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Applying geographic information systems to support strategic environmental assessment: Opportunities and limitations in the context of Irish land-use plans

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ABSTRACT

The strengthening of spatial database infrastructures, further promoted by the INSPIRE Directive adopted in 2007, has led to an increased use of spatial data in planning and decision-making. Given that land-use plans are intrinsically spatial, such evidence and approaches can significantly benefit plan-making. A spatial framework could especially support the specific Strategic Environmental Assessment (SEA) aspects of the plan-making process. Spatial tools such as Geographic Information Systems (GIS) are particularly well-placed to support the environmental integration sought in SEA by providing evidence through the spatial assessment of multiple environmental datasets. Moreover, GIS bring the opportunity to augment conventional assessment techniques (e.g. matrix-based assessments) by acting as visual mediators of spatial knowledge and by providing an effective tool for the spatial and temporal analysis of environmental impacts.

This paper presents a GIS-based approach to SEA (GISEA), and analyses the above premise by evaluating the barriers, limitations, opportunities and benefits of its implementation. The GISEA approach has been applied to seven development plans of differing scales in the Republic of Ireland. The results of the case studies revealed that current issues in SEA (e.g. restricted time-frames and institutional arrangements) condition the implementation of a GIS-based approach. Moreover, GIS expertise, data accessibility and quality remain limiting factors to an effective GIS application in SEA. However, the results also confirmed that GIS have the potential to increase the objectivity and accuracy of the assessment, enhance both the understanding of environmental and planning considerations and the delivery of information, and, therefore, help to improve the effectiveness of SEA practice.

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1. Introduction: the potential of GIS in SEA

Geographic Information Systems (GIS) are increasingly used to support decision-making in spatial planning. Given that development plans commonly link land use to location, spatial evidence and approaches can significantly benefit plan-making. Such a spatial framework could also support the specific Strategic Environmental Assessment (SEA) requirements of the plan-making process. Directive 2001/42/EC (CEC, 2001), commonly known as the SEA Directive, sets the requirements for the environmental assessment of plans and programmes (PP) that are likely to have significant environmental effects. SEA can be defined as a structured and participative procedure containing a set of tools to assist in the integration of environmental considerations and promote informed decision-making at PP level (González, 2010). The procedural requirements of the SEA Directive are commonly fulfilled through a series of actions undertaken during the plan-making process (namely: screening and scoping, description of PP alternatives, environmental baseline description, environmental assessment, mitigation measures, public consultation, and monitoring). The SEA process runs in parallel with plan-making, and culminates in the preparation of an Environmental Report (ER) to inform decision-making.

The methods and techniques applied in SEA vary (e.g. expert judgements, matrices, mapping and modelling). Matrix-based assessment techniques have probably been most widely used in SEA practice to date (Fischer, 2007; Therivel, 2004). Although matrices allow easy identification of conflicts and trade-off between PP and environmental objectives, they have a degree of subjectivity (Therivel, 2004), and often fail to address the spatio-temporal dimensions common to environmental and planning issues (Skehan and

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González, 2006; Vanderhaegen and Muro, 2005). GIS can overcome some of these restrictions by identifying the spatial and/or temporal variability amongst impacts (Patil et al., 2002), and have the potential to augment conventional techniques by providing spatial evidence to both the assessment and the plan-making processes (González et al., 2008a; González, 2010).

The use of spatial data and GIS in environmental assessment is promoted by Directive 2007/2/EC (CEC, 2007), for the creation of an INfrastructure for SPatial InfoRmation in Europe (INSPIRE). The INSPIRE initiative has also promoted the introduction of GIS into other environmental legislation, including the Water Framework Directive (CEC, 2000) and the Noise Directive (CEC, 2002), both of which require submission of certain geographic information in map form. It is anticipated that such an infrastructure will itself promote further use of spatial data by making relevant and quality geographic information available for the formulation, evaluation and monitoring of PPs (CEC, 2005). Although the SEA Directive does not formally require the use or generation of spatial datasets, it is considered that their application can provide several benefits when compared to traditional methods (González, 2010; Vanderhaegen and Muro, 2005).

Given the wide spatial and temporal scope needed for the SEA of PPs, the capabilities of GIS can confer significant advantages in the prediction and evaluation of spatially distributed and/or cumulative impacts. GIS facilitate the preparation of maps and, thereby, present a SEA support tool to illustrate and analyse data (Therivel, 2004), particularly in land use planning (Fischer, 2007). Presenting baseline data in graphic form improves the delivery of information, enhancing the understanding of the distribution, patterns and linkages between relevant environmental factors (DEHLG, 2004a; ODPM, 2005; Vanderhaegen and Muro, 2005). Therefore, GIS have the potential to facilitate a more robust spatial analysis as they enable integrating various datasets and visualising the juxtaposition or cumulative nature of different impacts (Harrison and Haklay, 2002). In addition, they enable the reuse of "old" datasets; combining them with current information incorporates a time-scale which facilitates the prediction of the cumulative effects of plans and projects over a number of years (Vanderhaegen and Muro, 2005). It can be argued that these advantages have the potential to lead to more transparent decision-making for spatial planning since decisions can be demonstrably based on spatially-specific and objective evidence (Skehan and González, 2006). Nevertheless, a number of constraints affecting the effectiveness of GIS have been reported, including data availability, accessibility, and costs, and data quality in terms of scale, completeness and currency (e.g. Rybaczuk and MacMahon, 1995; Vanderhaegen and Muro, 2005; van Loenen and Onsrud, 2004).

