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THEME 6: Environment (including climate change)

Contract for: **Collaborative Project**

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Report on the Impact Assessment Model for Urban Metabolism

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Table of Contents

1. Introduction

1.1 Purpose of the document

This document is Deliverable 5.2 – *Report on the Impact Assessment Model for Urban Metabolism*, produced from Tasks 5.1 to 5.3 on the development of impact assessment methods and monitoring systems, and Task 5.5 on the integration of the impact assessment methodology into the DSS. The **aim of this document** is to present the impact assessment methodology, which is based on the indicators defined in Deliverable 5.3 (Breil *et al*., 2010) supported by the findings of the socio-economic and environmental workshops presented in Deliverable 5.1 (González *et al*., 2010), and to describe the monitoring systems that are suggested to be implemented in the case study cities.

1.2 Acronyms

AHP	Analytic Hierarchy Process
BRIDGE	sustainaBle uRban plannIng Decision support accountinG for urban mEtabolism
CoP	Community of Practice
DPSIR	Driver-Pressure-State-Impact-Response
DSS	Decision Support System
EC	European Community
EIA	Environmental Impact Assessment
EU	European Union
GIS	Geographical Information Systems
ICT	Information and Communication
MCA	Multi-Criteria Assessment
MCDM	Multi-Criteria Decision Making
SA	Sustainability Appraisal
SEA	Strategic Environmental Assessment
UK	United Kingdom
WP	Work Package

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1.4 Project overview

Urban metabolism considers a city as a system and distinguishes between energy and material flows. “Metabolic” studies are usually top-down approaches that assess the inputs and outputs of materials, water, energy, etc. from a city, or that compare the metabolic process of several cities. In contrast, bottom-up approaches are based on quantitative estimates of urban metabolism components at local scale, considering the urban metabolism as the 3D exchange and transformation of energy and matter between a city and its environment. Recent advances in biophysical sciences have led to new methods to estimate energy, water, carbon and pollutant fluxes. However, there is poor communication of new knowledge to end-users, such as planners, architects and engineers.

BRIDGE aims to illustrate the advantages of considering environmental issues in urban planning, with particular focus on specific metabolism components (energy, water, carbon, pollutants). BRIDGE’s main goal is to develop a Decision Support System (DSS) which has the potential to propose modifications to the metabolism of urban systems towards sustainability.

BRIDGE is a joint effort of 14 Organizations from 11 EU countries. Helsinki, Athens, London, Firenze and Gliwice have been selected as case study cities. The project uses a “Community of Practice” (CoP) approach, where local stakeholders and BRIDGE scientists meet on a regular basis to learn from each other. The end-users are therefore involved in the project from the start. These meetings are used to discuss and define the key sustainability issues for each city. These provide the basis to determine the sustainability objectives and associated indicators, as well as their relative importance, which would help assess planning alternatives with the overall goal of promoting sustainable development.

The BRIDGE project 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. A Multi-Criteria Decision Making (MCDM) approach has been adopted in the BRIDGE DSS. To cope with the complexity of urban metabolism issues, the indicators measure the intensity of the interactions among the different elements in the system and its environment. The objectives are related to the fluxes of energy, water, carbon and pollutants in the case studies. The evaluation of the performance of each alternative is done in accordance with the developed scales for each criterion to measure the performance of individual alternatives.

The energy and water fluxes are measured and modelled at a local scale. The fluxes of carbon and pollutants are modelled and their spatio-temporal distributions are estimated. These fluxes are simulated in a 3D context and also dynamically by using state-of-the-art numerical models, which normally simulate the complexity of the urban dynamical process exploiting the power and capabilities of modern computer platforms. The output of these models leads to indicators which define the state of the urban environment.

Several studies have addressed urban metabolism issues, but few have integrated the development of numerical tools and methodologies for the analysis of fluxes between a city and its environment with its validation and application in terms of future development alternatives, based on environmental and socio-economic indicators for baseline and proposed situations. The innovation of BRIDGE lies in the development of a DSS integrating the bio-physical observations with socio-economic issues. It allows end-users to evaluate several urban planning alternatives based on their initial identification of sustainability objectives. In this way, sustainable planning strategies will be promoted, based on quantitative evidence in relation to energy, water, carbon and pollutant fluxes.

1.5 Setting the Context

The sustainability objectives and indicators defined through the various CoP workshops and agreed at the Umbrella CoP (Appendix A and Deliverable 5.1), and subsequently validated to fit them to the scope and requirements of the project (Appendix B and Deliverable 5.3), form the basis for the assessment of proposed planning alternatives in the case studies. Key principles of contemporary impact assessment methodologies, such Environmental Impact Assessment (EIA) and Strategic Environmental Assessment (SEA), are consequently applied to assess planning interventions and determine which is the best alternative (i.e. the one causing the least impact or having less effect on the relevant urban metabolism components). This is achieved by means of indicators, examining the increase/decrease on indicator values and, subsequently, establishing the sustainability of a planning alternative based on performance of one or several indicators (e.g. a decrease on air quality indicator values suggests a decrease on sustainability of the planning alternatives being assessed).

The impact assessment methodology is largely shaped by the framework of the DSS, which defines the user-choices and information management. As the DSS is based on GIS, the impact assessment methodology has a strong spatial component, combining multiple spatial datasets in a systematic manner to obtain geographically illustrated assessment results and, thus, use more concise evidence to inform planners and decision-makers.

The main objective of the impact assessment methodology is to integrate information on physical flows of energy and material with social and economic changes and policy priorities. Environmental and socio-economic indicators represent the interface between the sustainability objectives set by the DSS end-user and the underlying spatial data and numerical models, and thereby used to assess planning alternatives. Consequently, the final set of indicators (Appendix B and Deliverable 5.3) is used to assist decision-making for the optimisation of the use of natural resources in the urban environment through the use of the DSS.

2. Methodological Framework

2.1 Introduction

Land use planning can be defined as the spatial disposition of land, resources and services to allow for sustainable, efficient, safe and economically viable development in rural and urban settings. Sustainable urban planning in particular entails consideration of a number of aspects including: socio-economic characteristics; planning approaches to development patterns and infrastructure; and, most importantly for the BRIDGE project, existing and future environmental challenges. The effective integration of these considerations helps protect and improve urban environments, through the appropriate provision and management of natural resources.

Environmental assessment procedures, such as SEA or EIA, promote sustainable development by enabling the identification and mitigation of negative impacts arising from the implementation of urban development plans or specific projects. Directive 2001/42/EC (CEC, 2001), also known as the SEA Directive, sets out the requirements for the environmental assessment of plans (e.g. land use, transport) and programmes (e.g. waste management) that are likely to have significant environmental effects. In a similar way to SEA but including the assessment of social and economic factors, Sustainability Appraisal (SA) is used by UK planning authorities to assess whether proposed plans and policies meet sustainable development objectives (UKP, 2004). At a lower planning level, Directive 97/11/EC (CEC, 1997), amending 85/337/EEC (CEC, 1985) – also known as the EIA Directive, applies to the assessment of the effects of certain private and public, small or large scale projects (e.g. roads, housing states) on the environment.

Addressing the legislative requirements of both Directives has significantly shaped planning processes; which, as a result, need to evaluate the sustainability and environmental viability of proposed planning interventions. In addition, they are required to monitor implementation to ensure that any potential negative impacts are identified on a timely manner, and subsequently avoided, mitigated or remediated. Environmental assessment processes are facilitated by the development of socio-economic and environmental indicators against which planning interventions can be assessed. Such indicators are also utilised to monitor progress towards established sustainability objectives or to evaluate changes in officially set environmental quality targets/thresholds.

Given that land use plans are intrinsically spatial (i.e. commonly link land use to location), spatial evidence and spatial approaches can significantly benefit plan-making. Spatial tools such as Geographic Information Systems (GIS) can support the integration of socio-economic and environmental considerations by providing evidence through the spatial assessment of relevant datasets. GIS have the capability to integrate and simultaneously analyse multiple datasets, and help to address cumulative and large-scale effects. They can also present relevant socio-economic, environmental and planning considerations in a geographic and visual form and, thus, convey information in a more efficient manner, raising awareness on the spatial implications of a planning intervention. Moreover, they can be combined with external modelling tools to predict likely future socio-economic and/or environmental conditions, based on the characteristics of the planning alternatives.

The BRIDGE project aims at developing a robust DSS that avails of GIS to integrate multiple socio-economic and environmental spatial datasets and combine them with the spatial results of modelling operations. The methodology is based on Multi-Criteria Assessment (MCA) techniques, whereby each spatial dataset is weighted according to end-user or public values, prioritising parameters (i.e. criteria and/or indicators) according to planning or policy priorities for a given urban context and, thus, ensuring a transparent and participative approach to the sustainability assessment of urban planning alternatives.

2.2 Methodological Premises

The methodological framework for the assessment of the planning interventions in each of the case study cities has the overall goal of increasing the sustainability of the urban metabolism in the BRIDGE case studies. The final scope of the assessment methodology is to assist CoP members (or future DSS end-users) to better explore the decisions at hand; and to analyse the trade-offs between the competing criteria (i.e. the degrees to which the planning alternatives meet the predefined sustainability objectives, based on the defined sustainability indicators).

The methodological components include: environmental assessment principles, MCA techniques and GIS, all of which are combined into the BRIDGE DSS. The methodology has its foundations on the following premises:

- The methodology is based on impact assessment approaches, where the feasibility of the alternatives will be evaluated against their environmental and socio-economic impacts (i.e. sustainability of the proposal), illustrated by changes in the relevant sustainability indicators.
- The methodology is based on MCA techniques, combining multiple spatial and non-spatial, quantitative and qualitative considerations into a single assessment.
- The methodology is flexible enough to be applicable in the different socio-economic contexts of the case studies and to address the different nature of the planning interventions suggested by the CoPs.
- The methodology combines all available spatial and non-spatial quantitative information, including that produced by the models available within BRIDGE.
- Where necessary and feasible, it also incorporates additional considerations suggested by CoP (which cannot be modelled but for which data may become available). These criteria may rely on quantitative information from third parties (e.g. costs of planning interventions) or qualitative judgements of experts (e.g. order of magnitude of achieved improvements on human well-being).
- The methodology is able to combine quantitative information (e.g. indicator values) with stakeholders' opinion (i.e. qualitative judgements on the significance or importance of the different sustainability objectives and indicators specified by the CoP and based on the planning priorities for the city).
- The methodology considers costs of measures and other economic indicators without the need to translate all other criteria (e.g. environmental performance and social aspects) into monetary terms.
- To facilitate the assessment and enable comparison, all sustainability indicators are normalised according to their performance.
- The methodology takes into account the uncertainty in the model outcomes and the elicited end-users' trade-off judgements.
- The assessment approach allows the end-user to review the performance/outcomes of each planning interventions in form of a spider diagram (where the trade-off between the criteria are clearly depicted),

and, if the end-user wishes, to aggregate the various outcomes into a partial ranking (where each planning alternative is given a relative score or index allowing performance between alternatives to be compared).

- The methodology provides an assessment of alternatives for a given moment in time.
- The methodology is implementable in the DSS and applicable in the BRIDGE case studies within a given timeframe and human resources and constrains.
- A user-manual is included to guide the user through the assessment process, informing them about the need to define a-priori the decision problem and criteria, assist them in understanding the required inputs, address double-counting, and draw attention to accuracy and currency considerations when interpreting results.

