A CASE STUDY OF SUSTAINABLE URBAN PLANNING WITH THE USE OF A DECISION SUPPORT SYSTEM

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ABSTRACT

This paper aims to present the methodology for the development of a Decision Support System (DSS) that takes into account environmental and socioeconomic criteria, focusing on a case study that was carried out in Athens. The experimental campaign that was performed at city, neighbourhood and building scale and its main results are described. In addition, the results of the Communities of Practice that were organised are reported. A short description of the development of an ANN model for heat island prediction is given. Finally, the three different planning alternatives that were proposed and evaluated by the developed DSS are analysed.

KEYWORDS

Sustainable urban planning, Decision Support System, environmental measurements, Communities of Practice, UHI prediction

1 INTRODUCTION

In Europe, four out of every five citizens live in urban areas. Cities today face a number of environmental and socioeconomic challenges. These include environmental problems like increased levels of traffic, air pollution, and greenhouse gas emissions, neglect of the built environment, improper land-use, lack of open space, soil contamination, as well as the generation of large quantities of waste and wastewater. Increased energy consumption is another important issue taking into account Europe's increased dependence on energy imports and scarce energy resources. In addition, the generalized economic crisis and the impacts of climate change, form a new landscape within which it is required to develop coordinated and effective socioeconomic, energy and environmental strategies. Sustainable urban planning and management is a key issue in the effort to improve environmental conditions and the quality of life in cities (European Commission 2011).
In order to achieve sustainable urban planning and development, planners need to take into account environmental and socioeconomic issues and impacts simultaneously and tailor made

decision making tools provide the means to support such complex decisions and solve semi-structured or unstructured problems, presenting results in a readily understandable form.
An FP7 project called BRIDGE (sustainaBle uRban planning Decision support accountinG for urban mEtabolism), which was the joint effort of 14 Organizations from 11 EU countries, has illustrated the advantages of considering environmental issues in urban planning, focusing on specific urban metabolism components (energy, water, carbon, pollutants). The innovation of BRIDGE is the development of a Decision Support System (DSS), which assists urban planners in decision-making and provides a structured presentation of planning alternatives and the tools to evaluate them on the basis of environmental and socioeconomic impacts. The BRIDGE methodology is based on sustainability objectives and associated indicators addressing environmental, social and economic issues that are specific to each case study's planning alternatives. The indicators demonstrate the potential impact of each alternative to show the level of achievement of the sustainability objectives (based on associated defined targets and thresholds) in a quantified way. The BRIDGE project has used input from end users on their needs and requirements in the design of the DSS. A "Community of Practice" (CoP) approach was utilized to facilitate the interaction between the urban planning professionals and the BRIDGE researchers. During CoP meetings, planning priorities and core sustainability objectives were determined for each case study. Based on these, indicators were identified by participants and adjusted to the specific requirements of the planning alternatives that were analyzed. Indicators for each planning alternative were provided in quantitative and qualitative ways: environmental indicators arising from physical flows were calculated by spatial models; socioeconomic indicators reflecting objective values (number of houses constructed, number of jobs created, etc.) were given as data attached to planning alternatives and subjective value judgments (such as landscape or urban quality) were defined by end-users. In order to evaluate the biophysical/ spatial models used for the calculation of indicators in the case study cities, in situ observations were collected. Energy, water, carbon and pollutants fluxes in urban areas have been investigated by micrometeorological measurements and site studies, airborne and satellite remote sensing observations and numerical modelling approaches, leading to indicators which define the state of the urban environment. The BRIDGE DSS evaluates how the planning alternatives proposed by the end-users modify the energy, water, carbon and pollutants fluxes within the case study area. A Multi-Criteria Analysis (MCA) approach was used to address the complexity of urban metabolism issues reflected in the wide set of sustainability indicators and enabled comparison and ranking of different urban planning alternatives (Chrysoulakis et al., 2013). To develop and evaluate the DSS five case studies were chosen, each in a different city and country: Athens, Helsinki, London, Firenze and Gliwice.
This paper focuses on the Athens case study and reports the various activities performed in order to provide the required input for the development and evaluation of the DSS. More specifically, in the next sections we describe the process of consultation with end-users (CoPs) during the development of the DSS tool, the methods and results of the experimental campaign for the collection of environmental and socioeconomic data, the development of an ANN model for the prediction of heat island intensity that could potentially be included in the DSS and the use of the DSS to evaluate specific planning alternatives for the case study area. The details of the BRIDGE approach and the all the aspects of the research can be found in Chrysoulakis et al. (2013) and in the various reports and papers provided on the BRIDGE website (www.bridge-fp7.eu).

