How Sensitive We Build to Climate? Design for Comfortable Urban Environment

1. Introduction

Comfortable urban environment closely relates with the sensitivity of the design of the built environment to the urban microclimate. Climate sensitive urban design, being one of those approaches to consider the local characteristics and needs, is a useful tool to provide more sustainable solutions for the future developments. Climate sensitive urban design provides natural-based objectives to improve comfort through less consumption of world's resources and less destroying the nature as well as reducing the costs of energy consumption.

This study intends to gain insights into the relationship between spatial characteristics of the built environment and the perceived climate on the site. It also looks into the ways how climate sensitive design principles can be applied to the built environment to increase thermal comfort level. In this regard, Konak Square has been selected as the case study. This study investigates how the spatial structure of Konak Square in Izmir (Turkey) influences the comfort perception of the people in the summer season. Initially, the concept of climate sensitive design and its very core principles are reviewed. Following, spatial structure of the site including its location, general climatic conditions, surrounding urban texture, surface cover materials and shading elements have been analyzed. In order to analyze the people's perception regarding their thermal state in Konak Square, a questionnaire has been performed. Finally, the findings have been processed through evaluation of the people comfort perception in relation to the spatial structure of the site and to improve comfort conditions on the site specific design guidelines are offered based on climate sensitive design principles. This enhancement is expected to have not only a positive effect on outdoor but also on indoor space comfort in Konak Square and the surroundings.

2. Climate Sensitive Design

The built-up area and design related variables directly influence the micro climate in an urban environment (Eliasson & Svensson, 2002; Giridharan et al., 2004-2005; Gomez et al., 2004; Eliasson, 1996; Johansson & Emmanuel, 2006). Similarly, previous researches (Golany 1996; Johanssons 2006; Bosselmann and Arens 2005) demonstrate that the micro climate on a site is mostly dependent on the physical factors such as orientation, urban form, urban texture, urban density, surface materials, shading opportunities and so forth. Therefore, the climatic comfort of built environment both indoor and outdoor can be regulated by climate sensitive design through an appropriate physical composition.

Climate sensitive design approach intends to address opportunities and constrains of climate so that the comfort conditions of urban living can be improved and more livable cities can be achieved. Climate sensitive design provides fundamental principles specific to different climates, since the requirements of each climate differ with respect to their particular thermal needs. The objectives of climate sensitive design can be briefly summarized as follows;

- Maximizing the site's natural potential through a precise selection of location, orientation, H/W ratio and density,
- Obtaining maximum efficiency from the sun as reducing the reliance on artificial lighting and active heating/cooling systems, and from the wind as providing natural ventilation
- Reducing the amount of unpleasant wind flow and solar radiation,
- Advancing water efficiency; re-using all rainwater and wastewater,
- Utilizing a various plantings throughout the physical properties; vegetated roof, green walls, vertical gardens and vegetation-covered surfaces, sky courts,
- Enabling recyclable and renewable building materials, and advancing thermal insulation.

3. Spatial Structure of Konak Square, Izmir

Figure 1. Izmir located in the West Coast of Turkey (Adapted by the author, Source: WEB_1, 2011)

Figure 2. Konak Square in Izmir (Adapted by the author, Source: Google Earth)

Having a population of 3.2 million the city of Izmir is the third biggest city in Turkey. It is located on the west coast of the country by the Aegean Sea (Figure 1).

Izmir has a typical Mediterranean climate which corresponds one of the sub-groups of temperate climate defined in Koppen climate classification (Kottek, et al. 2006). The weather is characterized by long, hot and dry summers and mild to cool, rainy winters. 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 1).

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

Table 1. Izmir Long-Term Monthly Air Temperature, 1975-2008 (Adapted by the author, Source: Turkish State Meteorological Service 2009)

Konak Square, the main square of the city, is a nodal location in the Konak district of Izmir (Figure 2). Today it serves as a core of daily intersections. It is a combination of green open spaces, relatively new and tall building developments, and compact historical buildings. Since all of the spatial features and design elements influence people's behaviors, usage of outdoor spaces and climate perception, we investigate the spatial structure of Konak Square based around the following 4 categories; urban texture, surface cover materials, shading elements and periodical shadow maps. The spatial analysis has been conducted on August 20, 21 and 22, 2009 which demonstrate very typical summer days.

