Climate responsive urban design for Greek Public Space

Athens | Greece

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ABSTRACT: Greek public space has always reflected democratic values and freedom of speech. The ancient *agora* was the meeting place for philosophical discussions, cultural development and exchange of knowledge. Hence, it is a significant component of the Greek culture. The present situation in Greece has led to privatization, shrinkage and degradation of the public space. Urban outdoor spaces have been neglected and this has resulted to a lack of interest in the public realm. Additionally, Greece is located at the southernmost part of Europe and has already been greatly affected by climate change. Urban heat island phenomenon is evident in most Greek cities and outdoor spaces are no longer comfortable.

Constitution Square is the central square of Athens and it is located in front of the Greek Parliament. It is a space of high historical importance for Athens' residents, because the first Constitution of Modern Greece was signed there. Nowadays, it is a meeting place for social activities, a touristic spot and an important transportation hub for Athens. In terms of microclimate, very high temperatures (over 35 °C) can be developed in the summer period, and combined with other parameters (solar radiation, humidity, wind, etc.) can lead to high heat stress of the people. Regarding accessibility, the square is surrounded by big streets and there is not direct pedestrian access by pavement. The goal of this project is the redesign of Constitution Square in an integrated way, optimizing outdoor thermal comfort, accessibility and, in the end, creating a resilient and vibrant space for the Athenians.

For this purpose, an outdoor thermal comfort analysis was conducted, examining four representative points of the space. The analysis was carried out for the daytime hours, which represent the main occupancy hours of the space. Results showed that in the analysis period (summer), there is a very high percentage of heat stress (80% of the hourly data). Rearrangement of vegetation, creation of water surfaces, shading elements and pavement albedo increase were proposed in order to improve the existing situation of the square. Additionally, two adjacent streets were proposed to be pedestrianized in order to integrate the space in the urban fabric and improve the accessibility of the residents. Simulations of the proposed design showed that the interventions could lead to a reduction of heat stress up to 65%, creating a comfortable outdoor environment. The aim of these interventions is to improve the attractiveness of the space, increase its vibrancy, boost the local market, enhance the interaction of the people and lead to an urban regeneration, bringing agora back at the place it was born.

Keywords: outdoor thermal comfort, climate responsive design, urban sustainability

INTRODUCTION

By 2030, 60% of the world population will reside in cities (United Nations, 2014), so urban planners, designers, architects and engineers should generate a collaborative and comprehensive approach to respond to the forthcoming challenges. As the urban population is growing significantly, the quality of public spaces is becoming a key parameter for urban sustainability. The public space of a city is the place where people interact and exchange experiences, therefore its quality and vibrancy, are greatly important for social development. These spaces should be designed according to many criteria (climate, culture, etc.), taking also into account people`s needs. As the Danish architect Jan Gehl quoted; *Cultures and climates differ all over the world, but people are the same. They'll gather in public if you give them a good place to do it.* (Matan & Newman, 2016).

Greece is a country which has a strong historical relationship with the public space. The ancient *agora* was a public space where many democratic and philosophical values were developed throughout the

history. This development is mainly due to the dialogue and interaction of the people. Nowadays, the economic crisis has caused privatization, shrinkage and degradation of the Greek public space. These effects have resulted to a lack of interest in the public realm. Additionally, climate change is another challenge that Greek cities must deal with. Urban heat island phenomenon is evident in most Greek cities and high temperatures in summer (even above 40 °C) could cause heatstroke and aggravate cardiovascular or respiratory diseases (Chen et al., 2017).

The following paper examines in what way an outdoor public space in Athens should deal with the aforesaid challenges and provides design strategies for spaces of similar climate.

OBJECTIVE

The goal of this project is to examine outdoor thermal comfort optimization strategies combined with accessibility improvement for an outdoor public space in the center of Athens in Greece. Constitution Square (fig.1) is the central Square of Athens and is in front of the Greek Parliament. It is a space of high historical importance for Athens' residents, because the first Constitution of Modern Greece was signed there. Nowadays, it is a meeting place for social activities, a touristic spot and an important transportation hub for Athens.

