0,0	0,6	1,6	30,7	30,8	31,1
4	0,0	1,5	3,0	30,7	30,8	30,9
5	0,7	1,6	2,8	30,3	30,5	30,7
6	0,0	1,0	1,8	30,5	30,6	30,7
7	0,0	0,7	1,2	30,4	30,6	30,9
8	0,5	1,8	2,8	30,4	30,6	30,9
9	0,0	0,6	1,1	30,0	30,1	30,3
10	0,0	1,1	2,2	30,4	30,5	30,5
11	0,0	0,9	2,0	30,4	30,5	30,5
12	0,4	1,1	1,5	30,0	30,2	30,3
13	0,8	1,7	2,4	30,1	30,4	30,6
14	0,0	1,6	2,8	29,4	29,5	29,7
15	0,9	3,4	4,9	29,0	29,4	29,8
16	0,0	2,1	4,9	29,2	29,3	29,4
17	0,0	2,3	3,8	29,0	29,1	29,2
18	0,0	3,7	4,8	29,1	29,4	29,5
19	0,0	1,5	2,2	29,0	29,2	29,4
20	1,0	2,1	3,2	29,2	29,2	29,4
21	0,0	1,3	2,4	29,5	29,7	29,9
22	0,0	1,7	3,8	29,7	29,8	30,0
23	0,0	2,3	4,1	29,7	29,7	29,9
24	0,5	1,2	1,6	29,8	29,8	30,0
25	0,4	1,1	2,1	29,7	29,8	29,9
26	0,0	0,6	1,3	28,9	29,1	29,4
27	0,0	0,6	2,2	29,2	29,2	29,4
28	0,9	1,6	2,5	29,7	29,8	30,0
29	0,0	1,0	1,3	29,7	29,9	30,1
30	0,9	3,6	5,8	28,5	28,6	28,6
31	2,2	6,1	7,4	28,6	28,6	28,7
32	2,2	3,1	3,9	29,0	29,2	29,4
33	0,7	2,0	3,2	28,7	28,8	28,9
34	0,0	3,2	5,5	28,8	28,8	28,9
35	0,0	1,8	3,2	28,9	29,0	29,2
36	1,2	4,3	6,8	28,8	29,0	29,5
37	1,1	1,7	2,7	29,0	29,3	29,3
38	0,7	1,9	2,9	29,1	29,6	29,7
39	0,0	0.5	1,1	29,8	30,5	31,0
40	0,0	1,1	1,7	29,9	30,8	30,2

APPENDIX B

THE DATA OF KIZILAY SQUARE/ANKARA FIELD MEASUREMENTS

Table B.1. The data of field measurements, Morning Period, Kızılay Square/Ankara

29.08.2009	MORNING PERIOD					
Measurement Points	Wind Speed (m/s)			Air Temperature (°C)		
	Min.	Avr.	Max.	Min.	Avr.	Max.
1g	0,0	0,1	0,6	20,1	20,5	20,7
2g	0,0	0,7	1,0	18,5	18,9	19,3
3g	0,0	0,2	0,9	18,2	18,5	18,8
4g	0,0	0,6	0,9	18,1	18,2	18,6
5g	0,0	0,1	0,9	18,3	18,5	18,9
6g	0,0	0,6	1,0	18,5	18,7	19,1
7g	0,0	0,1	1,1	18,5	18,7	19,1
8g	0,0	1,2	1,8	18,5	18,6	19,0
9g	0,0	0,7	1,2	18,9	19,1	19,3
10g	0,0	1,1	1,5	18,8	18,9	19,4
11	0,0	1,0	1,5	19,4	22,8	25,0
12	0,0	1,2	2,1	22,0	22,4	22,9
13g	0,0	0,5	1,0	20,1	20,4	20,5
14g	0,0	0,9	1,7	20,9	21,4	23,7
15g	0,0	0,6	0,9	21,1	21,3	22,1
16g	0,0	0,9	1,2	20,2	20,5	21,3
17g	0,0	0,4	1,0	20,6	21,0	21,4
18g	0,0	0,8	1,7	20,7	20,9	21,1
19g	0,0	1,0	0,9	20,0	20,2	20,5
20g	0,0	0,4	1,2	21,2	21,3	21,6
21g	0,0	0,2	1,0	21,3	21,4	21,5
22	0,0	0,0	0,5	22,3	23,1	24,0
23g	0,0	0,9	1,1	22,0	22,7	23,0
24g	0,0	0,4	1,3	22,5	22,8	23,0
25g	0,0	0,5	1,1	23,1	23,4	23,9
26	0,0	0,6	1,1	23,6	26,0	28,0
27	0,0	1,1	1,6	25,7	26,5	28,0
28	0,0	0,5	0,8	26,0	27,6	28,4
29g	0,0	0,4	1,0	25,0	25,2	26,5
30	0,0	0,9	1,2	24,0	26,7	27,9
31g	0,0	0,7	1,3	24,5	25,0	25,9
32	0,0	0,0	0,6	24,8	26,5	27,7
33g	0,0	0,2	0,8	24,5	24,7	26,2
34	0,0	0,6	1,2	24,1	24,6	26,1
35g	0,0	0,8	1,0	24,1	24,7	25,9
36	0,0	0,4	0,9	24,9	26,6	29,3
37g	0,0	0,1	0,5	27,1	27,2	27,6
38	0,0	0,0	0,7	26,0	29,0	31,2
39	0,0	0,3	0,9	27,5	28,1	30,2
40	0,0	0,7	1,1	26,0	26,2	28,7

Table B.2. The data of field measurements, Midday Period, Kızılay Square/Ankara

29.08.2009	MIDDAY PERIOD					
Measurement	Wind Speed (m/s)			Air Temperature (°C)		
Points	Min.	Avr.	Max.	Min.	Avr.	Max.
1g	0,0	0,5	0,8	25,7	25,9	26,0
2	0,0	0,6	1,4	25,9	29,4	31,3
3g	0,0	0,4	0,9	28,2	28,5	29,0
4	0,0	0,3	0,9	28,4	33,4	37,7
5	0,0	0,1	0,7	32,9	35,1	38,2
6	0,0	1,1	1,5	31,7	32,3	36,1
7g	0,0	0,8	1,2	30,1	30,2	30,9
8g	0,0	0,2	0,6	29,5	29,8	30,0
9g	0,0	0,7	1,0	29,2	29,6	29,8
10	0,0	0,8	1,0	30,5	30,9	31,3
11	0,0	1,0	1,5	31,9	32,6	33,6
12	0,0	1,2	2,5	32,8	33,9	34,7
13	0,0	1,6	2,9	32,3	34,0	36,2
14	0,0	0,5	1,1	35,1	35,9	36,7
15	0,0	0,7	1,6	32,0	33,8	34,7
16	0,0	1,1	1,8	31,5	32,0	34,1
17	0,0	0,7	1,0	33,7	34,0	35,3
18	0,0	0,8	1,4	32,7	34,5	36,2
19	0,0	0,7	1,2	31,3	31,7	34,6
20g	0,0	0,8	1,6	31,5	32,0	34,0
21g	0,0	0,6	1,0	31,2	31,3	31,6
22	0,0	0,1	0,4	31,2	32,3	33,4
23g	0,0	1,4	2,1	31,8	32,0	34,0
24	0,0	0,8	1,5	32,6	35,0	37,1
25	0,0	1,8	2,6	33,3	33,8	34,8
26	0,0	1,1	1,6	34,5	35,0	35,7
27	0,0	1,1	2,2	36,0	36,5	37,3
28	0,0	1,5	2,3	33,3	34,3	36,5
29	0,0	1,5	2,1	35,3	35,5	36,4
30	0,0	1,8	3,2	33,4	34,6	36,8
31g	1,0	1,5	1,9	31,2	31,7	32,7
32	0,0	0,0	0,3	32,8	35,5	36,6
33	0,0	1,1	1,7	31,6	31,9	32,6
34	0,0	0,7	1,3	31,9	34,0	35,1
35	0,0	0,3	0,6	32,2	32,5	33,7
36	0,0	0,9	1,5	31,9	32,4	33,4
37g	0,0	0,9	1,6	32,1	33,0	33,8
38	0,0	0,7	1,2	32,4	33,4	34,0
39	0,0	1,3	2,0	32,9	33,7	34,2
40g	0,0	0,6	0,9	32,1	32,4	33,2