2.3 Environmental Assessment and Sustainability

SEA is a “systematic process of predicting and evaluating the likely environmental effects of implementing a proposed policy, plan or programme in order to ensure that these effects are appropriately addressed at the earliest appropriate stage of decision-making on a par with economic and social considerations” (Sadler and Verheem, 1996, p. 27). SEA is considered as a standardized sequence of activities with the key purpose of informing and substantiating a final decision, with similar procedures to those of EIA (Therivel *et al.*, 1992; Scott and Marsden, 2003; Stoeglehner, 2004).

SEA generally covers wider geographic areas and a larger amount of potential impacts than those of EIA, and the level of detail required for assessment is less than that for project-level. The higher planning hierarchy, the larger geographic extent and the larger time periods of plans/programmes, provide SEA with a better opportunity, than project-level impact assessment, to address large-scale and cumulative effects (Dalal-Clayton and Sadler, 2002; Therivel and Ross, 2007; González, 2010). Although there are significant differences between both assessment methods in terms of scope and purpose (Table 1), some valuable principles and concepts from project-based EIA are equally relevant to SEA. These include the consideration of alternatives, means to ameliorate adverse impacts, involvement of a range of disciplines in the assessment process and maximum stakeholder participation. In essence, both EIA and SEA share the common aim to minimise the potential environmental impacts of a proposed action.

	SEA	**EIA**
Objectives	Broad policies, actions	Local single project
Spatial Context	Extensive geographic zoning	Spatially-specific development/s
Data	Qualitative and quantitative	Mainly quantitative
Methods	Simple	Complex
Alternatives	Many strategic, few operational	Few strategic, many operational
Mitigation	Broad policy alternatives	Practical site-specific solutions
Outputs	Broad, generic	Detailed

Table 1. Key differences between SEA and EIA.

SEA is considered to be a strategic decision-making instrument, which must ensure that principles of environmental assessment are systematically integrated in the formulation of plans and programmes through the identification of objectives and alternative options for development, within a sustainability context (Therivel *et al*., 1992; Therivel and Partidário, 1996; Partidário, 1999). It has been noted that the rationale for SEA is linked to strengthening project EIA and integrating environmental considerations at higher planning levels, with special focus on cumulative and large-scale effects (Jacobs and Sadler, 1990; Lee and Walsh, 1992; Sadler and Verheem, 1996). These objectives have the potential to render a number of significant benefits to the field of environmental assessment (Table 2).

Objectives	Benefits
Environmental Protection and Sustainable Development	• Providing a systematic review of relevant environmental issues; • Providing the opportunity to consider a wider range of alternatives and options; • Improving and refining the basic strategic concepts of the PP; • Achieving a clearer understanding of the potential cumulative, synergistic and large-scale environmental effects; • Creating a better balance between environmental, social and economic factors; and • Enhancing the PPs' contribution to the overall goals of environmental sustainability and a high level of environmental protection.
Strengthen and Streamline EIA	• Allowing a tiered approach to decision-making; • Clarifying the strategic context and scope of future projects; • Anticipating the scope of potential impacts and information needs at project-level; • Addressing development options (i.e. types and locations) while they are still open; • Simplifying the process of environmental investigations at project-level; and • Reducing the time and effort necessary to conduct individual reviews.
Integration of Environmental Considerations into Decision-Making	• Promoting environmentally sound and sustainable proposals; • Providing guidance on the development of mitigation measures; • Helping to define environmental targets for monitoring purposes; • Enhancing the transparency of the plan-making process; • Winning public support for preferred options or strategies; • Facilitating informed decision-making; and • Changing the way decisions are made.

Table 2. Main benefits derived from SEA (adapted from: CEC, 1996; Fischer, 2003; Partidário, 2003; Therivel, 2004; Partidário, 2005; UNECE, 2007).

Although SEA has a stronger environmental focus, it is closely linked to SA in the UK, a requirement under the Planning and Compulsory Purchase Act 2004 for Local Development Documents and under the Planning Act 2008 for national Policy Statements. Although no other EU country has specifically implemented SA, it is widely acknowledged that environmental assessment processes, SEA in particular, can promote sustainable development by achieving a better integration of environmental, social and economic aspects, and by enhancing transparency and accountability of the decision-making process.

In the context of BRIGE, environmental assessment principles (namely consideration and assessment of alternatives, mitigation of impacts on the urban metabolism and stakeholder involvement) are at the core of the impact assessment methodology. The scale of application of the DSS enables: a) assessment of specific planning interventions at the local level (e.g. alternative layouts for a new residential area) through detailed modelling; and b) evaluation of strategic future urban development scenarios (e.g. flood risk associated to climate change) through simulations. In this context, both EIA and SEA methods are applicable. Local level assessments will resemble EIA-type procedures where high scale and detailed datasets will be utilised when assessing the sustainability of the planning alternatives defined by the end-user. In contrast, climate, energy and economic scenarios will be developed and simulated within the project to facilitate SEA-type decision-making frameworks. In both cases, alternatives/scenarios will be subject to a systematic assessment of impacts, based on sustainability indicators previously defined by stakeholders through participatory approaches (e.g. CoP). Increasing/decreasing trends of indicators will show improving/decaying environmental and socio-economic conditions, informing end-users about urban metabolism changes associated with each of the considered planning alternatives, which will enable them to select the most sustainable option and, where necessary, identify remedial action to mitigate any potential impacts.

2.4 Applying Multi-Criteria Assessment Techniques

Due to the complexity of an assessment where environmental, social and economic aspects need to be evaluated on a participative, integrated and systematic manner, an MCA technique has been adopted as part of the impact assessment methodology in BRIDGE. MCA is commonly used in the assessment of environmental policies (e.g. Hämäläinen and Alaja 2003; Wallenius *et al.* 2008). It constitutes both a framework for structuring decision problems which encompass multiple decision criteria and alternatives, and a set of methods to generate/elicit and aggregate preferences regarding the performance of these alternatives. Consequently, MCA benefits the decision process by helping the decision-maker learn about the decision problem and explore the alternatives available, as well as the decision outcome by helping elicit value judgements about trade-offs between conflicting objectives. In the context of BRIDGE, MCA techniques enable comparison and ranking of different planning alternatives and scenarios, through the structured prioritisation of a variety of sustainability indicators. Participation of stakeholders in the process is a central part of the approach.

Several studies have shown that MCA helps overcome the tendency of humans to be selective and biased. When unaided, decision-makers are inclined to select good news and avoid bad (Fantino, 1998), and disregard all but one or two of the most important criteria (Shepard, quoted by Hobbs and Horn, 1997). Combining the advantages of MCA’s formalism (transparency, consistency, structuring) with human judgement renders decision-making more explicit, rational and efficient, and contributes to more informed decisions. However, the lack of consensus about the general suitability of different MCA methods has prevented the broader application of MCA to real-world problems, such as environmental assessment or natural resource management.

In recent decades a large number of MCA methods have been developed. They differ considerably in terms of: a) the underlying theory (e.g. value/utility versus outranking methods); b) the approach adopted (e.g. generation of trade-offs versus elicitation of value judgements, a priori methods versus progressive or interactive methods); c) the assumed form of multi-criteria preference function (e.g. non-additive versus additive); d) the way value judgements are addressed (e.g. direct assessment versus elicitation of trade-offs); and e) the type of question used to elicit preferences and judgements (Hobbs and Meier, 1994; Hobbs and Horn, 1997). Because of the variety of methods, choosing the most appropriate one for a particular decision situation is difficult and, as a result, usually only a relatively small number of methods are applied.

The literature contains conflicting reports on the degree to which the results obtained by different methods tally. Some authors have achieved the same results for the recommended alternative when several methods were consistently applied to a decision problem (e.g. Goicoechea *et al.*, 1992). In contrast, there is ample evidence that the choice of method may potentially lead to different results and recommendations; and disagreements increase in situations which involve a high number of alternatives or criteria (Jia and Fischer, 1993), and which are characterised by strongly held yet conflicting values (Fischoff *et al.*, quoted in Hobbs and Horn, 1997). The differences in the results yielded by different methods are caused partly by the differences in the methods' underlying philosophy and assumptions. Which method is more appropriate depends on the set of assumptions that seems most valid for a given situation and person (Bell *et al*., 2001). In all cases, Hobbs and Horn (1997) note that these disagreements or inconsistencies are inevitable and should be welcomed as an expression of the different suitability of a method for a particular situation and a decision-maker. The ultimate aim of MCA is not only to help find a solution to a multi-criteria problem, but also to give the decision-maker an opportunity to learn about his/hers own preferences. According to French (quoted by Buchanan, 1994), a good decision aid should help the decision-maker explore not just the problem but also himself. In other words, the process of finding a solution is at least as important as the outcome of the process.

The MCA technique adopted in BRIDGE relies on Analytic Hierarchy Process (AHP) developed by Saaty (1980) and applied extensively in various branches of environmental studies (Wallenius *et al*., 2008). AHP provides a comprehensive and rational framework for structuring a decision problem, representing and quantifying its elements, relating those elements to overall goals, and evaluating alternative solutions. The technique entails decomposing the decision problem into a hierarchy of more easily comprehended sub-problems, each of which can be analysed independently. In BRIDGE, the decision problem hierarchy is composed of a sustainability goal, which branches into associated objectives, criteria and indicators against which different planning alternatives are assessed (Figure 1).

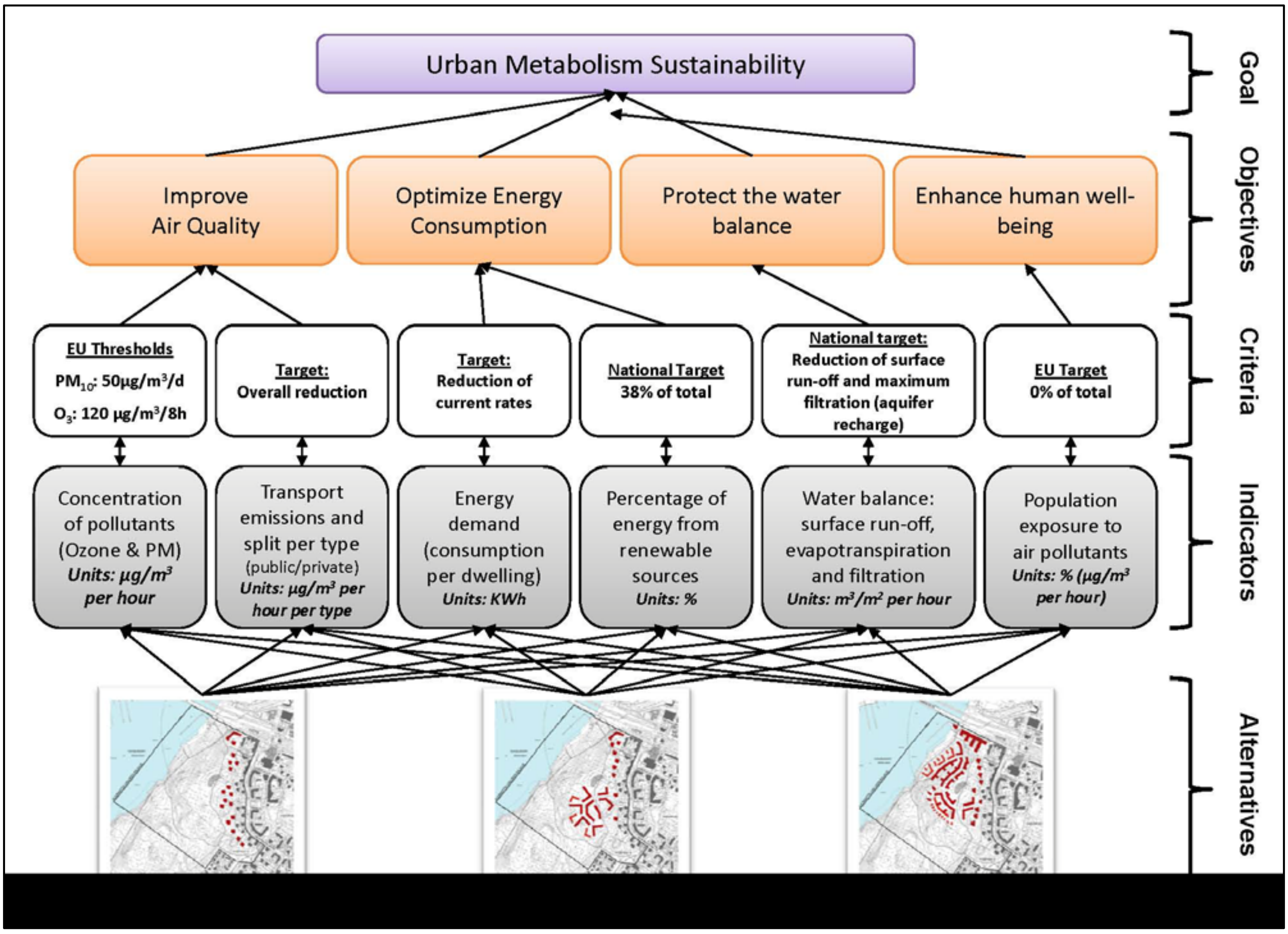


Figure 1. AHP structuring: example of decision-making tree in BRIDGE.