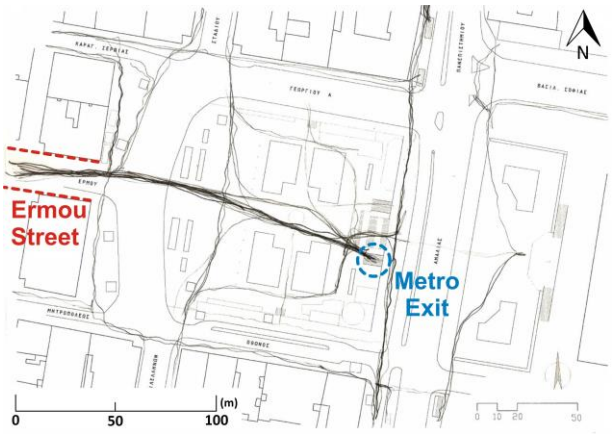
Fig. 1: *Constitution Square, Athens*

Source: *A.Savin, Wikimedia Commons, 2013*

According to the European Project "TREASURE", the summer mean and minimum temperature in Athens has increased by 3 °C and 3.5 °C respectively during 1975-2014. Furthermore, projections show that the number of days with maximum temperature above 35 °C (T_{max} > 35 °C), will increase to 55 in 2030 from 26 in 2015 (Treasure, 2015). This temperature rise will also affect the microclimate of the square and in combination with other parameters (solar radiation, humidity, wind, etc.), could lead to high heat stress of the people. Pantavou et al. (2017) examined the subjective assessment of thermal sensation of five people at the same point of Constitution Square for two summer days in 2010. The self-reported assessment of thermal sensation was recorded during daytime hours (10.30 – 19.30). Sixty-five (65) responses were collected for 13 different hours of the day. Results showed that 36 responses (55.5%) indicated neutral sensation, 25 (38.5%) uncomfortable sensation, 3 (4.5%) very uncomfortable and 1 response (1.5%) indicated comfortable sensation. Taking into consideration "TREASURE" projections and the finding that Constitution square is located in one of the hottest zones of Athens concerning mean summer temperature (Giannopoulou et al., 2014), outdoor thermal comfort conditions is possible to be deteriorated the next years. Thus, climate responsive design can be a great way to improve the microclimate of this space.

Regarding accessibility, the space is surrounded by big streets and there is not direct pedestrian access. This fact disconnects the space from the urban fabric in terms of pedestrian flows. Most people access the square from the exit of the underground railway and Ermou street, which is the most commercial street of Athens (fig. 2).

Fig. 2: *Pedestrian flows in Constitution Square*



Source: *Kostourou, 2012*

The aim of this project is to analyze and improve the design of Constitution square, in an integrated way, providing solutions for a comfortable, resilient and vibrant space in the center of Athens.

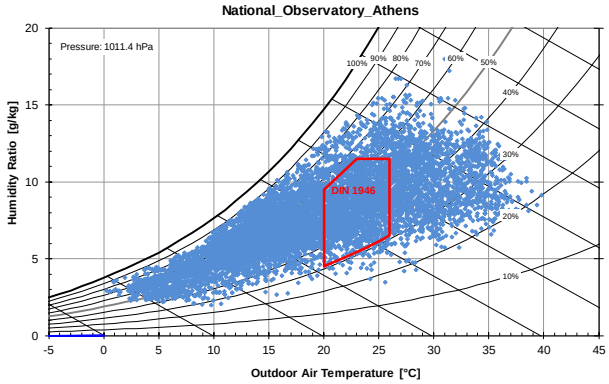
METHODOLOGY

A constant process of analysis and evaluation of the space was followed to reach an integrated design approach. Initially, the climate analysis of Athens was conducted to detect the main characteristics of the city's climate. Then, a generic outdoor comfort analysis of Athens was performed to decide the focus period of the study. The next step was to examine the existing outdoor comfort conditions in the Constitution square. After that, the urban design interventions were proposed based on the aforesaid analysis. Finally, the outdoor comfort conditions of the space were simulated depending on the interventions and were compared to the existing situation.