Table B.3. The data of field measurements, Afternoon Period, Kızılay Square/Ankara

29.08.2009	AFTERNOON PERIOD					
Measurement Points	Wind Speed (m/s)			Air Temperature (°C)		
	Min.	Avr.	Max.	Min.	Avr.	Max.
1g	0,0	1,6	2,3	30,0	30,2	30,3
2	0,0	0,9	1,7	30,4	32,8	34,8
3g	0,0	0,9	1,7	31,8	32,5	33,2
4g	0,0	0,4	0,9	31,3	31,5	31,9
5g	0,0	0,8	1,3	30,8	31,1	32,0
6g	0,0	0,1	0,6	31,7	31,8	32,0
7g	0,0	0,4	0,9	33,2	35,2	36,0
8	0,0	1,4	2,6	33,4	34,1	34,7
9g	0,0	0,6	1,2	32,5	32,7	33,0
10	0,0	1,0	2,0	32,3	33,4	34,5
11	0,0	1,0	2,1	33,5	35,1	35,8
12	0,9	1,5	2,6	34,9	35,2	35,8
13	0,0	1,9	2,6	33,2	33,5	35,2
14	0,0	1,0	1,3	33,9	35,0	37,3
15g	0,0	0,4	1,1	33,8	33,6	34,6
16	0,0	1,4	2,2	33,2	33,6	33,8
17	0,0	1,7	2,9	32,8	33,6	35,0
18g	0,0	0,7	1,2	32,3	33,0	34,6
19g	0,0	0,4	0,8	32,1	32,4	32,5
20g	0,0	0,9	1,8	32,4	32,5	32,7
21	0,0	1,1	1,7	32,5	32,6	33,2
22g	0,0	0,1	0,6	33,3	33,4	33,6
23g	0,0	1,1	1,5	32,2	32,6	33,4
24g	0,0	1,1	2,0	31,6	31,8	32,2
25g	0,0	1,5	2,8	31,4	31,6	31,8
26g	0,0	1,1	2,0	31,1	31,2	31,4
27	0,0	1,0	1,4	31,4	33,1	34,8
28g	0,0	0,7	1,7	32,0	33,0	34,6
29	0,0	1,1	1,7	32,5	32,7	33,1
30	0,0	0,9	2,3	33,1	34,0	35,0
31g	0,0	1,0	1,3	32,2	32,3	32,7
32	0,0	0,1	0,4	32,4	33,8	34,8
33g	0,0	0,3	0,8	32,8	33,0	33,4
34g	0,0	0,5	0,7	31,5	31,7	31,7
35g	0,0	0,2	0,5	31,2	31,4	32,0
36g	0,0	0,2	0,7	31,6	31,9	32,2
37g	0,0	0,7	0,9	30,8	30,8	32,2
38g	0,0	0,5	1,0	30,1	30,9	30,6
39g	0,0	0,7	0,9	30,8	30,9	30,9
40g	0,0	0,7	1,4	30,6	30,7	31,0

Table B.4. The data of field measurements, Evening Period, Kızılay Square/Ankara

29.08.2009	EVENING PERIOD					
Measurement Points	Wind Speed (m/s)			Air Temperature (°C)		
	Min.	Avr.	Max.	Min.	Avr.	Max.
1	0,0	0,4	0,6	28,4	28,4	28,5
2	0,0	0,9	1,4	27,8	27,9	28,5
3	0,0	0,5	0,6	27,4	27,5	27,9
4	0,0	0,1	0,4	27,7	27,8	27,8
5	0,0	0,8	1,3	27,8	27,8	28,0
6	0,0	0,4	0,6	28,3	28,6	28,8
7	0,0	0,3	1,1	28,1	28,3	28,5
8	0,0	0,8	1,4	28,5	28,9	29,0
9	0,0	0,7	1,2	28,5	28,9	29,0
10	0,0	0,2	0,9	28,2	28,5	28,6
11	0,0	0,6	1,0	28,4	28,8	29,1
12	0,0	0,9	1,4	28,5	28,7	29,0
13	0,0	0,7	1,3	27,4	28,0	28,1
14	0,0	0,3	1,0	27,8	27,9	28,1
15	0,0	0,4	0,9	28,4	28,5	28,6
16	0,0	0,8	1,2	28,4	28,5	28,6
17	0,0	1,1	1,6	28,4	28,1	28,8
18	0,0	0,4	0,8	27,6	27,8	27,9
19	0,0	1,2	1,4	28,3	28,5	28,7
20	0,0	0,7	1,2	28,0	28,3	28,6
21	0,0	0,2	0,9	28,1	28,7	28,9
22	0,0	0,0	0,1	27,8	28,9	29,1
23	0,5	0,8	1,1	28,3	28,2	28,4
24	0,0	0,9	1,2	28,1	28,4	28,6
25	0,5	1,0	1,3	28,1	28,2	28,4
26	0,0	0,6	0,8	27,3	27,6	27,8
27	0,6	1,0	1,3	27,2	27,5	27,7
28	0,0	0,5	0,9	27,3	27,6	27,9
29	0,0	0,5	0,8	26,7	27,0	27,1
30	0,0	1,1	1,5	26,6	26,7	26,8
31	0,0	0,6	0,8	26,9	27,1	27,2
32	0,0	0,0	0,0	26,8	27,5	27,7
33	0,0	0,5	0,8	27,0	27,1	27,5
34	0,0	0,2	1,0	25,7	26,2	26,2
35	0,0	0,5	0,7	26,3	26,9	27,2
36	0,0	0,3	1,1	25,9	26,2	26,3
37	0,0	0,6	0,7	26,1	26,5	26,8
38	0,0	0,5	0,7	26,5	26,5	26,6
39	0,0	0,3	0,5	26,5	26,6	26,8
40	0,0	0,1	0,4	26,2	26,6	26,8

APPENDIX C

THE METEOROLOGICAL DATA OF KONAK SQUARE

T.C.
ÇEVRE ve ORMAN BAKANLIĞI
DEVLET METEOROLOJİ İŞLERİ GENEL MÜDÜRLÜĞÜ

Saatlik Ortalama Sıcaklık (°C)

