217: Implementation of bioclimatic principles in the design of urban open spaces: microclimatic improvement for the cooling period of an open space adjacent to the sea

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Abstract

The paper refers to the role of the bioclimatic principles on the planning and design of urban open spaces in order to improve the microclimate and the comfort conditions. Its goal is to illustrate the importance of implementing bioclimatic design in public open spaces, which can lead to more sustainable cities.

The redesign of an open space in a residential area in Thessaloniki Greece (lat: 40° N), adjacent to the sea, is analysed. The case study aims at presenting the design principles as well as the design procedure which may contribute to an upgrade of the environmental conditions of urban open spaces for the summer period. The paper underlines the environmental factors that should be examined during the analysis of the site and describes the design process to the final proposal by taking into consideration both the various requirements of the area and the microclimatic profile.

Keywords: urban microclimate, open spaces, sustainable design, outdoor comfort

1. Introduction

During last decades, bioclimatic architecture appears as an essential means for the environmental improvement of the built environment, while the contribution of the bioclimatic approach to outdoor design for the achievement of better living conditions has not been evenly accentuated.

The acceptance and use of open spaces is influenced to a great extent by the thermal, visual and acoustic comfort conditions offered to people. Therefore the microclimate and the natural environment in the urban open spaces are of great importance, and the ultimate goal of the landscape design should be the creation of the best microclimatic conditions.

An essential aspect of the bioclimatic design process aiming at the microclimatic improvement, is to exploit the positive and eliminate the negative influences of the climatic factors.

The special characteristics of the site are important as well. Open spaces in cities are encountered in a large variety of forms and ground surface characteristics. Urban morphology is of first order significance on the outdoor microclimate: Orientation, adjacency to a water volume, existence of slopes and other natural elements, buildings, materials used etc determine the microclimatic profile of the area and must be taken into account when designing outdoor spaces.

Landscape design should be based on the proper manipulation of the above mentioned factors aiming at controlling solar access and solar shadowing, regulating air temperature and relative humidity, altering wind movement and improving air quality.

In this paper there is an effort to combine various bioclimatic strategies in the design procedure of an open air area in a Greek city, in order to improve the microclimatic conditions during summer.

2. Bioclimatic principles for the design of open spaces

2.1 Achievement of thermal comfort

Thermal comfort is crucial for the use of an open space and requires different actions in order to successfully provide a pleasant environment, according to the seasonal and daily use of the open space.

Regarding summer period, temperature control and solar exposure, airflow modification and regulation of relative humidity are essential for the achievement of comfort. Also wind channelling is significant for heat extraction from the open space.

However, in the Mediterranean climate when designing open spaces to be used during summer and winter, measures should be taken in order to assure best habitable conditions for both hot and cold weather.

The *control of insolation* aims at the definition of shaded or sun exposed areas according to the season, the time the open space is occupied and the special requirements of the users. The goal is

the shading of the used areas during the cooling season and the full sun exposure of them during the heating season. In regard to the urban space it is also important to consider the built environment and the existing vegetation because they significantly influence sun exposure.
Modification of the insolation of the area can be achieved by using plants and urban equipment according to the desirable seasonal shadow pattern, taking into account potential restrictions such a design may cause to the open space ventilation. Movable shading devices and deciduous trees are often the best solution.

The *control of air temperature* is very important for the creation of thermal comfort. However, it cannot normally be significantly modified through design. Shading is the most important factor for temperature control in summer. The use of vegetation, the selection of appropriate materials (e.g. cool materials), and the utilization of water elements or special features (e.g. cooling towers) can modify temperature as well, especially during the cooling season.

The *airflow modification* aims at the creation of comfortable outdoor living spaces in summer by exploiting cooling breezes and guiding them in the habitable areas. At the same time it aims at the creation of protected areas via redirection and reduction of the velocity of the unfavourable winds in the winter. Various plants and landscape constructions can be used to redirect or guide the wind. Finally, modifications in topography can alter the wind's velocity and can eliminate its turbulence as well.