2 THE ATHENS CASE STUDY

The Athens Case Study is focused on the municipality of Egaleo, which is a densely built urban area that lies in the Western part of Athens. Five main road axes divide the area in four quarters. One of the quarters is an industrial degraded area (brownfield) called Eleonas. The total area of Egaleo is 650 ha and it is flat in general. The population is 74.046, although it is estimated that at least 120000 people, mostly medium and low income, live and work in the area. The level of education of the inhabitants is low to medium and the rate of unemployment high. The average population density is estimated to be 225 inhabitants/ha. As it appears in the land use map of Egaleo, availability of free/ green spaces is limited.
Egaleo is considered an environmentally degraded area facing problems with:

- air pollution
- traffic and transport
- thermal discomfort
- lack of green/ free spaces
- poor quality of building stock
- energy

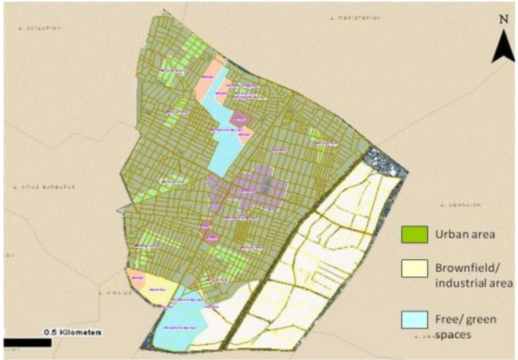


Figure 1: Land use map of Egaleo [Source: www.aigaleo.gr]

2.1 Athens CoP meetings

In the framework of the Bridge project 2 CoP meetings have been organized for the case study of Athens. These two local meetings were convened at the Municipality of Egaleo, which is the specific case study area for Athens. The participants included, apart from the BRIDGE researchers, academics, urban planners, architects, engineers and researchers all interested in sustainable urban planning. Most of them are working in the technical and planning dept. of the Municipality of Egaleo. The main outcomes of the CoP meetings were the following:

- enabling the Bridge partners and Athens planners to interact with each other and share experience on sustainable urban planning issues in Athens
- discussion of key issues of sustainable development in Athens and especially in Egaleo
- identification of planning priorities; Sustainability objectives and corresponding indicators with which to assess progress towards sustainable development (described below)
- selection, accordingly, of a planned intervention for the Athens case study and definition of underlying challenges, planning alternatives and collected indicators (described in Section 3.1)

The discussions in CoP meetings identified the following priorities for sustainable city planning in Athens:
Thermal discomfort, Energy, Quality of building stock, Transport, Green spaces and the Land use of Eleonas. Based on these sustainability priorities, and taking into account the previously defined challenges, the core sustainability objectives were established for the city by the CoP-participants: These objectives were divided to environmental and socioeconomic ones and can be summarized below:

Sustainability Objective (in order of priority)	Indicators
1. Reduce Thermal Discomfort	• Average outdoor temperature (air) and humidity; • Average surface temperature (roads, buildings, etc.); and • Wind speed.
2. Improve Air Quality and Reduce Emissions	• Concentration of pollutants (NOx, SOx, PM10, PM2.5); • CO2 concentration; • Source of emissions (% per building/sector type); • Number of days above established air quality thresholds; and • Effects of meteorological conditions (e.g. temperature) on concentrations.
3. Increase Green Space Areas	• Area (% or m2) of urban green space; • Number of trees planted; and • Types of trees planted.
4. Optimize Water Use	• Volume of water used (for irrigation).
5. Improve Energy Efficiency	• Energy consumption for lighting the avenue; and • % of energy from renewable sources (i.e. solar panels).
6. Optimize Quality of Materials Used	• Solar reflectance of materials used.

