May 2010

Issue 2

BRIDGE newsletter

Editorial

The FP7 project BRIDGE** (sustainaBle uRban plannIng Decision support accountinG for urban mEtabolism) 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**. **BRIDGE** was launched in 2008 in order to **assist urban planners to present and evaluate planning alternatives towards a sustainable city.

The 2nd issue of the BRIDGE newsletter presents the progress and achievements of the project regarding the data collection in each case study and models' implementation in the framework of BRIDGE, as well as the DSS architecture. It also includes an article on URBAIR model by C. Borrego et al., an article on CoPs in BRIDGE by B. Lietzke and J. Klostermann and an article on Sustainability objectives and indicators in BRIDGE by A. González et al.

BRIDGE partners:

1. Foundation for Research and Technology - Hellas (FORTH), Greece
2. King's College London (KCL), United Kingdom
3. Consiglio Nazionale delle Ricerche (CNR), Italy
4. Instytut Ekologii Terenów Uprzemysłowionych (IETU), Poland
5. Technical University of Madrid (UPM), Spain
6. University of Aveiro (UAVR), Portugal
7. University of Basel (UBAS), Switzerland
8. Trinity College Dublin (TCD), Ireland
9. University of Helsinki (UHEL), Finland
10. National and Kapodistrian University of Athens (NKUA), Greece
11. Centro Euro-Mediterraneo per i Cambiamenti Climatici S.c.a.r.l. (CMCC), Italy
12. Météo France Centre National De Recherches Météorologiques (CNRM), France
13. Alterra B.V., The Netherlands
14. University of Southampton (SOTON), United Kingdom

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Introduction

The main achievement and innovation of BRIDGE is based on the development of a Decision Support System (DSS) which reflects the multidimensional nature of the urban metabolism, as operationalised in comprehensive and transferable indicators easily understood by urban planners (end-users) and it has the potential to propose modifications on the metabolism of urban systems towards sustainability.

A DSS is a computer based information system that assists decision making processes by providing a structured presentation of alternatives and mechanisms for the comparative analysis, ranking, and selection among them. The problem with selecting options always is that options depend on the objectives that the end-user states. The objectives are usually conflicting, and therefore, the solution is a trade-off between them. The main function of the BRIDGE DSS is therefore to provide the tools for the evaluation of planning alternatives towards a sustainable city based on key urban metabolism components.

More specifically, the BRIDGE DSS integrates the bio-physical observations with socio-economic issues and allows end-users to evaluate several urban planning alternatives based on their initial identification of planning objectives. In this way, sustainable planning strategies will be proposed based on quantitative assessments of the urban metabolism components. More specifically, the fluxes of energy, water, carbon and pollutants are measured and modelled dynamically in a 3D context by using state-of-the-art numerical models. The outputs of these models lead to indicators which define the state of the urban environment and are incorporated into the DSS.

The most important processes, supported by the BRIDGE DSS, include:

- Storage, processing, and presentation of data required continuously, repeatedly or even once in relation with the specific problem.
- Presentation and user-transparent description of simple and complex relations between data inputs relevant to the decision process.
- Modelling and simulation of impacts deriving from desired, proposed and/or existing alternative solutions.

Urban planning is based on spatial processes which impose the use of Geographic Information System (GIS) in the DSS development. A GIS captures, stores, analyzes, manages, and presents data that is linked to a geographic location. The use of GIS allows for spatially-referenced data management and analysis, simulation and decision modelling, evaluation and presentation of the decisions that need to be made to ensure a sustainable future for the urban environment.

The BRIDGE Decision Support System

The BRIDGE DSS is based on an analytical and a design component, linking the bio-physical processes in urban environment with socio-economic parameters, as shown in Figure 1. The DSS estimates the trade-off between the environmental and the socio-economic dimensions of changes in the urban metabolism introduced by urban planning actions.

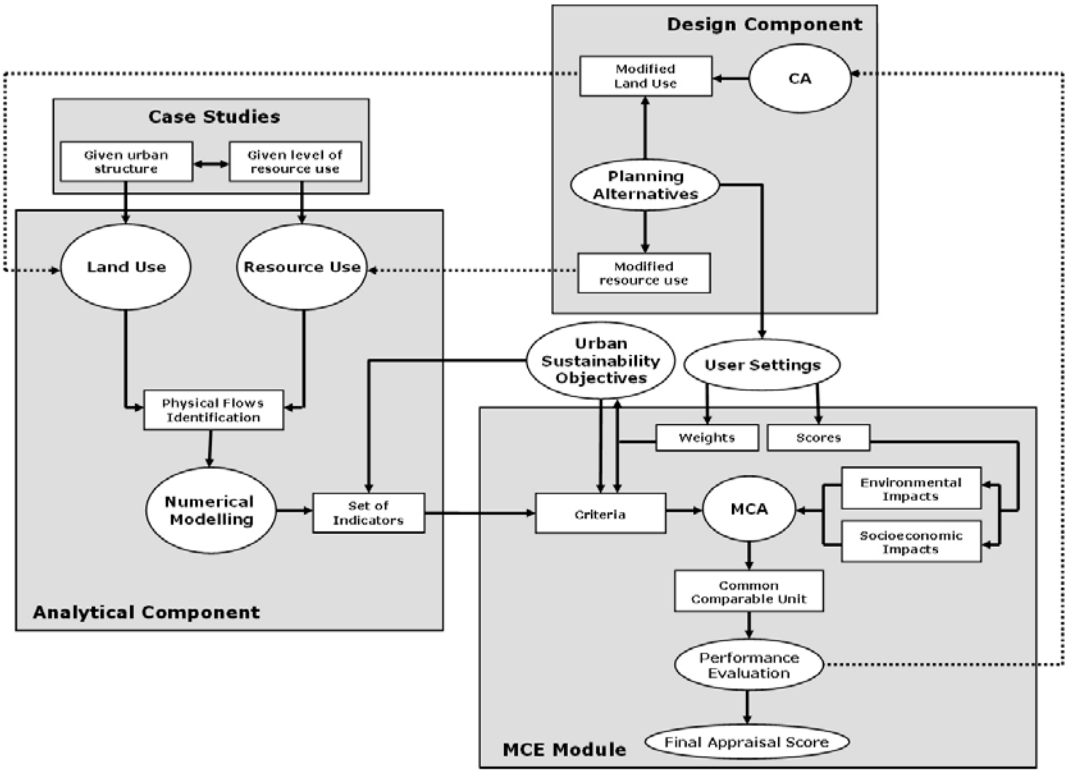


Figure 1: Conceptual illustration of the BRIDGE DSS.

The **analytical component** supports the assessment of the environmental impacts of the energy, water, carbon and pollutants fluxes, while the **design component** offers tools to assess different planning alternatives. These planning alternatives are practically modifications of land-use and resource and therefore modifications of the metabolism of the urban system. The link between the analytical and the design components is a **Multi-Criteria Evaluation (MCE) module** to supplement decision support capabilities. This module combines the environmental with the socio-economic aspects of urban metabolism and evaluates the performance of each planning alternative in terms of sustainability.

The environmental impact of urban metabolism for given urban structures and given levels of resource use in the case studies is addressed using the **analytical component**. The physical flows are identified using numerical modelling and a set of indicators is identified related to the urban sustainability objectives identified during participative processes (i.e. in consultation with stakeholders). This component has four major functions for analyzing energy, water balance, carbon and air pollutants and providing indicators which reflect the current state of the urban environment as well as the environmental pressures (or benefits) that every planning alternative will cause.

In the **MCE module** environmental indicators are combined with socio-economic indicators using a multi-criteria analysis approach. Both environmental and socio-economic indicators are at first evaluated, considering the modifications introduced by the planning alternative, in separate categories (i.e. commonly based on targets and thresholds set at European or national level). A score for each indicator results from this evaluation. The end-users determine the significance (i.e. weight) of the criteria defining weights according to their preferences.

The **design component** is used to handle and present modified land-use arrangements and practices for resource use on the basis of different planning interventions at specific sites in the case studies. These planning alternatives are provided by the end-users. Land-uses changes are handled in two scales. In the local scale, the planning alternatives provided by the end-users already include estimations of their impact. The modifications that they cause to urban metabolism are assessed by the analytical component on the basis of the estimation of changes in energy, water, carbon and pollutants fluxes. In a broader scale, these local land-use scenarios are used as inputs for a Cellular Automata (CA) model included in the design component, to simulate broader and long-term land-use changes. The broader scale scenarios obtained, are subsequently used to assess future environmental impacts on the basis of modifications to the physical flows that will be simulated by the numerical models included in the analytical component.

