Interaction of modern architectural design with the environment: Evaluation and application in urban open spaces for developing resilient cities

M Avramidou¹,² and S Manika¹
¹School of Science and Technology, Hellenic Open University, 26335, Patras, Greece
²std137940@ac.eap.gr

Abstract. The concept of urban resilience, either as a response to the effects of climate change or as a need to address the emerging challenges of the pandemic crisis, plays an important role in the modern forefront of urban policies. This article focuses, in the light of climate change, on the prospects of the adoption of the principles of urban resilience in the design of urban outdoor spaces, initially creating a clear framework for their definition. In order to achieve this, the article proceeds to the evaluation of successful European and Greek examples of urban open spaces in which the assurance of urban resilience is achieved through the application of bioclimatic design. Emphasis is placed on the factors of sunlight, ventilation, the role of water and greenery, and the properties of surface coating materials in urban outdoor spaces. Then the study area is analyzed, with qualitative and quantitative assessment of the factors that affect the outdoor environment. Keywords: urban open spaces, resilient cities, architectural design

1. Introduction
During the past 50 years, both humanity and the earth are facing the challenge of climate change as well as the outgoing consequences. Urban resilience, according to Meerow et al (2016) [1] refers to the ability of an urban system and its socio-economic networks at various temporal and spatial scales to maintain or quickly return to its desired functions when disturbed and adapted to change and tends to differ from the term of urban sustainability [2]. Outdoor urban areas contribute to enhancing the resilience of the city as an urban ecosystem and restoring balance [3,4]. The existence of outdoor spaces in an urban environment mitigates the effects of climate change, reduces the risk of natural disasters, and enhances social cohesion by shaping the urban microclimate of the city [1, 5, 6].

An urban system is considered resilient if it has the following characteristics: Reflective, Robust, Resourceful, Flexible, Integrated, Redundant, Inclusive [7]. Its resilient form is based on four basic pillars: resisting, recovering, adapting, and transforming [8]. Modern architectural provisions that follow the principles of bioclimatic design contribute to the improvement of comfort conditions [9,10]. The objective of this research is to confirm that the application of bioclimatic design in open urban spaces can increase urban resilience.
2. Literature review
Some successful European and Greek examples of urban open spaces are the following, in which the assurance of urban resilience is achieved through the application of bioclimatic design.

2.1. Enghaveparken – Climate park, Copenhagen
In an effort to enhance urban resilience to heavy rainfall affecting Copenhagen, this 35,000 m³ park was designed to handle Copenhagen’s current and future challenges with water with an optimistic, smart, and fun approach. Engahavaparken is a historical park which, in 2014, was transformed into a flood protection project holding 22,600m³ of water. The rainwater from the nearby roofs will be led to the park and a 2000 cubic meter retention basin where can be stored and used for watering a diverse range of plants and trees during dry periods. Furthermore, a low wall has been built along the perimeter of the park, to hold back a further 14,000 cubic meters of water. A mechanism that automatically shuts down the gates of the perimeter wall has been invented so that the climate adaptive elements of the park function to restrict the water from the city [11].

![Figures 1a and 1b. Images of Enghaveparken in different eras, Source [12].](image)

![Figures 2a, 2b, 2c and 2d. Concrete water tanks and retaining walls, Source[13].](image)

2.2. Stock Exchange Square and Commerce Square, Thessaloniki
The project concerns the total renovation of an area of 110 acres, in the historic center of the city of Thessaloniki. The interventions concern the coating with cold materials, the installation of bioclimatic
systems that promote the evaporation of water, water jets, water curtains, sprinklers. Outdoor fans create forced air movement, a traditional cooling technology of historic buildings.

Figures 3a and 3b. Renovation proposal of the squares, Source [14].

3. Methodology and data
A theoretical approach is made, describing the parameters that affect the durability of the outdoor space, with quantitative and mainly qualitative data. Initially, the climatic data of the area, the temperature, the exposure to sunlight, the rainfall, the intensity and direction of the wind, and the comfort conditions in the open air are studied. Next, other factors that affect the resilience of an outdoor area such as soil morphology, biodiversity, air pollution, energy saving, waste management, public participation, and accessibility, etc. are examined.

4. Case Study
The study area concerns a city in the Region of Western Macedonia of 30,000 - 35,000 residents, namely the city of Ptolemaida which, due to the industrial activity of the lignite steam power plants, is environmentally degraded with a severe problem of air pollution. The city of Ptolemaida is a provincial city with a lack of urban open spaces while the existing ones are degraded and non-functional. The park of the Cultural Centre which is going to be renovated has insufficient planting, green and water elements. There is an arbitrary occupation of surrounded open space by constructions and business activities.

