Integrating sustainability aspects in urban planning: the case of Athens

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ABSTRACT

This paper presents the objectives, approach and first results of the FP7-environment project BRIDGE (sustainaBle uRban plannIng Decision support accountinG for urban mEtabolism), which is a joint effort of 14 European Organizations aiming at incorporating sustainability aspects in urban planning processes, accounting for some well recognized relations between urban metabolism and urban structure. BRIDGE will provide the means to generate quantitative estimates of specific components of the urban metabolism (through measurement and modelling of fluxes of energy, water, carbon and pollutants), the means to quantify their impacts (socio-economic and environmental impact assessments and indicators), as well as the means for resource optimisation in the urban fabric (support the decision making in urban planning). Five European cities have been selected as case studies and a Community of Practice approach is adopted, whereby stakeholders are involved from an early stage to establish key sustainability issues and validate the project's achievements. This paper focuses on the Athens case study presenting the approach followed and some important outcomes. Athens needs to improve air quality, ameliorate the urban heat island and increase green spaces. At the administrative level, Athens needs to entrust science in its development plans to comply with local needs and demands.

1. INTRODUCTION

According to Eurostat, 74% of the population in the European Union lives in cities and this number shows an increasing trend. Regardless of the size, all cities face environmental problems which degrade the quality of life and influence development plans. Their target is the "sustainable city". BRIDGE (sustainaBle uRban plannIng Decision support accountinG for urban mEtabolism) is an FP7 project aiming to assist urban planners to design, present and evaluate planning alternatives towards a sustainable city. This is a joint effort of 14 European Organizations aiming at incorporating sustainability aspects in urban planning processes, accounting for some well recognised relations between urban metabolism and urban structure. Urban metabolism considers a city as a dynamic system and distinguishes between energy and material flows. BRIDGE will not perform a complete life cycle analysis or whole system urban metabolism, but it will rather provide the means to generate quantitative estimates of specific components of the urban metabolism (observation and modelling of fluxes of energy, water, carbon and pollutants), the means to quantify their impacts (socio-economic and environmental impact assessments and indicators), as well as the means for resource optimisation in the urban fabric (support the decision making in urban planning).

BRIDGE therefore follows a bottom-up approach to urban metabolism focusing on the fluxes of energy, water, carbon and pollutants.

BRIDGE's main goal is to develop a Decision Support System (DSS) which has the potential to propose modifications on the metabolism of urban systems towards sustainability (Chrysoulakis et al. 2009). More specifically, BRIDGE has the following targets:

- define urban metabolism by means of energy, water, carbon and air pollution fluxes in local scale;
- examine how the change of land use and resources use affects the fluxes of energy, water, carbon, pollutants;
- develop indicators to quantify the environmental impacts of the above urban metabolism components;
- develop a DSS based on these indicators;
- use this DSS to evaluate planning alternatives in several case studies;
- devise sustainable planning strategies based on these evaluations.

BRIDGE will achieve its goals by following a specific approach described in Figure 1: Multidisciplinary research will address urban metabolism and resource optimisation in the urban fabric. Energy, water, carbon and pollutants fluxes in urban areas are investigated by three main approaches of science:

- micrometeorological measurements and site studies,
- airborne and satellite remote sensing observations and
- numerical modelling approaches.

BRIDGE also adopts a Community of Practice (CoP) bottom-up approach, whereby stakeholders (end-users) are involved from an early stage to establish key sustainability issues and validate the project's achievements. A CoP represents individuals sharing a common interest, in this case, sustainable urban planning. More specifically, sustainability objectives and indicators are established for the different components through CoP meetings. In addition, the CoPs facilitate linkages between BRIDGE scientists and local planners/stakeholders, help define planning priorities as well as determine the case study area plan and the associated alternatives.

A set of indicators defined by the BRIDGE consortium will be estimated using the model outputs and the users inputs and subsequently integrated into the DSS for a holistic assessment. A set of associated criteria were developed to link the sustainability objectives with the indicators. BRIDGE integrates key environmental and socio-economic considerations into urban planning through Strategic Environmental Assessment. The BRIDGE DSS evaluates how planning alternatives can modify the physical flows of the above urban metabolism components using a Multi Criteria Evaluation (MCE) approach. The DSS will spatially assess proposed alternatives on the basis of relevant indicators. The outputs of the DSS will assist in predicting the measuring progress towards the established sustainability objectives. These results will be fed back to local planners to help make informed planning - decisions to promote sustainability in the urban context.