Once the problem is hierarchically structured, the various elements in each level are evaluated in a systematic manner by pair-wise comparison. In the example of Figure 1, objectives are compared to one another two at a time (e.g. indicating whether it is more important to improve air quality or to optimise energy consumption). Stakeholders can then compare criteria and, finally, indicators. In making the comparisons, end-users use their judgments about the elements' relative significance, which are commonly based on policy and/or planning priorities for the city in question (Figure 2).

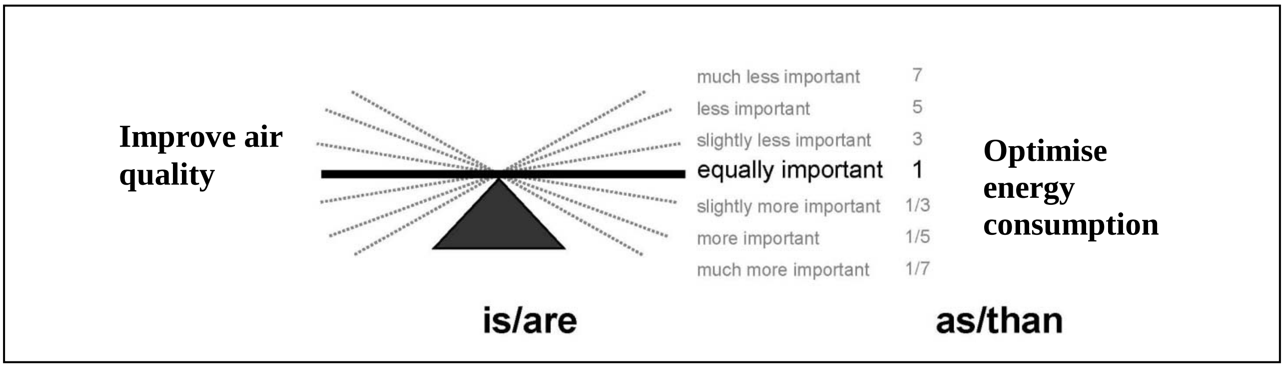


Figure 2. Example of pair-wise comparison.

This pair-wise comparison entails the prioritisation of elements. The resulting value judgements are represented as relative numerical weights (from 0 to 1), illustrating the elements relative contribution towards achieving the urban sustainability goal. AHP system use mathematical calculations to convert pair-wise comparison qualitative judgements into quantitative weights (see Section 3.2) and automatically checks the consistency of judgements.

2.5 Geographic Information Systems as Support Tools in Decision-Making

GIS provides a framework for gathering and organising spatial data and related information so that it can be displayed and analysed. Spatial data can be defined as any data with a direct or indirect reference to a specific location or geographic area (CEC, 2007). GIS is defined as the technology that facilitates the application of general principles (e.g. procedures, algorithms) to local contexts (e.g. spatial databases) for simulating scenarios and assessing alternatives (Goodchild *et al*., 1996).

Decision-makers at all levels are commonly required to assimilate relevant information in the form of large reports prior to any decision. In the planning context, this information load has been increased as a result of the requirement to consider environmental aspects under the EIA and SEA Directives. Conveying information quickly and efficiently is a significant challenge (Buchanan and Kock, 2000). GIS - with their ability to organise, analyse and display spatial information - provide a plausible alternative for relieving the information burden. They have the potential to provide significant advantages to current reporting methods, which may include: fast and systematic analysis; increased speed of information generation; enhanced functionality by combining multiple spatial datasets to provide new insights; and graphic representation of results (Bernhardsen, 1992; Vanderhaegen and Muro, 2005). The highly spatial and temporal dimensions of planning, socio-economic and environmental issues place specific requirements on data processing and analysis tools. Such requirements for decision support are clearly within the capability of GIS, which enable and improve the analysis and visualisation of data (Vanderhaegen and Muro, 2005) and increase the objectivity of evaluation (Antunes *et al*., 2001). Therefore, GIS have the potential to facilitate more transparent decision-making for spatial planning as results can easily be communicated and decisions can be demonstrably based on spatially-specific and objective evidence (Skehan and González, 2006).

The BRIDGE DSS is based on GIS to provide a spatial dimension to the assessment. GIS are used to integrate datasets, analyse the various spatial elements (e.g. environmental and socio-economic indicators), store the results and visualize them. Spatial datasets illustrate field observations, provide the key parameters to the available models, and are critical to the DSS in the assessment of planning alternatives. Therefore, the resulting model outputs and the assessment results are geographically displayed in the DSS, to help the end-user to better understand the problem at hand by identifying spatial patterns and correlations (Figure 3).

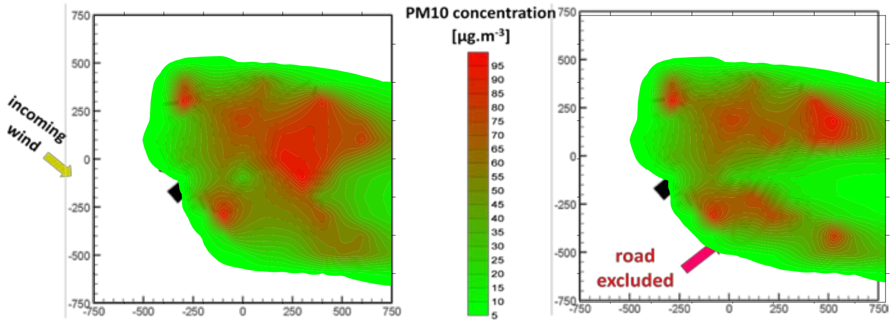


Figure 3. Example of GIS-based model output for PM10 pollutant concentrations, for a road network (left) and for the exclusion of a section of the road (right).

2.6 Decision-Support Systems

A DSS is a computerised and interactive knowledge-based information system, applied in BRIDGE for assessment of planning alternatives as described in Deliverable 6.1 (Mitraka *et al.*, 2010). DSS are commonly used to assist decision making processes by providing tools for compiling data and personal knowledge/perceptions, and for processing this information in order to present, compare and rank alternatives and, ultimately, select the one that satisfies the established decision criteria (Carsjens and Ligtenberg, 2007). Several disciplinary areas are relevant to the development of a DSS including: a) Information and Communication Technology (ICT) used to gather data, structure databases, and provide simulation models and programming support tools; b) management science and operations research applied to provide the theoretical framework of decision analysis and, thus, design comprehensive and valid approaches to decision-making; and c) organizational behaviour and cognitive science implemented to provide information concerning how humans and organizations process information and make judgments. These aspects are combined to develop a DSS for any given knowledge domain, with a structure and components that address the specific problem requirements and the characteristics of the stakeholders involved. Although DSS are commonly fit for purpose (i.e. designed to tackle specific decision problems and tailored to improve end-user interface), Böhner (2006) describes the most relevant processes that they support, including:

- Storage, processing, and presentation of data associated with the problem at hand;
- Presentation and user-transparent description of simple as well as complex relations between data inputs;

- Guiding generation of possible alternative solutions to the problem;
- Modelling and simulation of impacts deriving from desired, proposed or existing alternatives;
- Comparison of the performance of each alternative solution considered, based on decision criteria and/or preferences formulated by the end-user or decision-maker; and
- Analysis and evaluation of possible conflicts deriving from the different sets of criteria and preferences within the decision-making process.

Based on the above applications, the main benefits of DSS include: improved data structuring and management, creation of new evidence to support decision-making, exploration of personal knowledge and preferences, promotion of learning, and more informed problem solving.

The process of assessing planning alternatives based on sustainability criteria entails consideration of multiple parameters. These parameters can be spatial and/or non-spatial, qualitative and/or quantitative. In the light of this, the BRIDGE DSS has been designed to enable the integration of spatial and non-spatial, qualitative and quantitative datasets associated with sustainable urban planning. The BRIDGE DSS is based on GIS and, thereby, has the tools to gather and process spatial data and information, combine them with end-user values and/or preferences and present the result to support decision-making in the form of maps. Moreover, ICT tools are also incorporated into the DSS in the form of models, to provide quantitative and generally spatial measures of energy, water, carbon and pollutants fluxes. Additional non-spatial and qualitative parameters are included in the form or absolute numerical values to integrate other relevant environmental and socio-economic considerations.

In practice, problem-solving or decision-making tends to render differing results depending on the type and significance of the established criteria. Therefore, a given alternative may be good according to certain criteria, whereas other alternatives may perform better against differing criteria. Sustainability objectives and, consequently, decision-making criteria can often be conflicting. As a result, the final decision on the selection of alternatives commonly entails a trade-off between several sustainability objectives, which in turn depends on the preferences of the decision-makers (i.e. significance and resulting weights given to each criterion). To address these considerations, the BRIDGE DSS is based on MCA techniques, which enables the incorporation of weights or priority settings into each of the datasets (Chrysoulakis *et al*., 2009).

The several components and tools incorporated in the DSS have been designed to address the requirements of the BRIDGE project, ensuring that the detailed and quantitative results of model outputs are adequately exploited while enabling the incorporation of additional non-modelled considerations, which in the project mainly relate to socio-economic aspects (Chrysoulakis *et al*., 2009). In addition, the DSS components enable the incorporation of stakeholder values and perceptions, ensuring that the decision-making process follows a structured and participative approach. Moreover, careful consideration of the end-user interface, allows for a comprehensive display of DSS outcomes, by presenting the results in numerical, graphic (i.e. spider diagrams) and map form.