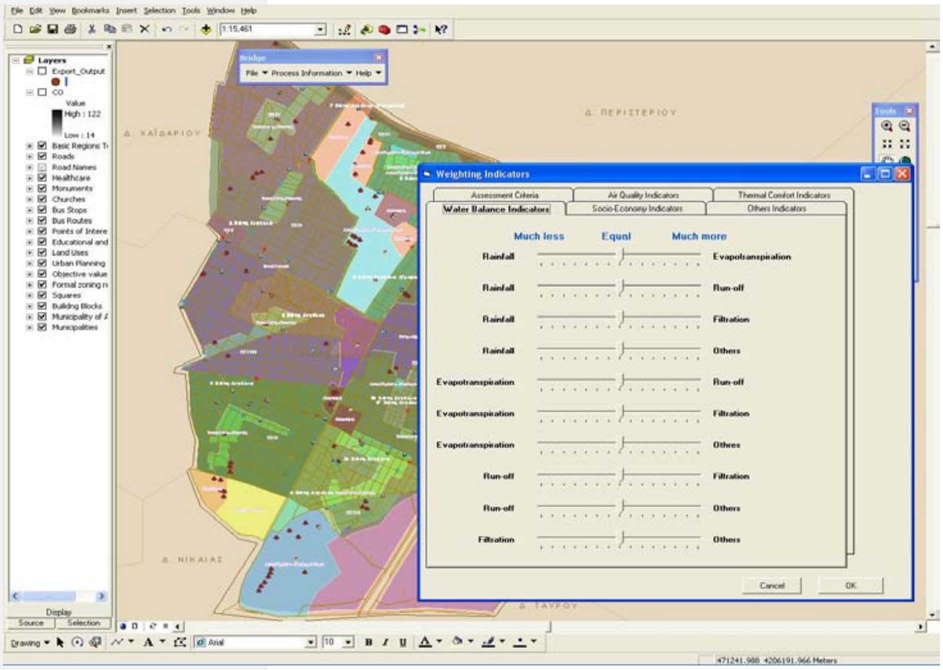


Figure 2: The GUI of the BRIDGE DSS.

The BRIDGE DSS framework is composed of modules serving different needs. The **GIS module** is used to integrate all datasets, analyze the various spatial entities, prepare the input for the physical flows models and the decision making models, store the results and then visualize them; the **communication modules** are used as middleware between the GIS and the physical flows models. The **impact assessment module** is used to assess the environmental and socio-economic components of urban metabolism; finally, the **Graphical User Interface (GUI)** is used to provide the interaction between users and the DSS.

Decision Making Methodology

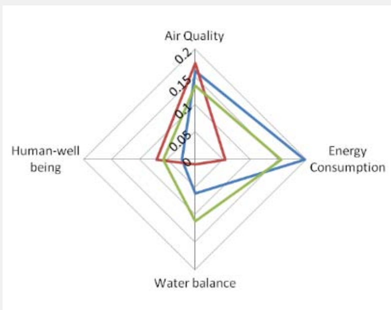
The BRIDGE DSS is based on sustainability **objectives** reflecting the intensity of the interactions among the different elements in the urban system (namely environmental and socio-economic) and are specific to each case study's planning interventions (i.e. suited to address the end-user needs). A set of **criteria** are associated to such objectives providing a link between the objectives and the indicators and usually have time limits and/or thresholds associated with them. The DSS relies on **indicators** as inputs. Indicators demonstrate the level of achievement of each criterion, in a quantified manner.

Indicators for each planning alternative are provided in different ways: environmental indicators arising from measurement of physical quantities are calculated by spatial models; socio-economic indicators reflecting objective values (number of houses constructed, number of jobs created, etc.) are given as data attached to planning alternatives; value judgments (such as landscape or urban quality) are defined by end-users. The users define the relative importance of each criteria and indicators. Having all this information available, the scores are determined for each alternative, using the measurement scales previously defined. An overview presentation follows, enabling end-users to access the merits of each planning alternative and eventually to perform sensitivity analyses, by changing the values of indicators' weights. MCE involves transformations of available datasets which characterize impacts of planning alternatives, resulting in a summary score. The idea of computing a summary score is to provide one measure used as the basis for ranking alternatives from best to worst.

When assessing the performance of indicators, targets/thresholds are used (e.g. maximum value permitted according to European and national legislation), where possible, as reference points to establish the nature of the indicator's performance. When targets/thresholds are not available, a comparable baseline is (e.g. business as usual scenario on an urbanized area where proposed alternatives consider upgrading the urban fabric), alternatives are contrasted against such do-nothing alternative (using it as a "reference" point). Where the baseline scenario is not comparable the alternatives are compared among themselves. This approach facilitates comparison and allows establishing which alternative represents the most suitable option. Therefore, it should be noted that the "reference" indicator is a determined threshold/target if such values exists at European or national legislation/guidelines for a given indicator (e.g. 50 µgm $^{-3}$ PM_{10}). If the defined value exists, the baseline value of the reference alternative is adopted.

DSS Results Example

Planning Alternatives



Star Diagram

	Final Appraisal Score
Alternative 1	0.443507
Alternative 2	0.308393
Alternative 3	0.457766

Final Score

Physical Flows Modelling

The modelling approach within BRIDGE integrates different types of models from mesoscale air quality models to urban canopy models. The cascade modeling technique from large to local scale is the main methodology applied in BRIDGE. This approach allows estimating the pollutant concentrations and the fluxes associated to varying geographical extents of urban development scenarios. Mesoscale meteorological models such as MM5 and WRF are used to simulate the atmospheric flow in a 3D cube with spatial resolutions on about 0.2 - 100 km with domains between 10 km and 50 km to thousands of km. These models give detailed information of all meteorological variables and fluxes involved in the atmospheric flow and provide inputs to chemical transport models such as CAMx and CMAQ (Figure 3). The chemical transport models simulate the atmospheric chemistry based on lumped carbon mechanisms (such as CB-IV or CB05 or RADM) and a detailed description of the photochemistry. They also use different aerosol models to estimate primary and secondary PM concentrations in the atmosphere. One of the most modern set of meteorological and chemical models named WRF/CHEM has been adapted in BRIDGE with urban and canopy parameterization (urbanization of mesoscale meteorological models). Nowadays version of WRF-UCM-NOAH (April, 2009) model includes on-line simulations of urban canopy models and land-surface iterations with resolutions up to 200 m.

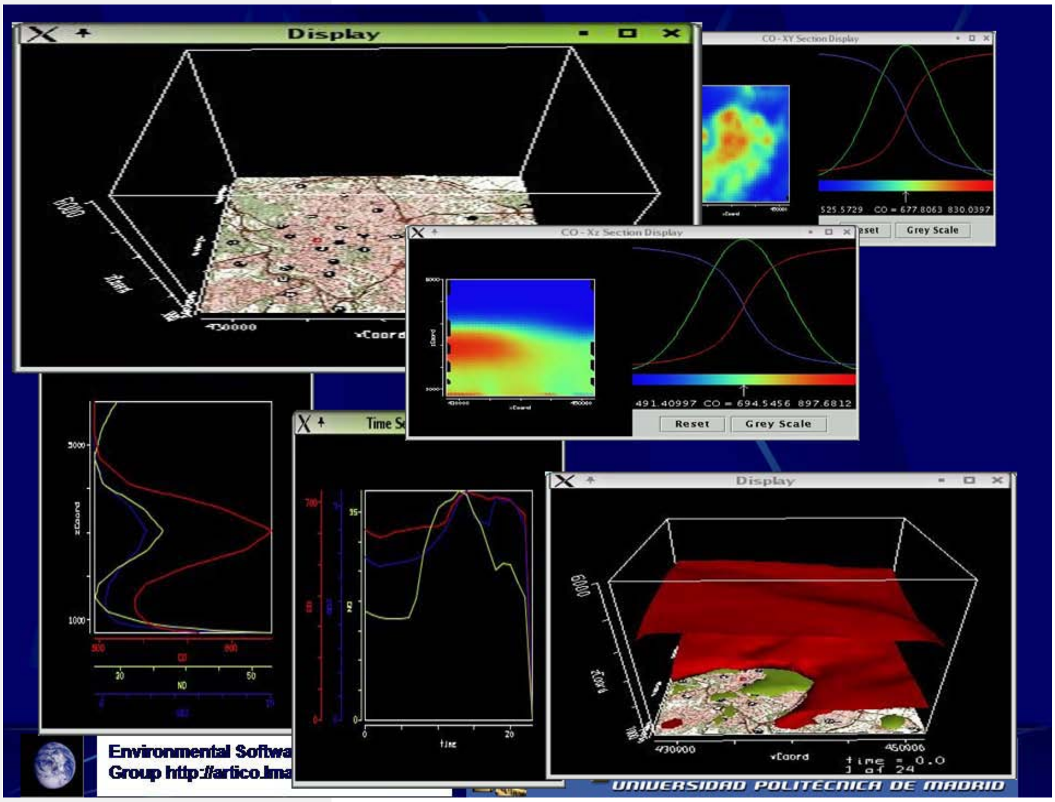


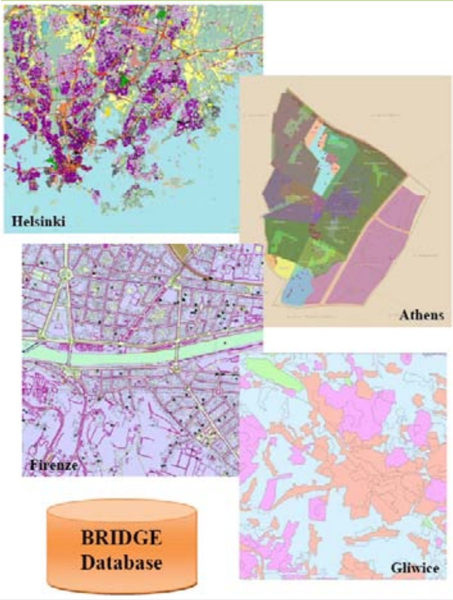
Figure 3: Visual representation of outputs of different mesoscale models such MM5-CMAQ or WRF/CHEM.