CLIMATE CONTEXT

Athens is located in the southeast part of Europe and is characterized by hot-summer Mediterranean climate (Köppen–Geiger climate classification). Outdoor air temperature ranges from 0 to 40 °C. The annual average temperature is 19.4 °C and the annual average wind speed is 3.1 m/s. The total annual solar radiation on a horizontal surface at ground level is 1804 kWh/m^2 (National Observatory of Athens, 2017). According to the sensation of the Athenians, the humidity level is moderate, which can be also detected in the psychrometric chart of Athens (fig. 3).

Fig. 3: *Athens Psychrometric Chart*



Source: *National Observatory of Athens, 2017*

The aforesaid climate analysis was conducted based on data of 2016 from the National Observatory of Athens (NOA). This data was selected because of the proximity of NOA weather station to the Constitution Square (1 km) compared to the available IWEC file weather station (8 km).

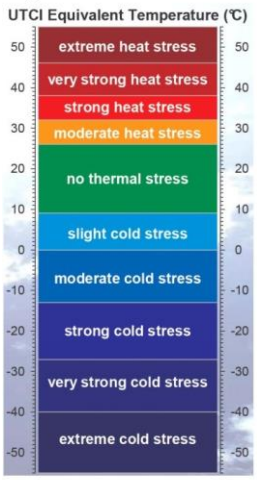
OUTDOOR COMFORT ANALYSIS

Thermal comfort is defined as 'that condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation' (ASHRAE, 2014). Outdoor thermal comfort is influenced by air temperature, humidity, wind speed, radiation, as well as, clothing and metabolic rate of a person. The assessment of outdoor thermal comfort conditions was performed with the Universal Thermal Climate Index (UTCI). The index is defined as the air temperature (T_a) of a reference condition causing the same model response as an actual condition (Błażejczyk, 2013). For the reference environment, the following parameters are used:

- Wind speed of 0.5m/s at 10m height
- Air temperature equal to the mean radiant temperature
- Relative humidity of 50% ($T_a \leq 29°C$) and vapour pressure of 2 kPa (Ta > 29°C)

The scale of the UTCI (fig. 4) correlates the Equivalent Temperature with the thermal sensation.

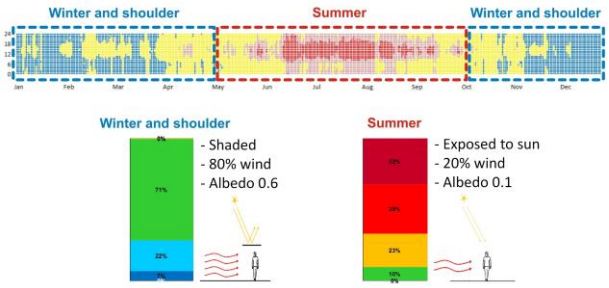
Fig. 4: *UTCI scale*



Source: *Bröde et al., 2009*

A generic outdoor comfort simulation with UTCI was conducted for the selection of the focus period of the analysis. The simulation was performed for two different periods; winter and shoulder (1 Oct. – 30 Apr.) and summer (1 May – 30 Sept). These were defined based on the outdoor air temperature of Athens. The range of simulation hours was selected to be 08.00 – 21.00 (occupancy hours of the space) and two worst case scenarios were set, one for each period. Results show that in winter and shoulder period, at 71% of the time there are comfortable conditions and 29% is cold stress. In summer period, at 10% of the time there are comfortable conditions and 90% is heat stress (fig. 5). Consequently, the summer period was selected as the focus period of the analysis.