İSTASYON ADI/NO: İZMIR / 17220
YIL/AY: 2009 / 8

GÜN/SAAT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	26.1	25.5	25.0	24.8	25.6	26.5	27.5	28.4	29.7	30.8	31.8	32.4	32.7	32.6	32.1	31.9	31.2	30.3	29.7	29.3	29.0	28.6	28.1	27.6
2	27.0	26.0	25.6	25.4	26.4	27.4	28.3	29.7	30.7	31.4	32.9	34.2	35.2	35.7	35.5	34.5	33.0	31.8	30.7	30.4	30.1	29.6	28.9	28.4
3	27.7	27.3	26.4	25.8	25.7	26.9	28.4	29.7	31.3	31.9	32.1	32.0	33.0	33.5	33.1	33.2	32.0	31.0	30.5	29.4	28.5	27.1	26.2	25.5
4	25.1	24.9	23.9	23.6	24.8	26.7	27.7	28.6	30.6	31.9	33.3	34.1	34.2	34.3	34.4	33.6	31.9	31.0	30.9	28.8	27.9	26.1	25.3	24.2
5	23.8	23.1	22.7	22.4	24.8	27.2	28.1	29.1	30.8	32.5	34.0	35.0	35.4	34.9	34.4	33.1	31.4	29.3	28.0	26.8	26.0	25.6	25.3	24.7
6	24.5	24.4	24.4	23.3	24.0	27.1	28.7	29.4	30.9	31.9	32.5	33.7	32.9	32.2	31.6	30.6	29.0	28.9	29.3	28.8	28.3	27.5	26.5	25.8
7	25.4	25.0	24.6	24.4	26.1	27.3	27.9	29.2	30.7	31.5	30.9	31.2	31.8	31.9	31.6	31.2	31.0	30.3	29.8	29.3	29.5	29.1	28.4	26.9
8	26.3	26.1	26.1	25.0	25.8	26.6	27.6	29.0	30.4	31.6	32.9	33.4	34.0	34.9	34.1	32.8	31.4	30.0	29.2	28.7	28.1	27.5	26.9	26.3
9	25.9	25.6	25.4	25.1	25.6	26.4	27.7	28.9	29.9	31.1	32.1	33.0	33.5	33.6	32.8	31.9	30.4	28.9	28.1	27.6	26.9	26.5	26.3	26.1
10	25.8	25.4	24.7	24.2	24.8	25.3	26.8	28.2	29.3	30.4	31.1	32.2	33.2	32.4	31.8	30.9	29.3	27.8	27.0	26.5	26.0	25.5	25.1	23.8
11	24.0	23.5	23.1	22.5	22.7	23.7	25.2	26.6	28.3	29.1	30.4	31.1	31.7	31.7	31.6	30.8	29.3	27.7	26.7	25.8	25.3	24.6	23.3	22.5
12	22.9	21.9	21.5	21.0	21.7	22.3	24.1	25.6	26.8	27.9	29.0	29.5	29.9	29.6	29.5	28.7	27.6	26.4	26.2	25.5	24.8	24.5	23.4	23.0
13	22.5	22.2	21.8	21.6	21.7	22.5	24.1	25.8	27.2	27.1	26.9	28.1	28.8	28.9	28.9	28.7	28.1	27.4	27.1	25.9	24.5	24.7	24.5	24.2
14	23.2	22.8	22.3	21.2	22.2	23.6	25.0	26.8	28.1	29.4	29.7	30.0	30.4	30.3	30.2	29.5	28.6	28.4	28.0	27.1	25.2	24.1	23.6	22.8
15	22.5	22.2	21.8	21.5	22.2	24.2	25.1	26.3	28.0	28.8	30.2	30.7	30.8	31.8	31.5	30.5	30.0	29.5	28.7	27.4	27.6	27.4	26.9	26.1
16	24.5	23.8	23.5	23.1	23.5	24.5	26.1	27.8	29.4	30.7	31.9	32.4	32.9	33.7	33.9	33.4	32.1	31.1	30.3	29.8	29.0	28.4	27.6	27.2
17	26.7	26.7	26.7	24.8	24.5	25.6	27.0	28.1	30.3	31.5	32.9	32.6	31.6	31.7	31.5	31.3	31.2	30.7	29.9	29.1	28.7	28.0	27.2	26.0
18	25.1	24.3	23.9	23.8	23.5	24.6	26.2	27.1	28.9	30.5	30.8	30.1	30.1	30.0	30.2	30.4	30.0	29.4	29.0	28.4	28.1	27.7	27.5	27.2
19	26.9	26.5	25.9	25.1	25.7	27.1	28.6	29.4	30.1	31.5	33.2	34.4	35.3	35.3	35.3	35.0	33.3	31.3	30.3	29.6	29.0	28.5	27.9	27.3
20	26.7	26.0	25.9	25.0	25.5	26.8	27.6	28.8	30.3	32.4	33.7	35.3	36.5	36.9	37.2	36.4	34.0	32.3	31.4	30.8	30.7	29.9	29.3	28.6
21	27.9	27.3	27.0	26.6	26.0	27.3	29.1	30.6	31.2	32.1	32.7	31.9	32.6	33.9	34.6	32.8	31.6	29.7	28.8	28.0	27.3	26.7	26.1	25.2
22	24.9	24.5	24.0	23.5	23.4	24.7	25.2	26.0	27.6	29.1	30.1	29.9	29.8	30.3	30.4	30.2	30.0	29.0	28.1	27.6	27.2	26.8	26.2	25.5
23	25.0	24.6	24.1	23.1	23.9	25.2	25.7	27.3	28.5	30.7	31.9	33.2	34.1	34.7	35.0	33.2	31.2	29.4	28.7	28.1	27.6	27.1	26.3	25.7
24	25.3	24.7	24.4	24.1	23.5	24.1	25.7	26.5	28.1	29.8	30.5	30.7	29.7	30.3	29.3	29.3	29.0	28.1	27.1	26.7	26.5	26.0	25.5	24.2
25	22.8	22.3	22.2	21.6	22.1	23.1	24.3	25.4	26.8	27.6	27.1	27.6	28.3	28.0	28.3	28.0	27.3	27.0	26.8	26.3	25.7	25.2	24.8	24.5
26	23.8	22.5	22.5	22.7	23.3	24.4	25.1	26.7	27.7	29.3	30.4	30.0	30.0	30.1	29.2	28.8	28.8	28.7	27.7	27.4	26.9	26.3	25.7	25.3
27																								
28	24.0	23.4	22.8	21.8	22.0	24.4	26.0	26.4	28.0	29.3	29.6	29.8	29.9	30.3	30.1	28.8	28.1	27.7	27.3	26.6	25.7	23.9	23.3	22.7
29	22.1	21.6	21.2	20.6	21.0	24.0	25.5	26.2	27.5	28.7	29.7	30.9	30.9	30.2	28.2	27.4	26.2	26.0	25.7	24.0	23.2	22.4	21.9	21.1
30	20.3	20.2	20.1	20.0	20.3	23.4	24.6	26.1	26.9	28.4	29.5	30.5	30.5	30.0	29.6	30.2	29.0	27.9	27.4	27.0	26.2	24.9	23.3	22.3
31	22.2	22.7	21.7	20.6	20.7	24.1	25.1	26.4	28.4	29.3	29.9	30.1	30.1	30.4	29.8	29.6	29.0	28.0	27.7	27.2	26.0	25.6	25.2	24.3

Figure C.1. The average air temperature data retrieved from the meteorological station for Konak Square (Source: Turkish State Meteorological Service-TUMAS)

T.C.
ÇEVRE ve ORMAN BAKANLIGI
DEVLET METEOROLOJI IŞLERI GENEL MUDURLUGU

Saatlik Ortalama Rüzgar hızı (m_sec.)

