



Web-based GIS for collaborative planning and public participation: An application to the strategic planning of wind farm sites

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ABSTRACT

Spatial planning typically involves multiple stakeholders. To any specific planning problem, stakeholders often bring different levels of knowledge about the components of the problem and make assumptions, reflecting their individual experiences, that yield conflicting views about desirable planning outcomes. Consequently, stakeholders need to learn about the likely outcomes that result from their stated preferences; this learning can be supported through enhanced access to information, increased public participation in spatial decision-making and support for distributed collaboration amongst planners, stakeholders and the public. This paper presents a conceptual system framework for web-based GIS that supports public participation in collaborative planning. The framework combines an information area, a Multi-Criteria Spatial Decision Support System (MC-SDSS) and an argumentation map to support distributed and asynchronous collaboration in spatial planning. After analysing the novel aspects of this framework, the paper describes its implementation, as a proof of concept, in a system for Web-based Participatory Wind Energy Planning (WePWEPE). Details are provided on the specific implementation of each of WePWEPE's four tiers, including technical and structural aspects. Throughout the paper, particular emphasis is placed on the need to support user learning throughout the planning process.

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1. Introduction

Spatial planning is a complex enterprise in which the planner (or decision-maker) often is not fully aware of the range of factors involved or the implications of each. Sometimes, it is not until after generating a proposed solution that unforeseen consequences become perceptible or evident and that a reconsideration of the process that generated this solution becomes necessary. From this point of view, spatial planning is an analytical and cyclical process. Due to the number of factors involved, the increasing segmentation of areas of expertise and the current trend to democratise planning and decision-making, spatial planning cannot be the enterprise of a sole person. Instead, it must result from a collaborative process, whereby a range of stakeholders (experts and lay-persons) are able to voice their concerns and work on a compromise solution. Only

through such a process can the final outcome be accepted by the majority.

The spatial planning support systems literature contains numerous references to tools that have been specifically designed to support either the analytical side of spatial planning or the communicative side. During the last decade, efforts have been made to develop an integrative tool, capable of dealing with both sides of spatial planning within a unique framework (Jankowski et al., 1997; Voss et al., 2004). The definition of such a framework assumes critical importance because the Internet appears to provide the primary mechanism for granting interested stakeholders the opportunity to participate in the planning process using asynchronous and distributed collaboration. Notwithstanding the constraints to participation in spatial planning that result from social groups' differential access to computers (see Carver et al., 2001; Kingston, 2002; Davison and Cotten, 2003), the continuous increase in Internet adoption makes it a suitable medium for collaboration. Moreover, the sophistication and widespread use of generalised devices, such as mobile phones, and the advent of interactive digital television, particularly when Internet-enabled, suggest that an integrative framework may not have to employ traditional computers and user interfaces.

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This paper describes a web-based application that integrates in a unique and cohesive framework two types of tools. Individually, each tool – a Multi-Criteria Spatial Decision Support System (MC-SDSS) and an argumentation map – is accepted as being capable of tackling different facets of the planning process. By combining the two tools in a single, coherent framework it is possible to create an innovative system that provides a new way of dealing with spatial planning problems.

This paper is divided into six sections. Section 2 provides background information: we examine the process of spatial planning and argue that it is essentially iterative and collaborative; then review what spatial decision support systems (SDSS) are, looking specifically into MC-SDSSs and, finally, consider the need for, and the tools available to support, spatially referenced communication in spatial planning and decision-making processes. These elements are then woven together in Section 3, in which we set out a proposed framework. Section 4 contains an overview of the onshore wind farm siting planning problem selected as a case study for an implementation of the proposed framework. The implemented system, described in Section 5, enables users to participate in the planning process at a time and location of their choice, i.e., asynchronous collaboration. Finally, Section 6 summarises the paper's content and presents some concluding comments.

2. Background

2.1. Spatial planning: an iterative and collaborative process

Planning problems are complex in essence: they entail many dimensions (including economical, social and environmental), a definitive problem statement often is not available beforehand and the consequences of a particular decision frequently are not obvious at the outset (Rittel and Weber, 1973). Insights into what the problem is and how it can be solved are commonly gained incrementally during successive problem exploration cycles (Hendriks and Vriens, 2000; Holz et al., 2006). Thus, the generation and evaluation of alternatives are important steps in the planning process.

From a different perspective, spatial planning cannot be an individual task. The multiple dimensions of a spatial problem require different areas of expertise to address them. In addition, the consequences of a planning decision call for public involvement in the planning process: citizens will be those who will have to live with an implemented solution. Thus, both experts and lay stakeholders must collaborate, jointly seeking a solution to their geographical problem. Hence communication is an essential stage in the planning process; only through communication is it possible to find a solution that reconciles the conflicting objectives that result from different people's opinions.

Information also plays a central role in the planning process. Typically, stakeholders that engage in exploring or debating a decision problem have background knowledge on the problem. This knowledge is gained through experience (local, empirical knowledge) or through reading scientific-based sources or other official documents. Both types of knowledge are important in decision-making (McCall, 2003). Whilst initial knowledge may or may not prove to be correct, exploring and debating the problem reveals more information and, frequently, the need to look for extra information to support or challenge a view. Fig. 1 depicts this conception of the planning process.

Five stages are identified: generate alternatives, evaluate alternatives, discuss plan, seek background information and articulate/voice views and concerns. Members of the public and experts alike typically experiment during these five stages while participating in and collaborating on a decision problem. Ideally, users should pass through all five stages although no particular

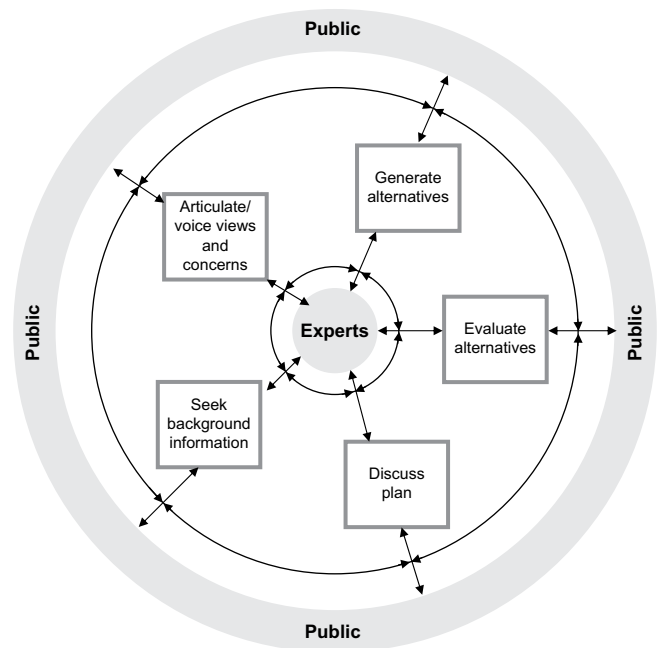


Fig. 1. Schematic view of the spatial planning process.

order exists to experimentation during these stages. Some people prefer to begin by discussing the problem as a precursor to crystallising their preferences; others prefer to read information on the topic and, after having developed a position, state and argue for their opinions, or test and evaluate the consequences of their preferences. The straight arrows in Fig. 1 depict the multiple ways in which experts and lay-persons can engage in the planning process; the circular arrows depict the iterative and interactive nature in which people engage in this planning process. Contrary to early views on planning (MacLoughlin, 1969), very rarely does the planning process develop linearly; instead, steps forward and backward are often required to adjust the solution *vis-à-vis* unforeseen consequences.