Fig. 5: *Air temperature and outdoor comfort analysis for Athens*

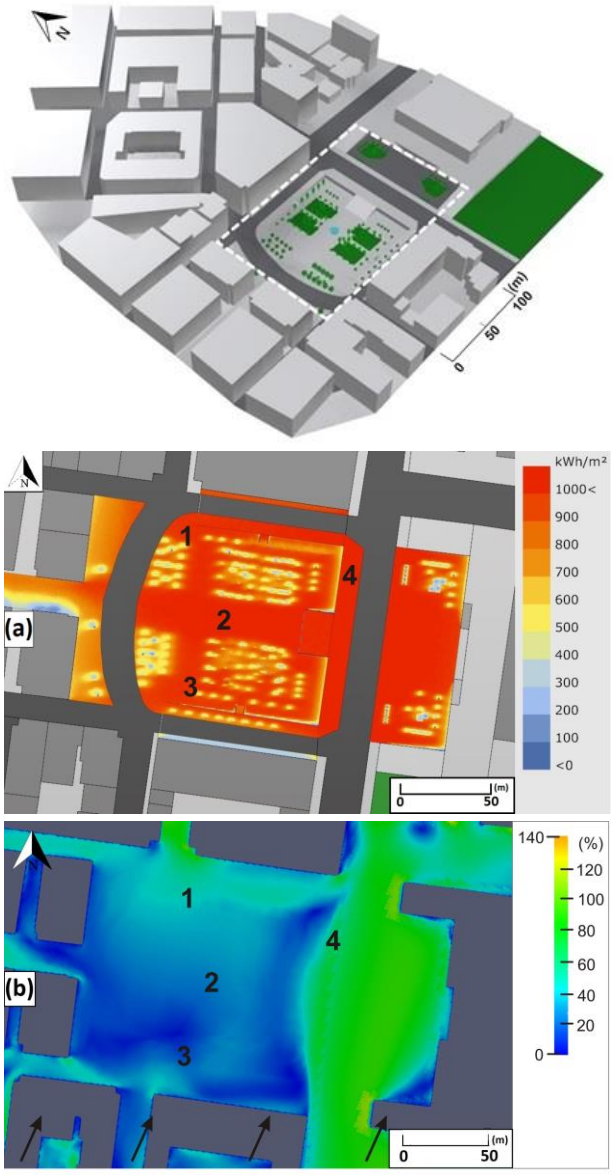


Source: *NOA & Transsolar Energietechnik GmbH, 2017*

EXISTING DESIGN

For the evaluation of the outdoor comfort conditions of the space for the existing situation, software simulations were performed regarding solar radiation and wind. A model of the square and surrounding area was created in Rhinoceros software (Robert McNeel & Associates). After that, a solar radiation simulation was conducted with Grasshopper plugin that runs within the Rhinoceros. Simulations results showed the amount of solar radiation that falls on the horizontal surfaces (fig. 6) for the focus period (1 May – 30 Sept.). Additionally, a Computational Fluid Dynamics (CFD) simulation was performed for the evaluation of the wind conditions (fig. 6). The prevailing wind direction and average wind speed were selected according to the weather data (focus period and occupancy time) as the boundary conditions of the simulation. Four characteristic points in the space were selected for the evaluation of outdoor thermal comfort (fig. 6).

Fig. 6: *(a) Solar radiation, (b) wind conditions at pedestrian level for the focus period – existing design*