ISTASYON ADI/NO: IZMIR / 17220
YIL/AY: 2009 / 8

GÜN/SAAT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	1.2	1.2	1.8	1.4	3.4	3.4	3.4	2.3	3.5	5.7	5.1	4.9	5.1	4.8	4.3	4.4	3.9	3.9	2.7	1.6	2.9	5.1	4.1	3.9
2	3.3	2.8	4.9	3.6	3.2	3.6	4.0	3.3	2.7	2.7	2.4	2.0	2.6	2.0	2.2	3.5	4.9	3.3	1.7	2.5	4.4	4.4	4.3	3.7
3	2.0	3.0	1.7	1.2	1.5	1.5	1.7	2.0	2.1	3.7	4.4	4.8	5.2	5.3	4.8	4.5	4.4	3.8	2.9	3.0	2.0	1.6	1.0	1.4
4	1.1	0.9	0.8	1.1	1.0	1.9	2.3	2.9	3.2	3.8	3.5	3.8	4.4	4.4	3.9	3.6	3.8	2.9	2.0	1.2	1.3	1.1	1.1	1.4
5	1.1	1.2	1.2	1.3	1.3	0.8	1.4	2.1	2.3	2.4	2.8	3.6	4.2	4.2	3.7	3.3	3.3	2.3	1.3	1.1	1.0	1.0	1.5	1.1
6	1.4	1.5	0.9	1.2	1.0	0.6	1.5	1.9	2.3	2.7	3.9	3.6	4.2	4.7	4.8	4.0	3.8	3.3	3.3	2.0	1.2	0.9	1.0	1.0
7	1.0	0.8	0.8	0.8	2.2	1.8	1.7	3.2	2.6	3.9	5.9	5.9	6.0	5.6	5.4	5.4	5.2	3.9	1.7	1.7	3.5	5.5	3.8	2.2
8	2.1	1.7	3.0	1.2	1.2	1.6	2.3	2.2	2.3	2.3	2.7	4.0	3.4	2.8	4.1	5.3	4.8	2.7	1.3	4.0	4.7	6.0	5.3	3.7
9	3.2	4.4	4.2	3.8	3.6	3.0	2.6	3.7	4.5	3.9	4.4	4.6	3.7	4.1	4.9	5.2	4.4	3.3	2.4	3.3	5.0	5.9	6.8	7.9
10	6.6	6.3	3.3	2.4	5.4	5.0	4.9	4.2	2.8	4.2	5.2	4.2	4.6	6.3	6.1	6.0	5.8	4.7	2.2	3.5	4.6	4.4	3.9	2.8
11	2.6	2.6	2.4	2.7	3.5	2.4	3.3	2.2	2.8	3.9	3.8	4.7	4.8	5.0	4.7	5.0	5.4	4.3	3.0	2.7	1.8	1.8	2.9	1.4
12	2.3	2.9	3.0	3.1	3.2	3.5	3.4	4.4	3.8	4.5	4.5	5.3	5.5	5.8	5.4	5.5	4.5	3.3	3.1	3.3	1.5	2.3	3.0	2.7
13	3.0	3.0	3.4	3.7	3.8	4.0	3.2	3.5	4.0	5.7	6.3	6.2	6.2	6.1	5.4	5.2	5.1	4.3	3.4	1.8	1.0	1.7	3.5	2.2
14	1.3	2.3	1.7	1.1	1.5	2.5	1.7	2.1	2.3	3.1	4.2	4.6	4.5	4.5	3.3	3.7	3.0	2.8	2.3	1.9	1.2	1.0	1.2	1.2
15	1.5	1.3	1.2	1.4	1.1	2.0	2.4	2.5	3.0	4.1	4.4	5.4	5.5	5.0	4.5	4.8	4.4	3.1	2.1	1.3	1.9	3.0	3.4	2.3
16	2.5	4.0	3.7	3.4	1.6	2.3	2.2	2.1	1.8	2.1	2.6	4.5	4.7	4.4	4.0	3.8	2.9	3.3	4.1	4.8	4.5	3.8	4.3	5.1
17	4.3	3.1	2.1	2.9	3.8	3.4	3.4	4.4	2.1	2.9	2.9	4.4	6.0	5.3	5.2	4.2	3.6	1.9	2.8	5.4	4.6	2.9	3.5	1.4
18	1.8	1.5	1.1	1.2	2.1	2.1	2.0	3.5	2.4	3.1	4.9	6.3	6.2	6.2	5.9	5.3	3.9	2.9	2.2	3.0	5.3	4.6	5.2	4.4
19	4.3	4.0	3.2	1.5	2.9	2.0	1.6	1.7	1.7	2.0	2.1	2.3	2.7	3.6	2.9	2.1	1.5	1.5	3.4	6.4	6.0	5.0	3.6	3.8
20	3.8	3.4	4.3	1.6	1.0	1.5	1.1	1.5	1.7	2.8	2.4	2.2	2.1	3.1	2.1	1.8	2.7	2.5	2.2	3.0	3.9	3.8	5.0	4.3
21	3.0	4.5	5.9	5.6	4.1	3.0	2.8	2.0	1.7	1.8	4.1	5.6	5.0	2.9	2.6	3.5	1.7	2.5	3.8	6.4	5.7	6.2	4.8	2.6
22	4.3	5.1	4.6	4.3	4.3	3.1	2.1	2.8	3.0	2.9	4.3	5.6	6.1	5.6	5.5	5.3	3.0	2.0	2.6	6.2	5.7	6.0	4.9	3.8
23	3.8	3.3	3.0	1.2	1.4	1.6	1.8	2.0	2.7	2.4	2.9	2.6	3.0	3.0	2.4	3.2	2.7	1.3	4.4	6.8	6.6	5.4	4.6	5.1
24	4.8	3.0	3.8	3.7	1.1	1.4	1.4	2.3	2.8	2.8	3.9	4.8	5.9	5.7	5.7	4.9	3.7	3.6	2.8	1.4	2.6	1.4	1.6	1.0
25	0.9	1.0	1.9	3.6	2.9	2.5	2.1	2.4	3.7	5.0	6.4	6.6	6.4	6.2	5.8	5.2	4.3	3.1	1.4	1.3	2.6	2.6	4.2	4.1
26	2.3	2.5	0.9	1.9	3.4	2.6	2.1	2.0	2.1	2.3	3.1	5.6	6.1	6.2	6.4	6.1	4.0	2.8	1.5	4.6	5.0	4.6	4.3	3.6
27																								
28	2.9	1.3	0.8	0.9	1.3	1.2	2.0	2.8	3.8	3.6	4.1	4.6	5.1	4.9	4.5	3.7	3.7	3.0	2.6	2.1	1.7	1.0	1.4	1.0
29	1.0	1.1	0.9	0.9	1.2	1.0	1.8	2.4	2.7	3.1	3.3	3.3	3.6	4.1	3.5	3.3	3.8	2.9	1.9	1.4	1.2	1.6	1.2	1.0
30	1.5	1.4	1.6	1.3	1.3	0.9	1.6	2.0	2.2	2.8	3.4	4.5	5.0	5.2	5.5	4.2	4.1	3.7	3.2	2.4	2.0	1.2	0.7	1.0
31	1.3	1.7	1.1	1.2	1.0	2.2	3.5	3.2	3.8	4.3	5.1	6.1	6.1	5.7	5.2	4.7	4.1	3.0	2.0	2.3	1.4	2.0	1.8	1.9

Figure C.2. The average wind speed data retrieved from the meteorological station for Konak Square (Source: Turkish State Meteorological Service-TUMAS)

T.C.
ÇEVRE ve ORMAN BAKANLIGI
DEVLET METEOROLOJI IŞLERI GENEL MUDURLUGU

Saatlik Ortalama Nem (%)

