Spatial Data Management Requirements and Strategic Environmental Assessment

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Abstract

The plans and programmes specified for evaluation by the Strategic Environmental Assessment have strong spatial and environmental dimensions. However unlike the Water Framework or the Noise Directives, there is no legal requirement for using or producing spatial information in Strategic Environmental Assessment (SEA) processes.

The spatial context of planning and environmental management, together with current demands for information in a format suitable for rapid absorption by decisions-makers, emphasize the need for suitable spatially based decision-support systems. In this context, the data display and analysis functions of Geographic Information Systems have the potential to facilitate scoping, baseline generation, impact analysis and evaluation, monitoring and public participation processes of SEA. However, a thorough understanding of a number of issues related to spatial data use and management is essential for the effective application of spatial data in SEA. This paper discusses spatial data management requirements that contribute to an effective use of spatial information in SEA.

1. Introduction

Decision-makers at all levels are commonly required to assimilate relevant information in the form of large reports or papers prior to any decision. In the planning context, this information load has been increased as a result of the requirements to consider their potential environmental effects under Directive 2001/42/EC [the SEA Directive]. Conveying information quickly and efficiently is a significant challenge (Buchanan, 2000). Geographic Information Systems (GIS) - with their ability to organize, analyse and display spatial information - provide a plausible alternative for relieving the information burden (Morain, 1999). GIS provide significant advantages to current reporting methods, including: the speed at which new data views or maps can be generated; the fast and systematic analytical potential; and the functionality of combining two or more datasets (i.e. sources of information) to produce a completely new dataset (Bernhardsen, 1992).

Moreover, it is estimated that 80% of the government's information used in support of policy development is of geographic nature (Chan and Easa, 2000; Wicks, *pers.comm.* 2006). The highly spatial and temporal dimensions of planning and environmental issues place specific requirements on data processing and analysis tools that are within the capability of GIS, enabling analysis and visualization of data in an understandable way (Vanderhaegen and Muro, 2005) while increasing the objectivity of the impact evaluation stage (Antunes *et al.*,2001). GIS can facilitate more transparent decision-making for spatial planning because decisions can be demonstrably based on spatially specific and verifiably objective evidence. It is recognised however that the resolution of complex environmental issues goes beyond the application of a systematic technology. However the provision of a sound factual basis improves the focus and effectiveness of political and social debate.

However well GIS technology can enhance the accuracy of report production and understanding of key issues it can also mislead outcomes by means of deficiencies in data quality or manipulation. A number of general benefits and drawbacks to applying GIS in environmental assessment and planning can be found in literature (Table 1).

Benefits	**Constraints**
The ability of GIS to perform spatial analysis and modelling contributing to better impact prediction and assessment.	Lack of spatial data standards; leading to quality problems and information gaps in data sets.
The ability of GIS to efficiently store, organise and easily update spatial digital data relevant for environmental assessment studies; allowing the comparison or integration of data from different studies.	Legal and institutional obstacles to data access that derive in spatial data knowledge, data sharing issues and high costs.
The ability of GIS to provide good visual display capabilities enhancing public information processes.	Lack of understanding of the meaning and accuracy of spatial data and limited user's GIS knowledge leading to potential errors.

Table 1.- Benefits and constraints of GIS-based environmental assessment (sources: Joao and Fonseca,1996; Joao,1998; Gavin and Gyamfi-Aidoo, 2001; Vanderhaegen and Muro, 2005; CEC, 2005)

These issues lie at the core of the need for improved management of spatial information systems. They need to be addressed and understood to help improve the accuracy and effectiveness of using spatial information in SEA. This paper examines the role of GIS in SEA, particularly in Ireland, and draws attention to the potential role and the potential limitations for its application in this important decision-support tool for spatial planning.

2. Current EU Spatial Data Requirements

The European Commission is currently tackling some of the identified barriers to the use of GIS by establishing a common, community-wide spatial data infrastructure. INSPIRE (INfrastructure for SPatial InfoRmation in the European Community) is based on the findings of the EC's five-year review of the EIA directive (CEC, 2003). As a result, the commission developed a proposal for a framework directive, approved by the European Commission in 2004, aimed at increasing the availability, accessibility, and usability of spatial data - environmental data in particular – throughout the Member States (CEC, 2005).

The proposed INSPIRE Directive (CEC, 2005) outlines five underlying principles on which the initiative is built.

- Data should be collected once then stored and maintained at a suitable level;
- It should be possible to (seamlessly) combine spatial data from all sources within the community (at national, regional and local level) and to provide data in a format suitable for a range of applications and users;
- It must be possible to share data collected by one level of public authority between all levels of governance;
- The availability of data should be such as not to inhibit their extensive use;
- It should be easy to determine which spatial data is available, to ascertain its fitness for purpose, and to know which conditions are applicable as to its use.