Several local scale models are available in BRIDGE, with different objectives. The CFD models MICROSYS (Figure 4) – including EULAG (UCAR) model - and VADIS receive boundary and initial conditions from the mesoscale models to simulate the closest urban domain with a 4D interaction between the biosphere and atmosphere. The traffic models CAMO and TREM were also adapted in BRIDGE. Additional models are also used regarding different turbulence schemes such as LUMPS and TEB turbulence models. These models are already suited to produce comfort index or energy indexes. Similarly, the ACASA model is also used to simulate the microscale urban metabolism as a stand-alone model (surface-atmosphere interactions and the distribution of trace gases). ACASA calculates, each independently, the output quantities (and associated vertical gradients) often used for output comparisons (among air, soil, or snowpack domains). The domain extends to a maximum of 100 m above the city skyline and plant tree canopy to ensure applicability of the turbulence assumptions.

At urban scale the URBAIR model is to evaluate air quality and dispersion patterns. This is a second generation Gaussian plume model appropriate for distances up to about 10 km from the source. Moreover, SIMGRO model produce detailed information on all the hydrological processes present in an urban environment. A Regional Climate Model (RCM3) is also integrated in BRIDGE modeling setup which can be used for producing information on the climate evolution for future scenarios, to provide climate variables (temperature, wind, humidity, PBL height, etc.) and fluxes under climate change.

Figure 4: Visual representation of outputs of MICROSYS and CAMO.

Finally, a CA module was integrated in BRIDGE DSS for the simulation of land use dynamics. The CA is used to determine the spatial distribution of an aggregate land-use demand, taking into account the interaction between different land-uses, as well as the physical, environmental and institutional factors characterizing each cell. CA can easily account for the planning decisions whose broader effects in terms of a spatial distribution of land-uses have to be evaluated. In CA adopted in BRIDGE the neighbourhood is defined as the circular region around the cell with a typical radius that ranges from 0.5 Km to 1.5 km depending on the grid resolution. The typical output of the CA are maps showing the predicted evolution of land uses in the area of interest, over a predefined period of time. By varying the inputs into the CA model, it can be used to explore the future urban development of the area under consideration under alternative spatial planning and policy scenarios.



The BRIDGE databases

The integrated BRIDGE database was established for the development and validation of models and methodologies estimating 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.

The BRIDGE database consists of the following data parameters:

A. In-situ datasets of air quality, energy, water, carbon and pollutants fluxes/concentrations

The following data are included:

• Time series and spatially extensive data sets of air quality and surface fluxes.

• Turbulent fluxes and distribution of trace gas and particle concentrations.

• Urban heat island characteristics and energy demand of buildings for cooling.

• Indoor environmental quality.

• Gas exchange of urban vegetation in relation to soil properties.

Athens case study

The Athens Case Study is focused on the municipality of Egaleo, which 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 (Figure 5). 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. 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 very little free/ green spaces.

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

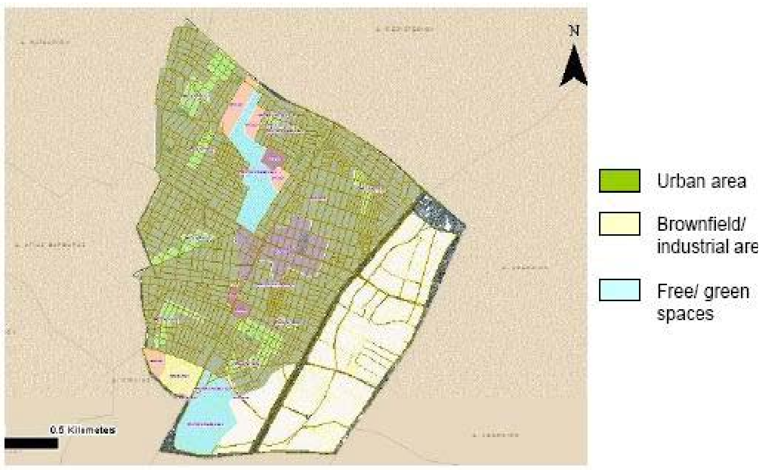


Figure 5. Egaleo land use map

The regeneration area is Thivon Avenue. Thivon Avenue runs through 6 Municipalities of Athens, one of these being Egaleo where major improvements are proposed to address key problems in the area. The objectives of this regeneration project 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. The project considers three alternatives which differing combinations in the application of photocatalytic technology and cool materials and asphalt, green spaces, earth to air heat exchangers, and solar control 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.

Helsinki case study

Measurements at Helsinki (Figure 6) are carried out in two locations, Kumpula and Viikki. The air quality and meteorological measurements are taken at the Kumpula site (60°12´N, 24°57'E, 26 meters above sea level), which is located at the University of Helsinki campus area about five kilometres from the Helsinki city centre. Most of the measurements of air quality, energy, water, carbon and pollutants fluxes are carried out at the urban measurement station SMEAR III. Measurements are carried out in a 31 meters high triangular lattice tower, which is equipped with meteorological instrumentation at several heights. The surroundings in Kumpula are heterogeneous consisting of buildings, paved areas and vegetation, and three distinct areas of land use have been recognized in different wind directions. In direction 320-40°, lays the urban sector with high fraction of building with mean height of 20 meters and paved areas. One of the main road leading to the Helsinki city centre with 45 000 vehicles per workdays passes the road sector (40-180°) with a distance of 150 meters from the measurement tower. The area between is covered with deciduous forest. The vegetation sector is located in direction 180-320°, where the University Botanical garden and an allotment garden are located.

The multidisciplinary urban ecosystem and plant research will take place in Viikki area, seven kilometers from the Helsinki city centre. Viikki area consists of the University campus area, new residential areas build since early 2000's and extensive green areas.

The BRIDGE databases (…continued)

More specifically the collected in-situ data are:

Air quality:

-Concentrations of H_2O, CO_2, NO_x, O_3, CO, SO_2

-Particle number flux (starting from 6nm)

-Particle number size distribution

-Principal outdoor pollutants (VOCs, contaminants, etc.)

-Soil gas profiles (at 3 depths)

-Particulate matter values - PM_1, $PM_{2.5}$, PM_{10}

-Particle number flux (starting from 0.32nm)

Indoor air quality:

-Particulate matter values -PM_1, $PM_{2.5}$, PM_{10}

-Internal temperatures

-Concentration of CO_2

-Air flow measurements

-Air infiltration

-Principal indoor pollutants (NO_X, VOCs, etc.)

-Thermal comfort parameters (e.g. air temperature (wet and dry bulb), humidity, air velocity, radiant temperature, black globe T)

Heat island measurements:

-Air temperature data from city centre and air temperature data from a reference station in a suburban area

Meteorological parameters:

-Air pressure

-Air temperature

-Air temperature (next to trees)

-Precipitation

-Relative humidity

-Stormwater quality (analysis of turbidity, conductivity and temperature, analysis of heavy metals, nutrients, organic pollutants, etc.)

The BRIDGE databases (…continued)

A. In-situ datasets

Meteorological parameters:

-Stormwater quantity

-u, v components

-Surface temperature

Micrometerological parameters:

-All three wind components (u, v and w)

-Friction velocity

-Sensible and latent heat fluxes and CO_2 flux

-Wind speed and direction

-Anthropogenic heat flux

-Turbulent fluxes

Plant:

-Diameter growth (6 trees)

-Diurnal stem and bark diameter variation (6 trees)

-Sapflow (6 trees)

-Biomonitoring of airborne trace metals

Radiation:

-Radiation PAR (next to trees)

-Up- and downward long- and short-wave radiations + PAR

-Diffuse solar radiation

-Total solar radiation

-Sunshine duration

-UVA & UVB radiation

Soil:

-Soil moisture profile

-Soil temperature profile

Visual comfort:

-Light distribution

Weather station:

-Temperature, rain, etc

The measurements are done on two streets with south-west and north-east direction. The streets are paved with local pillar type black alder and lime trees growing there. The streets have been build in 2002 using normal construction techniques, one street in normal modern residential area and one in an office area. Three different urban load bearing soil mixtures currently used in Helsinki are tested at the sites.