2.7 Limitations within BRIDGE

Environmental and sustainability assessment approaches require a comprehensive evaluation of an array of environmental and socio-economic aspects. EIA and SEA type processes in particular, call for the assessment of potential impacts of a given planning alternative on biodiversity, fauna, flora, population, human health, soil, water, air, climatic factors, material assets, cultural heritage and landscape. Sustainability assessment incorporates the socio-economic dimension by addressing additional non-environmental considerations such as cost of the proposed planning alternative or human well-being. Moreover, urban metabolism refers to the flows of the materials and energy within cities and, therefore, include for instance the assessment of waste or water pollution in addition to the water balance, energy and air pollutant fluxes considered within the scope of the BRIDGE project. As the models available within the project relate to energy, water, carbon and air pollutant fluxes, the DSS is built around these parameters. Nevertheless, even though the DSS may present certain limitations on the type and number of parameters against which planning alternatives are assessed (omitting certain relevant considerations such as biodiversity, cultural heritage or waste management), the flexibility of the tool enables the incorporation of additional models, their results, field measurements and/or other parameters if and when these available from the end-user. The integration of spatial and non-spatial, quantitative and qualitative indicators into the DSS has also proven difficult. A number of methodical compromises have been incorporated (see Section 3 for further detail) to facilitate the normalisation and aggregation of all indicator types.

The significance or weights associated with the established criteria applied in the case studies derive from CoP meetings, where the values and perceptions of key stakeholders were gathered and processed to prioritise sustainability objectives and associated indicators. Although these weights are used in the assessment of the proposed planning alternatives for each of the cities, the DSS allows the end-user to modify such weights and, therefore, adjust the values to reflect a given set of priorities and/or explore the effect that public perceptions may have on the end-results when selecting the most sustainable planning alternative.

Due to resource and time constraints, the assessment of planning alternatives within the case studies is limited to those planning interventions defined during the course of the project. In those cities where the proposed planning alternatives have been defined in generic terms (refer to Deliverable 5.1 for further detail), BRIDGE researchers have formulated a more detailed account of the intervention, defining for example, the exact extent of the areas to be greened or the density of new developments. Due to these limitations, the proposed monitoring programme described in Section 4.1 of this document contains generic recommendations for the case studies to ensure regular measurement of the relevant indicators and, thus, identify any negative trends on the urban metabolism components. It should be noted that monitoring arrangements fall outside the scope of the project and, therefore, are at the discretion of the case study cities to implement them.

3. Impact Assessment Methodology

3.1 Methodological Steps

The methodological approach to the assessment of planning alternatives in the BRIDGE DSS can be divided in a number of steps (Figure 4), which follow a decision-making logic and apply a MCA approach to impact assessment. Due to the nature of the DSS, and to the specific requirements in terms of definition of objectives, criteria and weights, the assessment is an interactive process where the end-user selects from multiple choices shaping the assessment criteria. An illustrative example is provided in Appendix C (the steps below correspond to the schematic representation presented in the Appendix).

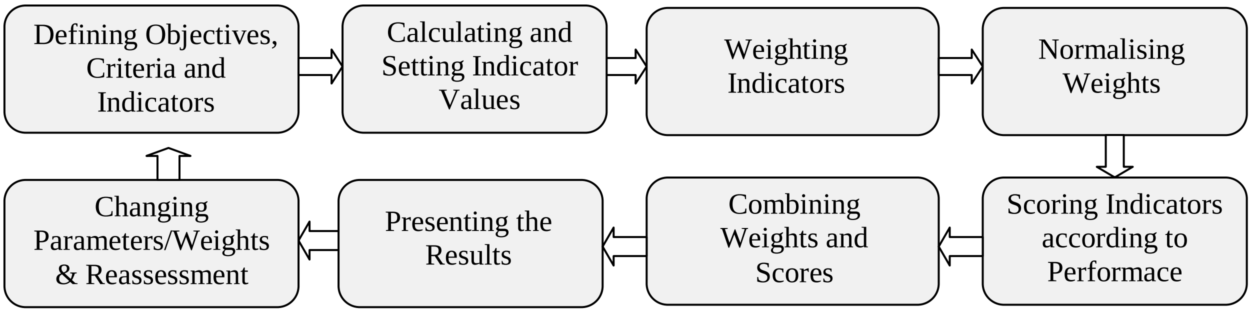


Figure 4. Flow-diagram illustrating the steps composing the impact assessment methodology in the BRIDGE DSS.

Step 1: Defining Criteria and Indicators for Assessing Planning Alternatives

The first step requires the end-used to define the sustainability objectives (e.g. improve air quality), criteria (e.g. PM_{10} threshold/limit set by EU legislation) and indicators (e.g. concentration) that are applied in the assessment of planning alternatives. This selection is commonly based on the policy objectives or planning priorities for a given urban context. As these issues have been explored during the relevant CoP meetings, key sustainability objectives, criteria and associated “core” (i.e. common to all case studies) and “discretionary” (case-specific) indicators provide a starting point in the BRIDGE DSS to the end-user (Appendix C).

The DSS contains a database with these sustainability objectives, criteria and associated “core” and “discretionary” indicators. Although the end-user selects the relevant objectives and indicators from a list, additional sustainability objectives and indicators can also be added if relevant, and assuming indicator values are available from the end-user (addressing the model and data limitations within the project).

Step 2: Calculating and Setting Indicator Values for each Alternative

In this step, indicator values are provided for each alternative considered. Where the indicators can be modelled within BRIDGE, the values for the indicators selected are automatically provided to the end-user as a modelling output. The results of the models are displayed in both spatial and average numerical form. Therefore, the DSS displays the spatial distribution of the values for a given indicator within the study area in the form of a GIS map. This is considered vital information for the end-user to contrast, for example, different building layouts within the development area and adjust them according to any identified land use conflicts or impact distribution patterns. Similarly, the value for the area is spatially averaged to obtain an overall value for that indicator and, thus, facilitate its aggregation with the non-spatial indicators.

Where models are not available within BRIDGE to compute certain specific indicators, the end-user is prompted to input the relevant indicator values (as total values that may or may not be spatially-specific) to progress the assessment. The multiple indicators can be combined in a spatial manner to explore the spatial distribution of scores obtained by the planning interventions.

Steps 3 and 4: Weighting Indicators According to their Priority and Normalising Weights

Once indicators are selected and their values defined, the end-user is requested to perform a pair-wise comparison of the relevant indicators (applying AHP). Each indicator is contrasted against another and the end-user is prompted to determine which one is more important/significant. As a result, the indicators are weighted according to their importance/significance set by the end-user and based on the sustainability goals (or planning priorities) for the city or other considerations of subjective nature. This results in indicator weights, which enable the integration of end-user perceptions into the assessment.

Step 5: Scoring Indicator Values according to Performance in each Alternative

The performance of indicators is automatically defined based on how close the indicator value is to a reference basis (i.e. criteria). When assessing the performance of indicators, targets/thresholds are used as reference points to establish the nature of the indicator's performance. Thresholds refer to the maximum value permitted according to European and national legislation (i.e. upper benchmark such as the 50 µg/m3 limit for PM10). In some instances, targets are applied referring to the minimum value the indicator should have (i.e. lower benchmark such as a minimum of 68% of employment).

Where a comparable baseline exists (e.g. business as usual scenario on an urbanized area), alternatives can be contrasted against such do-nothing alternative (in the case of BRIDGE, the 2008 baseline). Where the baseline alterative is not comparable (e.g. where a forested area will be converted into an urban settlement as is the case in the Helsinki case study) the planning alternatives can be compared against one of them, e.g. the simplest one, to establish which one presents the most sustainable option.

Step 6: Scoring Criteria Combining Relative Weights and Values of Indicators and Aggregating Criteria to Obtain Relative Values for Each Alternative

The score of each objective or criterion is automatically calculated as a function of indicator scores and weights. Similarly, the total score for a given alternative can be calculated as a function of the total objectives scores and weights, or of the total indicators scores and weights.

The relative importance of each indicator (defined in step 3 and normalized in step 4) is combined with the ratios between indicators for the alternatives being compared (calculated in step 5). These values are aggregated to obtain the relative performance or the total performance of one alternative when compared to another.

The indicators are operationalised to ensure that there is no double-counting or overlap on selected indicators (e.g. energy consumption and CO_2 emissions), as well as to ensure that contrasting indicators within the same criterion (e.g. population density and number of people exposed to pollutants) are adequately addressed.

Step 7: Presenting the Results

The results are presented in a comprehensive manner, including both spatial and non-spatial information. A single overall value for each alternative is provided (in the form of a performance index), based on the composite of the underlying objectives and indicators, to facilitate comparison between the alternatives. This obscures the performance of the individual indicators for each alternative and their relative significance and, therefore, individual objective and indicator results are also provided to evaluate the variations among alternatives in relation to specific socio-economic and/or environmental considerations. This is done in the form of absolute or mean values for each sustainability indicator, criterion or objective, or represented by means of a spider diagram which illustrates the performance of each indicators set.

Therefore, the impact assessment results combine summary values (e.g. total relative score of each alternative) with detailed values from each of the assessment stages (e.g. partial indicator values and weights or spatial distribution of indicator values) as illustrated in Appendix C. The reason behind this is that the methodology adopted in the BRIDGE project aims to inform/support decision-making (i.e. not to make decisions), with the premise that the more information that is provided the more informed the decision. Results are compiled and provided as a comprehensive summary for each of the alternatives by including:

- GIS maps available for the spatial-indicators;
- Mean, maximum or minimum values for the study area for spatial indicators;
- Absolute indicator values for the non-spatial indicators;
- Spider diagram combining the indicator results for each objective or criterion; and
- The total assessment value (or performance index) for each alternative.

Based on the above results, the end-user or decision-maker can make an informed decision on the suitability of alternatives by looking at how the different alternatives affect the socio-economic and environmental components of the urban context.

3.2 Algorithmic Considerations

The adopted impact assessment approach relies on AHP which structures the decision problem into a hierarchy and requires a pair-wise comparison of the various components (see Section 2.4). The methodological approach allows integration of spatial and non-spatial indicators and enables the incorporation of decision makers’ judgments on the relative importance of the various components.

The methodological steps noted above (Section 3.1) are revisited here to provide details on the algorithms applied. The Helsinki case study (the residential and business development alternatives considered around the Meri-Rastila Metro station) is used for representative purposes.

Step 1: Defining Criteria and Indicators for Assessing Planning Alternatives

End-user choices in relation to sustainability objectives, criteria and indicators enable the automatic construction of the AHP hierarchy (Figure 1). The hierarchy consists of decision goal (in the case of BRIDGE, sustainability of urban metabolism) and sustainability objectives, one or more criteria/indicator levels and planning intervention to reach such objectives.

Steps 3 and 4: Weighting Indicators According to their Priority and Normalising Weights

Using a number of pair-wise comparisons, the AHP assess all components of a given level, and subsequently assesses the components of a lower level with respect to each component of the next-higher level. During the pair-wise comparisons, the judgments are expressed in numerical values that can be processed and compared over the entire range of the problem. In the case of BRIDGE, the AHP uses an underling scale with values from 1 to 9 to describe the relative preferences for two criteria where 9 is significantly more important than 1 (Figure 5 left). The result of the pair-wise comparisons is a reciprocal quadratic matrix (Figure 5 right). It allows numerical weights (wj) to be established, where diverse and often incommensurable elements can be compared to one another.

The matrix is read as follows: how important is the row component (e.g. concentration of pollutants) compared to column component (e.g. population exposed to high levels of pollutants) on the premise of air quality? The answer to this question according to Figure 6 is 5 (i.e. population exposed to pollutants is of higher concern or has stronger importance from an air quality perspective, than pollutant concentration).

Air Quality	**Concentration of Pollutants**	**Emissions of GHG**	**Population Exposed**
Pollutant Concentration	1	1/3	1/5
Emissions of GHG	3	1	1/3
Population Exposed	5	3	1

1 - Equal importance
3 - Moderate importance
5 - Strong
7 - Very Strong
9 - Extreme

Figure 5. AHP scale and an example of a pair-wise comparison matrix in which the three indicators concerning air quality are compared.