ISTASYON ADI/NO: IZMIR / 17220
YIL/AY: 2009 / 8

GÜN/SAAT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	48.4	52.1	54.3	55.9	54.1	52.9	50.8	46.4	39.6	34.2	33.2	33.0	32.3	34.9	36.1	36.9	39.9	39.0	39.0	35.4	33.5	36.1	42.6	44.3
2	46.3	50.8	51.6	52.0	48.9	47.9	47.6	40.6	36.8	34.7	30.0	27.0	26.8	27.1	28.1	34.4	36.3	39.9	44.2	40.3	40.2	42.3	44.8	46.2
3	48.8	50.7	58.6	60.3	59.5	57.7	51.3	45.6	40.8	43.0	43.5	44.3	38.0	35.6	34.5	32.5	34.2	38.6	40.0	45.9	48.8	53.3	52.8	53.1
4	54.5	55.4	59.7	59.7	57.5	60.9	58.6	52.8	45.0	38.3	33.7	32.6	31.9	25.8	23.7	26.7	30.5	29.4	26.6	31.4	41.7	38.3	39.1	45.1
5	52.9	55.6	54.3	54.7	48.2	43.9	46.9	44.4	38.6	32.8	26.7	24.1	22.6	25.7	27.5	31.3	36.1	43.8	51.6	50.7	49.5	45.6	46.7	46.5
6	43.6	42.3	42.4	45.4	45.1	49.7	53.4	45.3	35.2	35.3	36.5	29.3	37.4	40.9	45.3	51.0	55.2	54.1	49.4	52.7	53.7	57.0	58.0	61.5
7	63.8	66.2	69.0	71.6	65.2	62.9	60.3	53.5	46.1	45.8	52.4	49.5	46.4	46.3	47.6	49.5	46.5	49.5	51.4	51.1	43.9	42.2	46.4	53.8
8	55.7	55.1	54.5	61.4	57.1	54.1	51.3	45.5	40.2	36.6	32.9	35.4	33.2	29.0	33.8	36.9	38.6	44.4	42.9	38.0	38.9	43.0	47.5	50.3
9	50.1	50.0	50.9	51.8	50.4	50.5	46.3	42.5	38.2	35.5	30.5	28.2	27.4	29.0	30.6	31.8	35.6	36.5	35.7	35.4	37.7	40.3	39.9	39.4
10	38.8	38.1	41.5	43.6	39.8	42.8	38.7	35.0	30.7	29.0	28.1	24.6	22.9	25.9	27.2	29.6	34.3	38.1	39.2	38.1	37.4	37.9	40.7	46.5
11	40.3	41.5	42.1	44.7	44.2	40.4	35.1	30.7	27.7	29.9	28.9	27.2	24.0	24.4	26.2	28.4	32.7	35.4	37.2	39.3	38.4	40.9	47.3	48.3
12	47.1	52.5	51.0	52.9	50.3	49.7	44.0	39.9	35.2	33.0	32.2	30.2	30.8	31.4	32.2	33.5	37.5	42.7	40.0	41.6	42.8	42.3	47.5	49.6
13	51.5	52.5	55.2	55.4	54.9	52.6	48.0	41.4	38.3	44.4	47.3	44.7	40.9	40.5	39.5	38.4	39.5	41.6	42.7	46.0	48.6	47.5	51.2	52.4
14	54.0	57.5	59.5	60.5	59.9	59.1	53.3	47.9	41.6	40.0	42.9	40.3	37.6	37.4	38.5	33.0	30.6	27.0	28.2	38.9	38.1	40.7	46.8	49.9
15	53.6	56.1	57.0	59.9	60.4	61.0	55.9	50.3	43.2	42.6	38.3	34.5	31.9	30.1	31.7	31.7	31.5	33.7	37.5	41.4	45.5	48.1	47.1	51.9
16	56.9	58.2	58.9	60.7	58.7	57.7	52.5	46.8	41.7	38.3	34.9	38.1	36.3	33.7	33.3	34.5	39.6	38.1	37.1	37.2	39.5	43.1	45.6	46.1
17	47.5	46.7	48.9	58.5	59.4	55.9	51.2	48.4	39.0	36.9	36.4	40.2	43.9	42.2	44.0	44.5	43.6	43.3	42.9	42.5	40.7	44.6	48.4	51.5
18	54.4	55.2	55.9	56.2	59.0	56.9	51.2	47.0	41.4	36.2	41.7	44.8	42.3	41.8	39.1	38.4	40.4	39.7	38.5	39.5	38.3	39.0	38.3	39.4
19	37.5	35.9	37.8	46.7	38.2	34.8	29.6	29.3	28.0	26.4	24.0	21.6	18.5	22.3	23.4	22.6	28.2	33.0	33.1	32.9	35.0	36.6	40.7	38.6
20	41.7	46.7	45.7	53.6	48.2	47.0	43.7	40.2	35.8	33.1	29.7	26.6	24.2	24.3	23.7	27.5	35.4	37.0	37.1	36.3	33.7	34.0	35.0	36.4
21	38.1	39.0	38.6	39.2	42.0	39.5	36.0	31.9	30.0	26.6	28.8	33.0	31.2	26.7	24.6	30.2	32.0	31.4	29.8	29.0	29.9	32.1	35.2	41.3
22	37.6	38.7	39.9	41.3	42.8	43.3	44.9	40.5	33.7	30.7	31.5	37.3	35.3	34.8	34.2	35.1	34.8	36.2	36.1	32.0	30.3	30.0	32.1	33.3
23	34.4	34.3	40.6	51.4	47.3	42.7	39.1	34.4	29.9	22.1	19.4	19.0	18.9	18.2	17.1	27.0	29.5	30.2	27.6	27.4	28.3	28.7	29.4	29.1
24	30.9	32.8	33.5	37.2	45.3	45.0	38.2	36.7	30.2	26.8	28.6	33.6	35.7	32.9	36.1	33.9	34.1	37.4	41.9	43.0	47.0	43.8	44.4	53.5
25	55.0	56.8	57.8	64.1	60.6	59.7	57.4	51.5	47.7	46.2	50.0	46.5	45.8	44.2	42.3	45.1	48.7	46.8	44.1	44.7	47.1	47.1	47.2	49.0
26	53.8	58.8	58.0	57.0	52.7	51.0	48.9	42.8	38.4	34.0	31.5	37.8	36.4	38.3	40.5	41.6	40.7	37.8	40.7	39.9	39.5	41.4	44.2	46.4
27																								
28	58.3	57.0	57.7	61.1	60.6	54.0	52.3	50.3	44.8	42.9	45.1	45.3	42.9	39.3	40.3	43.2	41.6	39.9	38.9	41.0	53.2	53.8	54.6	56.1
29	57.4	60.2	62.7	66.6	67.5	62.1	62.0	61.8	50.4	41.9	37.2	33.8	36.4	40.3	53.9	51.5	54.1	50.6	51.0	54.9	56.0	56.8	59.1	62.7
30	65.2	68.2	68.5	68.1	66.2	58.4	59.8	59.1	53.1	50.0	45.9	40.8	37.1	37.3	36.7	30.9	36.7	42.5	43.2	44.9	48.0	50.6	54.5	57.3
31	57.5	55.8	57.9	62.3	61.9	51.3	53.9	51.8	41.7	38.5	40.4	40.1	38.5	36.3	38.5	37.7	38.9	41.8	42.1	43.0	47.5	48.7	52.3	55.7