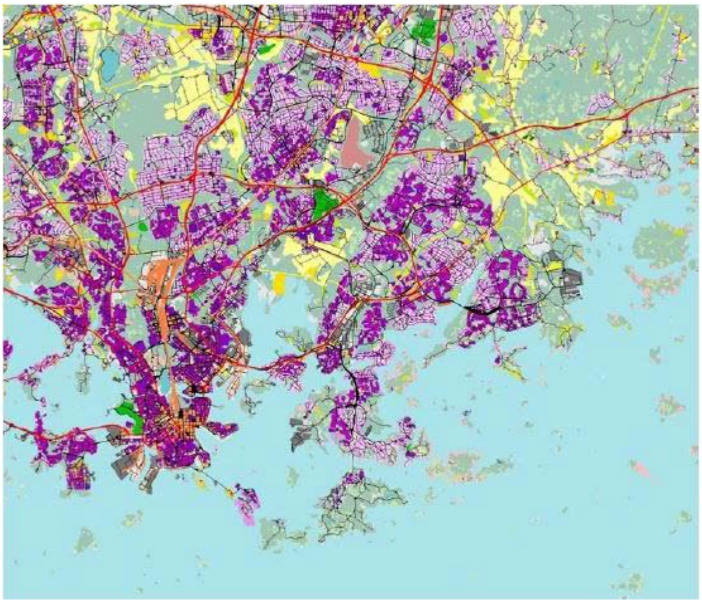


Figure 6. Helsinki land use map

The area identified for development is within 600m from the Metro station. The planning objectives for the area are: to provide new housing for the growing metropolitan areas, built to address climate change (i.e. densification of urban structure, focus on railway and metro stations); to provide and places of work mixed with housing; to deal with demographic polarization (i.e. immigration issue); to move towards more owned dwellings and bigger apartments; to improve services; to maintain sufficient and continuous recreation and habitats; and to improve accessibility to nature areas.

Three preliminary alternatives have been proposed with varying combinations of housing density and office space, and differing relative footprints. All alternatives include the protection of the waterfront and geological heritage on site. The alternatives will be assessed in terms of cost (realization and profit), social cohesion, air quality and energy consumption.

Firenze case study

Measurements at Firenze are carried out with the use of a recently installed micromet monitoring system capable to record urban mass and energy fluxes. More specifically, an eddy covariance (EC) flux station was installed in Firenze (43° 47′ N, 11° 15′ E) in September of 2005 at the Osservatorio Ximeniano, in the center of the city and is operating from 14 September 2005. Air quality datasets for a network of 5 air quality monitoring stations (placed in urban road and rural area) are available from 1 January 2003.

The case study comprises the future maintenance and development of Cascine Park (Figure 7). Considering the park's historic importance, operations on the Cascine must take into consideration its cultural heritage character and the legal bindings connected to them, leaving scarce room for modifying the present asset of plants. Therefore, the following alternatives are proposed: (a) refurbishment and restoration of the park; and (b) refurbishment and restoration of the park and planting of new trees along the city streets and on public places (and consequent effect on urban canopy layer and removal of areas for traffic and parking).

The case study will be mainly assessed with regard to its potential impacts on air quality and thermal comfort generated by an increase of the number of trees.

Figure 7. Firenze image mosaic and land use map

The BRIDGE databases (…continued)

B. Remote sensing and GIS data and maps of energy and water fluxes, pollution concentrations, land cover and vegetation, spatial and socio-economic development

The following satellite, airborne and GIS data are included:

- High resolution satellite data products
- Urban land cover/land use maps
- Urban vegetation data
- Urban vegetation as derived from the multispectral vegetation index NDVI
- Corine Land Cover 2000 database
- Land use classification maps from satellite data
- 3D maps of city (topography-3D surface characteristics)
- Airborne images (hyperspectral radiances, broadband radiances)
- Digital Elevation Model (DEM)
- Maps of surface albedo in the visible part of the spectrum by satellite data
- Land surface temperature by satellite data
- Maps of surface emissivity and albedo by modelling and satellite data
- Morphological characteristics
  - -Roughness length for momentum
  - -Zero plane displacement length
  - -Plan area index
  - -Frontal area index
  - -Sky view factors
- Anthropogenic heat flux
- Maps of sensible heat flux based on different modelling approaches
- Particulate profiles and Planetary Boundary Layer characteristics by LIDAR
- Concentration of pollutants (PM_{10}, CO_2, NO_X, SO_X, CO)

Gliwice case study

The BRIDGE databases (…continued)

B. Remote sensing and GIS data and maps

- Total emission predictions map (for each borough of London and emission sources)
- Emission of PM_{10} from traffic (emission from state, provincial, county and city roads)
- Maps representing extent of land use
- Population census data (density, distribution)
- Boundary data maps (administrative units: town, prefectures, municipal boroughs, districts)
- Building blocks (ex. Egaleo)

- Buildings and other structure (number of buildings per block, buildings by number of floors, buildings by construction period)
- Topography and Toponymy
- Digital topographic maps (roads/type, building type/height, green areas, etc)
- Road Network (ex. Firenze)

Gliwice is a satellite city with an Old Town in the central part and residential districts around the centre. Its area is 133,9 km2 and the total number of inhabitants amounted 191.232 in 2008 with decreasing tendency (100.149 woman and 91.083 man). The Gliwice Monitoring Station (part of the Silesian Air Monitoring Network) is located 1 km from the Academic District (Politechnika). An eddy covariance (EC) flux station was installed in Gliwice (50°16′45″ N, 18°39′20″ E) in December of 2009 on the flat roof of a 15 m high building close to the Gliwice Monitoring Station. The source area in easterly directions is dominated by urban area, while towards westerly directions rural areas prevail.

Although the Gliwice Town Development Plan (Figure 8) is currently under discussion, there is a number of areas that need more detailed planning (i.e. will be subject to local area planning). These areas include the Kopernika housing district and the Academic district. There is a necessity to create a fully equipped campus at the Academic District. The challenge is the limited geographical extent of the district and the need to optimise space and solutions, as well as the environmental loads to the carrying capacity of the area. The planning alternatives include: a) the construction of the trunk road which will influence communication and accessibility to the district; b) the construction of the sports hall, which will entail an additional load of people in the area; c) the construction of a centre for new technologies, a 7-storey building incorporating sustainable energy use (e.g. heat energy from solar collectors, energy recovery, etc.); and d) the development of all the aspects considered in scenarios a) to c).

The case study will be mainly assessed with regard to the environmental load in the area (particularly from the point of view of emissions and resource use) and the transport and economic implications to the city.

Figure 8. Gliwice plan of the Academic district.

London case study

London is an innovative city, with financial and globally oriented business services sectors and computing as important sources of employment. The 2008 European Cities Monitor ranked London as Europe's top city business location. Its' population is estimated at 7,56 million and its' total employment is about 4,7 million, mostly in the private sector and therefore rising and falling with the economic tide.

The case study area will be the Central Activity Zone (CAZ) (Figure 9). The CAZ covers the London central area, including the Central Business Area and the commercial centre, three major parks (Hyde Park, Regent's Park and Green Park) and some minor urban green areas. It has an overall area of approx. 3300 ha, covering 10 boroughs either entirely or partially with ca. 280.000 residential inhabitants. Physical Meteorology data at London are collected at two sites on the KCL Strand campus: KSK (King's Strand King's) and KSS (King's Strand). The main site is KSS which became operational 1 November 2009.

The policy objectives for the case study area identified were as follows:

- To reduce overheating (reduce the UHI effect)
- To increase urban greenspace
- To mitigate flash flooding
- To decentralize energy production: heating/cooling and power generation, and
- To improve air quality.

The assessment will mainly address air quality, thermal comfort and climate change (i.e. flooding) issues, within the context of greening the CAZ.