Urban Texture

The study area is located on a flat topography and open to the sea on the west end. It is 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. The surrounding buildings that face the square on the east end are parallel to the coast line. For the east end, the study area 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.

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. Especially clustered building group on the south-east end are characterized by many high-rise constructions up to 8-9 storey (Figure 4). 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 considerable height difference between adjacent buildings. Ground floor passageways are the major characteristics of the structures generally seen in the entire study area. Potential wind tunnels have been experienced in many locations due to the structure of the buildings which were built with ground floor passageways (Figure 3).

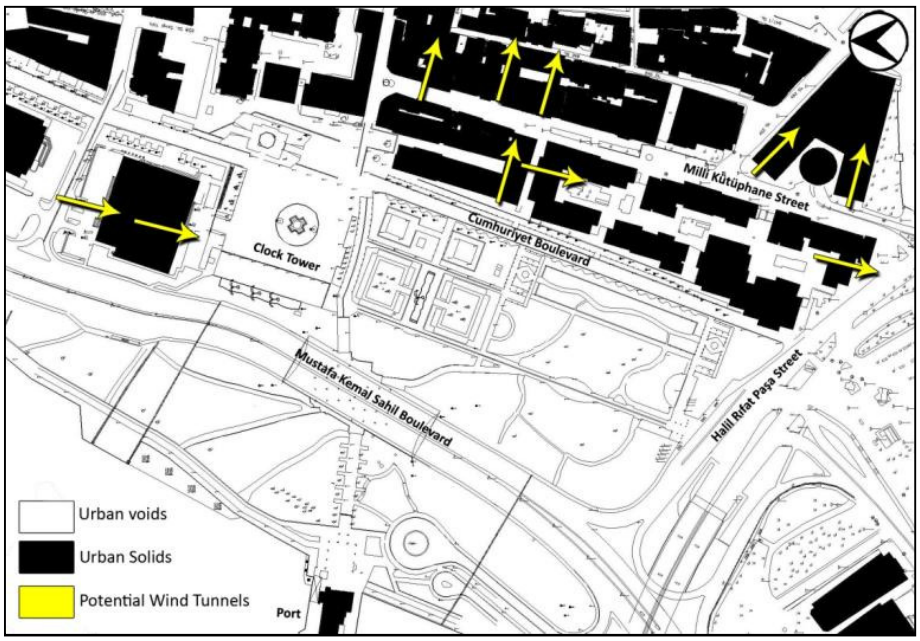


Figure 3. Urban Texture of Konak Square (Drawing by the Author)

Surface Cover Materials

On the surfaces of the buildings, standard materials are quite common comparing to the heat and sun reflective surface materials. Reflective materials are seen in the ratio of 15%. They are generally found on the surfaces of building groups in the south east. The dominant color of the study area is dark grey (Figure 4).