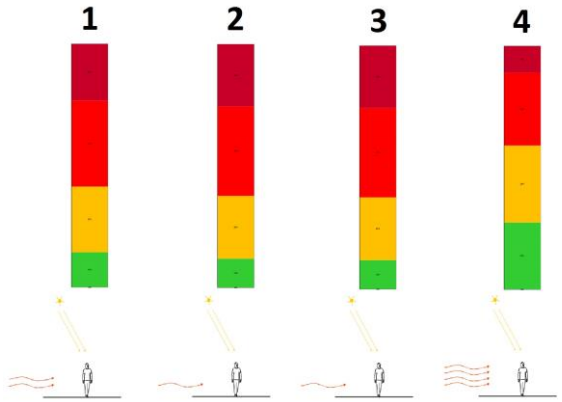


Source: *Transsolar Energietechnik GmbH, 2017*

The outdoor thermal comfort analysis of the existing design was conducted for the focus period (1 May – 30 Sept.) and occupancy hours (08.00-21.00) concerning four characteristic points in the space (fig. 7). The main variants of the simulation were the sun exposure, the wind conditions and the ground albedo. The thermophysical properties of the ground (thermal capacity, thermal conductivity, emissivity, etc.) were defined according to CIBSE Guide for Environmental Design (2006) values for marble and concrete. Simulation results showed 14% (of the time) comfortable conditions for point 1, 12% for points 2 and 3 and 27% for point 4. All the points showed a high percentage of strong/extreme heat stress (58%, 63%, 63% and 41% respectively), where UTCI > 38 °C. High heat stress can cause a range of health effects, such as heat stroke, heat exhaustion, increased risk of kidney diseases, etc. (Vatani et al., 2015). Hence, a climate responsive design proposal would be significantly beneficial, not only in terms of thermal sensation, but also regarding the reduction of health effects.

Fig. 7: *Outdoor thermal comfort analysis – existing design*

	1	2	3	4
Sun	Exposed	Exposed	Exposed	Exposed
Wind (% of weather data)	40	20	20	100
Surf. albedo	0.3	0.3	0.3	0.5



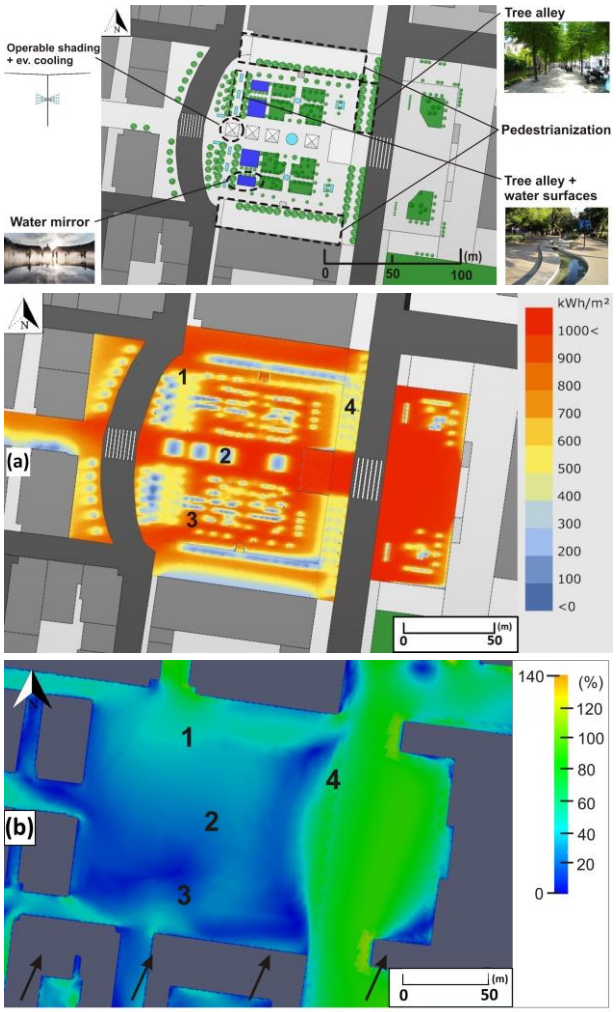
Source: *Transsolar Energietechnik GmbH, 2017*