Figure C.3. The average relative humidity data retrieved from the meteorological station for Konak Square (Source: Turkish State Meteorological Service-TUMAS)

APPENDIX D

THE METEOROLOGICAL DATA OF KIZILAY SQUARE

METEOROLOJİ

T.C.
ÇEVRE ve ORMAN BAKANLIĞI
DEVLET METEOROLOJİ İŞLERİ GENEL MÜDÜRLÜĞÜ

Saatlik Ortalama Sıcaklık (°C)

İSTASYON ADI/NO: ANKARA / 17130
YIL/AY: 2009 / 8

GÜN/SAAT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	16.5	16.2	15.9	16.1	18.7	21.1	23.2	24.0	25.0	26.1	26.7	26.6	27.1	27.1	26.8	26.6	25.5	24.5	22.9	21.4	20.8	20.2	19.4	18.3
2	17.7	17.2	16.6	17.3	19.9	22.1	23.5	24.3	26.6	28.3	28.1	28.0	29.0	28.7	28.1	27.3	25.9	23.5	22.5	21.8	21.1	20.0	19.3	18.5
3	18.0	17.3	16.6	17.2	19.6	22.3	23.3	25.1	26.1	28.1	29.2	29.8	30.3	30.2	29.9	29.1	27.5	26.6	25.2	24.1	22.5	21.4	20.3	19.6
4	19.0	18.5	18.0	18.6	21.3	24.2	25.2	26.7	28.2	29.1	30.0	31.0	31.6	32.4	32.3	32.0	30.0	27.8	26.7	25.6	23.8	22.7	21.9	21.2
5	20.7	19.8	19.4	20.1	23.0	25.2	27.0	29.1	30.6	32.0	33.2	33.5	33.9	34.1	34.4	33.7	31.8	29.8	27.6	27.5	25.8	24.3	23.3	22.8
6	22.1	22.0	21.3	21.5	24.0	27.4	30.7	31.6	32.3	33.5	34.5	35.0	34.3	34.4	33.9	33.0	31.4	29.3	27.5	26.1	24.8	23.4	22.1	21.6
7	21.3	21.1	21.1	21.0	22.6	23.4	26.7	28.1	28.6	29.4	30.1	31.1	31.0	30.2	29.6	28.5	26.9	25.3	23.5	22.6	21.7	20.9	20.4	19.8
8	19.4	18.3	17.9	18.3	20.3	22.2	24.4	25.6	26.9	27.7	28.5	26.5	25.9	27.8	26.7	26.2	25.2	23.1	21.8	20.8	20.0	19.2	18.7	18.3
9	17.7	17.0	16.6	16.0	18.5	20.7	22.3	23.3	25.6	25.9	26.0	26.4	26.3	25.9	26.0	24.6	23.2	21.5	20.5	20.0	19.3	18.7	17.9	17.4
10	17.1	16.5	15.4	15.4	17.6	19.2	21.1	21.8	22.7	23.8	24.3	24.9	24.8	25.4	25.2	23.6	22.5	21.5	20.0	18.7	17.8	16.8	15.8	14.8
11	14.1	13.3	13.0	13.7	15.4	17.6	20.0	20.8	22.1	22.6	23.1	23.3	24.3	25.4	24.7	24.3	22.4	20.6	19.3	18.1	17.3	16.3	15.1	14.6
12	14.0	13.4	13.1	13.5	15.7	18.9	21.6	22.7	23.6	24.4	25.5	26.1	26.9	27.1	27.2	26.8	24.9	24.0	22.2	20.7	19.6	18.9	18.3	17.3
13	16.3	15.9	15.5	15.8	18.1	20.2	22.1	24.2	25.2	26.5	28.9	28.6	28.5	28.6	28.4	27.6	26.4	24.8	23.3	22.2	21.3	20.5	18.7	17.8
14	17.3	16.5	15.8	15.8	18.4	21.2	23.2	25.4	26.5	27.8	29.1	30.0	30.9	31.3	31.2	30.7	27.6	25.3	23.1	22.2	21.1	20.2	19.6	18.8
15	18.3	17.7	17.1	17.2	19.8	22.8	25.6	27.4	29.5	30.3	31.6	32.1	33.2	33.5	33.3	32.3	30.1	28.1	26.6	25.5	24.5	23.8	22.7	21.2
16	20.5	20.2	19.4	19.6	21.5	23.6	25.6	27.2	28.8	30.1	30.6	31.2	31.1	30.7	29.7	28.2	26.6	25.2	23.7	22.4	21.3	20.3	19.3	18.5
17	17.9	17.4	16.8	16.5	18.9	21.9	22.8	24.6	26.1	27.0	28.0	28.3	28.8	29.1	28.9	28.0	26.4	25.7	24.5	23.5	22.5	21.6	20.8	20.0
18	19.3	18.6	18.0	17.8	20.0	22.7	25.0	26.3	27.2	28.3	29.1	29.8	30.3	30.5	30.3	29.2	26.9	25.1	23.8	22.8	21.9	20.8	19.4	18.9
19	18.4	17.8	17.3	17.5	20.2	22.6	24.4	26.7	27.9	29.0	29.6	30.6	31.0	31.1	30.9	29.6	27.7	25.9	24.7	23.7	22.7	21.8	20.9	20.1
20	19.3	18.7	17.9	17.7	20.1	21.9	24.1	26.2	27.4	28.4	29.5	30.1	30.5	29.9	28.8	27.8	26.2	23.8	22.6	21.5	20.7	19.8	18.7	18.3
21	17.5	16.3	15.1	15.0	17.1	19.5	22.0	23.3	24.2	25.8	26.8	27.7	27.7	27.5	27.7	26.6	24.8	23.0	21.6	20.6	19.7	18.8	17.8	16.9
22	16.0	15.3	14.7	14.8	17.1	19.0	20.8	22.3	23.7	24.9	26.3	27.8	28.2	27.9	28.1	27.1	25.2	23.2	21.6	20.2	18.8	18.4	17.9	17.0
23	16.1	15.5	14.7	14.3	15.9	18.5	20.8	22.0	23.5	24.3	25.4	26.2	26.7	26.8	26.3	25.2	23.5	22.0	21.1	19.3	17.8	16.7	16.0	15.9
24	15.4	14.9	14.3	14.2	16.0	18.1	20.6	22.1	23.6	24.2	25.2	26.2	26.8	27.7	27.1	26.4	25.0	23.2	21.9	20.0	19.1	18.4	17.6	17.0
25	15.7	15.3	14.4	13.8	17.0	19.7	22.5	24.6	25.9	26.5														
26																								
27																								
28	15.1	14.5	13.8	13.7	16.1	19.1	22.1	24.5	26.2	27.5	28.6	29.3	29.5	29.4	28.8	27.4	25.5	23.8	21.4	20.1	19.4	18.7	18.1	17.3
29	15.7	14.5	13.6	13.5	16.4	20.3	24.1	26.4	27.4	28.8	30.4	30.7	31.3	31.5	31.5	30.2	28.0	25.0	23.5	21.7	21.4	19.9	18.9	18.4
30	18.3	17.5	17.0	16.8	19.3	21.4	24.0	26.8	29.1	30.4	31.6	31.9	32.1	32.0	31.6	30.5	28.3	26.8	25.6	24.5	23.5	22.3	21.8	20.6
31	20.6	20.1	19.2	19.0	19.6	22.6	25.6	28.4	30.0	30.7	30.7	30.7	31.1	29.6	27.7	25.8	25.1	24.1	23.2	22.6	21.2	20.5	19.6	18.5

Figure D.1. The average air temperature data retrieved from the meteorological station for Kızılay Square (Source: Turkish State Meteorological Service-TUMAS)

T.C.
ÇEVRE ve ORMAN BAKANLIGI
DEVLET METEOROLOJI IŞLERI GENEL MUDURLUGU

Saatlik Ortalama Rüzgar hızı (m_sec.)