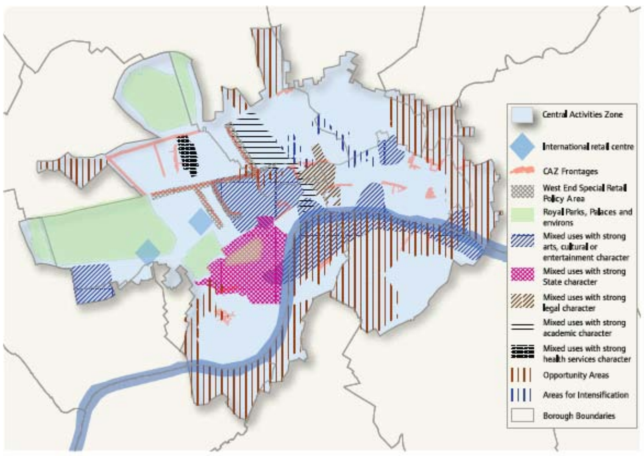


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Figure 9. Greater London Authority land use map

BRIDGE database (...continued)

B. Remote sensing and GIS data and maps

- Orographic element maps
- Hydrographical Maps
- Ecological Maps
- Infrastructure
- Social features per block (points of interests, healthcare, churches, educational and sport units, squares)
- Unemployment level
- Income level
- Average household size
- Education level
- Average price of old dwellings (flats)
- Migration figures
- Construction density
- Urban planning zones
- Car ownership
- Economic data per block (objective value zones)
- Number of flats heated by coal-fired boiler plant
- Number of flats heated by coal-burning furnace
- Networks of following facilities:
  - -waterworks
  - -sewage system
  - -central heating system
  - -gas pipelines
- Transportation facilities (bus stops, bus routes) (ex. Egaleo)

Communities of Practice in BRIDGE

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In the BRIDGE project, ten Community of Practice (CoP) meetings were organized in which end users could meet with researchers from BRIDGE. Each case study city (Athens, Firenze, Gliwice, Helsinki and London) hosted two of these meetings. We present a short overview of the results here.

The CoP reports show that a number of issues is shared in all five cities:

Sustainability priorities air quality, energy and water;

Transport, mobility, associated emissions and congestion.

Next to these shared issues, there also are areas of interest in which a selection of the cities has expressed interest such as green spaces and the services they offer, improving communication and cooperation within and outside governments, attractive land use, public health, urban heat and accommodation of economic growth.

Air pollution and public health

Main issue brought up by the participants is air pollution (NO_X, SO_X, CO, O_3, PM, Benzene) and its effects on human beings in the cities. Sources of harmful constituents of the air are mainly emissions by traffic, heating systems and industry. Every one of the five cities faces problems in the area of pollutants affecting public health. Every city has air pollution monitoring networks and plans to deal with this problem. While air pollution is perceived as a major issue in all cities, actions to reduce it have only been mentioned for London. The city of London has implemented several policies to improve air quality in the last few years. A congestion charge has been applied for the center of the city which reduced emissions, accidents, and traffic. A second effort is the London Low Emission Zone (since 2008) where goods and services vehicles have to comply with a low emission standard. However, air quality is still a problem in London and meeting the EU standards is difficult.

Thermal discomfort

The issue of thermal discomfort was raised in Athens, Firenze and London. Temperatures in urban areas are known to be higher on average and especially during the night than temperatures in their rural surroundings – the so called urban heat island (UHI) effect. Heat waves and hotter summer temperatures due to climate change make it an increasingly urgent problem. The main strategy to reduce thermal discomfort mentioned during the Cop's (Athens, Firenze, London) is to mitigate the UHI effect by using appropriate (surface) materials and to increase urban vegetation. Furthermore, increasing the energy efficiency of old buildings (Athens), reducing the likelihood of air conditioning by appropriate building types (London) and identifying vulnerable people in advance (London) were brought up as ways to reduce thermal discomfort impacts.

Energy efficiency and CO_2 reduction

Energy use and efficiency are perceived as key planning issues by all CoP's. A general decrease in energy use, improved efficiency and an increased use of renewable energy are mentioned throughout all cities as the main categories of solutions. According to the CoP reports, CO_2 reduction is also an objective in all cities. The influence of CO_2 as a greenhouse gas on global climate change and thus on the potential exposure of cities to more extreme temperature conditions seems to be the main driving force behind it. Even if national or regional guidelines for improving energy efficiency exist, they may not always be easily adopted as an example of Firenze shows: 90% of the old buildings are protected as a monument, so the regional guidelines are only applicable to new buildings.

Mobility and traffic

Congestions, emissions, accidents and climate change on one side; economic need and private interests on the other. Traffic and mobility are hot and difficult topics in urban planning. In general the problems and challenges that the BRIDGE case study cities seem to have today are more or less the same: Reducing private mobility and increasing public transport as well as non-motorized traffic use. The individual interest in private mobility can be an extremely difficult topic for urban planners. Traffic is on top of the list of environmental issues but can be politically too sensitive to be addressed. Emissions, accidents, congestions and a lack of coordination are making it a key priority, but on the other hand people react very emotional if e.g. parking space is being removed (Figure 1).

Figure 1. Traffic in Firenze

Urban green and open spaces

Green areas in a city play an important role as recreational spots for the population, they increase the amenity of a place, sequester dust and particulate matter and have a cooling effect. When they become an important issue in urban planning considerations, it seems to be mostly because of a lack of them, e.g. that urban growth has not been going along with an adequate growth of green areas or that green areas are unevenly distributed (Firenze). The reasons for lack of green spaces may be different for each city. In Athens it was mentioned that laws restrict the municipality from buying public spaces and turning them into green and that environmental degradation is taking place due to increased urbanization without proper planning. The vegetation coverage in London is already comparatively high (20%). An ambitious plan to increase it by 5% in 2030 and another 5% in 2050 exists but is said to be difficult to achieve (Figure 2).

Figure 2. Regents park in London.

Developing sustainability objectives and indicators in BRIDGE

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Introduction

BRIDGE entails the identification of sustainability objectives and indicators, which will be subsequently used for the assessment of planning alternatives in the DSS. These objectives and indicators have been developed in a participative manner, through a series of workshops undertaken in combination with the CoP meetings. These meetings have allowed identifying the key planning issues in the case study cities (refer to the section on Communities of Practice in BRIDGE for further information), as well as generic and case-specific objectives and indicators.

The outcomes of the meetings have been validated through a systematic approach. This entailed the revision of the objectives and indicators proposed at the first and second round of CoP meetings to obtain a final set, which was further discussed at the Umbrella CoP to reach a final consensus. The revision of CoP outcomes included comparison with existing sustainable development indicators at both European and national level, and validation with the measurements of WP3 and model outputs of WP4 (Figure 1). Therefore, indicators were included in the final set if they addressed the key sustainability objectives for the city, were within the scope of BRIDGE and were measurable/modellable within the project. Moreover, where an indicator was identified at the CoP but could not be provided by BRIDGE, it was still considered valid if included in any national/regional or European indicators list. Such indicators were also included in the final set as it was considered that indicator data/values were available and thus they could be potentially gathered and assessed through the DSS.

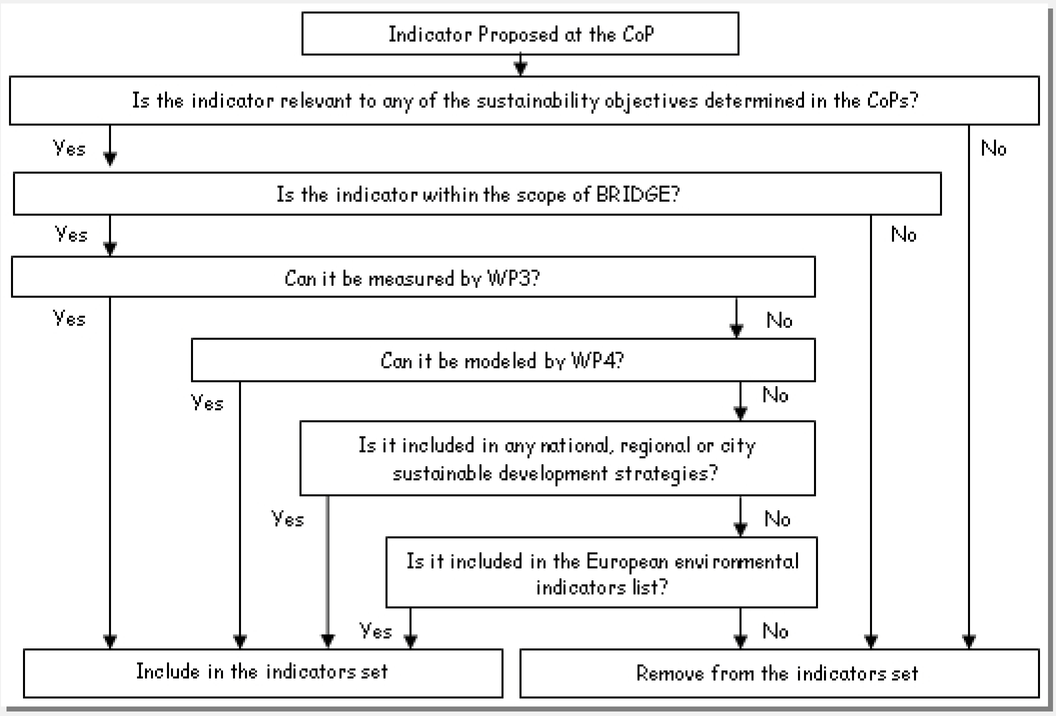

Figure 1. Indicator validation approach.