Sustainability Objective (in order of priority)	Socio-economic complement of the Environmental indicators
1. Mobility	• road traffic intensity, • quality of pedestrian sideways, • number of parking slots.
2. Public health and safety	• number and severity of road accidents and pedestrian injuries, • number of people suffering from short term effect of air pollution (upper respiratory infections such as bronchitis and pneumonia, allergic reactions) • number of people suffering from long term effects of air pollution (e.g. chronic respiratory disease, lung cancer, heart disease)
3. Social inclusion	• extent to which roads and sideways can be used by disabled or differently able people and groups (e.g. number of safe-street-crossing points, number of repose places along the street), • local community composition – compared to other areas: % of elderly people, foreigners, low-income families etc.
4. Economic criteria	• financial costs of the interventions, • estimated side-effects on local economy
5. Place identity	• aesthetic value of the area and changes due to planning intervention

Figure 2: Environmental and Socioeconomic sustainability objectives and indicators as defined by the CoPs

2.2 Experimental campaign and data collection

The main objectives of the Athens experimental campaign was to collect the necessary information needed as inputs by the models but also to estimate the urban heat island effect in the area, assess the air quality and the thermal outdoor environmental conditions, estimate the impact of outdoor environmental conditions on the cooling load of buildings in the area and the investigation of indoor environmental quality.
The observations and data collection for the Athens case study were performed at city scale, local and at building scale using different methodologies. The data collection includes tower based meteorological measurements, urban air quality data collection, heat island measurements, outdoor environmental assessment, building related observations, remote sensing and GIS data and statistical socioeconomic information. The following paragraphs briefly describe the measurement methodologies and results. All the collected data are available in the Bridge database (http://www.bridge-fp7.eu/).

a) Meteorological measurements
Meteorological measurements were taken at the Thission meteorological station of the National Observatory of Athens. The station is located on a hill in the center of Athens, very close to Egaleo. Hourly data for air temperature, RH, wind speed and direction, precipitation, diffuse and total solar radiation, sunshine duration and air pressure were collected. It was found that the case study area has high solar radiation levels and sunlight availability throughout the year and air temperatures range from 3°C (February) to 40°C (July). The yearly average value of relative humidity is about 60%. Wind directions are fairly consistent with the dominant wind direction being from the North-East reaching an average wind speed of 3m/s. Precipitation levels are quite low, especially during the summer.

b) Air quality measurements
Air quality data were retrieved from the Directorate of Air Pollution & Noise of the Greek Ministry of Energy, Environment and Climate Change, which is responsible for the operation of a network of stations, installed in the greater Athens area that measure air pollution (SO2, NOx, CO, O3, PM10, PM2.5, C6H6). The stations close to the case study area were used for analysis. It was found that exceeding of the limit occurred for certain pollutants, at the Egaleo area. PM10 pollutants exceeded limits at a number of measurement stations, NO2 presented exceedings of the indicative yearly average value and for ozone, exceedings of the warning

threshold as well as of the alert threshold occurred close to Egaleo suggesting an occurrence in Egaleo as well. These exceedings are due mostly to the high levels of sunshine and high temperatures that favour the formation of ozone.

c) Urban heat island measurements

In order to study the heat island phenomenon in the greater Athens area, a network of 17 fixed temperature stations has been set up (Table 1). These stations were located in four different zones grouped into Western, Eastern, Southern and Northern zone stations according to their geographical location and thermal balances. In all stations the data were measured with fully calibrated high precision automatic miniature sensors, which were placed in white wooden boxes with lateral slots approximating the Stevenson screen to be protected for solar radiation and rain. Temperatures were measured at 15 minute intervals.

Table 1 The location of the 17 stations and the monthly mean maximum and s.d. air temperature values for all stations for July, 2009, (*Reference station)