2.2. Spatial decision support systems

Spatial Decision Support Systems (SDSS) are explicitly designed to help decision-makers solve complex and semi-structured spatial problems (Densham, 1991). SDSS are rooted in the Decision Support Systems (DSS) literature and emerged from there in the mid 1980s (Armstrong et al., 1986), when technological advances enabled computers to process spatial information. Despite their roots, SDSS can easily be contrasted with DSS. The focus of SDSS is placed on spatial problems and is reflected in the functionality associated with such systems: the acquisition and management of spatial data; the representation of geographical objects and their spatial relations; the performance of spatial analysis; and the creation of map-based outputs (Densham, 1991). The spatial component of an SDSS is typically borrowed from a Geographical Information System (GIS), which is integrated into the SDSS as one of its components. A GIS is an information system used to input, store, retrieve, manipulate, analyse and output geographically referenced data (Maguire, 1991). While GISs are often used to support decision-making in planning and land use, they are distinct from SDSS because they lack analytical modelling capabilities and do not support multiple decision-making strategies (Densham, 1991). Hendriks and Vriens (2000, p. 86) explain this difference by stating that “GIS look at data, whereas SDSS look at problem situations”.

One particular type of SDSS focuses on Multi-Criteria Evaluation (MCE). MCE techniques have been developed to help decision-makers explore and solve problems that require trade-offs between multiple and conflicting objectives (Hwang and Yoon, 1981; Malczewski, 1999; Roy, 1996). To support planning processes, MCE techniques have been embedded into SDSS, yielding Multi-Criteria SDSS (MC-SDSS) (Ascough et al., 2002; Carver et al., 1996; Jankowski, 1995; Malczewski, 1999; Thill, 1999). The literature contains a wealth of references to MC-SDSS developments and applications in a variety of domains, including water resource management (Mustajoki et al., 2006), solid waste management (Rubenstein-Montano and Zandi, 2000) and habitat site management (Jankowski et al., 1997). A detailed list of operational MC-SDSS can be found in Malczewski (1999, pp. 336,337).

In the planning process, MC-SDSSs assist their users in articulating decision objectives and evaluation criteria, forming and articulating preferences, finding feasible decision alternatives and evaluating these alternatives so that better decision options can be identified. MC-SDSSs are thus capable of supporting three stages in Fig. 1 – “Articulate/voice views and concerns”, “Generate alternatives” and “Evaluate alternatives”.

Originally designed for single users (the “decision-maker”), MC-SDSSs were soon proposed for group use to accommodate the collaborative dimension of spatial planning and decision-making. Much work has been developed in the area of group MC-SDSS (Carver et al., 1997; Pereira and Quintana, 2002; Jankowski and Nyerges, 2001; Jankowski et al., 1997; Munda, 2004). The vast majority of group MC-SDSS are used in a face-to-face environment, although some Internet-based developments exist, including Carver and his colleagues’ Open Spatial Decision Making (Carver et al., 1996, 2002a,b), Web-HIPRE developed by the Systems Analysis Laboratory at Helsinki University of Technology (Mustajoki et al., 2004) and the map-centred exploratory tool, CommonGIS, developed by the German Fraunhofer Institut (Andrienko and Andrienko, 2001; Andrienko et al., 2003; Jankowski et al., 2001). Although these systems help to identify individual stakeholder’s preferences, which can be used as a basis for consensus seeking or research on a compromise solution, they do not support discussion amongst stakeholders in an asynchronous and distributed environment.

2.3. Spatially referenced communication

Communication plays an important role in spatial planning and decision-making (Healey, 1997). Collaborating stakeholders often refer verbally to geographical objects, for example “*the blue building next to the library...*”. Thus, collaboration in spatial planning requires two things: a map (i.e., the plan under discussion) and a means of communication. Traditionally, collaboration was carried out synchronously and in the same location – as in the case of a public meeting.

The advance of electronic communication opened up new ways for collaboration. An elementary form of asynchronous and distributed collaboration is to exchange maps and text files via email or a shared area on a computer server. Although feasible for a small group of participants (collaborators), this solution is impractical with larger groups due to the limitation of access to shared resources such as the server. A widely used alternative, especially in situations where public engagement is sought, is to create a website where the map (i.e., the plan) is published and participants submit their comments and concerns by email or by filling-in forms on the website. Conceptually, this solution mimics the traditional process of public consultation, whereby a plan is made available in public spaces, such as libraries, and people write letters to make their opinions known. However, a website offers the advantage of avoiding special visits to public facilities and also removes time

constraints but requires the use of computers in order to participate in the process. Whether comments are submitted by letter or electronically, comments typically are loosely attached to map features. Where authors are not specific in their comments, misunderstandings may well arise. For instance, in reference to the comment “*the building next to the library...*” the following question might arise: “*Does the author of this comment mean the building to the right of the library or the one just opposite?*”

Some interesting developments specifically link maps with written contributions. Al-Kodmany (1999) describes a public participation exercise, named Distant Participation for Pilsen Planning (DPPP), in which citizens could select a cell on a transparent grid overlay of a map of Chicago’s Pilsen neighbourhood and state their reasons for liking or disliking that area of the community. In a later stage, contributions referring to the same cell were grouped and, by clicking on a cell, participants could read others’ comments on that area. Kingston et al. (2000) describe a system with similar functionalities – Virtual Slaithwaite, which was used for planning a village in Yorkshire. One feature of Virtual Slaithwaite is that comments are attached to specific map features, such as buildings, open spaces, rivers or canals, instead of the centroid of a grid cell. A more sophisticated application is described by Ramasubramanian and Quinn (2004). Online sketch tools enable citizens to select an area on a map by drawing a line, a point or a rectangle shape and attaching written comments to it that are saved in a database. Previous users’ comments are available for consultation, an important feature that triggers critical thought, might help avoid duplication of inputs and makes possible the extension or elaboration of existing contributions.

Rinner (1998) first suggested a tool to support structured, geo-referenced debates. His idea was to integrate a discussion forum (named Zeno, now called Dito) and a thematic mapping tool (Descartes then, now CommonGIS), treating discussion contributions as individual objects, with well-defined relations amongst them, and links to individual map elements. Rinner (1999) extended his idea to an object-orientated model for geo-referenced argumentation, which he called an argumentation map (“argu-map”) and later updated (Rinner, 2005). Voss et al. (2004) describe the accomplishments made, and the challenges overcome, in integrating Dito and CommonGIS. Other researchers, such as Horita (2000a), have a similar focus but have followed different routes in system design and implementation.

Working on Rinner’s conceptual model, Keßler (2004) and Keßler et al. (2005a) present a prototype implementation that combines a thread-based forum, comparable to a Usenet newsgroup, with a map display. Users browse the forum and the map separately. In the forum users can read individual messages, respond to messages or create new discussion threads. Users can zoom in and out on the map and change the current extent; they can select spatial objects, and/or create their own graphical reference objects, and add them as references to their discussion contributions. In addition, the prototype provides some functions for querying and analysing the geo-referenced debate. For instance, when users select a discussion contribution in the forum, all reference objects on the map are highlighted. Similarly, selecting an object of interest on the map highlights all associated contributions in the forum. Users can also search the forum by keywords and identify potential areas of conflict – those map objects with the greatest number of written comments.