The *regulation of relative humidity* is extremely important for the cooling season and can be accomplished through vegetation and the use of water surfaces.

2.2 Improvement of visual comfort

The creation of *visual comfort* determines the use of outdoor space to a great extend. There should be control of the glare caused by unusually clear façades of the surrounding buildings, or extremely white and shiny surface materials. Possible problems are more intense during summer because of the high sun radiation. The selection of the suitable materials and vegetation can contribute to the creation of visual comfort.

2.3 Creation of acoustic comfort

The soundscape design aims at the elimination of traffic noise and certain annoying sounds, and the preservation and reinforcement of sounds that give character to a location. These can be accomplished with the help of defensive, offensive or creative interventions in the area. The use of vegetation and street furniture are useful for diffusing noise and together with acoustic- musical sculptures or running water can seriously improve the soundscape.

2.4 Improvement of building's energy behaviour

The interventions made in the outdoor space influence at a high level the energy behaviour of the buildings as well. Trees and shrubs used around buildings influence their exposure to the sun and the wind, and consequently the energy consumption for heating and cooling and sometimes the amount of electricity used for lighting. The effectiveness of the energy-saving role of the plants depends on their characteristics and their position in relation to the building.

2.5 Improvement of air quality

The improvement of air quality, which is crucial for the human well-being, is equally important. Airflow modification and selection of suitable vegetation could greatly contribute to this issue. Decrease of air pollution by natural ventilation and CO2 absorption from the plants, create healthier outdoor conditions.

3. Case study

3.1 Location of the site

The site is located in the SE part of Thessaloniki conurbation (northern Greece, lat: 40o N) in a short distance from the sea. It is an elongated of NE-SW orientation open space which extends in an area of 13000m^2 and serves various activities. The continuity of the open space is interrupted by four roads which cross through the area and create four distinctive sub-areas providing space for recreational activities, playground and relaxation. A school, church and cultural centre in the nearby area define additional needs for the use of the open space. (fig 1)
The hard surfaces dominate the site, while the permeable surfaces are limited. There are some planted spaces but they are randomly located and do not serve the need for shading, cooling, or wind modification. Many areas are overheated during summer because of the lack of shading and cooling.
Also, traffic from the adjacent streets, the air conditioning systems of the surrounding buildings and some restaurants which are located close to the area charge the open space with extra heating load.

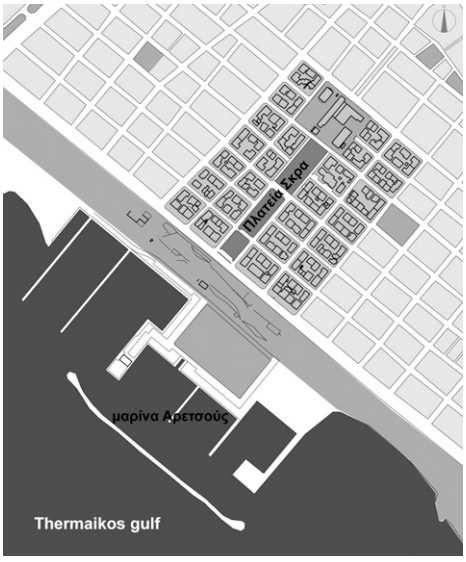


Fig 1. Site location

3.2 Climate

The city of Thessaloniki is developed along the coast of a closed gulf (Thermaikos); it is surrounded to the north and the east by low-rise mountains, and to the west four rivers discharge their waters into the gulf. The climate is highly related to the city's geographical position. The proximity to the sea and the presence of the mountains and rivers influence the local climate. Thessaloniki's temperate – Mediterranean climate is characterized by rather cool winters and hot summers. High level of temperature and sunshine in summer create uncomfortable living conditions to the inhabitants.