ISTASYON ADI/NO: ANKARA / 17130
YIL/AY: 2009 / 8

GÜN/SAAT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	2.0	1.9	2.0	1.5	1.4	2.0	2.7	2.1	2.1	1.8	2.3	1.8	2.1	3.0	2.0	3.5	4.3	3.9	5.3	5.1	4.9	3.4	3.3	3.5
2	3.1	3.1	3.3	3.3	3.5	3.2	2.2	1.7	2.8	3.7	2.7	2.6	3.4	3.4	4.0	3.3	5.2	5.2	4.6	5.0	3.9	2.7	2.9	2.9
3	3.2	3.4	2.9	2.9	3.5	2.6	1.9	2.2	2.1	2.8	3.4	3.4	3.4	2.8	3.1	3.6	3.4	2.5	2.1	2.9	3.2	3.8	3.3	2.8
4	3.0	3.5	3.7	3.5	3.0	2.5	1.5	1.7	1.8	1.8	2.2	2.2	1.8	1.8	1.7	1.2	1.4	1.5	1.2	2.8	2.8	3.3	3.7	3.9
5	4.4	3.7	3.6	2.2	1.9	2.1	1.5	1.3	1.8	1.7	2.1	1.9	1.8	1.6	1.6	1.6	1.3	1.4	1.0	2.4	2.5	3.5	3.9	4.4
6	3.0	3.7	4.1	3.5	2.6	2.9	2.9	1.8	1.7	1.9	2.0	2.3	1.7	2.9	2.7	3.0	1.8	5.9	6.7	2.8	3.0	2.8	3.4	2.1
7	3.5	5.6	2.6	3.1	3.5	3.9	3.4	1.8	1.7	2.6	2.4	2.6	3.0	3.1	3.1	2.4	3.6	4.5	4.6	5.0	6.5	3.7	2.4	2.6
8	2.5	2.8	3.8	3.4	2.5	3.7	3.3	2.6	2.7	2.9	2.4	4.2	3.5	3.3	3.1	3.5	5.3	5.0	4.8	4.7	3.5	3.4	3.1	3.5
9	4.3	3.6	3.3	3.4	3.5	3.2	2.2	2.2	3.5	3.3	3.0	2.5	3.1	3.5	3.5	4.0	5.1	5.2	5.1	5.2	4.9	5.7	5.4	4.6
10	4.6	4.4	4.2	4.4	3.8	2.8	3.1	3.4	3.6	3.8	3.4	3.2	3.4	3.6	3.5	4.6	4.6	4.6	4.3	4.9	4.8	4.1	3.2	3.1
11	3.0	2.4	2.5	2.6	3.3	3.2	2.5	2.2	2.6	2.2	2.5	2.2	2.7	2.5	1.8	1.9	4.8	4.8	5.2	5.5	3.6	2.5	3.6	3.6
12	3.4	3.1	3.2	3.7	3.7	3.3	3.2	2.1	1.7	2.1	2.0	2.2	1.8	1.7	1.3	1.5	1.0	1.8	3.7	4.7	4.1	4.2	4.3	4.2
13	3.8	4.3	3.9	4.3	4.7	4.6	3.9	3.0	2.1	2.5	3.6	2.5	2.1	2.1	2.1	1.2	1.7	5.1	4.1	4.0	3.8	2.9	3.7	3.3
14	3.7	3.0	2.3	2.6	2.3	2.4	1.5	1.8	1.9	2.2	2.1	2.0	1.7	1.8	1.7	1.4	1.1	1.2	1.4	3.0	2.9	3.2	4.3	4.3
15	3.9	2.6	2.3	2.6	2.8	2.5	1.9	1.5	1.5	1.8	1.9	1.6	2.2	1.6	1.5	1.5	1.2	4.9	4.9	5.4	5.3	5.2	4.2	4.4
16	3.5	3.6	3.5	3.5	3.6	4.5	5.3	4.5	3.6	4.1	4.4	4.7	5.7	5.6	5.8	6.0	5.2	5.0	4.6	4.7	4.7	4.2	4.6	4.5
17	4.0	3.5	3.6	3.0	3.3	3.4	2.3	2.4	3.4	3.7	3.7	3.0	2.8	2.3	2.5	2.4	3.1	2.5	2.2	3.5	3.9	3.5	3.8	4.1
18	3.9	4.1	3.1	3.2	3.3	2.4	2.2	2.0	1.5	2.2	2.0	2.8	2.5	2.2	2.1	3.0	3.8	5.2	4.9	3.3	2.2	2.2	2.1	3.2
19	3.6	3.4	3.9	3.8	3.7	4.4	3.6	3.3	3.0	3.3	3.0	3.1	3.0	3.2	2.8	4.4	5.0	5.7	5.3	5.3	5.2	4.1	4.5	3.5
20	3.2	3.8	4.6	3.6	2.7	2.9	3.3	4.6	5.5	5.5	5.5	5.2	4.7	5.5	5.6	5.3	5.6	5.5	4.8	2.2	2.8	2.0	2.6	3.5
21	3.1	2.7	1.7	3.4	2.8	3.1	3.3	2.8	2.9	3.8	4.0	4.1	3.3	2.9	3.5	3.5	4.7	5.1	5.2	5.0	4.9	4.9	4.3	4.9
22	4.8	4.5	4.0	3.8	3.5	3.7	3.1	2.5	2.3	2.7	2.9	2.8	3.8	2.3	3.5	4.5	6.5	5.7	4.4	2.7	2.7	4.5	4.7	4.4
23	4.2	4.5	4.3	3.5	4.5	4.7	5.1	4.6	3.7	3.7	3.7	3.1	3.1	2.9	3.6	4.0	4.2	3.5	3.4	3.4	3.3	2.9	3.2	3.7
24	4.4	4.4	4.4	4.7	4.7	4.2	3.4	2.5	2.8	2.6	2.2	2.3	1.7	1.8	1.8	1.2	2.2	1.9	2.3	2.4	2.7	2.7	3.3	2.8
25	1.7	1.7	1.1	1.7	1.6	1.6	1.5	1.8	2.3	1.8														
26																								
27																								
28	4.3	4.6	4.6	4.0	3.7	4.0	3.0	2.9	1.9	2.8	5.1	4.5	4.4	4.5	5.1	4.6	2.6	1.8	1.3	0.9	1.6	2.9	2.4	2.5
29	1.6	2.5	2.7	2.1	2.6	3.0	2.4	2.4	2.0	2.1	2.1	2.1	2.3	2.1	1.8	1.9	1.7	0.7	1.3	2.9	3.0	2.1	1.8	2.4
30	3.7	3.4	3.1	3.1	1.7	1.3	1.4	1.3	1.6	1.8	2.0	2.4	1.8	2.1	1.6	1.4	2.2	4.8	5.0	4.8	4.4	4.2	4.1	3.7
31	2.6	3.8	3.3	2.9	3.0	2.6	3.6	2.7	2.7	2.6	2.2	2.5	2.4	4.7	9.0	8.1	5.3	4.8	5.3	3.9	2.4	3.7	3.6	3.6