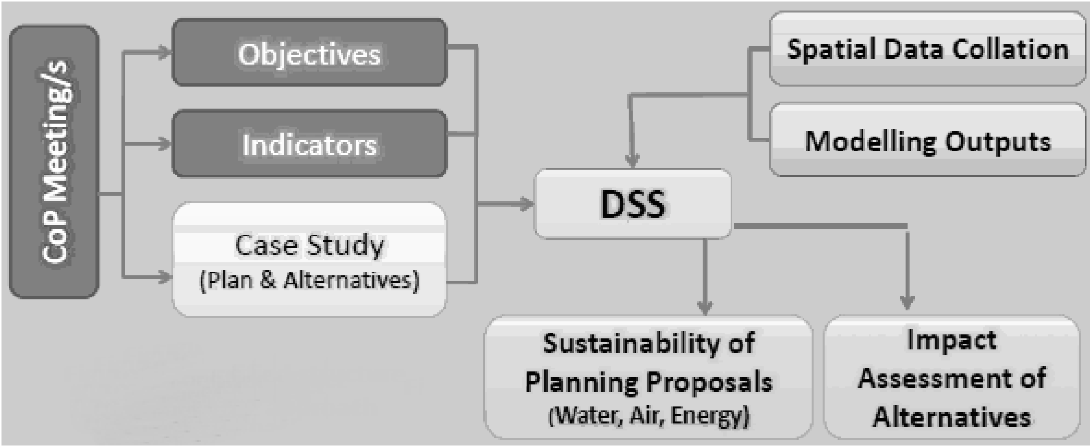


Figure 1: The BRIDGE approach [from poster: BRIDGE: SustainaBle uRban plannIng Decision support accountinG for urban mEtabolism. González A., Donnelly A. and Jones M. (2009)]

BRIDGE examines five European cities of varying size and character so as to develop tailor made "road maps" towards sustainability. Through this effort, the potential of science to support political decision making will be also demonstrated. The five cities that have been selected as BRIDGE case studies are: Helsinki, Finland; Athens, Greece; London, United Kingdom; Firenze, Italy and Gliwice, Poland.

This paper focuses on the work that has been carried out in the context of BRIDGE for the Athens cases study. The previously described approach is demonstrated for the case of Athens and the first results from the experimental campaign, the modelling efforts and the CoP meetings are presented.

2. THE ATHENS CASE STUDY

Athens, in general, has enjoyed a positive transformation due to the Olympic Games of 2004. However, the city still needs to improve air quality, to ameliorate the Urban Heat Island (UHI) and to increase open and green spaces. At the administrative level, the city needs to entrust science in its development plans so as to comply with local needs and demands. The BRIDGE team has selected the municipality of Egaleo, which lies in the Western part of Athens, as the BRIDGE case study area. Five main road axes divide the area in four quarters. One of the quarters is an industrial degraded area (brownfield) called Eleonas (Figure 2).

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 120.000 people, mostly of medium and low income, live and work in the area. The average density is estimated to be 225 inhabitants/ha. The area is inhabited by medium and low income people with medium and low education level and the unemployment rate is high.

According to onsite observations and research it was found that most of the buildings in the area were built between 1950's and 1980's, with several of them built around 1950's. These buildings are made of reinforced concrete, and have one to three floors height. A small amount of houses were built in the 1920's and onwards. These residences are made of stone and are in poor condition. Finally, there are buildings built in the last decades made of reinforced concrete reaching a height of up to 6 floors. As it appears in the land use map of Egaleo, there are only few open/green spaces.