Proposed Objectives and Indicators

The planning issues discussed during the kick-off CoP meetings were generally connected to the international debate on urban sustainability issues, and are potentially common to a big range of cities. Consequently, the sustainability objectives could contribute to an international comparison of performances. These objectives commonly relate to indicators which are reflected also in international indicator sets used for cross-national assessments of urban sustainability making the performances in case study cities comparable among each other as well as among other European cities.

The indicators proposed at the first round of CoP meetings were reviewed to suit them to the specific assessment requirements of the relevant case study alternatives. Socio-economic and environmental indicators where separately discussed. The specific characteristics of the case studies largely shaped the revised set of sustainability objectives and indicators. In all cases, the proposed indicators targeted key considerations to be assessed and monitored in order to ascertain the success/failure of those planning interventions.

It is worth noting that the indicators defined in the second round of CoPs are only able to consider some of the generic and long term sustainability objectives defined at the city level in the previous round of CoPs, given the more limited range and scale of the spatial and sectoral plans proposed as case studies. Therefore, these indicators will not allow for comparability across case studies, as planning problems identified are not similar among the case studies, neither in scale nor in kind, and so also trends and values observed will vary between the single applications. Nevertheless, the indicators identified at this level may contribute to the building up of an operative indicator set for planning with urban metabolism, where record is kept on type of measurements used, composition of data in case of composite indicators, data availability etc.

The objectives and indicators identified in each city were discussed at the Umbrella CoP meeting, and an agreement on common objectives and indicators was reached among participants. These environmental and socio-economic indicators are currently being validated and operationalised (in terms of their wording and units). The final set will be incorporated as default options into the DSS for the assessment of planning interventions.

OBJECTIVES	**INDICATORS**
ENVIRONMENTAL	
Critical Aspects	
Improve Air Quality	• Concentration of pollutants (PM, O_3, NO_X) • GHG and CO_2 emissions • Number of days above established thresholds
Improve Energy Efficiency	• Energy demand (kw per hour per m^2) • Potential for renewable energy • Additional heat generated • % of energy created (renewables)
Anticipate CC (Flooding)	• Flooding zones (m^2) & hot spots
Optimize Water Use & Mgmt	• Surface runoff evapotransporation and filtration • Water consumption per capita
Secondary Aspects	
Thermal comfort	• Ambient & surface air temperature (°C) • Number of days above established thresholds
Optimize Materials Used	• Volume of material re-use
Increase Green Space Areas	• Density of green areas (m^2 per habitant) • Canopy/green surface or area newly created • Accessibility to green areas
SOCIO-ECONOMIC	
Critical Aspects	
Urban land use	• New urbanized areas (land use changes) • Number of brownfields re-used • Density of development
Ensure Economic Viability	• Cost of intervention • Effects on local economy
Improve Mobility & accessibility	• Quality of pedestrian sideways • Length of cycleways provided • Length of new roads provided • Use of public transport • Number of persons close to public transport
Secondary Aspects	
Promote Social Inclusion	• Access to housing and services
Maintain Public Health/Safety Enhance Human Well-being	• Number of persons affected by flash flooding • Number of persons affected by heat waves & air pollution

Project meetings

Important technical meetings concerning the tasks of WPs 4 and 5 took place on 5 November 2009 and on 20 and 24 November 2009 (all Internet meetings), respectively, although the communication between the project participants is almost daily via email, via Skype or via the ftp web based server.

The 2nd Progress Meeting was held 2009 in Firenze, Italy on 2-3 December. During this meeting the progress of the project so far was presented and decisions were made on the project's evolution. The 6th Management board (MB) and the 3rd Steering Committee (SC) held a session also. During this period the 1st Advisory Committee (AC) Meeting and WPs 3-4-6 Technical Meetings were organized. There was also a Joint meeting of the Steering Committee and the Advisory Committee.

The 2nd round of CoP meetings has been finished in all case studies cities (Firenze on 3 December 2009, Helsinki on 20 January 2010, Gliwice on 28 January 2010, Athens on 18 February 2010 and London on 10 March 2010). Planning objectives, criteria and indicators, including socio-economic criteria, have been defined for each of these case studies. The definition of objectives and criteria has been achieved applying a participatory approach during the meetings with local participants of the CoP. Therefore, the sustainable urban planning objectives and correlating environmental and socio–economic indicators were clearly defined. The set of indicators has been contrasted with the existing European indicators and any relevant national legislation and sustainability initiatives.

The 7th and 8th MB meetings were held on 26 February 2010 and 20 April 2010, respectively, via Skype. The Umbrella CoP meeting took place in Athens on 5 May 2010, where the beta version of the BRIDGE DSS was demonstrated and tested and the final set of sustainability objectives and indicators has also been decided. During the 3rd Progress meeting, which was held in Athens on 6-7 May 2010, the future action list of the project was decided. The 9th MB and the 2nd AC Meetings were also organized, as well as the 2nd Joint SC and AC meeting.

Current status and upcoming events

The data collection and analysis has started on March 2009 and is carried out successfully. A list of measurements referring to the different case studies has been developed and measurement protocols for each of the five cities have been produced. Remote sensing measurements have started in case studies cities, as well as collection of socio-economic data. Therefore, the BRIDGE DSS database has already been developed and it is be updated frequently to include any available data.

The model selection has been completed. The specification of different modeling systems, their requirements and main definitions have been examined. The model capabilities and their relation to the project have been documented.

Available data so far have been fed to selected models and some model simulations have already started. In addition, the on-line models have been formed in a way adaptable to the DSS. Three on-line models (URBAIR, LUMPS and SURFEX) have been integrated in a DSS beta-version. This version comprises the keystone for the future development of the BRIDGE

DSS. After the analysis of the user requirements, the specifications for the DSS design were set and the conceptual design and technical design of the DSS architecture are defined and documented.

More specifically, the technologies to be adopted, taking into account the above specifications, were selected and also the specifications of the models to be integrated. All the above led to the conceptual design of the DSS architecture, taking also into account the adopted decision making methodology. The technical design was also clarified, defining the data storage and flow modules, the communication interfaces, the calculation modules, the visualization modules and the Graphical User Interface.

The urban planning priorities, objectives and indicators for each city were addressed during the CoPs to form the basis of the decision-making procedure to be implemented. A methodological framework for the assessment of the planning alternatives has been defined and consists of a series of techniques for weighting (i.e. prioritizing) and scoring indicators according to their performance with respect to the priorities and planning objectives defined in the local case study. The framework is currently being implemented and the DSS beta-version was demonstrated and tested at the Umbrella CoP meeting on 5 May 2010. The final set of sustainability objectives and indicators has also been decided at the Umbrella CoP.

The most important upcoming event is the Mid-term Review meeting to be held in Brussels on June 15, 2010.

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Deliverables

1. Project Management Plan, D.1.1 (delivered).
2. 1st Quarterly Progress Report, D.1.2.1 (delivered).
3. 2nd Quarterly Progress Report, D.1.2.2 (delivered).
4. 3rd Quarterly Progress Report, D.1.2.3 (delivered).
5. 4th Quarterly Progress Report, D.1.2.4 (delivered).
6. 5th Quarterly Progress Report, D.1.2.5 (delivered).
7. Dissemination and Use Plan, D.9.1 (delivered).
8. BRIDGE Web-Site, D.9.2 (operational).
9. Inventory of current state of empirical and modelling knowledge of energy, water and carbon sinks, sources and fluxes, D.2.1 (delivered).
10. Protocol to assess differences between knowledge supply and knowledge needs in the field, D.2.2 (delivered).
11. Protocol to Develop Communities of Practice in the Context of the BRIDGE Project, D.2.3 (delivered).
12. Datasets of air quality, energy, water, carbon and pollutants fluxes/concentrations, D.3.1.1 (delivered).
13. GIS data and maps of energy and water fluxes, pollution concentrations, land cover and vegetation, D.3.2.1 (delivered).

Deliverables (...continued)

14. GIS data and maps on spatial, socio-economic development and impact indicators, D.3.3.1 (delivered).

15. Model Selection Report, D.4.1 (delivered).

16. DSS Design Report, D.6.1 (delivered).

17. BRIDGE Published Material, D.9.3.i (see Publications section).

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URBAIR – an online air quality model for a decision support system on urban metabolism

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1 Introduction

In the last decades the study of the urban structure impacts on the quality of life and on the environment became a key issue for urban sustainability. Several studies recognise the importance of urban planning for the improvement of the interactions between different land uses and economic activities, and also towards a more sustainable urban metabolism [1]. Urban structure (sprawl or compact) is intimately related with urban fluxes (incoming and outgoing) of material, energy, information, people, etc. A major interest relies on understanding the role of planning on induced mobility patterns and thereafter on air quality, particularly related with the increasing use of private cars.