PROPOSED DESIGN

The design interventions were proposed considering the microclimatic characteristics of the plaza, aiming also to improve the accessibility and create a vibrant space in the centre of the city. Two adjacent streets were pedestrianized to connect the square with the urban fabric and enhance the pedestrian flows to the space (fig.8). In addition, pathways were created at the existing green spaces to increase their occupancy. Rearrangement and increase of vegetation (tree alleys) were suggested to provide shading and evaporative cooling. The tree alleys were proposed in parallel to the wind direction to allow wind ingress. The east alley was designed as very narrow with tall trees to provide shading for the most hours of the daytime. The west alley was designed wider and water surfaces were introduced at the central axis to provide evaporative cooling when the sun is almost in a vertical position (no shading from trees). The design of these tree alleys was also based on the pedestrian flow analysis of the space (fig. 2), targeting to improve the outdoor comfort of the pedestrians. Regarding the main pedestrian flow from the exit of the metro to the Ermou Street (fig. 2), the solar radiation analysis (fig. 6) showed a very high amount of solar radiation on horizontal surfaces. Four operable umbrellas with evaporative cooling devices at

the center were proposed at the main pedestrian flow. Water mirrors with trees were proposed at the other exposed areas to solar radiation. Additionally, an albedo increase of horizontal surfaces to 0.6 was proposed, aiming to reduce the surface temperatures and by extension to reduce convective heat transfer to the air.

Fig. 8: *(a) Solar radiation, (b) wind conditions at pedestrian level for the focus period – proposed design*

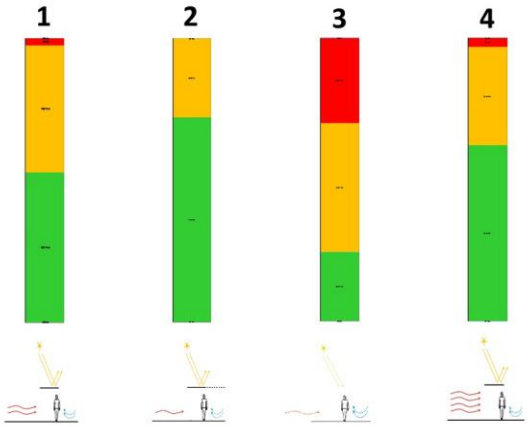


Source: *Transsolar Energietechnik GmbH, 2017*

Results show a significant improvement regarding outdoor thermal comfort conditions (fig. 9). At point 1, at 53% of the hourly data, UTCI is between 9 and 26 °C (comfortable conditions) and only 2% is strong heat stress. Point 2 shows the biggest improvement with 72% comfortable conditions and no strong heat stress. Point 3 shows a slight improvement (24% comfort) and 30% of strong heat stress and at point 4, the outdoor comfort percentage reaches 62%. The highest improvement at point 2 is explained by the opaque and operable shading membrane (sky cooling at night), combined with the high efficiency of the evaporative cooling. As the Psychrometric Chart for Athens shows (fig. 3), in summer period the relative humidity is low (20-50%), so there is a considerable potential for evaporative cooling. At points 1 and 4, the transmittance of shading (trees) is not zero and the evaporative cooling efficiency is less than point 2.

Fig. 9: *Outdoor thermal comfort analysis – proposed design*

	1	2	3	4
Sun	Shaded (trees)	Shaded (operable)	Exposed	Shaded (trees)
Wind (% of weather data)	40	20	20	100
Surf. albedo	0.6	0.6	0.6	0.5
Ev. Cooling efficiency (%)	50	80	80	30



Source: *Transsolar Energietechnik GmbH, 2017*

CONCLUSIONS

At the aforesaid work, a climate responsive design approach was presented based on outdoor thermal comfort analysis and investigation of different design strategies for an outdoor public space in Athens. An additional parameter that influenced the design was the accessibility in the space. Visual parameters were also considered, e.g. the visual contact of the pedestrians with the Greek Parliament (east). Results showed that a significant improvement of the outdoor thermal comfort conditions can be achieved. These interventions aim to improve the attractiveness of the space, increase its vibrancy, boost the local market, enhance the interaction of the people and lead to an urban regeneration, bringing agora back at the place it was born. As the Greek Philosopher Socrates quoted; *By far the greatest and most admirable form of wisdom is that needed to plan and beautify cities and human communities.*

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