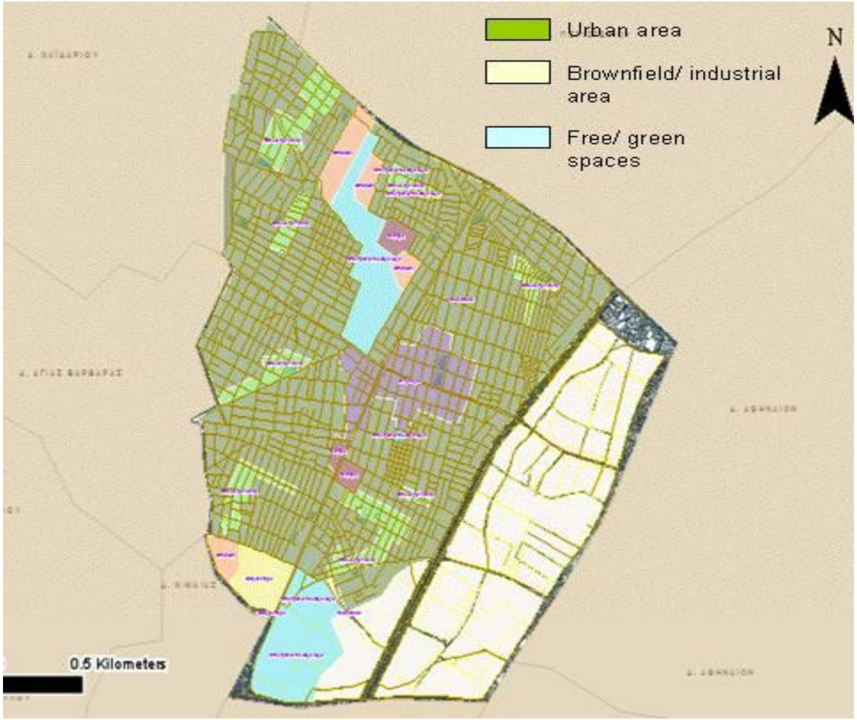


Figure 2: Land use map of the municipality of Egaleo

3. EXPERIMENTAL CAMPAIGN AND DATA COLLECTION

In the framework of BRIDGE project a unique attempt has been made to build an integrated database suitable for the development and validation of models and methodologies for the analysis of air quality, energy and water fluxes between the city and its environment, for the spatio-temporal mapping of land use and the city characteristics and for the assessment of socio-economic indicators, focusing of course on the five case studies cities.
This integrated database contains data from a) in situ experimental measurements b) satellite remote sensing data and c) Socioeconomic GIS data.

3.1 In situ data collection

The National and Kapodistrian University of Athens (NKUA) has launched an experimental campaign in order to measure and collect data for the case study area. More specifically, in an effort to investigate the UHI effect in the area of Athens, NKUA has set up a network of meteorological stations. In total 20 stations have been placed in 20 municipalities of Athens, including the reference station (Table 1). The meteorological stations have been placed on the Municipality Building and are north oriented, shaded and ventilated. Each meteorological Station contains a data logger (Tiny Tag data loggers) that measures air temperature every 15min.

Table 1: The location of the 20 meteo stations

i	Municipality	LATITUDE	LONGITUDE	i	Municipality	LATITUDE	LONGITUDE
1	Ag. Paraskevi	38° 0'50"	23°49'28"	11	Ano Liosia	38° 4'48"	23°42'16"
2	N. Erythraia	38° 5'24"	23°49'9"	12	Ag. Ioannis Rentis	37°57'46"	23°40'28"
3	Maroussi	38° 3'10"	23°48'30"	13	Nea Philadelfia	38° 2'7"	23°44'18"
4	Egaleo	37°59'50"	23°40'5"	14	Kaissariani	37°58'8"	23°45'41"
5	Korydalos	37°58'45"	23°38'33"	15	Vyronas	37°57'24"	23°45'44"
6	Haidari	38° 0'45"	23°39'35"	16	Ilioupoli	37°55'58"	23°45'29"
7	Ag. Barbara	37°59'22"	23°39'37"	17	Glyfada	37°51'58"	23°44'51"
8	Peristeri	38° 0'47"	23°41'43"	18	Elliniko	37°53'28"	23°44'50"
9	Kamatero	38° 3'35"	23°42'50"	19	Kallithea	37°57'29"	23°42'14"
10	Zefyri	38° 4'7"	23°43'4"	20	Moschato	37°57'14"	23°40'54"

Nea Erythraia, which is a suburban area in the Northern part of Athens, was chosen as a reference station. Preliminary results for Egaleo (the case study area) have shown that UHI is always present. Average daily temperature difference between the two stations show a heat island intensity ranging from 0 to 5°C (depending on time, local conditions etc.), with an average value of 2°C. The estimated temperature difference between the two stations for the months of May to November is shown in Figure 3.