The coolest month in the city is January with average monthly temperature of 5.2 ^{o}C and 106 hours of sun-shinning, while the highest temperatures appear in July and August. The highest temperature recorded is 42^{o}C in July, a month with 342 hours of sun-shinning.

The months with the highest average monthly precipitation are: December; November; May; October and Mars, which means that the rain protection at open spaces used in winter is essential.

The wind that mostly affects the climate of Thessaloniki during winter is a dry and cold wind with NW direction and an average speed of 2.0 m/sec. In the summer, due to the proximity to the sea, cooling breeze blows towards the city marked at SW and SSW direction with a speed of 1.5 m/sec.

Furthermore, the sea increases the humidity levels in the area affecting the comfort conditions in the summer.

3.3 Analysis

The analysis examines the microclimatic conditions in the area which are created by the interaction between the prevailing climatic factors and the urban environment.

Shading analysis: Insolation and shading of the space by the surrounding buildings and the existing evergreen and deciduous plants during summer was examined using a 3d model of the area. Insolation diagrams were produced for all the hours of the day (morning, noon, afternoon), (fig.2) and were overlapped to create seasonal shadow casting profile of the area, showing the spaces which are permanently exposed to sun (unfavourable) or shaded (suitable for use in summer) (fig.3,4). Since certain open spaces may be used at a different time of the day during summer, the maps give an indication for possible areas for development and identify areas that need design intervention

Analysis of the prevailing winds: Estimation on how the buildings and the existing vegetation affect the velocity of the prevailing winds has been made using also the 3d model of the area (fig.5) and the wind speed/frequency rose for Thessaloniki in order to map wind shadows. An important result is that the south west cooling breeze, which blows from the sea during summer, has a direction parallel to the main axis of the site which allows its guidance into the open space. From the study of the influence of vegetation on the wind pattern, it is concluded that in many areas trees and shrubs block the favourable winds. Another important observation, which refers to the heating season but is equally important, is the fact that the prevailing strong NW winds have the same direction as the streets which cross the open space. This means that the surrounding buildings may cause a channel effect, which affects the comfort conditions and the heating demands in the area and must be taken into account.

Acoustic environment: The sounds that dominate the open space are separated into wanted and unwanted, pointing out which areas receive the negative sounds and need interventions for sound elimination.

Air pollution levels: The basic source of pollution is the high traffic in the two arteries which cross the open space. In addition, the high density of the built environment and the narrowness of the streets do not allow the release of the polluted air masses to the atmosphere. The open space can contribute to the improvement of the air quality, especially via vegetation.

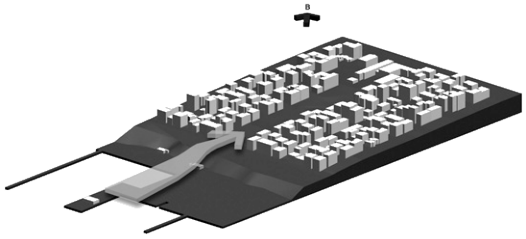


Fig 5. 3d model of the area showing the southerly sea breeze guided into the open space

3.4 Proposal

The proposal is the result of the combination of the above analysis and the several socioeconomic and cultural requirements of the area. The basic points, such as areas which serve various activities, recreational areas with a nice view, the access to the site, etc, were gathered in a map and were taken into account for the proposal.

Different design interventions have been considered. The comparison and assessment between the alternative design conceptions was achieved with the overlapping of the insolation and wind diagrams which were created for different hours for each season. The proposed masterplan is shown in figure 6.

The outdoor space is reorganized for the creation of comfort conditions and for best serving the great range of activities people are engaged in.

New activity areas are designed and the existing ones are extended and relocated, so that the activities match with the season and the time of the day during which they mostly take place. The designed activity areas include: 1. the "Monument square"; 2. a playground at a lower level; 3. the "water square"; 4. the sheltered areas; 5. the "cultural square", the sitting areas, 6. the enlarged school yard and finally 7. the pedestrian zone which provides access to all of them.