The exploration of empirical applications of GIS in SEA is limited, with most published literature focusing on one of the various SEA stages (e.g. Geneletti, 2008; Haklay et al., 1998). Similarly, the use of GIS within environmental assessment is underdeveloped in the Republic of Ireland ('Ireland' from hereon), their use being largely limited to mapping operations. Such limited experience probably constrains effective decision-making, given the documented advantages of applying GIS in environmental assessment and the opportunities for its incorporation. This paper focuses on assessing the capability of spatial data and GIS for enhancing SEA and examines the factors that enable/impede their effective application.

2. Methodology

The research methodology covered two core areas. Firstly, developing a GIS-based approach for SEA (GISEA) and, secondly, testing it in case study settings to ascertain the opportunities for and limitations to its application. Field observations were complemented with interviews of representatives from local authorities who had a central role in the preparation of the case studies. These were supplemented with a critical review of SEAs, which focused on their spatial comprehensiveness.

2.1. Development of the GISEA approach

The novelty of GISEA lays in the adaptation of existing GIS techniques to support SEA processes. GISEA was structured on a series of actions to be undertaken within the various SEA stages, incorporating spatial data and GIS tools where they could contribute to the process (Fig. 1). Therefore, GIS techniques were applied and customised to fit the requirements of each SEA stage. The approach relied on the ArcGIS family of products, particularly *ArcView* desktop and *ArcIMS* web server, as these provided the versatility needed.

2.1.1. Basic spatial datasets for SEA in Ireland

The availability and use of spatial data within Irish local authorities have significantly increased in the last decade. The majority of these datasets have been created at national (e.g. Natural Heritage Areas as part of the Natura, 2000 network), regional (e.g. River Basin District water risk assessments as part of the Water Framework Directive) and county level (e.g. Record of Protected Structures as part of the Irish Planning and Development Act 2000). The number of locally specific GIS-based studies (e.g. habitat surveys) is limited. Although a comprehensive array of both privately and publicly generated spatial data is available, no central spatial data repository exists in Ireland. Not all spatial datasets are in the public domain, and there is a lack of serious knowledge of datasets created by private businesses.

Annex I of the SEA Directive requires specific consideration of biodiversity, flora and fauna, population and human health, soil, water, air and climatic factors, material assets, cultural heritage and landscape. Relevant planning considerations may also be incorporated in the assessment with regard to existing and proposed infrastructure (e.g. transport corridors and waste water treatment plants), population changes (i.e. census data) and planning applications (e.g. location of new housing, industrial expansion zones, etc.) to address any socio-economic needs and development pressure areas. Annexes I to III of the INSPIRE Directive (CEC, 2007) also list thematic layers relevant to SEA, such as protected sites or land cover. These considerations were used to develop a specific (albeit basic) thematic list of datasets, essential for a workable use of spatial information in SEA of land use

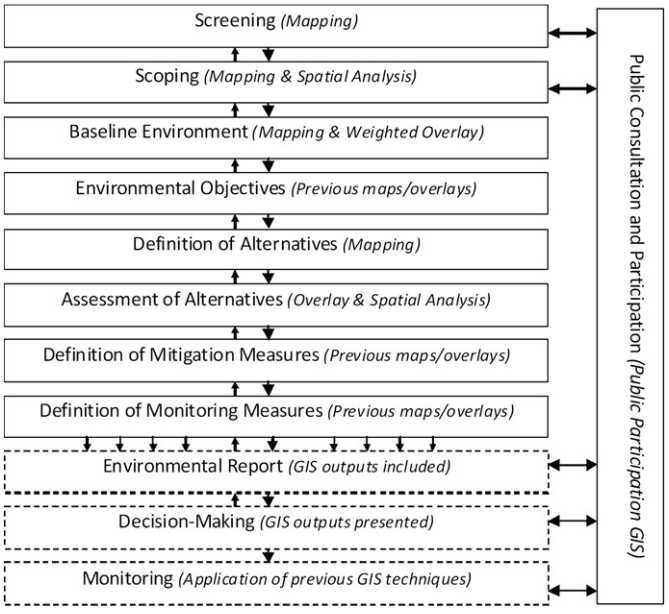

Fig. 1. SEA stages and GIS techniques applied in each of those stages. [Note that some SEA stages (e.g. definition of mitigation and monitoring measures) were assisted by maps and overlays prepared in the relevant previous stages.]

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