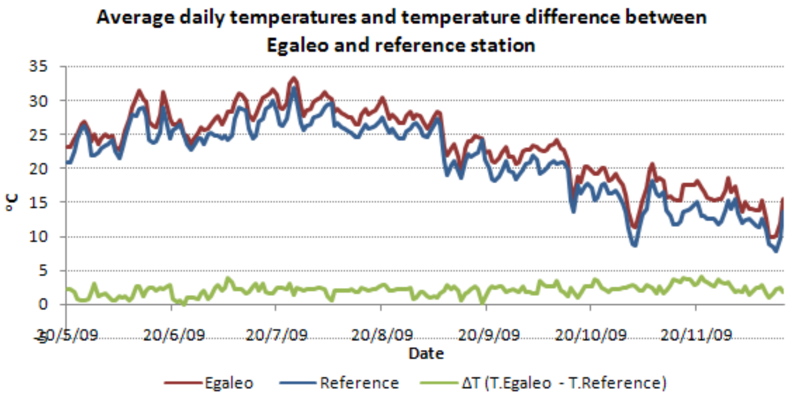


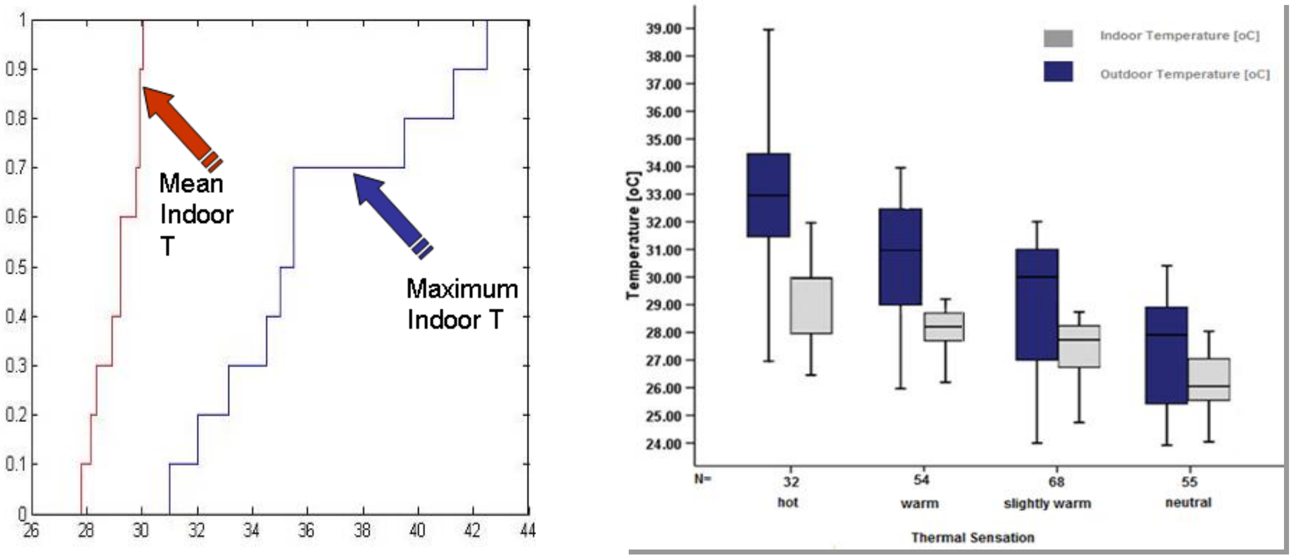
Figure 3. Average daily temperatures and temperature difference between Egaleo and reference station.