Station	Lat.	Long.	July	Station	Lat.	Long	July.
Western				**Southern**			
Egaleo	37°59'50.40"S	23°40'4.29"E	33,8 ± 2,4	Elliniko	37°54'27.35"S	23°44'32.43"E	35,0 ± 2,4
Agia Varvara	37°59'22.58"S	23°39'36.70"E	34,2 ± 2,3	Glyfada	37°51'52.72"S	23°44'39.97"E	32,8 ± 2,1
Korydallos	37°58'44.84"S	23°38'32.82"E	33,1 ± 2,1	Kallithea	37°57'25.18"S	23°42'9.91"E	35,0 ± 2,1
Haidari	38° 0'44.42"S	23°39'34.40"E	34,1 ± 2,5	Moschato	37°57'12.44"S	23°40'55.58"E	35,9 ± 1,8
Zefyri	38° 3'3.33"S	23°42'40.90"E	35,3 ± 2,8	Renti	37°57'45.94"S	23°40'27.88"E	35,9 ± 2,9
Mean			**34,1 ± 2,4**	**Mean**			**35,0 ± 2,3**
Eastern				**Northern**			
Agia Paraskevi	38° 0'50.34"S	23°49'27.79"E	31,0 ± 2,0	Kamatero	38° 3'34.80"S	23°42'50.66"E	35,3 ± 3,1
Vyronas	37°57'24.21"S	23°45'44.23"E	35,1 ± 2,7	Nea Filadelfia	38° 2'6.78"S	23°44'17.99"E	32,6 ± 2,4
Ilioupoli	37°55'57.37"S	23°45'30.88"E	33,7 ± 2,2	Nea Erythrea*	38° 5'23.69"S	23°49'9.11"E	32,4 ± 3,2
Kessariani	37°58'8.95"S	23°45'42.44"E	33,8 ± 2,9				
Mean			**33,4 ± 2,5**	**Mean**	**38° 3'34.80"S**	**23°42'50.66"E**	**33,4 ± 2,9**

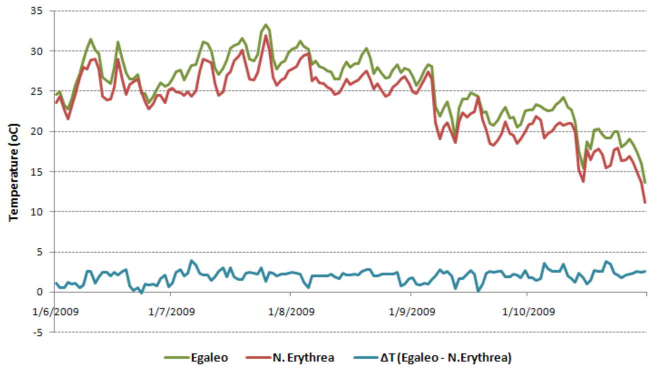


Figure 3 Daily average temperature distribution for the Egaleo and Nea Erythrea area and temperature difference, ΔT (TEgaleo – TN.Erythrea) for months June to October, 2009

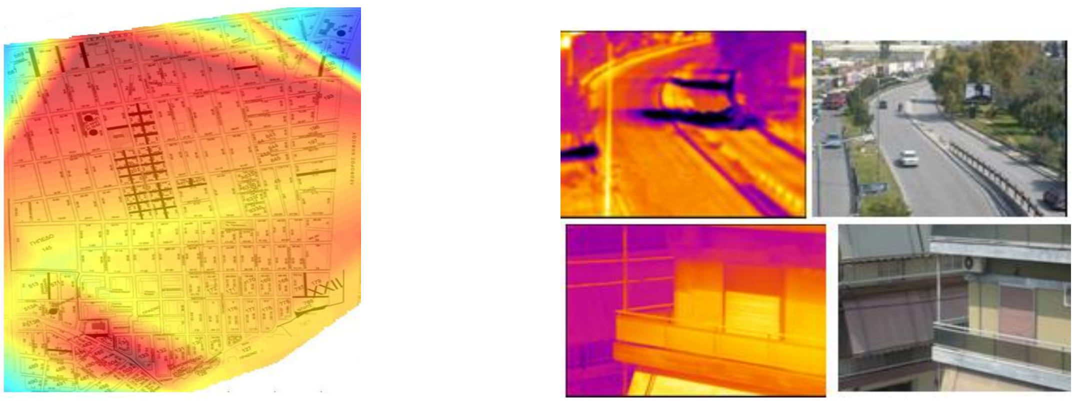
The analysis showed that the case study area suffers from a strong heat island effect. Measurements between Egaleo and a suburban station indicate a mean heat island intensity for the monitoring period of 2 -3 °C, reaching however in many occasions a difference of 6 - 8 °C.   Higher air temperatures were found in the industrial western part of the city and also the center while lower values (by 1-2°C) were presented at the northern and the eastern parts. More information on this work can be found in Giannopoulou et al. (2011).