INSPIRE addresses technical standards and protocols, organizational and coordination issues as well as data policy issues including (creation, maintenance and accessibility). The Directive's implementation, pending full approval, will consist of a number of steps, unlocking existing spatial data first and gradually harmonising all existing spatial data documentation (i.e. standardisation of metadata). Removal of the political barriers to data sharing, creation of a common access system and harmonising existing spatial data will follow (Vanderhaegen and Muro, 2005). It is expected that the INSPIRE Directive will help to improve availability and quality of information needed to develop and implement Community environmental policy by making information more accessible and transparent and by modernising current reporting methods.

The provisions of the Water Framework Directive 2006/60/EC already require that Member States report a considerable amount of information in spatial format. As indicated under Article 3 of the Water Framework Directive, Member States shall provide information on the geographical coverage of river basin districts in a format suitable for introduction into a GIS. Similarly, Article 1 of the Environmental Noise Directive 2002/49/EC requires that the exposure to environmental noise and monitoring results are reported through noise mapping. In contrast, the SEA Directive, despite its direct application to land use and sectoral plans and programmes, lacks any reference to the relevance of spatial information in the assessment process.

On the basis of these factors it is evident that the use of geographic information is rapidly expanding and it can be anticipated that it will rapidly move to occupy a central position in the implementation of environmental and planning legislation.

3. Spatial Data in SEA

Despite the lack of legal requirements for spatial data use in SEA, the use of geographically referenced information provides a number of benefits when compared to traditional methods. Conventional environmental assessment methods (e.g. checklists, matrices, weightings, etc.) lack the spatio-temporal dimension common to environmental and planning issues. Geo-spatial techniques that avail of GIS overcome these restrictions by identifying and defining the spatial and/or temporal variability amongst impacts (Patil *et al.*, 2002). A wide scope of environmental management and planning decisions are based on methodology that utilise the spatial analysis tools provided by conventional GIS technologies (digital mapping, spatial analysis, environmental modelling, etc.). Taking into account the wider spatial and temporal scope needed for the SEA of plans and programmes, the capabilities of GIS become can confer significant advantages in the prediction and evaluation of spatially distributed and cumulative impacts. The various sequential stages of SEA (namely, screening and scoping, description of plan/programme alternatives, environmental baseline description, environmental assessment, public consultation and participation and monitoring) can significantly benefit from spatial information. GIS can bring spatial data together, assist with analytical tools and act as integrative framework for the entire process. It can lead to robust spatial analysis and evidenced based decision-making in SEA.

Screening & Scoping -. As a result of the diversity and range of spatial factors that are considered in the evaluation of plans and programmes scoping for SEA is performed at a lower level of detail than would be normal for EIA. This is facilitated by the tiered nature of the SEA approach, addressing only the impacts that are relevant to the current decision-level of the proposed plan/programme (Hildén *et al.*, 1998). By this means scoping of more detailed impacts is undertaken in the next SEA decision-level tier or at the project level (EIA).

Screening and scoping stages can sometimes overlap. Scoping is often performed within a short time and with only limited resources available (UNECE, 1991). Therefore, the development of a tool that assists by automation can facilitate these initial steps of SEA. Existing EIA and SEA scoping techniques such as matrices, checklists, networks, etc. all involve tasks that are fairly well structured but lack spatial and temporal dimensions. GIS can usefully augment traditional systems by automatically checking the relevance of potential impacts by reference to spatially-specific and quantifiable factors/data. When successfully applied this technique results in the identification of spatially-specific potential impacts that need to be further considered during SEA.

Baseline Information - The role of GIS in environmental assessments largely focuses upon the generation of baseline maps (João and Fonseca, 1996). Gathering baseline data in spatial form can significantly contribute to the SEA process. Spatial data layers relevant to potential impacts - such as physical factors (e.g. land cover, DTM, geology, etc.), fieldwork data (e.g. water quality sampling data) and statistical data (e.g. population distribution) - are all gathered from various sources (e.g. digitised maps, remotely sensed imagery) to form a spatial database. These help to provide a better understanding of the spatial implications of the proposed plan or programme for the environmental sensitivities in the area.

Environmental Assessment of Alternatives - The higher decision-making level of SEA involves considerations of greater geographical scope, greater complexity and higher degree of uncertainty, leading to complex impact assessment processes (Von Seht, 1999; Glasson *et al.*, 1994). In such circumstances traditional methods for assessment of alternatives, such as matrices, are limited as they fail to address the spatial context of alternatives (Vanderhaegen and Muro, 2005).