The experimental campaign carried out by NKUA in the case study area includes outdoor measurements like wind speed (m/s) (also the 3 components of the wind speed x,y,z) and direction at selected canyons, PM1, PM2.5, PM10 measurements, wind speed and direction at different heights and air, surface and radiant temperatures on selected days. In an effort to depict the outdoor thermal environment spatially a mobile meteorological station has been used.

The analysis of the collected data reveals that Egaleo faces significant problems with thermal discomfort.

Figure 4. Visible and thermal infrared images from the case study area depicting high surface temperatures that contribute to thermal discomfort

Another category of measurements performed by NKUA include the assessment of the thermal indoor environment at selected residential buildings in the case study area. Extensive information about the 10 selected buildings has been collected (plans, energy consumption data etc.). In addition 320 questionnaires-ASHRAE std 55(long and short) have been distributed and collected from the residents and they are currently being analysed. The measurements performed inside the residences include air temperature, PM1, PM2.5, PM10 (units: mg/m^3), humidity (%), air velocity (m/s) and brightness temperature (°C).



A B

Figure 5. (A) Cumulative % Temperature of selected residential buildings during August 2009 (B) Indoor and outdoor recorded temperatures vs thermal sensation as voted by the residents

The analysis of the results shows 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. The thermal comfort perception of the users from the analysis of the questionnaires is in agreement with the Tair measurements.

In addition the following data have been collected for 2008 and 2009.

- Meteorological data including air temperature (°C), relative humidity (%), wind direction and wind speed (m/s), precipitation (mm), diffuse solar radiation (W/m^2), total solar radiation (W/m^2), sunshine duration (hours) etc. [Source: National Observatory of Athens]
- Hourly values of air pollutants' concentrations (CO, NO_2, NO, SO_2, O_3) [Source: Ministry 's of Environment, Energy and Climate]
- Traffic data: Number of vehicles that have passed through specific measurement locations (per hour), Average velocity (km/h) of the vehicles that have passed through specific measurement locations (per hour), Percentage of time (%) that each measurement location is engaged (per hour)) [Source: Ministry of Infrastructure, Transport and Networks]

3.2 Satellite remote sensing data

The monitoring and analysis of the main fluxes investigated in the framework of BRIDGE was also supported by using satellite remote sensing data and techniques.

On a local scale perspective, processing of the satellite images in the visible and thermal infrared part of the spectrum was performed leading to the measurement and mapping of the following bio-geophysical variables for Athens (including the Egaleo test site):

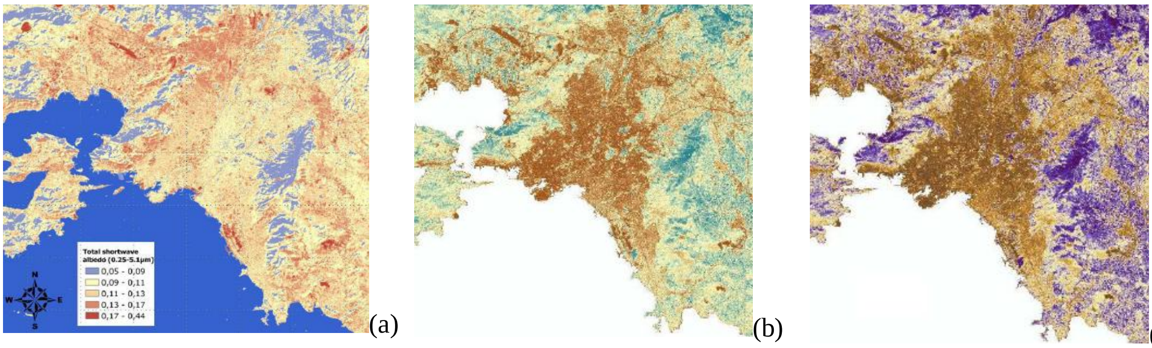
1. Narrowband (spectral) and broadband surface albedo at 30-m spatial resolution produced from the Landsat TM sensor (Figure 6a). The wavelengths (0.25-5.0 μm) correspond to total shortwave broadband albedo, whereas (0.4-0.7 μm) and (0.7-5.0 μm) correspond to visible and near-infrared broadband albedos (6). The methodology applied is described in Liang et al. (2002) and Liang (2004). Lambertian conditions were assumed.