Based on the results of the pair-wise comparison matrix $A \in \mathbb{R}^{n \times n}$ a numerical weight (wj), or priority for each component of the hierarchy, can be determined to normalise values. This is achieved using the algorithms below:

1. Estimate the maximum eigenvalue λ_{max} of the comparison matrix, which fulfil the formula below:

$$\det(A - \lambda \times I) = 0$$

2. Determine the solution $\tilde{w}$:

$$(A - \lambda \times I) \times \tilde{w} = 0$$

$$\tilde{w}_i \geq 0$$

3. Normalise the $\tilde{w}$:

$$w_j = \frac{\tilde{w}_j}{\sum_{i=1}^{n} \tilde{w}_i}$$

Applying the above algorithms, the pair-wise comparison matrix in the example in Figure 6 results in the following weights: Population exposed = 0.657; Emissions of GHG = 0.258; and Pollutant concentration = 0.105. As a result, the numerical weights of all elements are synthesised to yield a set of overall priorities for the hierarchy. This is done additively. The results represent each alternatives' relative ability to achieve the decision goal, so they allow a straightforward consideration of the various courses of action.

The AHP approach enables consistency checks of the pair-wise comparison matrix to be performed systematically. A consistent matrix means, for example, that if the decision-maker establishes that objective x is equally important to objective y (so the comparison matrix will contain value of axy = 1= ayx), and that objective y is more important than objective w (ayw = 9; awy = 1/9); then objective x should also be more important than objective w (axw = 9; awx = 1/9). Decision-makers or end-users are often not able to express consistent preferences in the case of multiple criteria. AHP measures the inconsistency of the pair-wise comparison matrix, setting a consistency threshold that cannot be exceeded and, thereby, ensuring that the weights are consistent or prompting the end-user to re-establish conflicting weights.

Step 5: Scoring Indicator Values according to Performance in each Alternative

The indicator scoring (Si) is calculated on the basis of the changes introduced by the planning alternative:

$$S_{xi} = \frac{I_{xi}}{I_{Ri}}$$

where x stands for any alternative and R for the "reference" alternative.

It is necessary to clarify if the increase or decrease of the indicator represents more or less sustainability (i.e. improvement or decay on environmental and/or socio-economic considerations). When the increase in value of an indicator means the decrease of the value of the alternative, the indicator score is the inverse of the formula above (i.e. indicator R for the reference alternative is contrasted against indicator x of the alternative under consideration).

Step 6: Scoring Criteria Combining Relative Weights and Values of Indicators and Aggregating Criteria to Obtain Relative Values for Each Alternative

Finally, the total score for a given alternative is calculated as a function of the objectives scores and weights, or of the indicators scores and weights. This is done by applying the Cobb-Douglas function (Cobb and Douglas, 1928):

$$S_i = S_1^{\alpha 1} \cdot S_2^{\alpha 2} \cdot S_3^{\alpha 3} \cdot S_n^{\alpha n}$$

where indicator scores and weights are multiplied to obtain a total relative value (i.e. performance index) for each alternative.

4. Monitoring Systems

4.1 Monitoring Indicators

The provision of evidence-based assessment of planning alternatives improves decision-making processes and enables the formulation of evidence-based planning policies, which in turn, can assist monitoring their implementation. The achievement of sustainability objectives can be measured during monitoring by using indicators. Therefore, the formulation of clear and concise environmental and socio-economic indicators and their associated targets facilitates consistent and meaningful monitoring. Monitoring of relevant indicators by means of periodic measurements (as required under Article 10 of the SEA Directive), is essential in order to identify at an early stage unforeseen adverse effects and to undertake appropriate remedial action.

Monitoring results enables any changes in an indicator value to be detected by comparing them against the documented baseline environment, and evaluating their upward/downward trend and resulting beneficial/adverse effects on the environment or on the socio-economic parameters. Existing monitoring arrangements (e.g. water run-off or air quality monitoring stations) can be used where available and appropriate in terms of location and periodicity. Additional monitoring schemes may be required depending on which effects need to be monitored and upon the intervals between revisions or assessment updates.

Monitoring arrangements can take the form of individual or combinations of many approaches (Barth and Fuder, 2002):

- Impact-related monitoring: measures the impact of an activity in contrast to state-related monitoring.
- State-related monitoring: used to observe and describe the state of the environment (including changes) independently from any planning intervention or activity.
- Performance-led monitoring: consists mainly in controlling the implementation and effectiveness of certain measures foreseen in a planning intervention.
- Objective-led monitoring: focuses on controlling whether specific environmental quality and/or sustainability objectives or targets are attained within a given amount of time.

For planning control purposes and in the context of both impact-related and performance-led monitoring, the implementation of the planning alternatives in the BRIDGE case studies will require regular measurement of indicator values to ensure that the urban metabolism components do not deteriorate as a result of the planning intervention. Both quantitative and qualitative indicator values can be easily updated and compared in the DSS, facilitating monitoring processes and helping to identify any causal links between the implementation of the selected planning alternative and the likely significant effects. Monitoring the accuracy of impact predictions and the effectiveness of mitigation measures may only require systematic updating of baseline datasets followed by re-implementation of pre-existing analysis, prediction, and evaluation routines. In BRIDGE, this can be easily achieved by incorporating the monitoring results into the DSS and systematically re-applying the previously established methodological steps (as per Sections 3.1 and 3.2). The results of this new analysis can be visually and numerically compared with the baseline scenario to identify and compare changes over time. Such an approach has the potential to enhance the efficiency and transparency of the monitoring process.

Taking into account the scope of the BRIDGE project (in respect of the specific considerations under assessment and the type and extent of planning alternatives assessed) and the methodological requirements for monitoring under Article 10 of the SEA Directive, the following are recommended to be adopted in the case study cities to ensure a consistent and coherent monitoring process:

- The monitoring process should be linked to the assessment framework (i.e. correlate with the defined sustainability objectives, criteria and indicators).
- The monitoring system can apply existing arrangements for the regular measurement of indicators as long as these arrangements are compatible with the scale and scope of the assessment.
- Where monitoring arrangements are not available for relevant indicators, these should be immediately established to ensure data are available before and after the implementation of the proposed plan (or project under study).
- The authority responsible for monitoring each indicator should be defined at an early stage to ensure accountability (where monitoring arrangements exists, relevant research institutions, organisations and/or planning authorities can be contacted for data updates).
- The frequency of monitoring should be clearly defined. Although there is no general rule for how often and in which period of time monitoring should be undertaken, legislative requirements often determine reporting periods and these should be taken into consideration when defining monitoring frequencies.
- The monitoring results should provide sufficient level of detail to identify any potential adverse effect.
- The evaluation of monitoring results should be based on the previously established procedures to facilitate interpretation and ensure that assessment outcomes are comparable.
- The monitoring plan should indicate remedial actions - to be undertaken where indicator values reach alert thresholds or limits.
- The definition of objectives and thresholds needs to be periodically checked against new knowledge and new legal frameworks, adjusting them as required, as well as updating plans and monitoring procedures.

4.2 Assessing the Utility of Indicators

A useful indicator must produce results that are clearly understood and accepted by scientists, policy makers, and the general public (EPA, 2000). Based on the popular principles of “you can’t manage what you don’t measure” and “not everything that can be counted counts, and not everything that counts can be counted”, indicator sets have to be defined to appropriately address the specific assessment questions. The utility or applicability of indicators is commonly tied in to their ability to address context-specific issues and monitor progress towards definite goals set at the local level. In this context, Rees *et al*. (2008) highlight the need to promote dialogue during the construction of indicator-based management frameworks to optimise their applicability and operational use.

Favourable characteristics of indicators have been reviewed widely (Cairns *et al*., 1993; Schomaker, 1997; Fisher, 2001; Hanson, 2003; EEA, 2005; Rees *et al.*, 2008) and commonly include:

- Capable of conveying information that is responsive and meaningful to decision-making (directly tied to assessment questions and linked to thresholds relative to specific sustainability goals);
- Specific, unambiguous and user-driven with the ability to communicate potential cause-effect relationships;
- Capable of measuring change or its absence with confidence (sensitive to influences of environmental and socio-economic factors with the ability to provide early warning of potential effects);
- Applicable over a variety of spatial scales and conditions (to support global as well as local comparisons) and, where possible, linked to a geographic location;
- Quantifiable and measurable on a regular basis and on a timely manner within the assessment or decision-making process without entailing excessive cost; and
- Scientifically and legally defensible (robust to peer review) and easy to communicate and understand by non-specialists.

In an attempt to optimise the utility of indicators within the BRIDGE project, the following measures have been undertaken:

Participative Approach to the Definition of Indicators

A bottom-up approach was adopted in BRIDGE for the development of indicators. This was achieved through consultation with key stakeholders and potential DSS end-users during the CoP meetings (see Deliverable 5.1 for further detail). This participative approach allowed insight into the case study cities be gained in relation to sustainability considerations and key planning issues, resulting in a set of indicators that responds to the sustainability objectives in each city and, thus, effectively addresses issues and requirements at the local level.

Validation against Selection Criteria

The indicators were verified against the selection criteria (ensuring that they were if possible spatial, and in all cases specific, measurable, achievable, relevant and timely as specified in Deliverable 5.1) and validated to ascertain their applicability by ensuring that they addressed the key sustainability objectives for the city, were within the scope of BRIDGE and were measurable/modellable within the project.

Comparison with Existing Indicator Sets

The development of indicators included cross-checking with European (EEA, 2005) and national indicator sets (e.g. AI, 2003; DEFRA, 2009; FNCSD, 2009). Where an indicator was identified at the CoP but was not measurable/modellable by BRIDGE, it was still considered valid if included in any national/regional or European indicators list as such indicators are policy-relevant, data/values are available and thus they can be potentially assessed and monitored.

Data Availability, Modelling and Scale Considerations

Uncertainty on the indicator’s performance (associated to scale, data availability and model outputs) should be documented. The effects of sample size, monitoring duration, and other variables affecting the precision and confidence levels of measured or modelled results should be communicated to the end-user to ensure transparency and accountability. In the context of BRIDGE, such considerations are examined and, where appropriate, included as part of the DSS outcomes (see Deliverable 5.3 for further detail).

The assessment of the effectiveness and efficiency of both core and discretionary indicators selected in the case studies in accounting for changes on urban metabolism performance as a result of planning alternatives will only be demonstrated once the case studies are fully assessed through the DSS. Once the DSS has been fully implemented, the relevancy, applicability and responsiveness of the indicators will be ascertained. This will also determine if the DSS results are useful to the assessment of planning alternatives and whether they are clearly understood by planners and decision-makers. Therefore, the DSS outcomes may lead to a re-examination of indicators utility and conceptual significance, and may result in a redefinition of individual indicators or a refinement of the original assessment questions (i.e. objectives).

5. Conclusion

5.1 Final Remarks and Next Steps

The impact assessment model developed and applied in BRIDGE is tailored to the specific project requirements and, as such, does not strictly follow any regulatory or regularly applied assessment methodology. It applies decision-making theory and impact assessment principles promoting a participative, systematic and coherent assessment of planning alternatives.

The methodology is currently being implemented in the DSS and will be subsequently tested in the case studies. Any adjustments needed (as identified during the testing phase) will be undertaken to ensure that a robust impact assessment methodology is provided as part of the DSS tool at the end of the project.