Tang et al. (2005) and Tang (2006) describe a conceptually similar prototype. Many functionalities are similar to Keßler’s prototype but it offers two original features: users can consult and explore electronic documents (e.g., PDF files or video clips) made available through the user interface; and a function informs participants about possible spatially-related issues discussed under a different topic. Technology-wise, the two prototypes are very

different. While Keßler's is based on a Java Applet, requiring a Java-enabled browser or a Java plug-in, Tang's prototype makes use of technology (the popular phpBB bulletin board and the webGIS server ArcIMS) that does not impose such a requirement. Another difference is that Keßler's prototype provides greater flexibility in manipulating spatial references associated with previously submitted contributions: while he treats each spatial reference associated with a contribution as an individual object, Tang treats all such spatial references as a single "spatial context". Thus, a participant must add the whole "spatial context" rather than selecting and adding a single spatial reference to their contribution.

With reference to Fig. 1, an argumap can support the stages "Articulate/voice views and concerns" and "Discuss plan".

3. The proposed GIS-based collaborative framework

MC-SDSSs support decision research processes for complex spatial problems by providing a framework where users can explore and formalise their problems and learn about their preferences with respect to decision-making by iteratively generating and evaluating alternative solutions. The formalisation of solution strategies, through the clarification of the weights assigned to decision criteria, provides a framework for discussion. However, MC-SDSSs lack the capacity to support discussion (as noted by Gottsegen, 1998): they neither clarify the reasons behind stated preferences nor provide a way of assessing the interests and concerns of stakeholders. Argumentation maps on the other hand, are platforms specifically designed to support geo-referenced discussion – but are limited in their ability to show different alternatives. Providing an Internet-based system that integrates these two tools would yield an environment for asynchronous and distributed collaboration in spatial planning that, potentially, overcomes the individual shortcomings of both tools.

We propose the conceptual framework depicted in Fig. 2. Fundamentally, it consists of an information area, an MC-SDSS and a map-centred communication tool (argumentation map) integrated in a cohesive manner, and accessible through a single user interface via the Internet. The purpose of the information area is to provide background information on the spatial problem being addressed and references for further reading.

The same conceptual framework can be derived from the point of view of an individual who wants to be involved in the planning process. It is very unlikely for a person to hold, at the outset, a comprehensive view and in-depth knowledge of all aspects of a planning problem and their respective implications. Thus, participating in the planning process is a learning experience, and

should be considered from the point of view of a learning theory (Hamilton et al., 2001). Many learning theories, including George Kelly's personal construct psychology (Kelly, 1955), argue that individuals learn by making sense of personal experiences and by interacting with other individuals. A planning support system designed to enhance learning should thus help its users to make sense of their own experiences and tacit knowledge and enable them further to develop personal knowledge through easy access to different information sources and interaction with other individuals who are stakeholders in the decision-making process. Such a design is compatible with what we are proposing here: the MC-SDSS component enables users to explore the problem and iteratively explore alternative solutions; the argumap component enables sharing of tacit, local and scientific knowledge among users; and the information area provides some introductory information and facilitates access to other resources.

In a later section we present an implementation of the proposed conceptual framework. In Section 4, however, we introduce our case study application.

4. Wind farm siting: a selected application

Two aspects of onshore wind farm siting make it an appealing case study. Firstly, wind farm siting is a controversial issue, due to both the number of impacts associated with wind farms (for a comprehensive review see Gipe, 1995) and the mismatch between these impacts, which are relatively localised and impinge on a few particular spheres, and the largely public benefits of wind energy. This has led many to advocate collaboration in the planning of, and decision-making surrounding, wind farms (Beddoe and Chamberlin, 2003). Secondly, it is an issue where misleading information is published in the media (see, for instance, BWEA, 2006) and, thus, stakeholders have incomplete knowledge of the issues involved and of their own preferences for characteristics of a solution.

There are two driving forces behind wind energy development: the threat of climate change and the need for countries to secure their own energy production (Warren et al., 2005). A significant part of most countries' energy production comes from burning fossil fuels. This process releases carbon dioxide (CO₂), contributing to the greenhouse effect and global warming. Thus, governments are under pressure to promote and encourage new forms of energy production with zero CO₂ emissions (Department of Trade and Industry, 2003, 2006; European Parliament and the Council, 2001b; United Nations, 1997). Amongst the various endogenous and clean energy sources, wind is arguably the most economically viable today (Sustainable Development Commission, 2005). Energy security is important in a country's internal context: most fossil fuel is imported and represents a dependency on the exterior in a strategic area; moreover, such imports typically involve fluctuating, externally driven prices.

4.1. Local versus strategic planning

The UK government's regional strategic approach to planning and targets for renewable energy (Office of the Deputy Prime Minister, 2004a) applies only at the policy level. In practice, onshore renewable energy planning, and particularly wind energy planning, is driven by developers: they choose a suitable location for their project, develop a proposal and, finally, seek planning consent from the local planning authority. To help obviate likely local resistance to such a project, developers are encouraged to engage in early dialogue and consultation with stakeholders and local communities (BWEA, 1994; Regen, 2004). Hence, despite a policy-level strategic planning approach, in practice, wind energy planning happens at the local level.

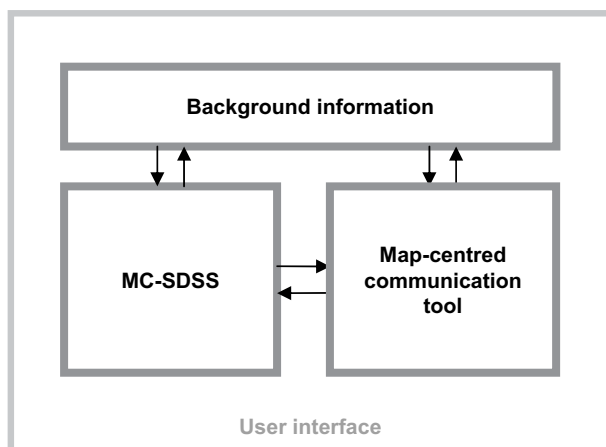


Fig. 2. Proposed conceptual framework for collaborative spatial planning.

Other nations follow a different process. The Danish government, for instance, requires local governments to provide space for wind turbines. Regional plans set the framework for municipalities' plans: municipalities can initiate planning for wind turbines only in those areas designated for such use in the regional plan and developers still require planning consent (or a building permit) from municipalities in designated areas (Centre for Sustainable Energy and Garrad Hassan, 2005). A similar strategy was adopted by National Assembly for Wales (NAW) during their elaboration of the Technical Advice Note (TAN) 8: Renewable Energy (National Assembly for Wales, 2005). Acknowledging that country level is the most appropriate scale at which to identify areas for onshore wind energy development, the NAW defined seven Strategic Search Areas where large scale (over 25 MW) onshore wind energy developments should be concentrated.