In this context, the current challenge to urban planners and environmental engineers is to reverse the impacts on environment and human health resulting from the problematic cohabitation between intense road traffic and high population densities, as a way to promote a better quality of life to urban populations. At the same time, the rapid and continuous growth of hardware capabilities opens a vast number of new possibilities to air quality models, especially through the development of online tools, to be implemented in new Decision Support Systems (DSS).

In the core of the BRIDGE Project DSS development, the need to include an online air quality model capable to simulate the dispersion of road traffic pollutants in the atmosphere at urban scales leads to a new challenge for the UAVR team. Although Computational Fluid Dynamic (CFD) models (e.g. VADIS model) applications within urban environments were foreseen, the simulation of three-dimensional (3D) flow and dispersion fields represents an extremely demanding task due to the highly complex geometries and numerical approach, resulting in a high time consuming task that needs big computational capacity. These motives exclude the use of CFD models to work as an online tool. As a result the Urban Air Quality model (URBAIR) was developed to bridge this gap.

This work presents the main features of URBAIR model "beta" version and its application to a specific study case, in order to evaluate its capabilities for urban planning decision process, namely to assess the impact of different road traffic mobility patterns.

2 URBAIR model description

Taking into account the generalized application of Gaussian dispersion models to local and urban scale air pollution phenomena prediction, the URBAIR (Urban Air Quality) model was developed to be implemented in the BRIDGE Project DSS as an online air quality model. The URBAIR model has been developed from the POLARIS, a Gaussian model previously developed by the UAVR team [2]. This model is significantly different from traditional Gaussian dispersion models, because its dispersion parameters have a continuous variation with the atmospheric stability. The model is suitable to be used for distances up to about 10 km from the source. The model is a steady state atmospheric dispersion model, based on boundary layer scaling parameters, such as the Monin–Obukhov Length instead of relying on Pasquill-Guifford stability classification. A pre-processor calculates the meteorological parameters needed by the dispersion model, such as atmospheric turbulence characteristics, mixing heights, friction velocity, Monin-Obukov Length and surface heat flux.

To characterize the meteorological conditions within the simulation domain, the model requires meteorological information driven by surface measurements and upper air soundings databases or, optionally, data from on-site instrument towers. Instead vertical meteorological profiles can be obtained from mesoscale meteorological models.

URBAIR requires also the characterization of topography, land-use, buildings and the emissions of anthropogenic sources, which can be provided by inventories. Traffic emissions can be estimated by the Transport Emission Model for Line Sources (TREM) [3], using vehicles counting data. Emission and meteorology information is defined on an hourly or daily basis.

Regarding the type of most road traffic related air pollutants the model enables the simulation of passive or buoyant gas dispersion and deposition at local and urban scales. It was also designed to allow consideration of dispersion in rural or urban areas, including the treatment of building effects.

The output data includes the meteorological parameters and pollutant concentration at user-specified receptor points or spatially distributed over a regular grid. Different mean averaged concentration values can be defined, depending on the purposes.

3 Model application to a selected case-study

The case study selected is located at the centre of a medium sized town in Central Portugal, Viseu.

3.1 General description

Located in the interior of Portugal, Viseu is a city with approximately 93.000 inhabitants and an area of 507 km^2 [4]. Viseu is an important industrial and commercial area and a strategic point for international trade, benefiting from several road transport networks. Presently, there are no indications of critical air quality problems in Viseu, however according to the SAUDAR Project findings, future development scenarios point to an air quality degradation due to the increase of population, the use of energy and the consequent increase of emissions [1][2]. In order to test URBAIR model output and type of information provided, a case study domain was defined for the city centre (as shown in Figure 1).

Figure 1 presents the location of the Viseu city and an aerial photograph of the study area, providing a detailed image of the urban built-up area. The main roads within the domain, distinguished by the yellow colour, are identified by the respective names.

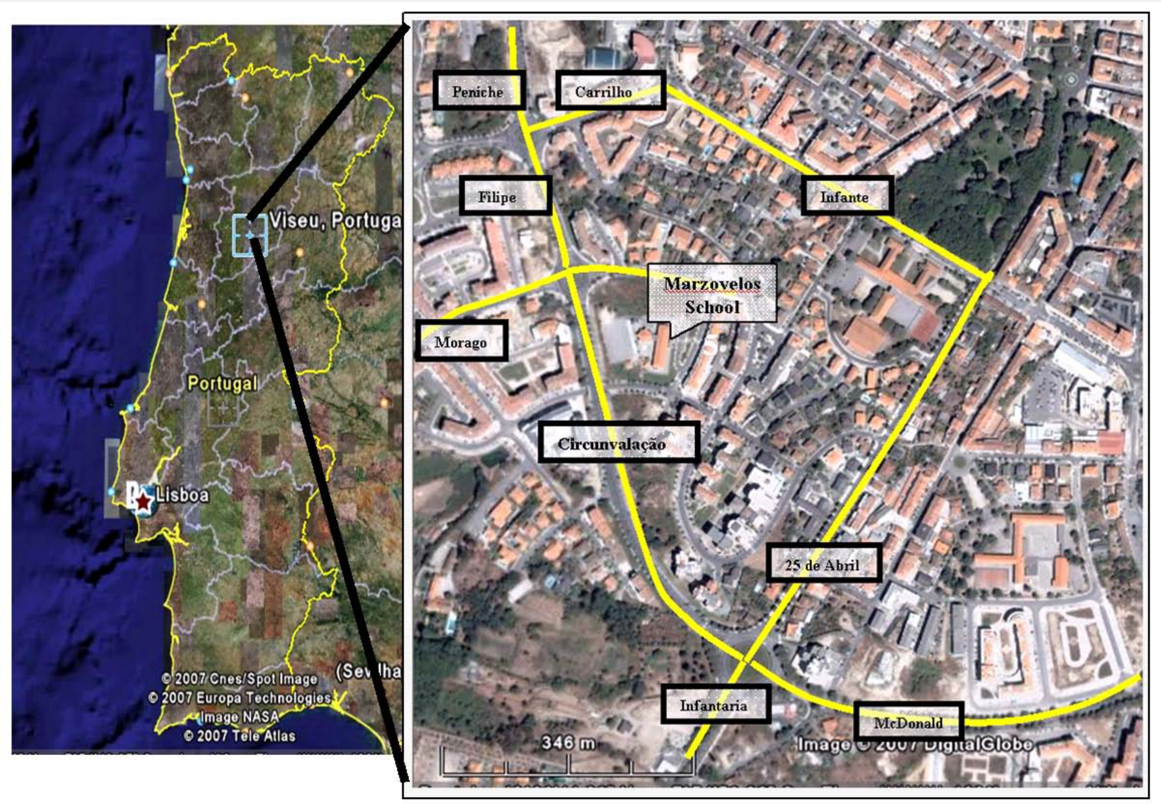


Figure 1. Location of the study area: (a) within Portugal and (b) within the urban area of Viseu.

3.2 Computational domain

The URBAIR computational domain, with approximately 1500×1500 m^2, with a resolution of 100 m, was defined at the centre of Viseu, in an area with residential, educational and commercial characteristics. It is centred at the Marzovelos school that is placed near the Circunvalação Avenue. This is one of the most important thoroughfares of the town, a ring that makes the connection between regional/national network and the city centre. The urban built-up area of the study domain was represented by 142 buildings with different configurations ranging from 9 to 27 m height. Figure 2 presents a 3D view of the buildings volumetry introduced in the model.