d)Outdoor environmental assessment

In order to assess the quality of the outdoor environment of the case study area the following measurements have been carried out using a mobile meteorological station and portable instrumentation:

- Concentrations of PM1, PM2.5, PM10 (Lighthouse 3016 IAQ Laser Particle Counter) wind speed and direction by anemometers that have been placed in three different heights-3.5, 7.5, 15.5m – in the antenna of NKUA’s mobile station.
- Air temperature, RH, air velocity and Radiant temperature at a height of 1.5m.
- Measurements of the surface temperature of the urban fabric (building facades, roads and pavements) using an infrared thermometer (Cole Palmer) and infrared camera (Thermovision 570).

The monitoring campaign was conducted during several several days the summer of 2009 between 10:00 and 17:30, in several locations in Egaleo area. The analysis of the results showed that increased surface and air temperatures and low wind speeds result in thermal discomfort for the people in the area.



A *B*

Figure 4. Spatial air temperature distribution in the BRIDGE case study area (June 2009) (A) and infared and visible images taken in the case study area to assess the thermal environment (B)

e) Building related observations

The impact of the outdoor environmental conditions (mainly thermal comfort and air pollution) on the indoor environment of residential buildings in the case study area was also assessed. The process followed is outlined below:

a) Data collection on the residential building stock of Egaleo and selection of ten representative buildings

b) Data collection of the selected residential buildings

c) Distribution and collection of questionnaires answered by the residents

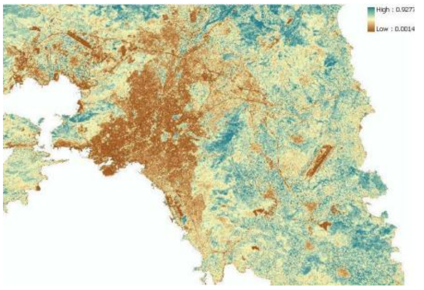
d) Indoor thermal comfort measurements: Air temperature, RH, Air velocity and mean radiant temperature

e) Measurements of PM1, PM2.5, PM10 concentrations

The results indicate that thermal discomfort inside the houses is a serious problem. It was found that over 40% of the maximum indoor temperatures are up to 35 °C, while 70% of the mean indoor temperatures are up to 30°C for the specific monitoring period. Indoor temperatures up to 38ºC have been recorded as well as hot spells of almost 21 consecutive hours over 34ºC. Comparative analysis of the occupants' responses received from questionnaires and the measured indoor conditions indicate that the thermal comfort perception of the users is in agreement with the air temperature measurements. Also, particle number concentration measurements indoors is generally correlated with outdoor concentration characteristics in the absence of important indoor sources. In addition, although concentrations outside the residences were quite high, for well air tight buildings, concentrations were significantly lower (given the fact that no internal PM sources were found inside). On the contrary, poor construction and high infiltration rates due to e.g. old wooden frames resulted in high indoor concentrations. The presence of internal sources e.g excessive smoking and cooking (e.g. frying) as expected resulted in high concentrations during the activity. More information on this work can be found in Sakka et al. (2012).

f) Remote sensing data

High-spatial resolution satellite images were used to describe the surface characteristics of the metropolitan area of Athens: land cover and land use (LCLU), land surface albedo (LSA), land surface emissivity (LSE), land surface temperature (LST), vegetation and topography (DEM). More specifically, information on the spatial distribution of the various land cover and land use types found within the metropolitan Athens area was obtained from the Corine Land Cover 2000 (CLC00) database for Greece. Maps of LSA, LSE, LST and vegetation (NDVI index) were derived by processing of the appropriate high-spatial resolution satellite images acquired over the Athens metropolitan area from the Landsat TM sensor. It was found that the case study area is characterised by low albedo values ranging from 9% to 13% and low vegetation index with NDVI values ranging from 0.5 to 0.25.