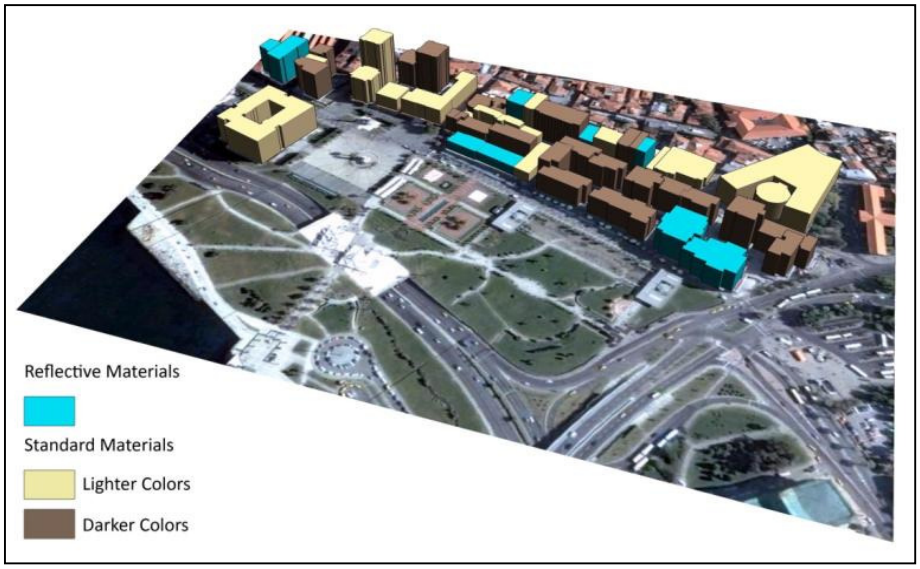


Figure 4. Building height and surface cover materials
(Drawing by the author on the image from Google Earth)

On the ground surface, the square is surrounded by an asphalt paved road and dominated by the stone paved pedestrian ways. The color and type of the materials used remain the same along the pedestrian ways. On the other hand, around %40 of the field is covered by green spaces (Figure 5). Furthermore, rectangular shaped History Park and Open Exhibition Area locating in the center and the area on the way to the port on the west end are paved with special lighter colored ground cover materials. The Cactus Garden on the south end and through the paths along the garden are intended to be left natural, and covered by soil.

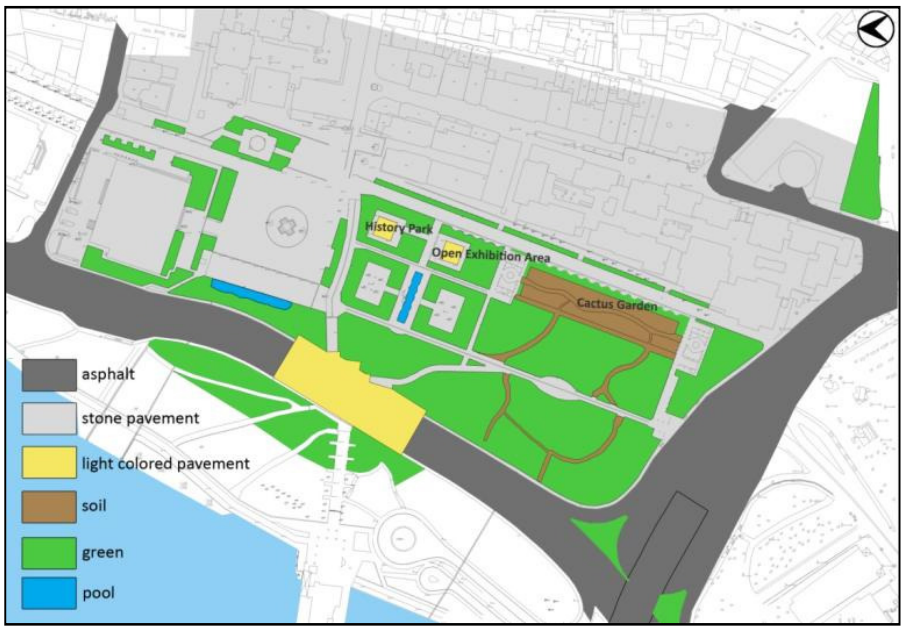


Figure 5. Ground Cover Materials (Drawing by the Author)

Shading Elements

The following map has been realized to illustrate the trees and canopies located in the study area (Figure 6). 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 surrounding buildings. Similarly, the large part of the trees can be seen along the pedestrian ways and close by the seating niches.