The English wind energy industry's stance on local versus strategic planning of wind energy favours the local approach. It argues that finding an adequate location for a wind farm requires a detailed site evaluation, which is not compatible with the type and scale of the mostly desktop studies that are conducted at a strategic planning level. In contrast, the study described in this paper evaluates a plan at a strategic level and thereby explicitly considers predictable wind farm impacts, rather than adopting a case-by-case approach to planning applications.

There is value in studying the impacts of wind farms at a more strategic level because a regional, or sub-regional, analysis can raise issues of cumulative impacts and can also help to manage expectations: communities in areas with high wind farm potential will be aware of this before any local planning applications are submitted. Strategic planning also directs developers and reduces uncertainty about the evaluation of their projects. A further argument focuses on conducting environmental assessments for plans containing wind energy infrastructures. European Directive 2001/42/EC (European Parliament and the Council, 2001a), transposed to UK legislation in 2004, requires environmental assessment where there are likely to be significant environmental effects. In many situations, proposed wind farms would have had a significant effect on the environment (people, local business, landscape and wildlife)

and their planning applications refused. Strategic assessment would allow this identification to occur at an early stage.

4.2. Problem statement and the case study area

The strategic sub-regional planning of wind farm locations is the problem chosen for our implementation of the proposed conceptual framework. In England, strategic sub-regional planning used to be a county council responsibility. With reform of the planning system in 2004 (Office of the Deputy Prime Minister, 2004b), county councils lost some of their responsibilities but kept that of strategic planning for minerals and waste. However, the county appears to offer a useful, and natural, unit for planning. Whilst county councils enjoy a level of detachment impossible for local planning authorities, enabling them to take an integrated view of their area of jurisdiction, at the same time, such councils, unlike regional authorities, are close enough to their citizens to be able to engage them in the planning process. Furthermore, Beddoe and Chamberlin (2003) suggest that county councils are ideally placed to determine medium-size wind energy schemes because they are more distant from the public opposition to which district councils are subject.

The number of geographical information layers that are needed to estimate the likely impacts of wind farms, and the detail required to assess impacts *vis-à-vis* the available resources to perform these tasks (namely, human and computational), forced a contraction of the area used for the case study. Fig. 3 depicts the 40 by 40 km square within Norfolk (in East Anglia) used for the case study. Simão and Haklay (2005) describe the rationale behind, and the three-stage procedure applied to, selecting this area.

5. An implementation of the conceptual framework

With the study area selected, the conceptual framework was implemented to enable stakeholders (experts and the public) to collaborate in sub-regional strategic planning of wind farm locations. The implementation was called WePWEP – Web-based



Fig. 3. Location of the case study area used in developing the prototype.

Participatory Wind Energy Planning – and specifically supports asynchronous collaboration.

5.1. Key design considerations

Each module of the proposed conceptual framework is implemented as a tier in the prototype, i.e., an independent system component. A fourth tier was conceived to facilitate evaluating the prototype. Despite the four tiers, the system must be a holistic and seamless environment. For that, a cross-tier navigation bar and visually consistent web pages across all tiers are key design elements.

The prototype's target users are the general public, including people with little experience of the Internet. Thus, the user interface must be designed for ease of use and in compliance with web usability principles. For example, user interface elements involved in a particular task should be integrated; interface elements should have a traditional appearance to foster user familiarity with the system/tool; the number of tools available should be kept to a minimum; and tooltips and labels should be used to assist/guide the users.

An analysis of each tier's functional requirements yielded a series of more specific design considerations. For a detailed discussion of these requirements/considerations, please refer to Simão (in press). In the remainder of this paper, these requirements will be alluded to during the description of the corresponding tier and/or will be reflected in the snapshots of the system shown.

5.2. System description

5.2.1. First tier – information area

WePWEP's first tier is essentially an information area; structurally, it is divided into four sections. Three sections comprise of a single web page: the home page introduces the initiative and briefly explains what can be done within the system; the second page describes the structure of the website and how to use it; and the third page is a registration form (extended to a second page to capture the user's profile). User profiles are used to characterise the types of users interested in the system, to investigate general assumptions such as the NIMBY (Not In My Back Yard) syndrome frequently associated with wind energy, and to learn about users' proficiency with computers, Internet usage and reading and understanding maps.

The fourth section is the actual information area and contains multiple pages. Several topics related to wind energy, wind farm siting and the planning process are covered here. In addition, information on wind energy projects proposed for Norfolk (currently operating, approved but still in the pipeline and refused) has been included. This section is structured around a web page that works as a "portal", giving access to the web pages listed in Table 1. Although the "portal" page is part of the WePWEP main menu, the web pages in Table 1 are organised in a different menu, which only becomes visible when the user enters the portal.

The implementation requirements for this tier mostly relate to the user interface and navigation within the tier. To improve readability, information is structured and presented in a way that allows the user to scan it easily. An informative and neutral writing style was adopted and potentially controversial sentences are backed up by credible sources, to avoid the reader leaving the website with the impression that distorted messages are being sent. Basic rules for Internet navigation were followed: all pages link to the home page, a "breadcrumbs trail" provides user location information and shortcut links to previous categories and different and standard colours are used to differentiate between visited and unvisited hypertext links (Nielsen, 2000; Timberlake, 2000).

Table 1

Topics covered within WePWEP's information area

Wind energy	Wind farm siting	Wind energy in Norfolk
Facts and figures	A feasible site	Wind farm projects in the county of Norfolk
Why wind energy?	The planning application process	Ecotech wind farm: planning application process
The debate around wind energy	Public involvement in wind farm planning	Swaffham II wind farm: planning application process
Public opinion on wind energy	Learn more on these issues	Learn more on these issues
Learn more on these issues		

5.2.2. Second tier – MC-SDSS

The second tier corresponds to the MC-SDSS. Here users can explore the problem of wind farm siting and express their views on where wind farms can, should and should not be located. The approach adopted here is to provide users with information about which sites are technically feasible for a wind farm and to ask their opinions on which locations: (a) they would *recommend* for wind farms; (b) they would deem *acceptable* as wind farm locations, even though they do not recommend the site for that purpose; and (c) they would oppose (view as *non-acceptable*) for an infrastructure proposal.

If three categories are pre-defined (*recommended*, *acceptable* and *non-acceptable sites* for wind farms), technically the problem becomes a multi-criteria sorting problem. Such problems consist of assigning alternatives (here feasible sites) to pre-existing categories (Roy, 1996). The assignment depends on the category definitions, the performances of the alternatives on a set of decision criteria, and the importance (weights) of these decision criteria for decision-making. A system of 19 decision criteria is used to assign feasible sites to pre-defined categories. Fundamentally, these criteria estimate both the impacts that a wind farm, at a specific site, would induce in the neighbourhood and those elements that determine the suitability of a particular site for a wind farm, including the annual average wind speed at the site and its proximity to large settlements.

Within the case study area, 117 sites were identified as feasible locations for wind farms. In each of these sites, hypothetical wind turbines were located to estimate the site's performance on each of the 19 decision criteria. Detailed information on the methodology and criteria used to identify the feasible sites, the procedures used to estimate performance on the 19 decision criteria, and other information used to carry out the multi-criteria evaluation is available in Simão (in press).