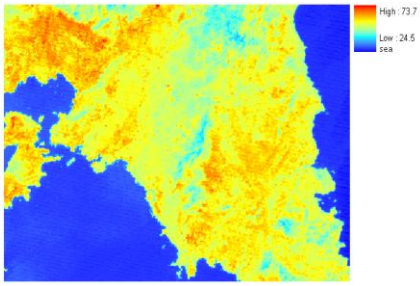


Figure 5 NDVI index and mid morning summer LST maps of Athens

g) Impact of heat island characteristics on energy loads

In an effort to estimate the impact of outdoor environmental conditions, namely of the documented urban heat island effect, on Egaleo's buildings cooling load, the following process was implemented. Based on the collected data previously analysed, a building typology that is representative of Egaleo's residential building stock was selected. Numerical analysis using TRNSYS software was then performed in order to estimate the cooling load of this same building in a)Egaleo (urban area) and b) Nea Erithrea (suburban area). In order to run the model and estimate the impact of outdoor thermal conditions on the building load, we have used the meteorological measurements performed at those sites. It was found that the assumed building in Egaleo area has an increased energy demand for cooling by 74% than the suburban area of Nea Erithrea.

3 DEVELOPMENT OF AN ANN MODEL FOR HEAT ISLAND PREDICTION

The measured data described in Section 2.2c have been used in order to develop an ANN (Artificial Neural Network) model able to predict the heat island effect in the area of Athens, focusing on the Egaleo area. The prediction problem using neural network models is separated into three steps: designing the neural network architecture, conducting the learning or training process, and testing. From the different neural networks architectures, training and transfer functions tested, the most suitable NN architecture for the urban heat island intensity prediction in terms of accuracy was found to be the Elman type using Levenberg-Marquardt as transfer function. The specific network architecture was used for predicting the urban heat island intensity in the sites described in Table 1.

Training and verification of the ANN was performed using the data collected during the period from 06/04/2009 to 07/09/2009 for each experimental site. The remaining data was used to verify the quality of network and adaptation of the neural network to the new data.

Isothermal images have been developed to imprint the UHI intensity over Athens. For each day that the UHI over Athens is analyzed, a set of four images is constructed to visualize the ANN prediction:

- The first image maps the isotherms over Athens using the measured data of the specific day and time.
- The second image represents the isotherms of Athens urban heat island based on the 1 hour prediction results for the specific day and time.
- The third image maps the isotherms of Athens urban heat island based on the 24 hour prediction results for the specific day and time.
- The fourth image plots the isotherms of Athens urban heat island based on the 48 hour prediction results for the specific day and time.

Indicatively the isothermal maps of the UHI intensity over Athens for the day of 1/7/2009 are illustrated in Figure 6. The prediction of the maximum temperatures for the 1/7/2009 has a maximum error of 1.6 °C and 1.9 °C for the 24 hour and 48-hour prediction horizon respectively. Moreover the visualization of UHI intensity prediction shows that the isotherms of the 24 hours prediction are very close to the actual measured ones while the 48 hours prediction presents a slightly different picture.

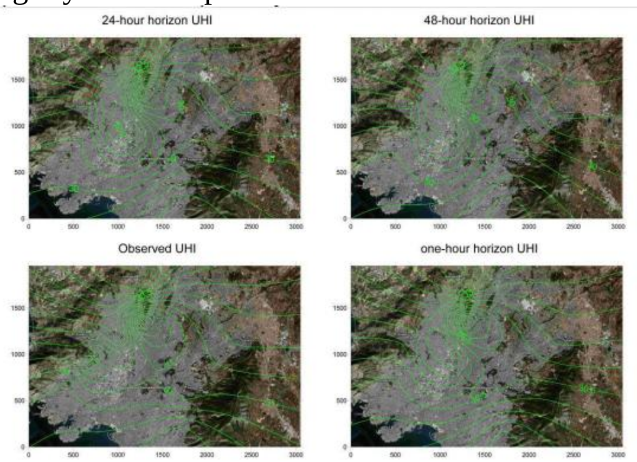


Figure 6: Measured and predicted (1h, 24h and 48h) UHI in Athens during 01/07/2009

The quality control and assurance procedures included testing of the model’s accuracy in predicting temperature fluctuations, seasonal variations and sudden changes in weather conditions. It was found that the specific NN architecture and methodology is accurate for the 24 hours prediction horizon. In addition the calculation of R^2 was found to be close or higher than 0.9 for all sites which represents a good prediction of the urban heat island intensity. The methodology presented here showed that the urban heat island intensity can be predicted quite accurately for at least a 24 hours prediction horizon using a limited set of data. Therefore the NN prediction methodology can be an important tool for peak energy load predictions during heat waves and hot summer days contributing to the demand and supply energy management.