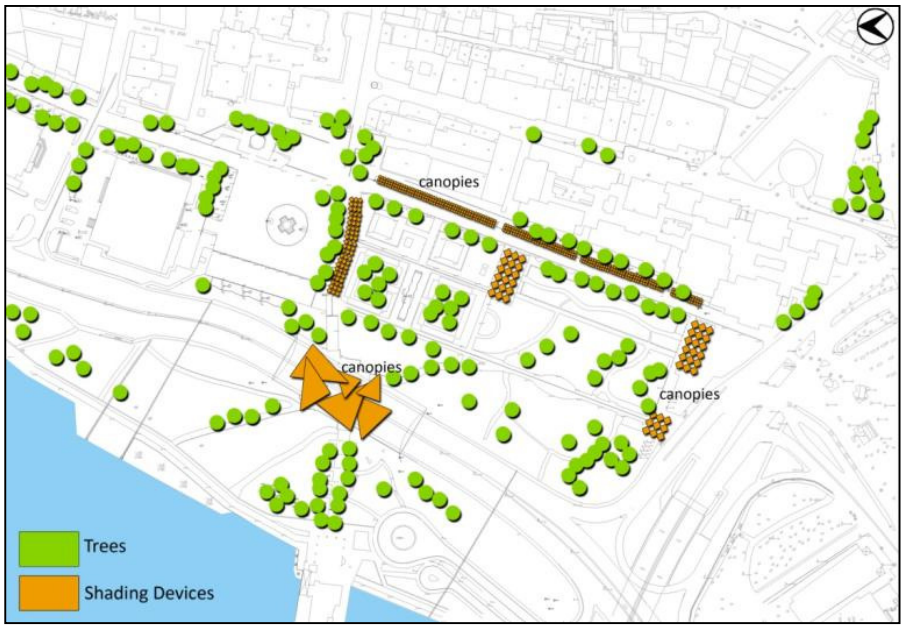


Figure 6. Shading Elements (Drawing by the Author)

Shadow Map

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

Morning period (08.00h): The major pedestrian axes are fully shaded (Figure 7). Especially, Cumhuriyet and Milli Kutuphane Streets can benefit from shadows of the buildings. Also, the courtyards in the 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 but shadow lengths in that area are longer comparing to the others on the site. On the other hand, the whole green spaces as well as special design areas such as History Park and Open Exhibition Area cannot benefit from the shadow of the surroundings.

Figure 7. Shadow map of morning period
(Drawing by the author on the image from Google Earth)

Midday period (12.00h): Large part of the study area is in the sun (Figure 8). Around the Clock Tower, particularly the places without any shading elements, has been monitored being exposure to the excessive sun. Two major pedestrian ways are half shaded. The courtyards in the south-east end are partly in the sun.

Figure 8. Shadow map of midday period
(Drawing by the author on the image from Google Earth)

Afternoon period (16.00h): In this period, again large portion of the study area is in the sun (Figure 9). The open green spaces, all of the special design areas and the areas around the Clock Tower are exposure to the sun. They can only partly be protected from the sun by the trees which are inadequate for shading. The courtyards in clustered area and the other major pedestrian way Milli Kutuphane Street are fully in the shade.

Figure 9. Shadow map of afternoon period
(Drawing by the author on the image from Google Earth)