Similarly, indicators will be reviewed during the testing phase to validate the utility of indicators and ensure that the final set includes specific, measurable, achievable, relevant and timely indicators that clearly illustrate positive or negative changes resulting from the implementation of planning alternatives.

APPENDIX A – Sustainability Objectives and Indicators Agreed and the Umbrella CoP

ENVIRONMENTAL	
Objectives	**Indicators**
Common Aspects (Core)	
Improve Air Quality	• Concentration of pollutants (PM_{10} and $PM_{2.5}$, O_3, NOx) • GHG and CO_2 emissions • Number of days above established air quality threshold
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
City-Specific Aspects (Discretionary)	
Increase Green Space Areas	• Density of green areas (m^2 per habitant) • Canopy/green surface or area newly created • Accessibility to green areas
Thermal comfort	• Ambient & surface air temperature (^{o}C) • Number of days above established threshold
Optimize Materials Used	• Volume of material re-used
SOCIO-ECONOMIC	
Objectives	**Indicators**
Common Aspects (Core)	
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
City-Specific Aspects (Discretionary)	
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

APPENDIX B – Final Set of Sustainability Indicators

CORE ENVIRONMENTAL INDICATORS	UNITS	TARGET / LIMIT
POLLUTANTS AND CARBON		
Green House Gases:	Kg/h (or tones/year) Flux: µg/m^2/sec	*Specific national targets (commonly referred to in % of reference values or as Tones CO_2-equivalent over 5 years)*
Carbon dioxide (CO_2) emissions		
Carbon dioxide (CO_2) flux		
Methane (CH_4) emissions		
Concentrations of toxic substances per hour and concentration limits	µg/m^3	
Nitrogen dioxide (NO_2)		200 µg/m^3 per hour
Thoracic particle (PM_{10})		50µg/m^3 per day
Fine particle ($PM_{2.5}$)		*No limit defined yet.*
Ozone (O_3)		120 µg/m^3 per 8 consecutive hours
Carbon monoxide (CO)		10000 µg/m^3 per 8 consecutive hours
Sulphur dioxide (SO_2)		350 µg/m^3 per hour
Number of cases where the numeric value for the following pollutants is exceeded	days	Non-consecutive:
NO_2 limit (200 µg/m^3 - alert threshold 400 µg/m^3 in 3consecutive hours)		18 days/year
PM_{10} limit (50µg/m^3)		35 days/year
O_3 limit (120 µg/m^3 - alert threshold 240 µg/m^3 hour)		25 days/year averaged over 3 years
SO_2 limit (350 µg/m^3)		24 days/year
ENERGY		
Energy consumption in the building sector for air conditioning (cooling/heating in buildings)	KWh/m^2	*Reference value**
Anthropogenic heat flux	W/m^2	*Reference value**
Sensible Heat Flux and Latent heat Flux (Bowen Ratio)	Bowen ratio	*Reference value**
Percentage of energy from renewable energy sources	**%** (KWh) of total	*Specific national targets (commonly referred to as % of total)*
WATER BALANCE		
Water consumption per capita	m^3/capita/year	*Reference value**
Water consumption (external – e.g. irrigation)	mm^3/year	*Reference value**
Evapotranspiration	mm^3/m^2	*Reference value**
Infiltration (in green surface areas)	mm^3/m^2	*Reference value**
Surface run-off	mm^3/m^2	*Reference value**
Potential flood risk	Peak mm^3/m^2 discharges	0

* Reference value: Targets limits are not applicable and, therefore, the alternative will be compared against the do-nothing or reference values.

DISCRETIONARY ENVIRONMENTAL INDICATORS	**UNITS**	**TARGET / LIMIT**
THERMAL COMFORT		
Thermal comfort (CP)	Wind speed (m/s) and temperature (°C)	*Specific national thresholds* *or Reference value**
Air Temperature (outdoors) at 2m above ground	°C	
Number of days above established thresholds	Cumulative °C Days	*Specific national thresholds*
GREEN SPACES		
Number of inhabitants per green area	Inhabitants/m^2 of green area	*Specific national targets* *or Reference value**
Newly created canopy surface or green area	m^2	*Reference value**
Number of inhabitants with access to green areas	No. of inhabitants *(within 300m)*	*Reference value**
MATERIALS		
Volume of material re-used (recycled)	m^3 of total	*Reference value**

* Reference value: Targets limits are not applicable and, therefore, the alternative will be compared against the do-nothing or reference values.

CORE SOCIO-ECONOMIC INDICATORS	UNITS	TARGET / LIMIT
LAND USE		
New urbanized areas (land use changes including greenfield and brownfield)	m^2 (or % change)	*Reference value**
Brownfields re-used	m^2 (or % change)	*Specific national targets or Reference value**
Density of development	built m^2/total m^2	*Specific national targets or Reference value**
ECONOMIC VIABILITY		
Cost of proposed development	€ (or €/m^2)	*Reference value**
Effects on local economy (employment)	No. of new jobs created	*Reference value**
Effects on local economy (revenue)	€ (or €/m^2)	*Reference value**
MOBILITY/ACCESSIBILITY		
Quality of pedestrian sidewalks	N/A *(qualitative)*	*Reference value**
Length of cycle-ways provided	m	*Specific national targets or Reference value**
Length of new roads provided	m	*Reference value**
Use of public transport	% of total population using public transport	*Specific national targets or Reference value**
Number of inhabitants with access to public transport	No. of inhabitants	*Reference value**

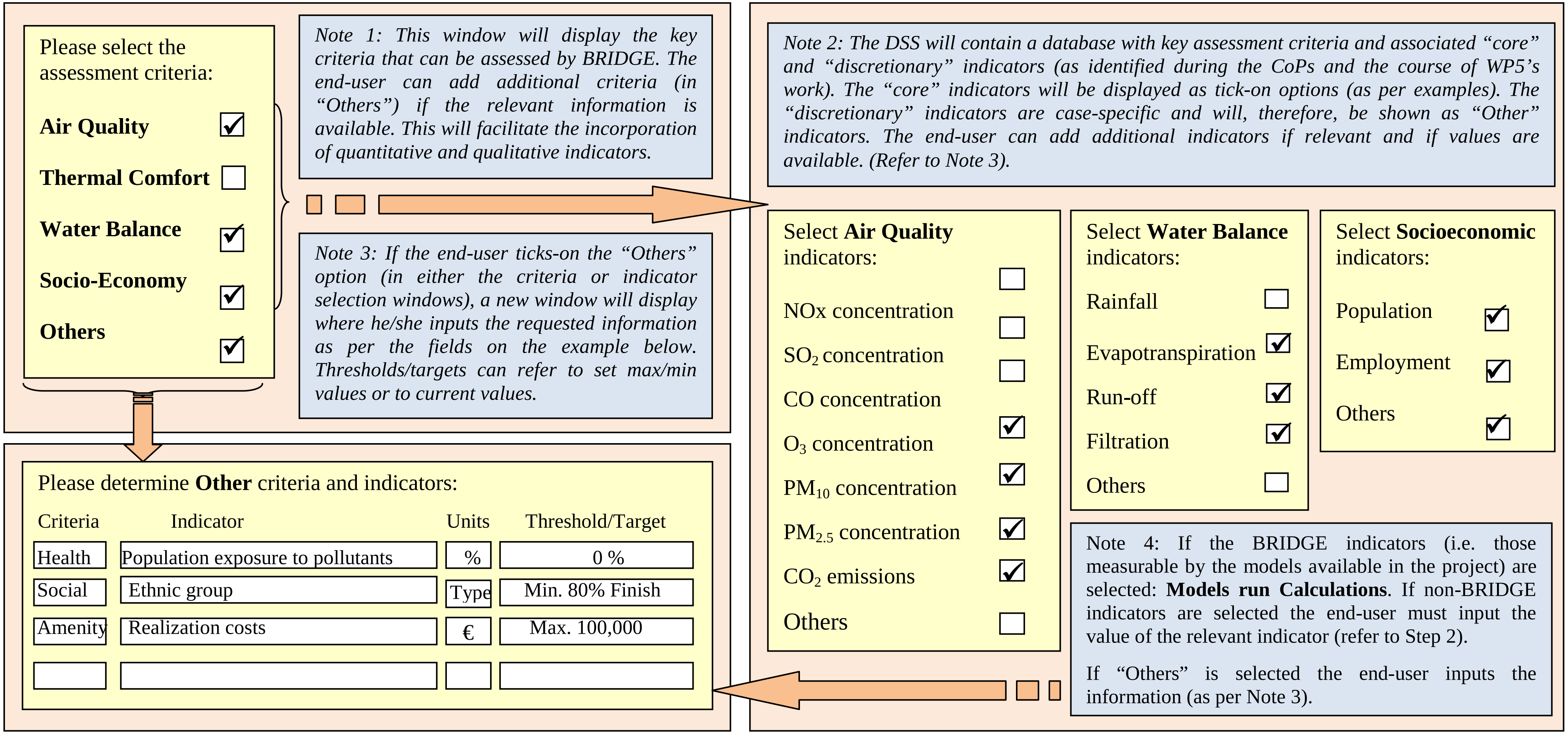
	(within 500m of public transport)	
HUMAN WELL-BEING		
Number of inhabitants exposed to NO_2 concentrations above the threshold	No. of inhabitants exposed	*200 µg/m^3 no more than 18 times a year*
Number of inhabitants exposed to PM_{10} concentrations above the threshold	No. of inhabitants exposed	*50 µg/m^3 no more than 35 times a year*
Number of inhabitants exposed to 0_3 concentrations above the threshold	No. of inhabitants exposed	*120 µg/m^3 for 8 hours no more than 25 times a year*

DISCRETIONARY SOCIO-ECONOMIC INDICATORS	**UNITS**	**TARGET / LIMIT**
SOCIAL INCLUSION		
Number of inhabitants with access to services	Number of services/m^2 (or inhabitants/service)	*Reference value**
Number of inhabitants with access to social housing	No. of inhabitants (% of total)	*Reference value**
HUMAN WELL-BEING		
Number of inhabitants affected by flash flooding	No. of inhabitants	*0*
Number of inhabitants affected by heat waves	No. of inhabitants	*0*

* Reference value: Targets limits are not applicable and, therefore, the alternative will be compared against the do-nothing or reference values.

APPENDIX C – Schematic Representation of the DSS Interface

STEP 1: DEFINING THE CRITERIA AND INDICATORS FOR ASSESSING PLANNING ALTERNATIVES



Please select the assessment criteria:

Air Quality ☑
Thermal Comfort ☐
Water Balance ☑
Socio-Economy ☑
Others ☑

Note 1: This window will display the key criteria that can be assessed by BRIDGE. The end-user can add additional criteria (in "Others") if the relevant information is available. This will facilitate the incorporation of quantitative and qualitative indicators.

Note 3: If the end-user ticks-on the "Others" option (in either the criteria or indicator selection windows), a new window will display where he/she inputs the requested information as per the fields on the example below. Thresholds/targets can refer to set max/min values or to current values.

Note 2: The DSS will contain a database with key assessment criteria and associated "core" and "discretionary" indicators (as identified during the CoPs and the course of WP5's work). The "core" indicators will be displayed as tick-on options (as per examples). The "discretionary" indicators are case-specific and will, therefore, be shown as "Other" indicators. The end-user can add additional indicators if relevant and if values are available. (Refer to Note 3).