More information on the development of the ANN for the UHI prediction can be found in Gobakis et al. (2011).

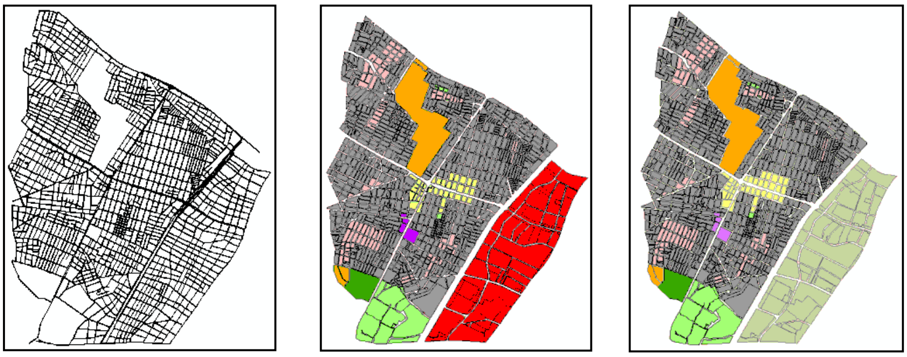
4 DSS APPLICATION ON THE ATHENS CASE STUDY

In order to use the DSS for the evaluation of the planning alternatives the end user has to follow certain steps. The BRIDGE DSS allows the end user to select a specific case study with its associated urban planning alternatives. Then he has to select the sustainability objectives and indicators and define their relative importance by weighting using scale bars. The end user runs the models integrated in the DSS for specific time periods and being able to change the initial conditions for these models. He has to provide the (relative or absolute) values of socioeconomic indicators that are relevant for the case study. The outputs of the BRIDGE DSS are: a) indicators maps for each planning alternative and b) spider diagrams that show the comparative performance of each alternative for each sustainability objective (Chrysoulakis et al., 2013). The sections below describe the application of the DSS on the Athens case study.

4.1 The planning alternatives

One of the outcomes of CoP in each city was the definition of a "real life" project. A part of the city that needed to be redesigned was chosen and specific planning alternatives were proposed. For Egaleo, the discussions between the CoP participants and the results of the experimental campaign carried out in the area lead to the following three planning alternatives.

1. applying cool materials on all buildings and roads in the Egaleo municipality (Figure 7A);
2. changing the land use of Eleonas area with the municipality from its current brownfield/industrial use to urban fabric, including housing and newroads (Figure 7B);
3. changing Eleonas from brownfield/industrial to green space (Figure 7C);



A B C

Figure 7: The three planning alternatives

These three planning alternatives are evaluated by the BRIDGE DSS.

4.2 DSS results

For the Athens case study the issue of thermal comfort was addressed. Figure 8 presents the spatial distribution of the mean evening (20:00–23:00 LST) air temperature (K) for summertime over the municipality of Egaleo. As it can be seen, Planning alternative 1 would reduce the summertime evening air temperature by approximately 0.5 K. The application of cool materials (i.e. materials with high solar reflectance and infrared emittance) on the urban fabric of Egaleo has an impact on the urban energy budget. Solar radiation is reflected rather than absorbed by building roofs and other pavements resulting in lower surface temperatures. This means that less heat is transferred to the ambient air. Consequently, the air temperature values were lower than those of the base case. This reduction of air temperature during the evening hours was considered beneficial for the comfort of residents, as well as for the energy consumption for cooling, with obvious socioeconomic impacts. The 2nd planning alternative slightly increased the summertime evening air temperature over the brownfield of Eleonas when this was converted to residential area. However a small but measurable decrease over the residential area of Egaleo was also observed, which may have been caused by advection.