Figures 4a and 4b. Location of the study area, views of the Cultural Center, Source [15].

5. Analysis
The main issue of the region is the air pollution due to the steam power stations. During the past 10 years, the emission levels are lower because of the gradual withdrawal of 3 out of 5 power stations that were operating in 2007.
Figures 5a and 5b. Total arsenic emissions and particulate emissions from industry, Source [16].

The climate is characterized as cold continental, with long cold and wet winters and short dry and hot summers. The altitude of the area is about 606 m and according to the data analysis, the average annual temperature is 13.15°C. The coldest month is January when the temperature drops to -1.2, whereas the hottest month is July when the temperature rises to 29.6 °C.

Chart 1. Monthly temperature chart for the area, Source: E.M.Y., Source [17].
Charts 2 a and b. Qualitative and quantitative Bioclimatic diagram Olgyay for the region of Kozani Source [18].

Table 1. Analysis of the quantitative bioclimatic map of the prefecture of Kozani (climatic zone D), Source [18].

| Month | Radiation needs (W/m²) | Shading needs (%) | Wind needs (m/sec) | Moisture needs (gr/Kgr) |
|-------|------------------------|------------------|------------------|-------------------------|
| Jan   | >560                   | 0                | -                | -                       |
| Feb   | >560                   | 0                | -                | -                       |
| Mar   | >560                   | 0                | -                | -                       |
| Apr   | -140-340              | 0                | -                | -                       |
| May   | 0-380                  | 14%              | -                | -                       |
| Jun   | 0-180                  | 50%              | -                | -                       |
| Jul   | 0-80                   | 82%              | 0.5              | 0.15                    |
| Aug   | 0-80                   | 82%              | 0.5              | 0.15                    |
| Sep   | 0-240                  | 38%              | -                | -                       |
| Oct   | 80-480                 | 0                | -                | -                       |
| Nov   | >560                   | 0                | -                | -                       |
| Dec   | >560                   | 0                | -                | -                       |

From the diagram, we observe that in the climatic zone D, where the study area belongs, the monthly lines May, June, July, August, and September are within the comfort zone. According to the analysis table of the bioclimatic map of the prefecture of Kozani, we observe that there is a need for exposure to sunlight from November to March, greater than 560 W / m². On the contrary, in July and August, there is the lowest need for sunlight up to 80W / m². While at the same time 82% shading is necessary during these months. For the same months, there is a need for ventilation up to 0.5 m / sec and relative humidity up to 1.0 gr / Kgr.

Figures 6 a and b. Shadow analysis during summer and monthly solar irradiation chart for the area Source [19].
6. The proposal

The landscaping was done according to the principles of bioclimatic design and consequently the strengthening of urban resilience in the area. The uses proposed are mild intervention, with places of recreation and cultural expression. The area will include walking routes, stopping points, outdoor amphitheater, playground, parking lot and a space specially designed for the cultivation of various species. The terrain is flat with small slopes, which will become more intense in order to have some gradations on the ground. These gradations will serve both the configuration of the levels for the outdoor amphitheater, but at the same time a lower level will be created, where rainwater will be collected, creating an artificial lake. Solar canopies are formed which have photovoltaic systems to serve the energy needs of users such as charging devices, lighting, etc. Surface coatings are water-permeable with high reflectivities, such as compacted soil and porosity that allow water to pass through the ground.

Figure 7. 3d Design illustration of the renovation proposal.

Figure 8. Outdoor amphitheatre and photovoltaic shelters.
7. **Conclusions**

Based on the successful examples of urban resilience and the specific characteristics of the study area, we apply an evaluation system of the resilience and viability of the outdoor space based on both its qualitative and quantitative characteristics. We proceed to a redesign proposal, we present the indicative results of the intervention, we assess its effectiveness, while we make assumptions and proposals for future pilot research by opening a discussion for equivalent proposals. The study area is selected as a basis for pilot research and aims at becoming a methodological tool for promoting urban resilience in other areas.

The limitations that result from this research concern both the climate and the atmospheric situation of the region, but also the limited data. A similar study could be applied to areas with colder climates to compare the results obtained. In addition, the Actual Sensation Vote (ASV) can be used to quantify the observations by analyzing the data that has been collected and be compared with the Predicted Mean Votes (PMV) calculated from the mathematical model. There are potentials in the improvement
of relationship between thermal comfort and microclimatic parameters in each different environment. Some measures of urban resilience in the open air could differ the colder the climate.

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