Select **Air Quality** indicators:

NOx concentration ☐
SO_2 concentration ☐
CO concentration ☐
O_3 concentration ☑
PM_{10} concentration ☑
$PM_{2.5}$ concentration ☑
CO_2 emissions ☑
Others ☐

Select **Water Balance** indicators:

Rainfall ☐
Evapotranspiration ☑
Run-off ☑
Filtration ☑
Others ☐

Select **Socioeconomic** indicators:

Population ☑
Employment ☑
Others ☑

Note 4: If the BRIDGE indicators (i.e. those measurable by the models available in the project) are selected: **Models run Calculations**. If non-BRIDGE indicators are selected the end-user must input the value of the relevant indicator (refer to Step 2).

If "Others" is selected the end-user inputs the information (as per Note 3).

Please determine **Other** criteria and indicators:

Criteria	Indicator	Units	Threshold/Target
Health	Population exposure to pollutants	%	0 %
Social	Ethnic group	Type	Min. 80% Finish
Amenity	Realization costs	€	Max. 100,000

STEP 2: CALCULATING AND SETTING INDICATOR VALUES FOR EACH ALTERNATIVE

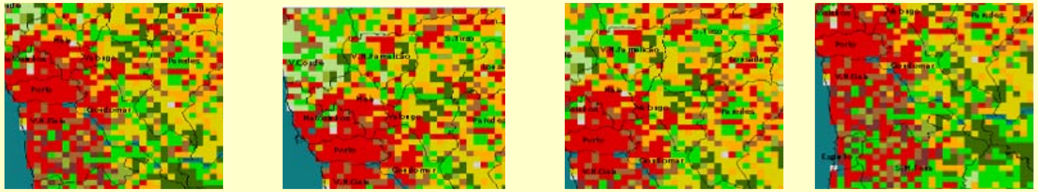
Note 5: Indicators values will be provided for each alternative. The results of the models will be displayed in both spatial and average value form. Therefore, the DSS will display the spatial distribution of the values for a given indicator within the study area in the form of a GIS map. This is considered vital information for the end-user to contrast different building layouts within the development areas (as it is the case in Helsinki) and adjust them according to any identified land use conflicts or impact distribution patterns. Similarly, the value for the area will be averaged to obtain an overall value for that indicator and, thus, facilitate its aggregation with the non-spatial indicators. This will be done by multiplying the different indicator values by the number of pixels in which that value occurs, and dividing the result by the total number of pixels, applying the formula: $Va = (\square Vi \times Pj) / Pn$

Where: Va= Resultant average value for the spatial indicator (a); Vi= Indicator value (there will be i number of values for indicator a); Pj= Number (j) of pixels with indicator value Vi; Pn = Total number of pixels in the study area.

Air Quality indicators – Averaged Results:

O_3 concentration	30 µg/m^3
PM_{10} concentration	80 µg/m^3
$PM_{2.5}$ concentration	24 µg/m^3
CO_2 emissions	12,000 tonnes

Air Quality indicators – GIS Results:

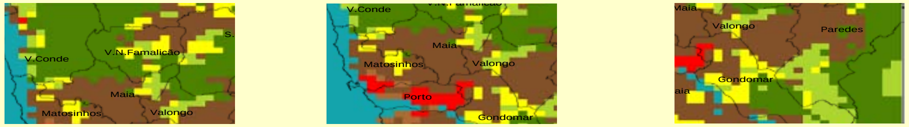


O_3 concentration — PM_{10} concentration — $PM_{2.5}$ concentration — CO_2 emissions

Water Balance indicators - Averaged Results:

Evapotranspiration	0.6 m^3/m^2/h
Run-off	3 m^3/m^2/h
Filtration	1.2 m^3/m^2/h

Water Balance indicators – GIS Results:



Evapotranspiration — Run-off — Filtration

Socio-economic indicators - Averaged Results:

Population	2,700 people
Employment	67%

Other indicators - Averaged Results:

Population exposure to pollutant	4 % (µg/m^3/h)
Realization costs	123,000 €

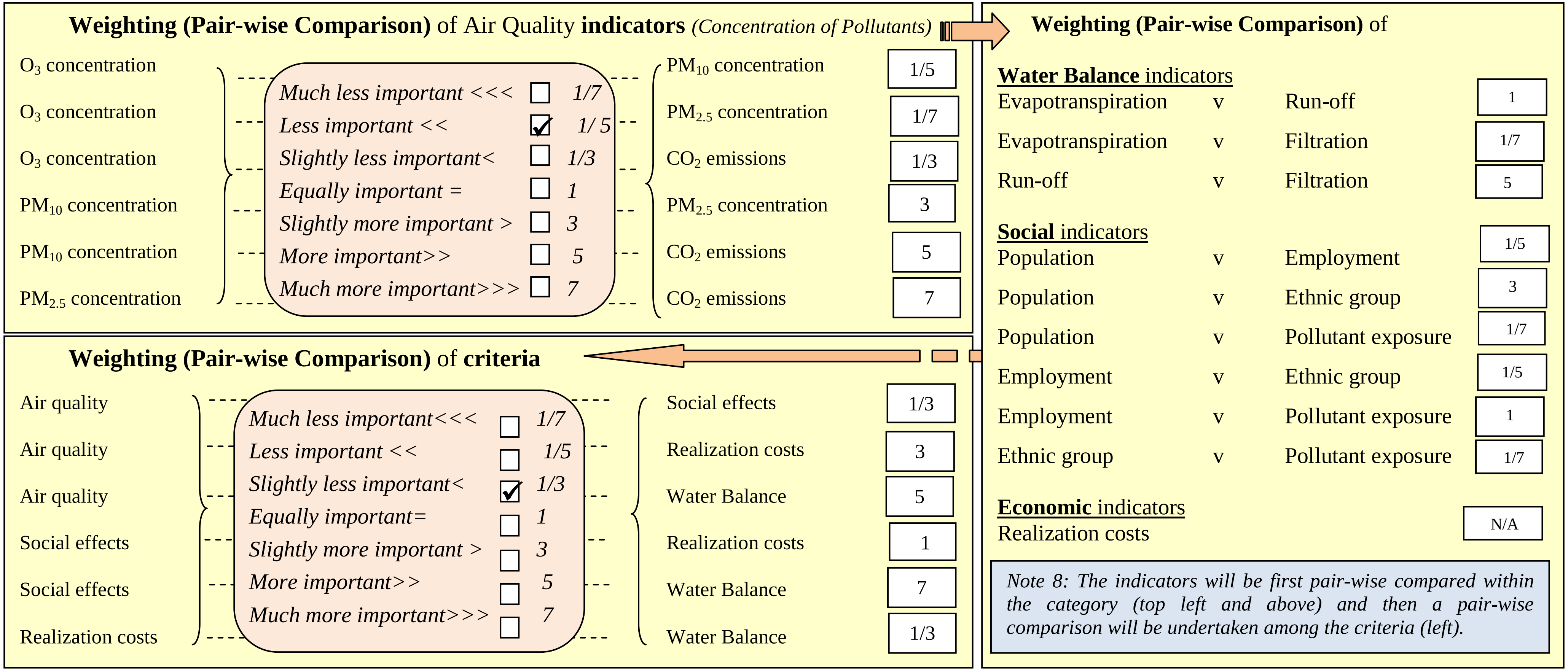
Note 6: The averaged results for the indicators shown and the GIS maps do not correspond to the Helsinki case study and are for illustrative purposes only.

These GIS maps will include corresponding site boundaries and alternatives (alternatives should be able to be turned on/off by the end-user). The legend, scale and bar and north arrow will also be shown.

Non-spatial indicators will be presented as total values only. The end-user will input "Other" indicator values at this point.

STEP 3: WEIGHTING INDICATORS ACCORDING TO THEIR PRIORITY

Note 7: The DSS will automatically build a hierarchical relation of the criteria and indicators selected in Step 1 using the AHP approach. Consequently, the end-user will perform a pair-wise comparison of the relevant indicators. The pair-wise comparison will be undertaken within the category of indicators (i.e. among the indicators belonging to the same indicator group or the same criteria and among the criteria itself). Thus, the indicators will be weighted by the end-user according to their priority/importance/significance to the sustainability of the city. The DSS should display a window for each pair-wise comparison (the example below includes them all in a single interface for illustration purposes only). The corresponding value (as per tick-on importance level – illustrated in brackets in the example below) will be automatically assigned to the indicator. The end-user can come back to these windows anytime to change weights and "play" with the assessment criteria and outcomes or undertake a sensitivity analysis. The applied weights are for illustrative purposes only.



Weighting (Pair-wise Comparison) of Air Quality **indicators** *(Concentration of Pollutants)*

Much less important <<< ☐	*1/7*
Less important << ☑	*1/ 5*
Slightly less important< ☐	*1/3*
Equally important = ☐	*1*
Slightly more important > ☐	*3*
More important>> ☐	*5*
Much more important>>> ☐	*7*

O_3 concentration	PM_{10} concentration	1/5
O_3 concentration	$PM_{2.5}$ concentration	1/7
O_3 concentration	CO_2 emissions	1/3
PM_{10} concentration	$PM_{2.5}$ concentration	3
PM_{10} concentration	CO_2 emissions	5
$PM_{2.5}$ concentration	CO_2 emissions	7

Weighting (Pair-wise Comparison) of **criteria**

Much less important<<< ☐	*1/7*
Less important << ☐	*1/5*
Slightly less important< ☑	*1/3*
Equally important= ☐	*1*
Slightly more important > ☐	*3*
More important>> ☐	*5*
Much more important>>> ☐	*7*

Air quality	Social effects	1/3
Air quality	Realization costs	3
Air quality	Water Balance	5
Social effects	Realization costs	1
Social effects	Water Balance	7
Realization costs	Water Balance	1/3

Weighting (Pair-wise Comparison) of

Water Balance indicators

Evapotranspiration	v	Run-off	1
Evapotranspiration	v	Filtration	1/7
Run-off	v	Filtration	5

Social indicators

Population	v	Employment	1/5
Population	v	Ethnic group	3
Population	v	Pollutant exposure	1/7
Employment	v	Ethnic group	1/5
Employment	v	Pollutant exposure	1
Ethnic group	v	Pollutant exposure	1/7

Economic indicators

Realization costs	N/A

Note 8: The indicators will be first pair-wise compared within the category (top left and above) and then a pair-wise comparison will be undertaken among the criteria (left).

7

1/3

Note 8: The indicators will be first pair-wise compared within the category (top left and above) and secondly a pair-wise comparison will be undertaken among the relevant criteria (left).

STEP 4: NORMALISING INDICATORS WEIGHTS

Note 9: The pair-wise comparison matrices are converted into numerical weights (wj) using a sequence of formulas as indicated below:

Estimation of the maximum eigenvalue λ_{max} *of the comparison matrix:* $\det(A-\lambda\times I)=0$

Determine the solution $\tilde{w}:(A-\lambda\times I)\times\tilde{w}=0$ *where* $\tilde{w}_i \geq 0$ *and finally, normalise the* $\tilde{w}$*:* $w_j=\frac{\tilde{w}_j}{\sum_{i=1}^{n}\tilde{w}_i}$

Normalised Weights for Air Quality **indicators**

O_3 concentration	0.05
PM_{10} concentration	0.51
$PM_{2.5}$ concentration	0.34
CO_2 emissions	0.10

Normalised Weights for Water Balance **indicators**

Evapotranspiration	0.16
Run-off	0.51
Filtration	0.33

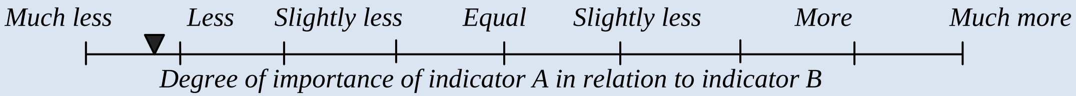
Normalised Weights for Social **indicators**

Population	0.13
Employment	0.21
Ethnic group	0.20
Pollutant exposure	0.46

Normalised Weights for **criteria**

Air quality	0.29
Social effects	0.44
Realization costs	0.14
Water Balance	0.13

Note 10: The user's manual will include a non-technical description of the pair-wise weighting approach. The DSS will allow the end user to prioritize the indicators. This can be done using a tick-box approach (as shown in the pink box in Step 3) or using a scale bar (scroll up and down a measured bar) as follows:



The DSS interface must have the flexibility to facilitate the comparison of each contrasting pair of indicators. It would be preferable that the DSS displays a window for each contrasting pair, but these may make the process more cumbersome for the end user. Different interface options should be explored to optimize usability and user-friendliness. In all cases, the results (both the relative values and the normalized weights) will be automatically calculated by the system. The relative values will be hidden from the user (to avoid confusion).