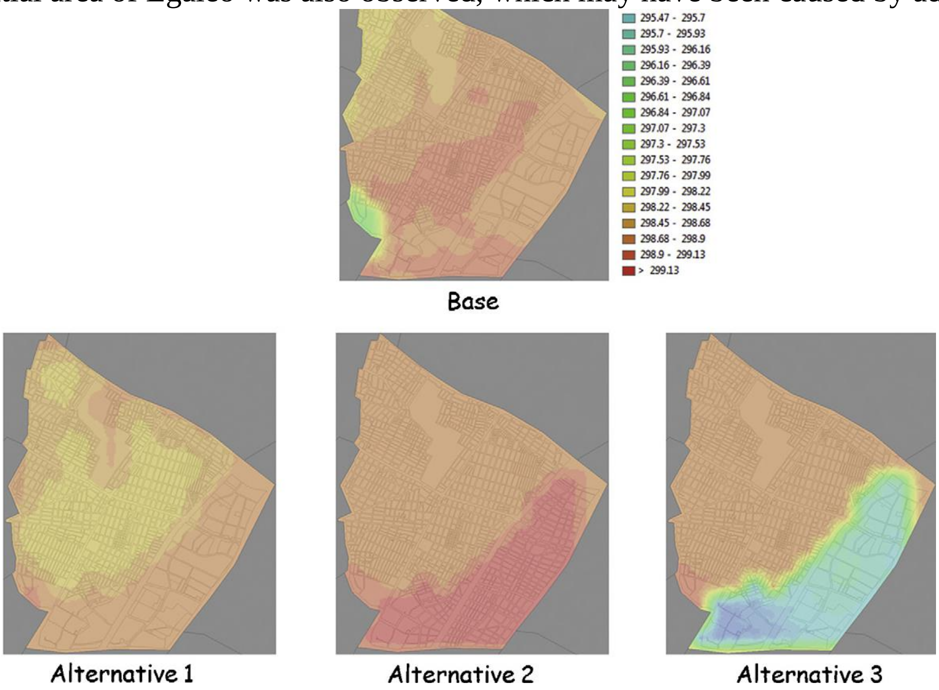


Figure 8. Mean air temperature (K) for the evening period (20:00–23:00 LST) for summertime for Athens base case (top) and planning alternatives (bottom), which are maps of differences (common scale on the right)[taken from Chrysoulakis et al. (2013)].

According to the 3rd planning alternative the brownfield of Eleonas is converted to green area. This change also affects the urban energy balance as trees and vegetation lower surface and air temperatures by providing shade and through evapotranspiration. It was found that this intervention would strongly decrease (around 1.5 K) the summertime evening air temperature. A small but detectable decrease over the residential area of Egaleo was also observed. It can be therefore concluded that all the Athens urban planning alternatives have the potential to create relatively more sustainable urban structures.

The spider diagram produced by the BRIDGE DSS for the Athens case study shows that the 2nd alternative performed better followed closely by the third alternative, although the 1st alternative obtained the highest score for the dimension "thermal comfort". For the above calculations, default weight and socioeconomic indicators values have been used.

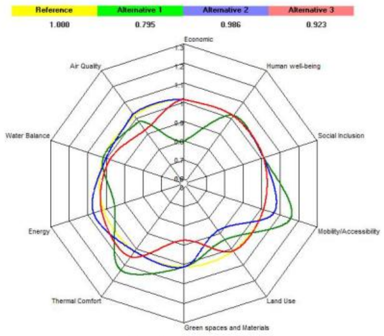


Figure 9. Spider diagram and final appraisal score the Athens case study [taken from Chrysoulakis et al. (2013)].

5 CONCLUSIONS

This paper presents the various activities performed in the framework of the BRIDGE project focusing on the case study based in Athens, in order to provide the required input for the development and evaluation of the DSS. The main outcomes of the CoP meetings were the identification of key planning issues, sustainability objectives and indicators for the city. Also, three planning alternatives were defined. The analysis of the in situ data collection that was undertaken demonstrated that the Athens case study area is characterized by: large solar availability, hot climatic conditions and low precipitation levels, low albedo and vegetation index, air quality problems for some pollutants, strong heat island effect (mean UHI intensity of 2 -3 °C reaching on occasions 6 - 8°C, increased surface and air temperatures and low wind speeds resulting in thermal discomfort for the people in the area (during summer) poor environmental conditions inside buildings (thermal discomfort and lack of IAQ) and increased cooling loads due to the heat island effect. An ANN was developed for the prediction of the urban heat island intensity and was found to accurately predict it for a 24 hours prediction horizon using a limited set of data. The evaluation of the planning alternatives by the DSS showed that all of them have the potential to create relatively more sustainable urban structures.

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