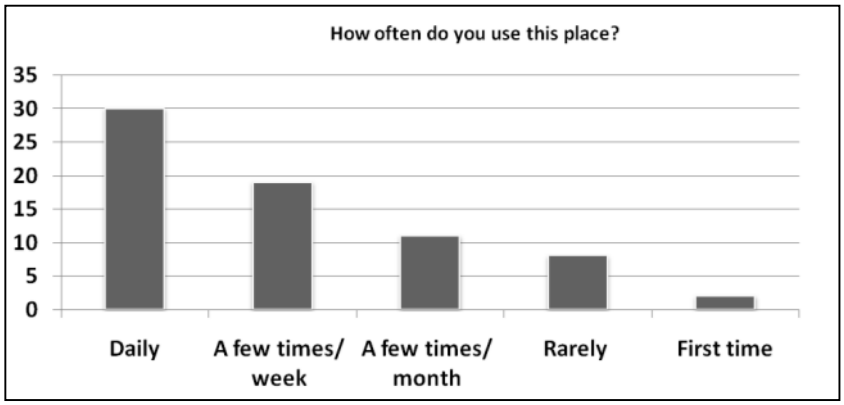
4. User Comfort Perception on the Site

The user comfort perception has been investigated through the questionnaire. Initially, a user map has been prepared through site monitoring on 21 August 2009 in order to determine specific locations for conducting the questionnaire. The user map illustrates how people use those locations on the site in midday period from 14.00 to 15.00h, and evening period from 19.00 to 20.00h (Figure 10). On 23 August 2009, the questionnaires were carried out in those locations where people rest, sit and gather in Konak Square. Total 70 people; 50 in day and 20 in evening periods have been questioned.

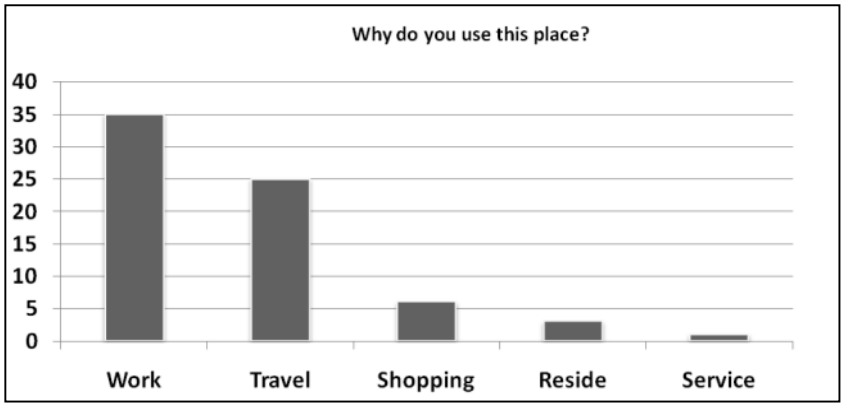
Figure 10. User map (Drawing by the Author)

In midday period, frequently used locations are the ones with the trees or canopies. In evening period, people prefer the places with a natural ground surface such as the ones on the south-west, close to the sea on the west or the ones around the Clock Tower. Regardless, people use larger areas on the site but less in numbers in evening period comparing to midday period. Some nodes such as bus stops, metro exits and seating niches are excessively used in both periods.

Most of the people use the site daily or weekly (Graph 1), for work, travel and shopping purposes (Graph 2). According to their participation rates to the questionnaire, the average age of the people on the site is between 25-50 year old for day, under 25-year old for evening period. While the site is used by those who work or do shopping in the surrounding buildings during day, it is used for recreation purposes during evening periods.



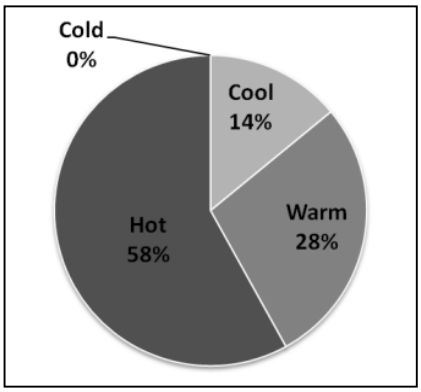
Graph 1. Frequency of use



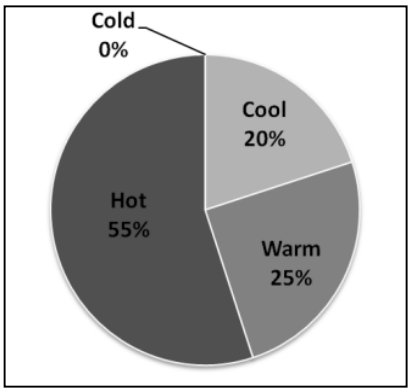
Graph 2. Purposes of use

User Perception of Environmental Parameters (air temperature, air velocity, humidity)

- People on the site have been questioned how they find the current weather in terms of air temperature (Graph 3 and Graph 4). 58% of the people in day, %55 of them in evening period have reported the current air temperature hot.