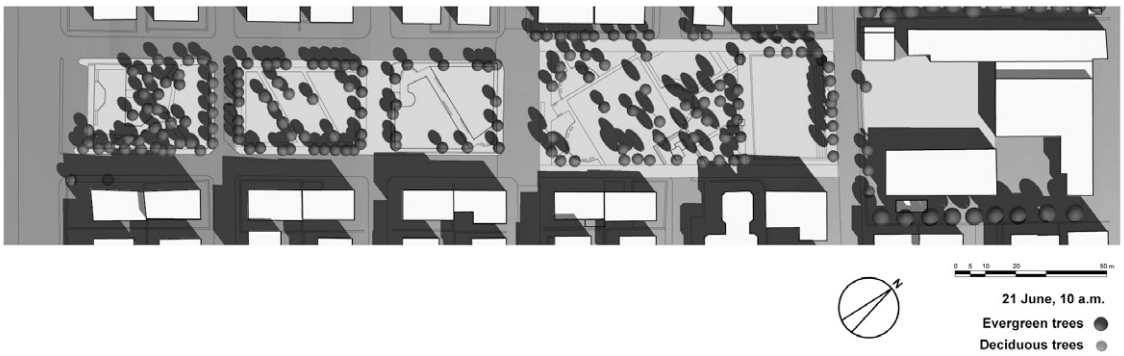


Fig 2. Shaded and insolated areas due to the surrounding buildings and the existing vegetation (21 June, 10:00a.m.)

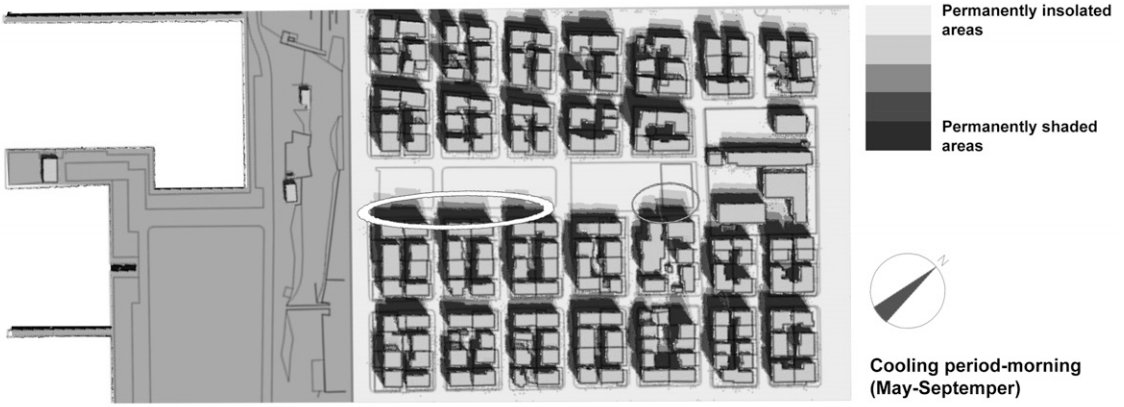


Fig 3. Shadow casting profile of the open space for the cooling period: Lighter areas correspond to insolated areas while the darker ones to the shaded areas

Fig 4. Map showing the permanently insolated areas during winter.(favourable) which derived from the overlap of the monthly insolation diagrams for the heating season