An important user input is to set the relative importance of the decision criteria that determines the assignment of feasible sites to categories. In accordance with Cohon (1978) and Jankowski et al. (2001), 19 decision criteria were judged too many for a user to evaluate because this represents a highly complex cognitive task. Thus, the decision criteria are grouped into five meaningful domains and, within each, decision criteria are combined using default weights. Each of the five domains thus becomes a new decision criterion with the original decision criteria becoming factors upon which each new decision criterion depends. Consequently, users must be provided with the capability to access and modify the default set of weights.

Within the MC-SDSS, users must be able to generate and evaluate as many solutions (classifications of feasible sites) as needed until they obtain a solution that matches their ideas. The user should be able to submit this solution as her/his contribution to the problem analysis. Carver and his colleagues' Open Spatial Decision Making (OSDM) (Carver et al., 1996; Carver et al., 2002a,b) offers these functionalities. However, three aspects of their system fall

short of the requirements envisaged for our prototype. First and foremost, their map viewer component is too static: users cannot manipulate maps, such as zooming into particular areas of interest. Because of the NIMBY syndrome associated to wind energy projects, typically reflected on local communities' opposition to such projects, the prototype must enable users to explore estimated impacts of wind farms at a local scale. This capability can also be justified from another point of view. Typically, before "adopting" a system, users experiment with it to assess its reliability. One way of gaining users' confidence is by enabling them to zoom into known areas and, when they find the expected information (e.g., recognise some landmarks), the system gains credibility. Secondly, OSDM is based on raster datasets. Since the purpose of our prototype is to classify feasible sites (small units of land) in categories, vector data are more convenient. Finally, the method employed by OSDM to elicit weights for the decision criteria map is not suitable because users are asked to weight criteria without any basis for reference. Besides, OSDM does not show the user the precise value of the weight that is being attributed to a criterion on the slider bars, making it difficult for users to rationalise relationships (proportionality or trade-offs) between decision criteria.

Structurally, this tier is a sequence of eight web pages. The first page introduces the task that users are to carry out. The second page maps the feasible sites and introduces the five decision criteria that the users must weight to classify the feasible sites. By

following hyperlinks, users can access detailed information on how these sites were selected and on the decision criteria: maps depicting the performance of each feasible site on the decision criteria (i.e., the impact that the imaginary wind farm sites would generate on each criterion); the factors used to estimate these impacts; the indicator used to estimate the impact on each factor; and the assumptions underlying each estimate. Fig. 4 shows this web page. If the user is logged in, this web page enables them to select the criterion, out of the five available, that they consider the most important in deciding whether or not a feasible site is suitable for a wind farm. The selected criterion is given 100 points; the four remaining criteria are weighted with respect to this one. This technique is a simplification of the ratio estimation procedure described in Malczewski (1999, p. 181) with reference to Easton (1973). The weighting procedure is explained to the user in the next web page, which also shows information on the criterion selected as the most important. Users can change the most important criterion at any time, either by accessing this web page, or later on when refining their overall classification. Because changing the most important criteria changes the reference basis, the system forces the user to produce new weights for the four remaining criteria.

The following four pages are all similar: each of them provides information on one of the decision criteria and asks users to weight it with respect to their most important criterion. A slider bar,

Fig. 4. Web page showing the feasible sites for wind farms and the criteria that need to be considered when classifying them. Links (shown in lighter colour) enable users to access detailed information on each topic. Selection of the most important decision criterion is only possible when the user is logged in.

ranging from 0 to 100 with an associated text field that displays the exact value, is provided for this purpose. Moreover, the text field is editable, so users can type in criterion weights directly.

After weighting all the decision criteria, a final page displays the classification of feasible sites into pre-defined categories – pressing the “Submit weights” button immediately updates the classification map. The resulting classification can be refined using this web page, see Fig. 5. Rather than providing this single page to weight all five criteria, the previous sequence of pages helps users to explore each criterion individually, comparing it against the most important one at their own pace: when users arrive at this page, they are more aware of the task that they are involved in and, arguably, are better able to judge the relationships amongst the five criteria.

All web pages within this tier have a text form inviting users to comment on the set of decision criteria selected for a classification; the methodology used to estimate sites’ performance on the decision criteria; and the method used to create the classification. These comments help in understanding users’ perceptions of how the problem has been structured for them. Indeed, MC-SDSSs characteristically are used to help users to structure their problem. However, to simplify the users’ task, this tier assumes a particular structure for the problem – naturally, this is only one possible formulation. Although users may feel that some decision criteria are not relevant, and hence give them zero weight, they cannot add

new decision criteria that they deem important. Similarly, users might have different opinions on how performance on decision criteria should be estimated. Collecting comments on these topics will facilitate improving the current prototype.

The grouping of the decision criterion into five classes imposed a further requirement: enabling users to access and change the default weights used to combine the factors. This requirement is met by five other web pages within this tier, each accessible from the pages of the pertinent overall decision criteria. Hyperlinks on text, such as “overall visual impact”, provide access to these web pages – as depicted in Fig. 6 via the hyperlink “overall visual impact”.

5.2.3. Third tier – map-centred communication tool

The aim of this tier is twofold: first, to provide feedback to users and, second, to support communication on, and discussion surrounding, wind farm siting (Simão and Densham, 2004). The proposed conceptual framework suggests that this tier consists of a map-centred communication tool. An argumentation map is seen as a necessary and sufficient tool around which to build this tier. In particular, Keßler’s argumap prototype (Keßler, 2004; Keßler et al., 2005a) meets most of the requirements for this tier. Firstly, it integrates a map and a discussion forum in a single user interface. Secondly, the tree structure of the discussion forum and the easily

The screenshot displays a web application interface for wind farm siting. The main content area is titled "Classification - refinement" and features a central map showing the coastal region of East Angles, including areas like Hunstanton, Wells-next-the-Sea, Fakenham, Dereham, Swaffham, and Kings Lynn. The map is overlaid with colored markers representing different site classifications: green for "Recommended", yellow for "Acceptable", and red for "Non-acceptable". To the left of the map, there are five sliders for adjusting the weights of different decision criteria: "Impact on landscape" (set to 100), "Visual impact" (0), "Local impact" (0), "Impact on ecology" (0), and "Site characteristics" (96). A "Submit weights" button is located below these sliders. To the right of the map, there is a legend for "Feasible sites" with checkboxes for "Considered wind turbine", "Wind farm typology" (Single, Small), "Feasible sites" (Recommended, Acceptable, Non-acceptable), "Case study area", "Main rivers", "Counties", and "Large settlements". Below the legend is a smaller map showing the region's location. At the bottom of the page, there is a text box for comments and a "Send comments" button. The page footer includes logos for UCL, CASA, and FCT, along with a "Contact us" link and the date "Last updated: Sunday, March 22 2006".

Fig. 5. Web page that displays the feasible sites classified with users’ submitted weights for the five decision criteria. Users can refine their classification by changing and re-submitting sets of weights, which updates the map. Hyperlinks provide access to further information.