Figure D.2. The average wind speed data retrieved from the meteorological station for Kızılay Square (Source: Turkish State Meteorological Service-TUMAS)

T.C.
ÇEVRE ve ORMAN BAKANLIGI
DEVLET METEOROLOJI IŞLERI GENEL MUDURLUGU

Saatlik Ortalama Nem (%)

ISTASYON ADI/NO: ANKARA / 17130
YIL/AY: 2009 / 8

GÜN/SAAT	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	65.0	65.7	66.6	66.7	57.7	51.2	44.9	41.3	37.7	34.3	32.6	31.6	30.2	30.1	30.9	31.7	34.0	36.6	45.9	53.5	54.9	57.1	60.5	64.2
2	66.2	68.4	70.8	68.0	59.0	53.1	48.5	38.0	31.0	26.3	24.7	25.2	23.7	23.1	26.1	28.3	33.3	39.9	46.8	49.6	53.0	57.3	59.7	63.0
3	65.6	68.4	71.1	68.9	60.7	52.8	49.5	41.7	36.0	28.0	24.4	24.6	23.6	24.5	25.0	25.6	28.0	30.5	34.2	37.2	42.2	46.0	50.0	53.9
4	58.6	63.1	66.8	66.3	58.5	48.1	42.3	37.5	34.1	31.6	29.2	26.1	23.4	19.7	18.1	17.9	21.0	25.7	28.4	29.8	32.9	34.2	36.0	38.1
5	40.5	44.7	49.2	50.1	44.6	39.5	33.9	26.6	22.5	20.2	16.7	16.6	15.8	15.1	14.4	14.4	17.3	21.3	25.4	25.5	29.1	34.7	36.9	39.1
6	40.6	41.3	45.1	47.7	42.4	32.6	25.2	22.5	20.7	17.0	13.8	12.2	12.3	12.7	13.6	13.7	16.3	25.3	35.0	40.8	43.3	46.3	48.6	49.3
7	50.5	49.3	47.0	46.0	42.0	40.2	34.1	29.5	27.3	25.8	23.5	23.3	24.6	26.0	28.7	30.8	36.4	42.7	47.9	52.2	57.8	61.5	61.7	62.0
8	61.9	65.8	67.1	66.0	59.6	53.7	47.3	42.3	37.3	34.0	31.7	41.6	42.3	32.3	32.9	33.4	37.6	43.7	49.3	51.3	54.2	57.5	59.1	61.0
9	62.0	64.1	66.1	66.9	59.5	54.4	50.3	45.3	34.5	30.1	29.9	28.6	27.1	27.7	27.7	28.8	33.6	40.1	42.8	44.1	47.6	52.4	55.7	58.2
10	60.0	61.9	66.0	65.5	58.5	52.2	45.0	40.8	34.0	28.9	25.3	24.8	25.2	24.1	24.1	26.4	28.5	32.2	39.6	46.3	47.5	48.8	52.0	54.5
11	56.4	59.1	60.6	59.0	54.0	46.8	39.4	37.5	33.7	31.5	29.3	27.6	25.4	22.0	22.2	22.8	27.2	33.6	39.8	46.5	49.8	51.6	54.8	57.2
12	59.8	63.5	66.5	66.3	59.7	50.2	41.8	34.9	30.9	26.7	23.8	20.9	19.6	18.8	17.7	17.6	20.8	27.1	31.6	32.8	33.9	37.7	42.1	48.9
13	54.4	57.4	59.1	58.7	52.5	46.1	40.7	35.0	31.7	27.8	20.6	19.4	17.8	17.5	17.9	19.4	22.2	27.6	30.6	34.6	37.3	39.9	45.5	48.1
14	48.3	50.6	52.9	54.2	48.0	41.1	33.9	28.1	24.1	19.1	12.2	8.1	6.2	6.5	7.3	7.7	10.7	14.6	19.5	21.4	26.2	27.2	28.0	32.0
15	36.2	40.3	44.4	46.6	43.3	37.0	29.7	24.1	16.3	13.4	14.0	13.9	12.3	11.7	11.8	12.4	15.5	25.9	30.4	32.2	35.1	37.6	41.3	45.2
16	47.4	48.9	51.2	49.9	42.3	32.9	25.5	26.4	24.1	22.5	19.6	17.5	17.3	17.9	20.3	25.5	30.2	34.2	38.8	44.6	48.6	52.5	56.5	59.3
17	62.5	65.4	66.6	67.0	59.4	51.4	47.7	41.6	37.1	34.7	31.1	28.4	26.4	25.3	25.5	27.2	29.7	29.3	33.5	38.5	44.3	45.6	51.1	54.4
18	57.4	61.5	64.9	65.7	60.3	50.5	41.8	38.4	34.9	31.6	28.5	25.5	22.9	22.6	22.6	24.6	33.5	40.5	45.1	48.9	51.8	54.7	58.6	58.9
19	59.8	61.6	63.5	63.8	56.8	49.9	44.9	38.4	35.3	31.4	25.9	20.2	19.0	18.3	18.6	22.0	29.2	37.9	42.8	46.1	52.3	54.9	57.5	60.2
20	63.4	66.1	69.5	70.6	63.0	57.2	49.0	35.4	26.1	23.2	21.2	19.7	19.9	20.9	23.0	25.3	29.9	41.4	44.0	48.2	48.3	51.6	55.2	57.9
21	62.3	66.6	71.5	71.5	62.3	52.1	44.4	40.3	34.1	29.6	21.0	17.8	19.2	19.8	20.3	18.4	23.7	30.5	35.9	40.2	44.5	48.9	53.6	57.7
22	61.7	64.6	66.7	67.0	59.5	52.8	46.9	41.4	35.7	29.4	20.9	16.5	20.5	23.1	22.4	22.7	20.2	25.3	30.0	33.3	38.8	43.1	46.0	49.4
23	51.5	52.7	55.3	57.5	53.5	49.4	40.3	33.7	29.3	24.4	20.6	17.0	18.0	19.5	20.2	21.3	24.4	26.3	26.6	29.9	33.5	40.1	48.9	55.6
24	58.9	62.2	65.5	66.9	61.1	54.1	46.2	39.5	34.7	32.6	29.6	27.4	25.6	23.0	22.9	23.5	24.2	28.7	28.9	32.5	33.3	36.1	39.8	41.7
25	45.7	49.5	52.2	53.6	45.8	42.1	37.6	32.4	27.2	26.0														
26																								
27																								
28	55.3	56.7	58.9	59.6	52.5	45.3	34.6	24.1	17.0	14.4	15.0	12.2	11.2	9.8	9.3	9.7	12.1	16.7	23.1	25.8	27.4	27.7	29.3	31.4
29	35.9	39.5	42.7	44.1	38.8	33.5	27.1	20.0	15.7	12.5	10.6	10.3	9.7	9.3	8.6	9.1	10.1	15.8	18.2	16.4	21.2	26.7	31.4	35.0
30	35.1	35.7	37.3	37.7	33.0	29.7	25.9	19.9	15.2	11.4	9.7	9.4	9.1	9.0	8.9	9.9	15.7	23.0	27.3	29.3	30.3	32.1	32.8	35.8
31	36.3	38.2	40.3	41.0	40.2	34.7	25.9	20.1	15.8	14.3	13.4	13.3	13.0	18.4	23.4	27.0	27.8	30.2	32.1	36.7	43.5	44.2	47.0	52.2

Figure D.3. The average relative humidity data retrieved from the meteorological station for Kızılay Square (Source: Turkish State Meteorological Service-TUMAS)