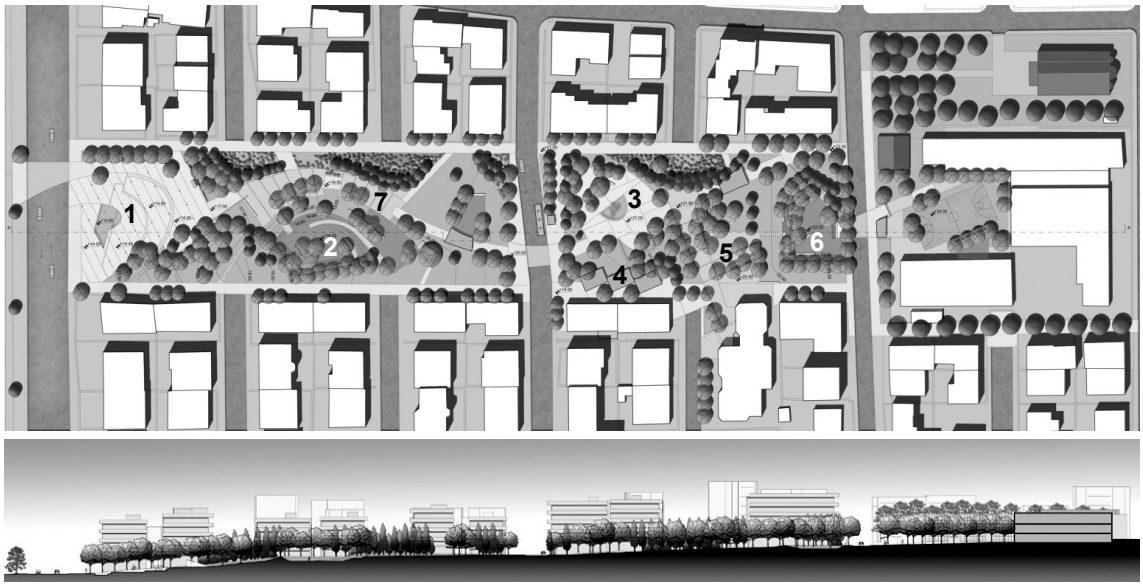


Fig 6. Masterplan and longitudinal section

Vegetation, small scale constructions, shading devices, landscape equipment and different building materials are suggested in order to improve the thermal and visual comfort conditions during the hot summer period. Restrictions concerning the use of the open spaces during winter are also taken into account. The way the materials, vegetation and constructions are used is described as follows (fig.7,8,9):

Materials: The surfaces covered with asphalt are significantly reduced by 80%, and replaced by other materials with better thermal properties.

In the areas which receive a large amount of anthropogenic heat or they are surrounded by materials with high emissivity, the interventions aim at regulating air temperature during summer.

Materials with high thermal capacity, high reflectivity and light colour are applied to the overheated areas (with caution to avoid optical glare), especially in the places with large sky view, so as multiple reflections on the surrounding surfaces are limited. Also, the permeable surfaces are increased by 60%, in order to contribute to the decrease of temperature in summer and to the prevention of flooding in winter.

Vegetation: Measures are taken using vegetation in order to funnel the cooling southerly sea breezes into the area and the urban tissue, during summer. Also, evergreen trees and shrubs are used to obstruct, deflect or filter the strong and cool NW winter winds without lowering the effectiveness of summer breezes. Thus, leeward and protected areas are formed for winter while are exposed to pleasant cooling wind in summer.

Vegetation also satisfies the seasonal use of space. Shaded spaces are created to be used during summer, in different hours of the day according to activities taken place. The same areas planted with deciduous trees of multiple porosities can be also used during winter.

Vegetation has an additional cooling effect through evapotranspiration. Other “cooling constructions”, such as ponds or fountains, using water evaporation for increasing thermal comfort conditions during summer are proposed as well.

Vegetation is suggested in a way that it improves the thermal behaviour of the surrounding buildings as well, by permitting their exposure to sun in winter while shading their façades in summer.

Plants are also used in order to eliminate the annoying unwanted sounds.

Constructions: It is proposed landscape equipment which addresses to bioclimatic criteria. For example, along the pedestrian zone, shelters for rain protection are provided. Small scale constructions are also used to redirect the wind. Furthermore, shading devices are proposed for the creation of good thermal conditions during summer (fig.10,11,12). The design of the constructions is based on the seasonal use of the space, so ephemeral and movable equipment is suggested such as tents, pergolas or permeable shelters (fig7). The constructions are made from light or translucent materials in order not to block daytime natural light and at the same time to avoid hot air enclosure underneath.