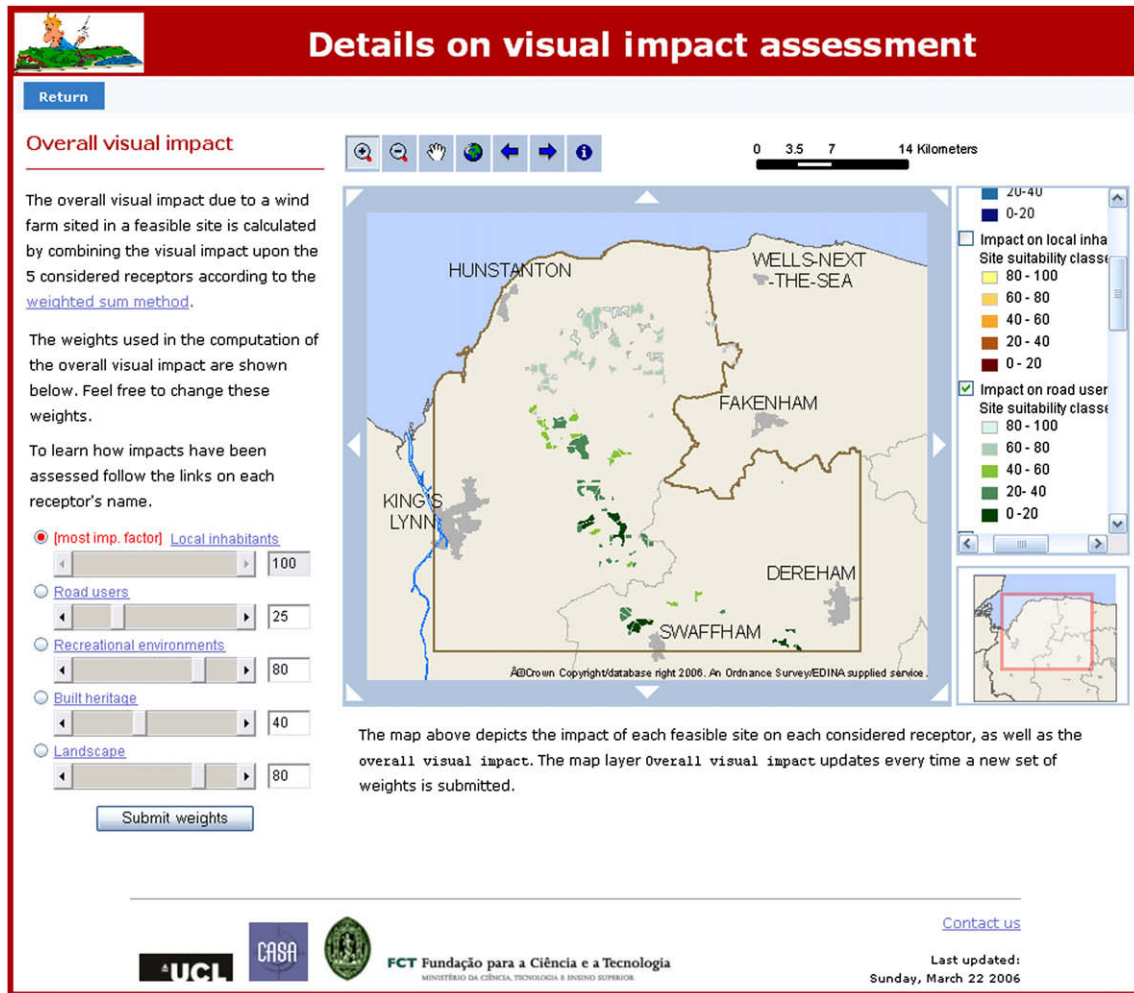


Fig. 6. Example of a web page that enables users to change the default weights underlying the overall decision criteria. Hyperlinks enable users to access further information on the topic.

understood types of contribution (question, suggestion, neutral comment and pro or contra argument) make possible some type of discussion structuring without imposing undue loads on users. Unlike a true argumentation structure, such as one based on Toulmin logic (Toulmin, 1958), Keßler's discussion forum approach does not force users to dissect their contributions on each issue addressed and provide a logical chain of arguments accompanied by the grounds underlying each one. This is an important point because structuring arguments requires highly developed skills and experience (Tweed, 1998), and Horita (2000b) reports that participants have been unable to code their arguments according to an introduced argumentation logic. Thirdly, users can manipulate the map (zooming, panning, selecting layers) to explore particular areas in greater detail. Fourthly, users can select particular geographical objects (feasible sites), create their own graphical objects, such as the limits of their house, and associate written contributions with these objects. For example, by referring to the limits of his property a user could argue against siting a wind farm in a particular feasible site because it is too close to his property. Fifthly, users can explore previous contributions starting either from the map or the discussion forum. Finally, but very importantly, Keßler's prototype is web-based, the open-source code is adaptable to different use cases and does not require the purchase of any other piece of software (Keßler et al., 2005b).

Keßler's source code was adapted to meet the specifications of the prototype's third tier. In particular, modifications provide

users with feedback on previous users' classifications of feasible sites, yielding a strong sense of the public's feelings about wind energy development for that area. Carver and Openshaw (1996) suggest that combining individually developed "idea maps" supports the identification of physically and socially robust solutions to siting problems. In wind farm siting, such a "composite map" would expose sites where a wind farm would generally be accepted and those over which controversy would exist. Such a map constitutes a good geographic basis for discussing wind farm siting. It could, for instance, spur debates around particular feasible sites and facilitate information finding (Keßler's prototype enables users to retrieve written contributions by selecting geographic and/or graphic reference objects on the map). In cross-site topics, including the general impacts of wind farms such as noise, the retrieval of those feasible sites where this concern arose would also be immediate (users of Keßler's prototype can search discussion contributions by keyword and finding the map objects to which they refer).

We have implemented this composite map concept using two maps: one is called "social classification of feasible sites" and the other "controversy associated with social classification". The former depicts each feasible site in its most frequently assigned category; the latter depicts each feasible site in a colour that represents the degree of controversy associated with its social classification. This degree of controversy is calculated using:

$$\text{Degree of controversy}_i = 1 - \frac{|2 \times \text{Recom}_i + \text{Accept}_i - 2 \times \text{NonAccept}_i|}{2 \times \text{Recom}_i + \text{Accept}_i + 2 \times \text{NonAccept}_i}$$

where, i – feasible site index;

Recom_i – number of times that feasible site i has been classified in class Recommended;

Accept_i – number of times that feasible site i has been classified in class Acceptable; and

NonAccept_i – number of times that feasible site i has been classified in class Non-acceptable.

This formula yields a degree of controversy that varies between 0 and 1. A value of 0 means that all users have assigned this feasible site to the same class, i.e., there is an absolute consensus on this feasible site. A value of 1 indicates an even split of perspectives amongst users – equal numbers classified a feasible site in the categories Recommended and Non-acceptable. Coefficients in the formula have been thought in a way to position competing positions on different sides (positive and negative) and give stronger weights to more extreme positions. This justifies why Accept_i appears in the formula with a unitary coefficient while Recom_i and NonAccept_i have weight 2.

The most significant change to Keßler's code makes it capable of loading several layers into the map viewer so that the social classification and its associated controversy map can be displayed simultaneously. To make it easier for a user to compare their own classification (henceforth called “personal classification of feasible sites”) with the social classification and associated controversy map, a third layer is also loaded into the map viewer. The rationale is that, by displaying the differences between a user's solution to the problem and those of others, the user is more likely to consider and make explicit the reasons behind their position.