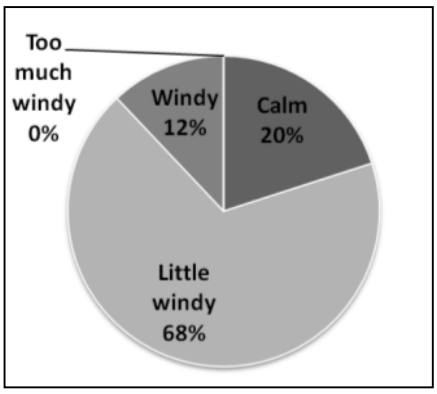


Graph 3. Temperature (Day period)

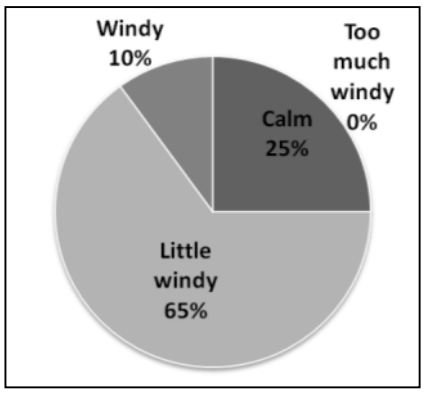


Graph 4. Temperature (Evening period)

- Participants have responded to the question of how they experienced the wind on the site (Graph 5 and Graph 6). 68% of the people in day, %65 of them in evening period have reported the current wind conditions little windy. Referring to the user map, people have generally been questioned in the places away from the buildings. Therefore, there are not any built-up settings that lower the wind speed, especially in the places people questioned.

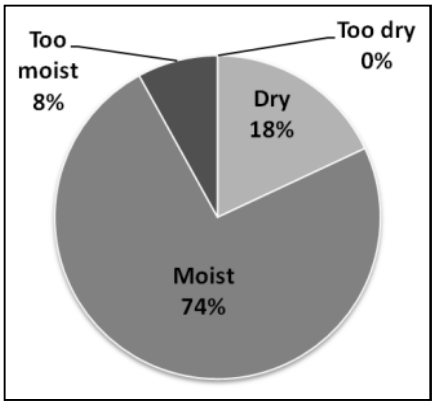


Graph 5. Wind (Day period)

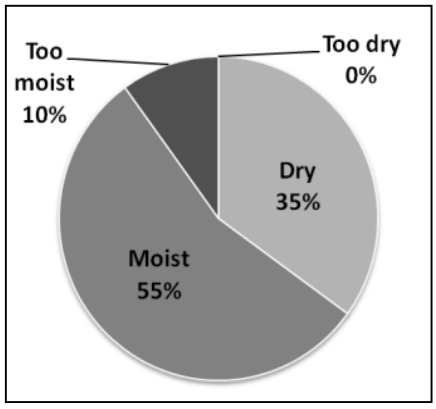


Graph 6. Wind (Evening period)

- Participants have responded to what they think of the humidity that they perceive on the site (Graph 7 and Graph 8). 74% of the participants in day period reported the current weather being moist. This falls to 55% in evening period.



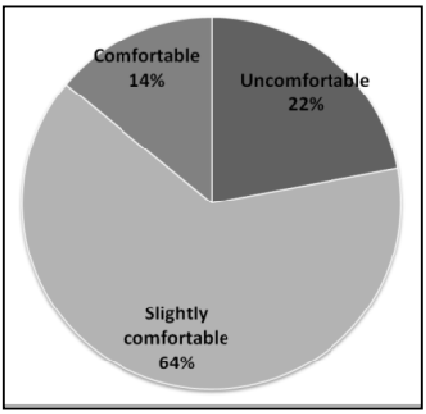
Graph 7. Humidity (Day period)



Graph 8. Humidity (Evening period)