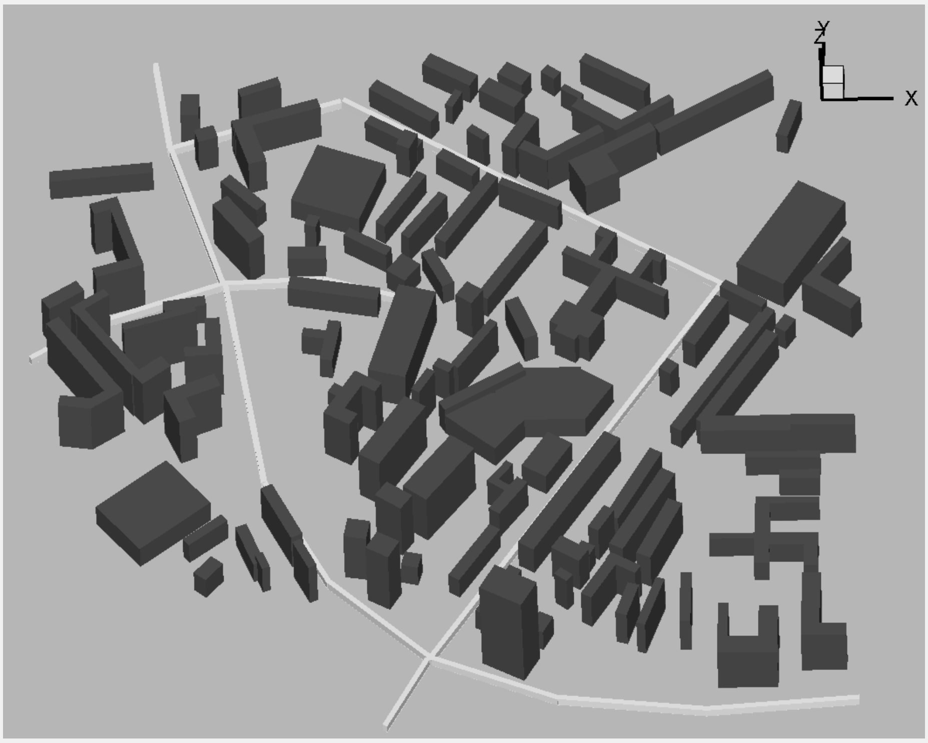
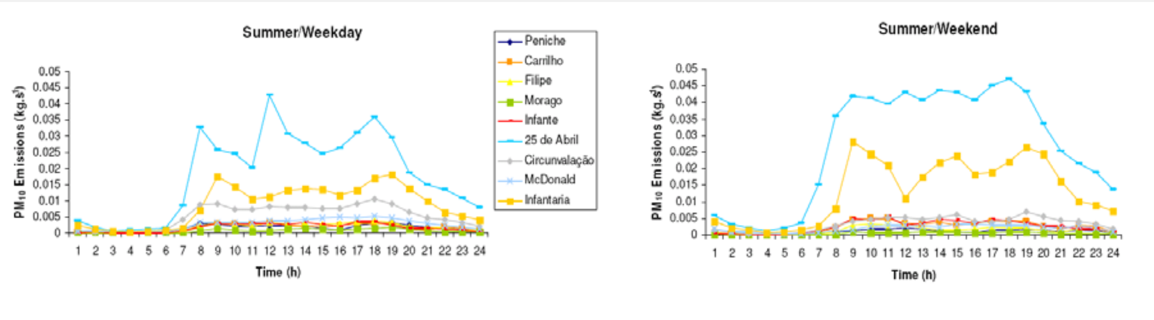


Figure 2. 3D representation of buildings in the study area.

3.3 Traffic emissions

Traffic is considered the main pollutant source of the study area. In this sense, the location of the nine main roads of the domain was introduced in the model according to Figure 2. Traffic emissions of PM_{10} were estimated with TREM model for the nine main roads and for both, winter and summer periods, using traffic counting data from the SAUDAR experimental campaigns [6]. To exemplify the range of traffic emissions used in URBAIR, Figure 3 presents hourly PM_{10} emissions during a typical summer week and weekend day.

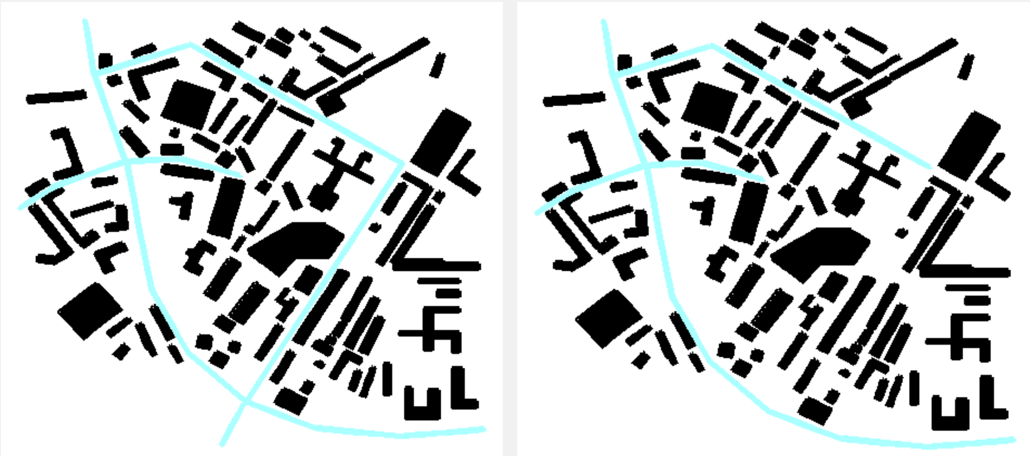


(a)

Figure 3. Hourly PM_{10} emissions during a typical summer weekday and weekend for the roads considered in the domain.

3.4 Reference and intervention scenarios

In order to evaluate the impact of road traffic emissions in the study domain and the utility of the model to evaluate traffic planning alternatives two simulation scenarios were tested. The reference scenario considers all nine main roads identified in the study domain (see Figure 1). The intervention scenario considers 8 of the 9 roads, i.e., all the roads with the exception of the 25 de Abril Avenue were considered (see Figure 4).



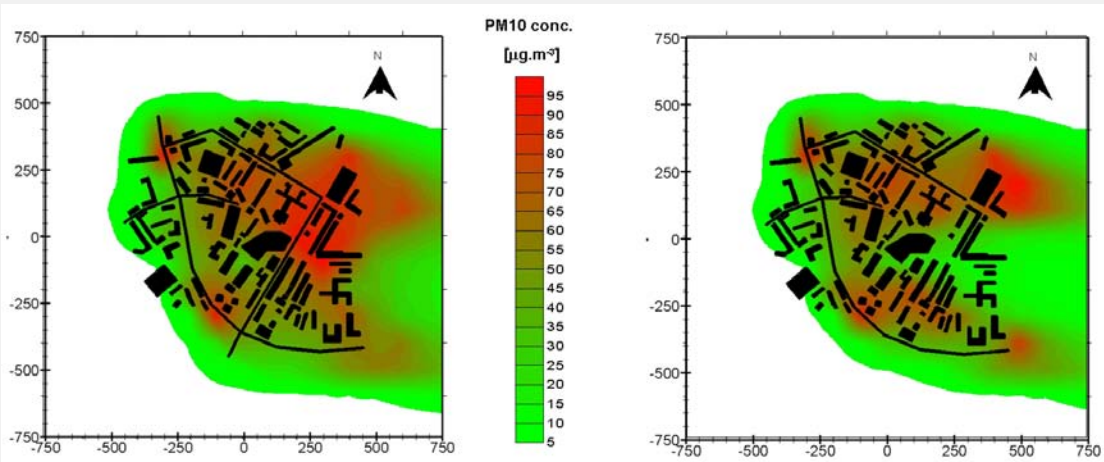
(a) (b)

Figure 4. Simulation scenarios: (a) reference scenario and (b) intervention scenario.

Road Traffic emissions were kept identical for the simulation scenarios. Typical summer week and weekdays were simulated based on SAUDAR Project monitored data. Moreover, meteorological conditions were also kept the same.

4 Modelling results

As mentioned before, URBAIR output mean concentration values time periods are defined by the user. In the present example application, hourly PM_{10} averaged concentrations were estimated and represented. To analyze URBAIR outputs, averaged concentration data may be plot graphically or in concentration fields. As an example, Figure 5 shows the horizontal PM_{10} concentration fields, for a height of 1.5 m (the typical value for exposure studies) at 4 p.m. for a typical summer weekday, corresponding to both scenarios.



(a) (b)

Figure 5. Comparison of 1.5 m high horizontal PM_{10} concentration fields at 4 p.m. for: (a) reference and (b) intervention scenarios, with a NW wind direction.

From the differences between results observed in Figure 5 is possible to conclude that the 25 de Abril Avenue has an important contribution to local air quality degradation. A more detailed analysis could be made by the evaluation of concentrations at specific points, comparing long term simulation results with air quality regulation or even estimating population exposure to air pollutants.

Regarding the main purposes to implement the URBAR in the BRIDGE Project DSS, a preliminary test concerning time duration of simulations was performed. Different mesh resolutions and simulation periods were tested. A preliminary test showed that URBAIR can be run for most cases in less than a minute. Concerning the example, corresponding to a domain with 1500x1500 m^2, a 100m mesh resolution (i.e. 225 grid cells) and hourly concentration values for two days, a running time of approximately 45 seconds was observed. However, it must be stated that the running times increase when mesh resolution is also increased or when simulation time period increases.

5 Final remarks

The URBAIR simulations have shown that, mobility patterns and urban traffic planning alternatives may influence local air quality. Distinct levels of the air pollutants inside the study domain were found for the different scenarios due to the prevailing wind direction. Nowadays air quality models allow a better understanding on road traffic and urban planning impacts from the point of view of a better quality of life in urban environments.

Overall, the exercise describes URBAIR model by showing a typical application to an urban area, in order to evaluate the impact of road traffic on local air quality.

Moreover, the URBAIR enables fast simulation, showing the possibility to be implemented in the BRIDGE DSS as an online air quality model, keeping in mind a fit for purpose commitment (domain dimensions, mesh resolution and period of simulation).

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