Structurally, the third tier has two web pages: the first introduces the argumentation map, its appearance and uses; the second displays the argumentation map. Fig. 7 shows the second page, with the “Map Layers” tab active. On this page, two buttons on the navigation menu are worth noting: one labelled “How to use this web page?” and the other “Revise sites classification”. The first results from early prototype testing experiments because those participants unfamiliar with GIS technology experienced difficulties using the argumentation map. In particular, and despite the tooltips shown when the mouse hovers over a button, it was not obvious to them how they should manipulate the map, control the visible map layers, and use the tools to create graphical reference objects. Following a usability analysis of Keßler's prototype in a quasi-naturalistic case study, Sidlar and Rinner (2006) report similar findings: lay-users of argumentation maps did not take advantage of more advanced functions such as zooming, layer management and multiple geo-references. The second button was part of the conceptual design of the prototype and supports the iterative and cyclical nature of the spatial planning and learning processes. Users reading previous contributions, and learning about other people's perspectives on the suitability of sites for locating wind farms, might wish to revisit, and possibly revise, their own classifications of feasible sites. In addition, users that opted to access the discussion forum directly can use this button as a shortcut to the web page where they can create their own classification.

5.2.4. Fourth tier – feedback questionnaire

The fourth tier receives user feedback on the system. This tier is composed of two web pages: the feedback questionnaire and a final page that thanks users for their participation. The feedback questionnaire seeks users' opinions on three topics: personal gains from using the system; their opinions on the system's implementation;

and their views on public participation issues. Data collected are intended to improve further the current implementation of WePWEP.

5.3. Workflow within the system

A default path through the system was established for users. This path guides users consecutively through the information area, the MC-SDSS, the argumentation map and, finally, the feedback questionnaire. Users navigate this path using the “next” and “back” arrows at the bottom of each web page. WePWEP also has a navigation menu that enables users to determine their own path through the system – such freedom is generally considered an important aspect of Internet usability. An additional navigation feature is that returning registered users are able to proceed to their choice of tier directly after logging in. There is no fundamental need to guide familiar users through the system, for example, if they simply want to check how the discussion forum has evolved.

WePWEP supports users who are logged in and those that are not. All system functions are available to users that log in. Users that choose not to log in are able to wander through the system and read all available information, including that submitted by other users, but cannot actively participate in the planning process – they cannot classify feasible sites or contribute to the map-based discussion forum. Such users can, however, comment on how the wind farm siting problem has been structured and the methodology adopted to solve it using the text fields on the second tier web pages. Within the third tier, users can submit questions about problems with the argumentation map and can complete the exit questionnaire in the fourth tier. All pages in WePWEP encourage users to log in. Special attention is paid to returning users that log in: WePWEP automatically loads previously submitted information including decision criteria weights and submitted feedback. This information can be edited at any time.

5.4. System architecture

As a web-based system, WePWEP employs a client–server architecture. On the client side, a web browser that includes the Java Runtime Environment is required to access WePWEP because it embeds several Java applets (e.g., the argumentation map itself and slider bars). On the server-side, WePWEP integrates several technologies. A wealth of geographical information, both in raster and vector format is used: the backdrop in the second and third tiers, for instance, consists of three different scales of Ordnance Survey raster maps that are selected and displayed automatically to reflect the current map viewer scale. All geographical information is stored in an Oracle database managed by ArcSDE. This information is accessed by two products: ArcIMS and ArcGIS Server.

ArcIMS publishes all geographical information backdrop layers in the argumentation map's viewer. Any other Web Map Server (WMS) compliant with the Open Geospatial Consortium's (OGC) specifications could be used instead of, or in combination with, ArcIMS (Keßler, 2004; Keßler et al., 2005a). ArcGIS Server publishes all geographical information in the MC-SDSS (backdrop layers and decision criteria maps). Moreover, it serves as the development platform for WePWEP's second tier. It permits the creation/re-use of shapefiles at runtime, required to display personal classifications of feasible sites (which are produced based on the current user's inputs); as well as the update of the social classification and

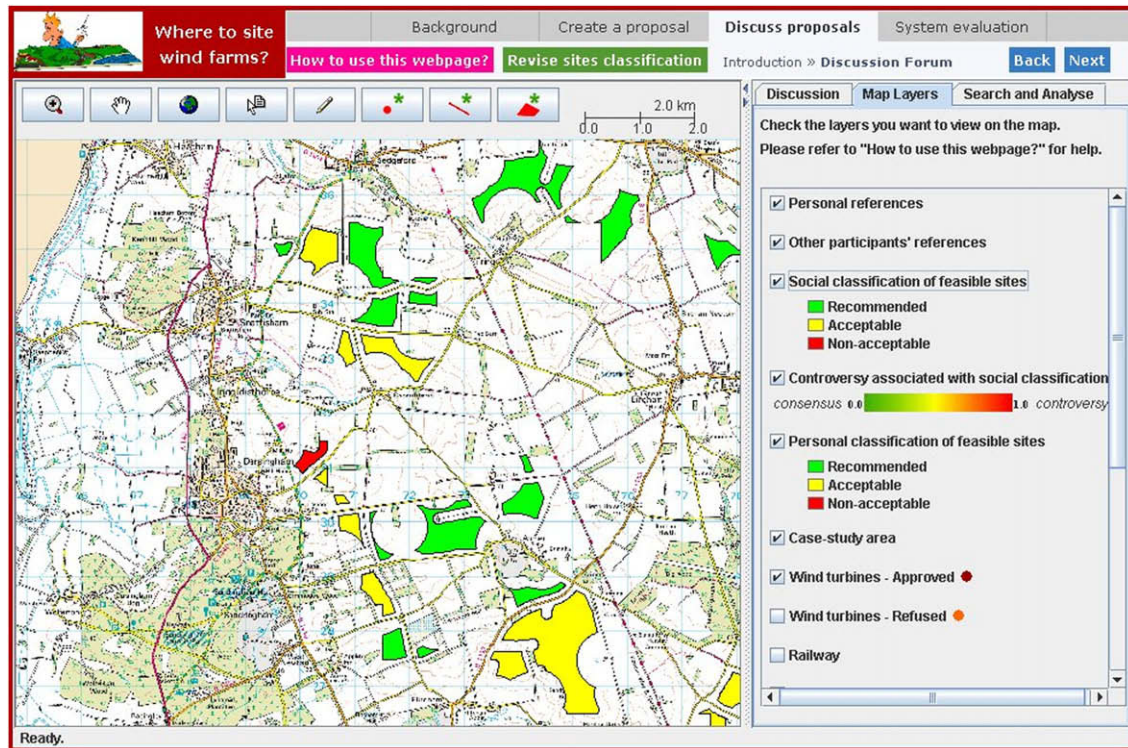


Fig. 7. Screenshot of the argumentation map embedded in WePWEF with the Map Layers tab selected.

associated controversy shapefiles each time a user submits a new classification or revises an existing one. ArcIMS would enable the same; however, at the cost of extra programming load.