Finally, elimination or restriction of the annoying unwanted sounds is achieved with the implication of noise abatement and the use of structures, such as a “water wall”.

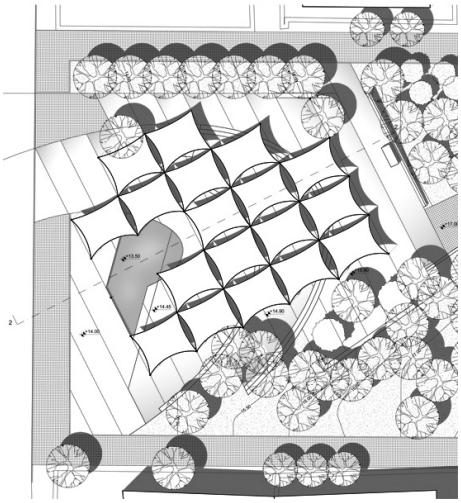


Fig 7. The "Monument square" with movable shading tents

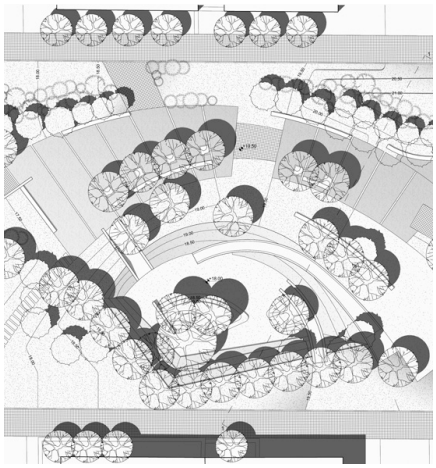


Fig 8. The playground, mostly covered with permeable and soft materials

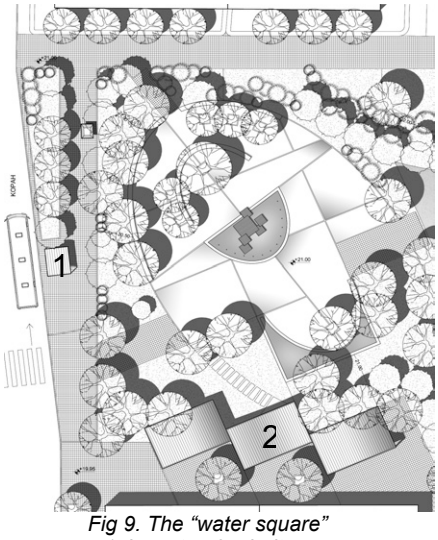


Fig 9. The “water square”
1. bus stop 2. shelters

4. Conclusion

This paper has reported the ways to achieve better living conditions in the urban environment through the bioclimatic design of urban open spaces. It focused on the summer period, which for many areas around the world is the most attractive period to live outside and at the same time the most uncomfortable period due to high air temperatures.