2. Urban vegetation as derived from the multispectral vegetation index NDVI at 30-m spatial resolution produced from Landsat TM (Figure 6b).

3. Land surface emissivity (LSE) in the thermal infrared at 30-m spatial resolution produced from Landsat TM (Figure 6c). The methodology applied is described in Sobrino et al. (2004) and Stathopoulou et al. (2007).

4. Land surface temperature (LST) at 120-m spatial resolution produced from the Landsat TM sensor. The LST algorithm applied is the one proposed by Jiménez-Munõz and Sobrino (2003).

Corine Land Cover 2000 database (scale of 1: 100.000) was used to describe land cover and land use types in Athens. In addition extraction and post processed ASTER GDEM for the broader area of Athens was provided. The product was delivered in both Geographic WGS84 and UTM WGS84 projections with EGM96 vertical datum. Its spatial resolution is 30 m. A validation of this product has given by Chrysoulakis et al. (2010).



(a) (b) (c)

Figure 6. TM derived map of a) total shortwave albedo b) urban vegetation and c) surface emissivity for Athens.

Egaleo is found to be densely urbanized with albedo values ranging from 0.09 to 0.13 and mean surface emissivity values around 0.93. Urban vegetation of Egaleo is also limited with a mean NDVI value of 0.14, resulting to high surface temperatures (> 303 K) that deteriorate the thermal comfort sensation of the inhabitants.

3.3 Socioeconomic GIS data

In effort to gather data in order to define socioeconomic features of the case study the following information has been collected from the National Statistical Service of Greece: Vector maps (census block) of buildings, topography, census block and road network; Population; Number of buildings per census block; Number of floors/ year of construction/ building use; education level; employment status. All the above mentioned data are available in BRIDGE database.

4. MODELLING OF THE ATHENS UHI

The experimental results of the urban heat island in Athens have been used in order to develop a neural-network-based model for predicting UHI intensity of Athens. The spatial variability of the surface temperature is estimated by using these techniques and compared with those data observed in standard meteorological stations. Feed-forward, Cascade and Elman back propagation networks Artificial Neural Networks (ANN) have been tested as well as several training functions (trainlm, trainscg, trainbfg, trangda, traingdx). Elman had the best performance with traingdx as training function. The experimental results have shown that the ANN achieved good all day temperature predictions as well as maximum temperature of the day. Also those results were calculated with minimum amount of data of 30-40 days and easy acquired data, ambient temperature and global solar radiation of the region (Gobakis et al., 2010). The model can potentially be integrated in the DSS.

5. THE COMMUNITY OF PRACTICE OF THE ATHENS CASE STUDY

The role of the end-users for each case study area, in the BRIDGE project that is fulfilled through CoP meetings, is to:

- meet and exchange ideas on sustainable urban planning issues among scientists, urban planners and local stakeholders
- define sustainable urban planning priorities for the case study area

- define sustainability objectives
- define indicators i.e. the parameters that allows us to assess if the sustainability objectives are achieved.
- select an area within the case study city and propose alternatives/ interventions for increasing its sustainability.
- assess the DSS

The Athens case study area is the Municipality of Egaleo. Two local CoP meetings have been carried out at the Municipality of Egaleo, with 51 and 29 participants respectively. The participants included 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 objectives of the two meeting were a) to enable the BRIDGE partners and Athens planners to get to know each other, share experience and through a number of talks to identify key issues of sustainable development in Athens and especially in Egaleo and b) to identify, through group discussion, Egaleos' planning priorities, sustainability objectives and indicators with which to assess progress towards sustainable development; c)familiarize with the planned intervention for the Athens case study and discuss underlying challenges, planning alternatives and collected indicators, d) To discuss further and define sustainable urban planning objectives and correlating environmental and socio –economic indicators related to the real life project.

The priorities for sustainable city planning for the Athens case study as defined by the local stakeholders are: Thermal discomfort; Energy; Quality of building stock; Transport; Green spaces; and Land use of Eleonas. The outcome of the Athens CoP meetings are summarised in the following tables.