Shapefiles created and updated by ArcGIS Server (i.e., personal classifications, the social classification and the associated controversy shapefiles), which subsequently are published in the argumentation map, are stored in a separate folder. The same happens with Web Map Contexts (WMC), needed and created by the argumentation map. These are XML-based files that store the visible map layers and map extent at the moment that a contribution is submitted. These files can be later loaded into the argumentation map to visualise the spatial context that the authors of the contribution had in view when they submitted it (Keßler et al., 2004). Storing these files in separate folders reflects the original argumentation map's architecture.

All alphanumeric data used by WePWEF is stored in a database (MySQL). This includes user input (registration data, criteria weights and users' feedback), data required by the second tier (for example, performances of feasible sites on decision criteria) and, all data associated with the third tier (textual contributions and point coordinates of user-defined graphical references). Finally, all the code that links system components together is Java-based and runs within a servlet container (Apache Tomcat). Fig. 8 depicts WePWEF's overall architecture.

The code comprises servlets, JavaServer Pages (JSP), which ultimately translate into servlets, and Java classes. Java classes are used, for instance, to implement the argumentative map interface and to interact with the ArcGIS/ArcGIS Server objects that permit the creation/update of shapefiles. Servlets permit communication with server software. They are invoked from Java classes or other servlets (including JSP), and are responsible for any communication with the alphanumeric database. It is through a servlet, for example, that user input is written in the database, or data stored there is read and subsequently displayed in a web page. A different group of servlets forms an OGC compliant WMS client: this collects maps

from ArcIMS, overlays them, and hands them over to the client side Applet, i.e., displays them in the argumentative map's map viewer. These servlets also manage the WMC files (Keßler et al., 2005a).

To display a personal classification a shapefile is created. This implies that as many shapefiles will be created as the number of WePWEF users. To avoid storing all these shapefiles, some of which might never be reused (as the user might not revisit the website), a procedure was implemented to delete all shapefiles older than 3 days and reuse an existing shapefile if one is available, instead of creating a new one. Since all user entered data, including the weighting scheme for decision criteria, are stored in the alphanumeric database, it is possible to recreate any returning user's shapefile. This happens either when the user logs in at the argumentation map web page or when she/he proceeds to this page from the third tier's introduction page.

WePWEF's modular design means that the underlying code can be adapted to, and reused in, different applications. Although the web pages, particularly those containing application-specific information, require the greatest changes, the underlying structure can be retained. All other application-specific information can be easily modified because it is loaded from either the alphanumeric database or the web application configuration file. The only real hindrance to the easy reuse of WePWEF code is financial – purchasing the licences required for ArcGIS Server, ArcIMS, ArcSDE and Oracle, although the last three can be replaced with open-source software.

6. Conclusion

This paper describes the design and implementation of an innovative conceptual framework for distributed and asynchronous collaboration in spatial planning. The proposed framework integrates three components: an information area, a Multi-Criteria Spatial Decision Support System (MC-SDSS) and an argumentation map. The information area provides background information on the

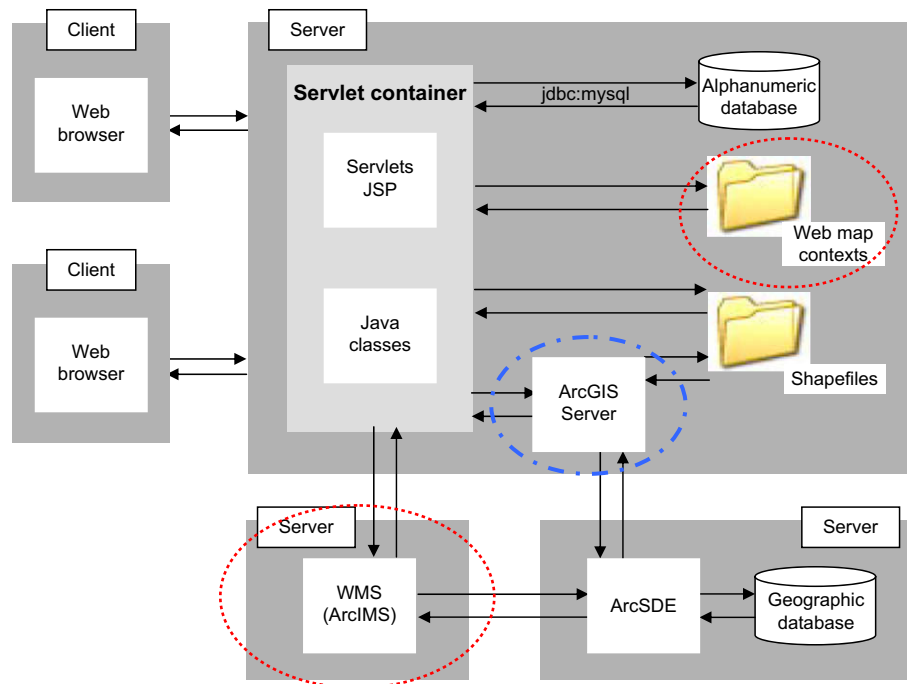


Fig. 8. WePWEP architecture overview. Components encircled by a dashed and dotted line are elements of the second tier of the system; components enclosed by dotted lines are specific to the third tier of the system.

topic under discussion and references to further readings on the topic. The other two components are tools that individually have been proposed and developed to support collaboration in spatial planning. As argued above, spatial planning provides both a context and a rationale for integrating these tools. While the MC-SDSS enables users to learn interactively and iteratively about the nature of the problem, and their own preferences for desirable characteristics of a solution, the argumentation map supports and stimulates the sharing of opinions and, hence the clarification and discussion of interests behind users' preferences.

From the perspective of advocates of MC-SDSS, the integration of such systems with argumentation maps can be seen as a response to the criticism that MC-SDSS are not responsive to the argumentative structure of planning (Gottsegen, 1998). For advocates of argumentation maps, such integration is beneficial because users may well find it easier to argue objectively about their own position after having explored the problem and crystallised their individual preferences within the MC-SDSS. The information area supports both problem exploration and discussion of alternative solutions.

Implementing the proposed framework to yield the WePWEP system was technically challenging. WePWEP integrates several software systems and embeds an existing, but modified, prototype of an argumentation map (Keßler, 2004; Keßler et al., 2005a). While the reuse of existing code reduces the programming effort needed to accomplish an objective, it creates other types of difficulties, namely setting up a suitable framework into which software can be embedded and learning the original source code so that changes can be made.

The application chosen to be at the core of the implementation is the sub-regional strategic planning of wind farms. This is an interesting and timely spatial and environmental planning problem: many authors urge collaboration, in particular the involvement of local communities, in planning wind energy development. Distributed and asynchronous collaboration is also required in many other spatial planning problems; thus, research is needed that makes widely available web-based planning support tools similar to that described above.

WePWEP currently is a proof-of-concept implementation. Usability tests and effectiveness analyses in quasi-real and real contexts are required to improve the proposed integrative framework and to realise its true benefits and potentialities. An initial and experimental evaluation of our implementation has been completed and the results are being prepared for publication. Overall, the evaluation of the system was rather favourable, with participants in the experimental event noting that they have learnt from all the three tiers in different ways. Interestingly, some participants valued more the interaction with other participants and learning from first-hand experiences; while others have stated that the MC-SDSS was particularly helpful in making sense of concepts read in the first, informative tier and in realising the complexity of wind farm siting and the large number of aspects that need to be considered.

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