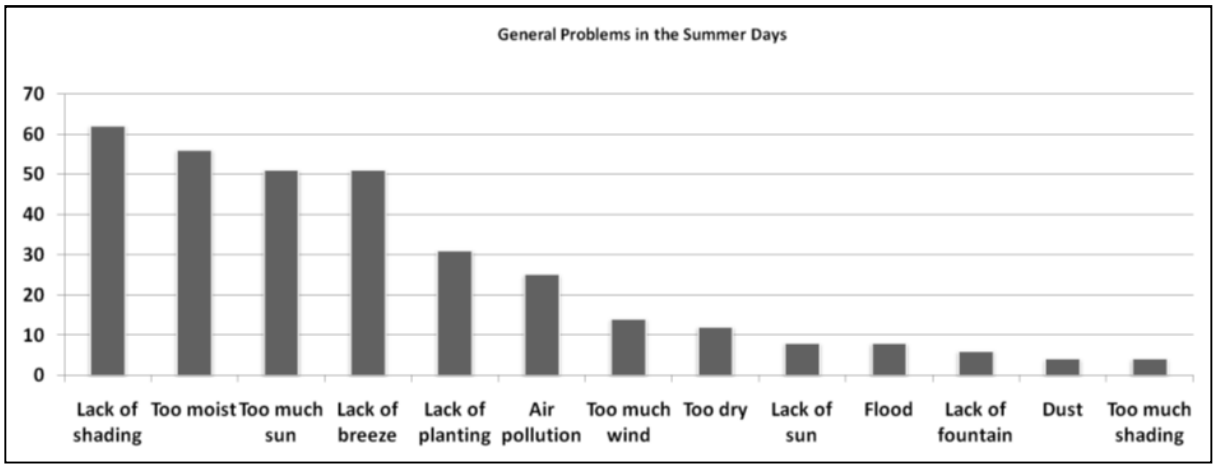
- The participants have been asked if they feel comfortable with the overall weather conditions on the site. Majority of the participants in both periods, reported being slightly comfortable on the site. In day period, 22% of the participants reported being uncomfortable whereas 14% of them comfortable (Graph 9). In contrast, 10% of the participants stated

being uncomfortable whereas 30% of them state being comfortable in evening period (Graph 10). Therefore, the site is felt more comfortable in the evening time comparing to the day time in the summer.



Graph 9. Comfort perception (Day period) *Graph 10. Comfort perception (Evening period)*

- User comfort has been investigated concerning the problems that people confront on the site in the summer days and the user's satisfaction with current weather conditions. The leading problems of the study area were mentioned as the lack of shading, experiencing too much moist, lack of breeze and greatly exposure to the sun (Graph 11).



Graph 11. General problems in the summer days

5. Climate Sensitive Approach to the Problems Experienced on Konak Square

Konak Square is surrounded by dense buildings, however the square itself is dominated by large open spaces so that most of the area do not benefit from the mutual shadings of the buildings. There are more urban voids than solids in the study area. This makes the square highly subjected to the impacts of the climatic conditions. For instance, the site is exposed to too much sun in day period and the heat that the built-up area absorbed starts to reveal in evening period while those open spaces help with catching more wind from the sea.

The average air temperature records of the closest meteorological station (morning period: 29.6℃; midday period: 34.4℃; afternoon period: 30.6℃; evening period: 27.4℃) show slightly uncomfortable characteristics in each period. This is in accordance with the findings of the questionnaires. The participants' perception of the site as being hot and the leading problem mentioned as lack of shading illustrate that the site is greatly exposed to the sun. Even the people questioned during resting in the shaded places reported again the weather hot, since the shading opportunities are limited and not efficient.

Secondly, average wind speed recorded by the meteorological station shows comfortable environment in each period (morning period: 2.6m/s; midday period: 3m/s; afternoon period: 2m/s; evening period: 6m/s). Since the site is located by the coast, it can catch the prevailing wind and people can sense the wind speed more accurately. 80% of the participants in day period and 70% of them in evening period were pleasant with the wind conditions on the site.