STEP 5: SCORING INDICATOR VALUES ACCORDING TO PERFORMANCE IN EACH ALTERNATIVE

Note 11: Indicator values will be normalized by scoring them according to their performance. The performance is set by how close the indicator value is to a reference basis. Where a comparable baseline exists alternatives can be contrasted against such do-nothing scenario. Where the baseline scenario is not comparable (e.g. where a forested area will be converted into an urban settlement as is the case in Helsinki) the alternatives will be compared against the simplest one to establish which one presents the most sustainable option.

The indicator scoring (Si), is based on the changes introduced by the planning alternative: $S_{xi} = \frac{I_{xi}}{I_{Ri}}$ *where x stands for any alternative and R for the "reference" alternative.*

Targets/thresholds will be used to establish the nature of the indicator's performance. Thresholds refer to the maximum value permitted according to European and national legislation (i.e. upper benchmark such as the 50 µg/m^3 *limit for* PM_{10}*). In some instances, targets will be applied referring to the minimum value the indicator should have (i.e. lower benchmark such as a minimum of 68% of employment as per example below). When the increase in value of an indicator means the decrease of the value of the alternative, the indicator score will be the inverse of the formula above described. (i.e. indicator R for the reference alternative is contrasted against indicator x of the alternative under consideration).*

ALTERNATIVE 1 (Reference Alternative)

Air Quality indicators	**Threshold/Target**	**Value**	**Score**
O_3 concentration (-)	120 µg/m^3 max.	30 µg/m^3	1
PM_{10} concentration (-)	50 µg/m^3 max.	80 µg/m^3	1
$PM_{2.5}$ concentration (-)	50 µg/m^3 max.	24 µg/m^3	1
CO_2 emissions (-)	355^M t max.	12,000t	1
Water Balance indicators			
Evapotranspiration (-)	0.6 m^3/m^2 max.	0.6 m^3/m^2	1
Run-off (-)	5 m^3/m^2 max.	3 m^3/m^2	1
Filtration (+)	5 m^3/m^2 min.	1.2 m^3/m^2	1
Socio-economic indicators			
Population (+)	2,500 p min.	2,100 p	1
Employment (+)	68 % min.	67 %	1
Other indicators			
Population / pollutants (-)	0 % max.	4 %	1
Ethnic group (+)	80 % min.	81 %	1
Realization costs	100,000 € max.	123,000€	1

ALTERNATIVE 2

Air Quality indicators	**Threshold/Target**	**Value**	**Score** (Inverted when -)
O_3 concentration (-)	120 µg/m^3 max.	40 µg/m^3	0.75
PM_{10} concentration (-)	50 µg/m^3 max.	87 µg/m^3	0.92
$PM_{2.5}$ concentration (-)	50 µg/m^3 max.	64 µg/m^3	0.38
CO_2 emissions (-)	355^M t max.	16,000t	0.75
Water Balance indicators			
Evapotranspiration (-)	0.6 m^3/m^2 max.	0.6 m^3/m^2	1
Run-off (-)	5 m^3/m^2 max.	5 m^3/m^2	0.60
Filtration (+)	5 m^3/m^2 min.	5 m^3/m^2	4.17
Socio-economic indicators			
Population (+)	2,500 p min.	2,500 p	1.19
Employment (+)	68 % min.	72 %	1.07
Other indicators			
Population / pollutants (-)	0 % max.	5 %	0.8
Ethnic group (+)	80 % min.	86 %	1.06
Realization costs	100,000 € max.	142,000€	0.87

STEP 6: SCORING CRITERIA COMBINING RELATIVE WEIGHTS AND VALUES OF INDICATORS and AGGREGATING CRITERIA TO OBTAIN TOTAL VALUES FOR EACH ALTERNATIVE

Note 12: The score of each criterium is calculated as a function of indicators scores and weights (it is possible that in some cases, indicators are equivalent to criteria - e.g. investment costs). Similarly, the total score for a given alternative can be calculated as a function of the criteria scores and weights, or of the indicators scores and weights and of the criteria weights.. This will be done applying the Cobb-Douglas function: $S_i = S_1^{\alpha 1} \cdot S_2^{\alpha 2} \cdot S_3^{\alpha 3} \cdot S_n^{\alpha n}$

The relative importance of each indicator (defined in step 3 and normalized $\sum \alpha_m = 1$ *in step 4) is combined with the ratios between indicators for the alternatives being compared (calculated in step 5). These values are aggregated using the Cobb-Douglas function above to obtain the relative performance (i.e. per criteria as illustrated in the boxes below) or the total performance of one alternative when compared against another. In the Helsinki example, the values are aggregated as follows for the alternative 2, compared to alternative 1:*

$$V_2 = (0.75^{0.05} \cdot 0.92^{0.51} \cdot 0.38^{0.34} \cdot 0.75^{0.10})^{0.29} \cdot (1.00^{0.16} \cdot 0.60^{0.51} \cdot 4.17^{0.33})^{0.13} \cdot 0(1.19^{0.13} \cdot 1.07^{0.21} \cdot 1.06^{0.20} \cdot 0.80^{0.46})^{0.44} \cdot 0.87^{0.14} = 0.87$$

Therefore, it can be concluded that alternative 2 represents a decrease of 0.87 in relation to alternative 1.

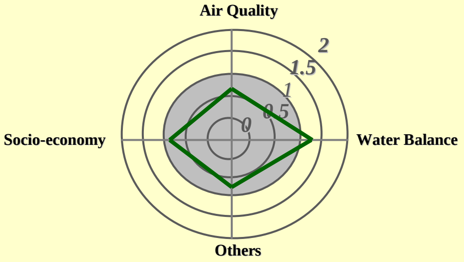
ALTERNATIVE 2

Air Quality: $S_{AQ} = 0.75^{0.05} \cdot 0.92^{0.51} \cdot 0.38^{0.34} \cdot 0.75^{0.10} = 0.66$

Water Balance: $S_{WB} = 1.00^{0.16} \cdot 0.60^{0.51} \cdot 4.17^{0.33} = 1.23$

Social: $S_S = 1.19^{0.13} \cdot 1.07^{0.21} \cdot 1.06^{0.20} \cdot 0.80^{0.46} = 0.95$

Economic: $S_E = 0.87$



Total = 0.87

Note 13: What one can conclude from these results is that alternative 2 is worse than alternative 1, in what concerns air quality, as well as social and economic aspects. Additional alternatives (n) could be compared against the "reference" alternative. The spider diagram above shows the performance of each criterion in alternative 2 against the reference values of alternative 1 (illustrated by the grey circle, referring to performance reference 1). The spider diagram is only valid for the alternatives being compared, as the performance of the reference alternative is considered the baseline (refer to example of spider diagram in step 7).

Note 14: This is only a tentative example. The indicators will have to be operationalised to ensure that there is no double-counting or overlap on selected indicators (e.g. energy consumption and CO_2 *emissions), as well as to ensure that contradictory indicators within the same criterion (e.g. population density and number of population exposed to pollutants) are adequately addressed.*

STEP 7: PRESENTING THE RESULTS

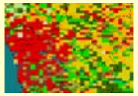
Note 15: It is considered that the results should be presented in a comprehensive manner, including both spatial and non-spatial information. Moreover, the provision of a single overall value for each alternative, based on the composite of the underlying criteria and indicators, facilitates comparison between the alternatives but dismissed the details (i.e. the performance of the relevant indicators for each alternative and their relative significance).

In the example above, alternative 2 performs overall slightly worse than alternative 1. However, water balance performs better in alternative 2 than in alternative 1. Considering the weight of water balance being the lowest (refer to step 4), it could be concluded that alternative 1 is the best solution. However, the end-user may want at this point increase the weight of water balance considerations and assess any variation in results. This will help him/her consider the relevance of the different criteria and the consequent effects on the "best" alternative.

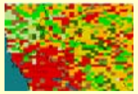
Therefore, it is considered crucial that the end-user has access to all the relevant information so he/she can compare total results with partial ones and with changing weights. The DSS should inform/support decision-making (i.e. not make decisions). It is proposed that the DSS provides the results in an "escalated" manner, compiling the results from the previous stages and providing a comprehensive summary for each of the alternatives by including: a) GIS maps available for the spatial-indicators; b) indicator values for the non-spatial indicators; c) spider diagram combining the indicator results for each criterion; and d) the total assessment value for the alternative.

ALTERNATIVE 1

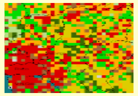
Air Quality



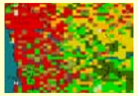
O_3 ~30 µg/m^3



PM_{10} ~80 µg/m^3

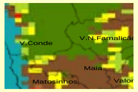


$PM_{2.5}$ ~24 µg/m^3

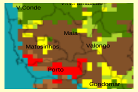


CO_2 ~12,000t

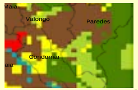
Water Balance



Evapotr.~0.6 m^3/m^2



Run-off.~3 m^3/m^2



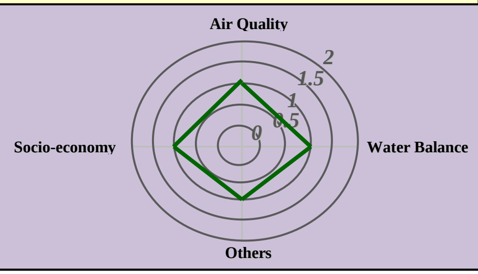
Filtration~1.2 m^3/m^2

Socio-Economy

Population = **2,100 people**
Employment = **57% population**

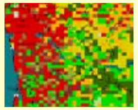
Others

Population exposure pollutants = **4%**
Ethnic groups = **81 % finish**
Realization costs = **123,000€**

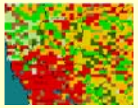


ALTERNATIVE 2

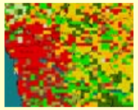
Air Quality



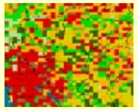
O_3 ~40 µg/m^3



PM_{10} ~87 µg/m^3

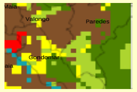


$PM_{2.5}$ ~64 µg/m^3

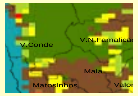


CO_2 ~16,000t

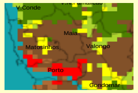
Water Balance



Evapotr.~0.4 m^3/m^2



Run-off~4 m^3/m^2



Filtration~5 m^3/m^2

Socio-Economy

Population = **2,500 people**
Employment = **67% population**

Others

Population exp. pollutants = **5%**
Ethnic groups = **86 % finish**
Realization costs = **142,000€**