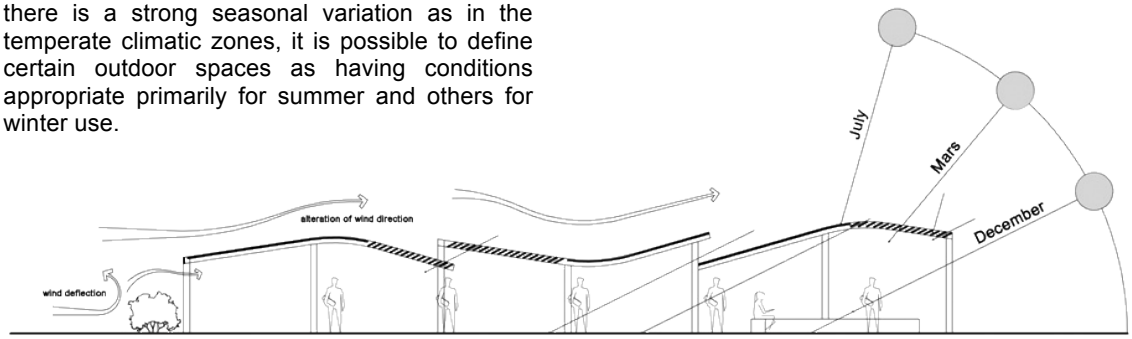
The paper demonstrated that drawing several maps of climatic factors can lead to the appropriate decisions in the open air space planning process, which can decrease high air temperatures, increase the relative humidity, provide better ventilation and cooling, improve the air quality, reduce the noise levels, and affect the thermal comfort conditions in the outside habitable areas.

With the design proposal for the amelioration of the microclimatic conditions of an open area in Thessaloniki, it is shown that in places where there is a strong seasonal variation as in the temperate climatic zones, it is possible to define certain outdoor spaces as having conditions appropriate primarily for summer and others for winter use.

According to the main seasonal use, surface materials and urban equipment should be suggested. Also, it is necessary to provide suitable vegetation, and movable or ephemeral landscape equipment to offer shading and enhance cooling by evapotranspiration and by encouraging air movement in summer, while to permit the insolation of the site and create wind protected areas in winter.

Furthermore, the good knowledge of the special characteristics and the use patterns of the area, along with the implementation of bioclimatic criteria during the design procedure lead to the design of outdoor spaces that allow different activities to be carried out, upgrade the urban environment and contribute to the improvement of social life.

Ultimately the bioclimatic design of open air areas can contribute essentially to the sustainable development of cities.



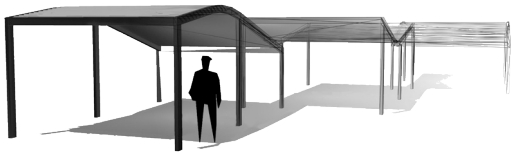


Fig 10. Shelters: 3d model and section

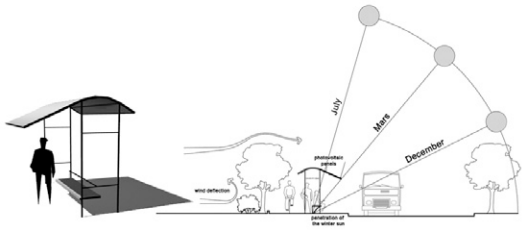


Fig 11. Bus stop: 3d model and section

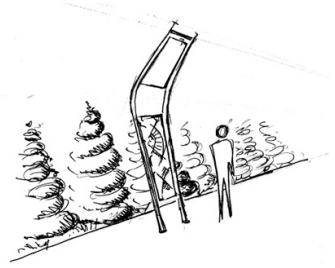


Fig 12. Exhibition panel which redirects the wind

5. Acknowledgements

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6. References

1. Axarli K. and Eumorfopoulou E., (2001). Energy efficient vegetation design for temperate climate. *Proceedings of PLEA 2001 International Conference on Passive and Low Energy Architecture,* Florianapolis- Brazil, 7-9 November 2001, p.517-521.

2. CRES, (2004). *Ruros-Rediscovering The Urban and Open Spaces*, key Action 4, Energy, Environment and Sustainable Development, European Union Programme, City of Tomorrow and Cultural Heritage, [Online], Available: http://alpha.cres.gr/ruros.

3. Dimoudi A. and Nikolopoulou M., (2003). Vegetation in the urban environment: microclimatic analysis and benefits. *Energy and Buildings,* 35, p.69-76.

4. Givoni B., 1998. *Climate considerations in building and urban design*. Van Nostrand Reinhold.

5. Yannas S., (2001). Toward more sustainable cities. *Solar Energy*, Vol. 70, No3, p. 281-294.