Table 1. Environmental sustainability objectives and the corresponding indicators as defined in the 2 Athens CoPs

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); • CO_2 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 m^2) 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.

Table 2. Socioeconomic sustainability objectives and the corresponding indicators as defined in the 2 Athens CoPs

Sustainability Objective (in order of priority)	Socio-economic complement of the Environmental indicators
7. Mobility	• road traffic intensity, • quality of pedestrian sideways, • number of parking slots.
8. 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)
9. 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.
10. Economic criteria	• financial costs of the interventions, • estimated side-effects on local economy
11. Place identity	• aesthetic value of the area and changes due to planning intervention

A real life project "The regeneration of Thivon Avenue" has been selected for the demonstration/validation of the DSS. Thivon Avenue is a main axis road that runs through 6 Municipalities of Athens, one of these being Egaleo where major improvements are proposed. The key problems in the avenue include: heavy traffic load; air pollution ; environmental problems due to the neighbouring industrial area of Eleonas; lack of open and green spaces; lack of parking spaces; degraded urban infrastructure (e.g. destroyed pavements making very difficult the mobility of pedestrians, especially for disabled people); poor quality of buildings; "visual pollution" (e.g. large publicity panels, etc.); and high temperatures experienced in the city as a whole (thermal discomfort).

The goal of this project is to create an oasis in this problematic area and present a pilot project that other municipalities will also follow. The objectives of the regeneration are to a) create thermal comfort conditions, b) improve the microclimate, c) increase green spaces and improve ventilation/ air circulation conditions, d) appropriate choice of materials e) respect the traditional architectural style of the area. Some of the proposed interventions include:

• Use of photocatalytic cool asphalt (with self cleaning, anti pollution properties, antimicrobial properties)

• Use of ceramic tiles on pavements (cool materials that do not absorb sunlight, natural materials, easy to clean).

• PV, and PV lighting devices.

• Installation of Earth to air heat exchangers for cooling and ventilation.

• A bioclimatic solar tower that collects air pollution from near the road and transfers it at a height over the canopy. It also collects solar energy that can be used and is aesthetically pleasing.

• Use of pergolas for shading.

• Increasing green spaces by tree (already mature, appropriate, non allergenic) and bush planting for microclimate improvement and shading.

• Rehabilitation of the main squares around the avenue.

For the assessment of the DSS three alternatives have been proposed:

a) Use of photocatalytic technology and cool materials and asphalt, green spaces, earth to air heat exchangers, solar control chimneys.

b) Same as alternative ‘a’ but without the photocatalytic technology.

c) Same as alternative ‘a’ but without the earth to air heat exchangers or solar chimneys.

The assessment of alternatives will focus on the economic implications of the different technologies and materials, the effects on air quality and thermal comfort and the effects on traffic circulation and associated impacts.

Figure: Challenges of Thivon Avenue and proposed interventions (interventions designed by ALD architects)

A third “umbrella” CoP meeting, with representatives from all case studies’ CoPs, took place in Athens and a common set of sustainability objectives and indicators has been defined for all cities. Despite the different urban settings and the differences between the identified planning issues, the results of the CoP meetings illustrate, as expected, a clear correlation among the cities in relation to a number of sustainability objectives like air quality improvement, the improvement of energy efficiency of the building stock and the mitigation of climate change effects.

CONCLUDING SUMMARY

This paper outlines the work that has been carried out in the framework of an EU supported project BRIDGE. The main target is the development of a DSS and the quantitative description of the approach that has been used for the achievement of these goals includes experimental measurements, remote sensing measurements, numerical modelling as well as the involvement of the end users via CoP meetings. This process, as well as available results are described for the case of Athens, which is one of the five case study cities examined in the project. The focus is on the Municipality of Egaleo and the analysis of the collected data has shown that the area is facing problems with thermal comfort, poor air quality, lack of green spaces and poor quality of building stock. A heat island is present in the area as measurements and modelling studies report. These findings are in line with the results of the CoP meetings and the end users sustainability priorities and objectives for the area. The next step will involve the development and assessment of the DSS that will be done based on the data collection and modelling results as well as the end users views.

ACKNOWLEDGMENTS

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