Thirdly, average relative humidity recorded by the closest meteorological station (morning period: %26, midday period: %18.5, afternoon period: 30%, evening period: %28.5) gives relatively comfortable conditions. On the other hand, while 74% of the people in day, %55 of them in evening period have reported the current humidity conditions moist, 60% of the participants both in day and evening period were pleasant with the perceived humidity on the site. Regarding, it can be seen that the people questioned in Konak Square were not very good at judging the humidity levels.

A spatial arrangement for the main square of a city requires consideration of many factors such as emphasis of the main square perception, provision of functional diversity and relations or thermally comfortable environment, etc. To upgrade the comfort level on the site both meteorological records and user evaluations help to determine what guidelines should be followed for the rearrangement of the square. The guidelines are grouped and summarized as follows:

Structures: The site is completely a built-up area, no new buildings will be constructed on the site yet several should be offered for the renewal of these structures. Existing buildings give some hints about these issues. The attached and row building groups along the major pedestrian ways in Konak Square provide good shading opportunities over the sidewalks for each period, especially in the morning period. But, massive building groups have been experienced lowering the wind speed during the day and increasing the heat gain of the built-up area in day period (Mengi, 2009). Structure of the buildings which were built with a passageway at the ground floor helps accelerate wind speed at the street level. It has also been experienced that the heterogeneous building heights in certain locations around Konak Square contributes to acceleration of the wind speed.

Shading elements and planting: The major problems reported in Konak Square are rather related to poor design of the devices designed inappropriately for shading. The shading devices have been observed not enough in numbers nor suitable for shading in general. Similarly, the recreation areas have inadequate planting and trees in Konak Square. Those places have been experienced uncomfortable during the day. There have been only a few trees providing the protection from the sun in the whole area. Especially, the area around the Clock Tower has lack of shading devices and enough planting. It has been reported that air temperature perceived here is higher than the other locations in the sun. Still, there are still some good shading devices over the metro exits, which protect the places where people wait underneath throughout the day. For a more comfortable environment, it is easy to offer more trees and shading devices. However these should not contradict with the urban square perception and vision of the historical buildings which symbolize the square and with straightforward accessibility and orientation on the site. At the same time while blocking the negative impacts of the sun, air circulation and specially wind catch should not be cut. Therefore these arrangements should be based on detailed climatic measurements.

Surface cover materials: The colors of the building surfaces are dominated by darker colors. Even though the ratio of the use of reflective materials on the building surfaces is 15%, these materials cause uncomfortable environments for outdoor spaces. This type of materials increase the amount of the heat and glare released to the outdoor space (Mengi, 2009). This type of materials should not be allowed in the surrounding buildings. Also, the color of the surfaces has been found affecting sun glare and general comfort of the users.

Water elements: It has been reported by a large number of people that Konak Square does not provide sufficient cooling design elements such as pools or fountains in its design. In fact the square has few water elements, but it seems that they are not perceived enough. The pools or any water elements play a considerable role for overall user comfort, especially in hot summer days. The water elements may be designed more attractive and active, and related to shaded areas and frequently used activities and paths.

6. Conclusion

The case study we conducted for Konak Square in İzmir, Turkey provided a pilot study through which we can understand the importance of the user comfort factor in outdoor design practices and what analyses have to be carried out before these design attempts. The analyses should include detailed site survey, long-term (for all seasons) climatic measurements and user perceptions and opinions.

This approach will provide comfortable indoor and outdoor spaces as well as contribute to the urban life by less negative impacts to the nature and lower energy costs.

References

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.

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.

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

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.

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.

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.

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.

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.

Mengi, O. (2009) Analysis of climate sensitivity in outdoor space: evaluating urban patterns in different climates, *Master's Thesis, Izmir Institute of Technology*, Izmir, Turkey.

WEB_1, 2011, Turkeycity, 09.08.2011
www.turkeycity.net

Nursen Kaya* & Onur Mengi**
*Assist. Prof. Dr. / Izmir Institute of Technology, Dept. of City and Regional Planning
**Research Assistant / Izmir University of Economics, Dept. of Industrial Design
TURKEY