GIS methods such as overlay analysis, buffering, reclassification, and interpolation are commonly used to produce thematic layers allowing quick and easy visual comparison of a range of potential impacts associated with different scenarios. Complex analysis and forecasting of impacts (e.g. erosion, air pollution dispersion, etc.) can also be performed by integrating modelling systems into GIS (João and Fonseca, 1996). The visual representation of such results provides a more comprehensive means for decision-making (Pettit and Pullar, 1999).

GIS has been used in impact evaluation of linear projects (e.g. roads, pipelines, power lines) and site assessment and selection processes (e.g. housing developments, coast and flood protection works, dams, tourism-related projects, ports, etc.), as well as in a wide variety of land use planning and environmental risk assessment projects worldwide (see for example, Jurgens, 1993; Mason *et al.*, 1997; Bartels *et al.*, 1998; Senes and Toccolini, 1998; Besio *et al.*, 1998; Zerger, 2002). It has also been suggested (João, 1998) that GIS can be even more useful in strategic planning than in the environmental assessment of individual projects.

Public Participation and Consultation - GIS is already being used as a support tool for communicating with the public in both environmental assessment and spatial planning. Spatial visualisation tools embedded in GIS can help overcome communication problems and promote meaningful and valuable public input (Al-Kodmany, 2002).GIS can also help to improve community knowledge of issues thereby improving involvement through communicating information more effectively. For example, by providing a visual link between existing environmental conditions and the spatial distribution of environmental resources. GIS has also proven useful for illustrating the emergence and development of alternatives and possible future scenarios.

The apparent division between computer-skilled and 'traditional' citizens, as well as between planners and the general public (Jordon, 1998; Furlong, 2005) are being dealt with recent developments in GIS leading to more user-friendly software and GIS distribution through the Internet. Usability barriers are being improved and a number of research case studies indicate that GIS can be successfully used as a tool in participatory processes to facilitate spatial comprehension, stimulate debate and encourage submission of personal perceptions (Al-Kodmany, 2002; Jordan and Shrestha, 2000; Bojórquez-Tapia *et al.*, 2001; Wood, 2005).

Monitoring - The potential of GIS as a central repository for spatial data, facilitates visual analysis of monitoring data providing an extra dimension to cumulative impact assessment (Haklay *et al*., 1998). Integration of GIS in earlier stages of the SEA process - particularly within baseline generation and impact prediction - can provide the foundation for impact monitoring particularly where data sources and methods created and developed during impact analysis stages are suitable for reuse during monitoring. In such circumstances monitoring the accuracy of impact predictions and the effectiveness of mitigation measures may only require systematic updating of the baseline database followed by re-implementation of pre-existing analysis, prediction, and evaluation routines.

4. Spatial Data in Environmental Assessment – An Irish Perspective

GIS started to be used in environmental and urban planning in early 1970s (Munn, 1977). Applications have considerably expanded since but GIS usage through Europe varies significantly. While some countries, such as the UK, the Netherlands or Spain have adopted GIS technology as a standard practice in cartography, local management and planning, other countries are slower in implementing this technology (Wegener and Junius, 1991). In Ireland, the Ordnance Survey is in charge of creating and maintaining national mapping and related geographic databases. Despite efforts made in the early 1980s by the Local Government Computer Services Board to promote the use of GIS, Local Authorities have only recently started moving towards a geographically referenced database system. Today, the majority of Planning Departments within the Local Authorities in Ireland have a dedicated GIS section. In some counties (such as Clare, South County Council, Limerick and Fingal) GIS use and application is widespread in resource planning; in some cases representing also a means for informing and involving the public.

The use of computer models and GIS for statutory environmental purposes appears to be limited at the international level, despite the increase in GIS-based methodologies and their application to a wide variety of projects (e.g. topographical modelling; industrial, landfill and wind farm site selection; computation of zones of visual influence; modelling the effects of urban expansion on the landscape; etc.). Joao (1998) noted that only 6% of the bibliographic environmental assessment database of GEOBASE[1] mentioned both GIS and impact assessment. Similarly, it has been observed that only approximately 5% of environmental publications included in Science Direct[2] address GIS applications to environmental science (over 10,000 environmental publications, approximately 3,000 GIS publications and only 472 environmental GIS publications). However, a recent study suggests a well established use of GIS within the field of EIA (94%) and SEA (86%) in Europe (Vanderhaegen and Muro, 2005). In contrast, environmental GIS applications in Ireland are generally limited to mapping by public and private organisations. The EPA is currently developing a web-based GIS[3] where all relevant spatially-referenced environmental data is made available for SEA scoping purposes.

Spatial data within Local Authorities in Ireland has significantly increased in the last decade. The majority of Local Authorities have established a GIS department, where all spatial data management and mapping is undertaken. Considerable spatial data is now available, covering areas such as electoral divisions, planning, parks, housing, environmental resources, transport corridors, road network, utilities, etc. However, practical application of such spatial data seems to be limited. A review of the County Development Plans (CDP), Development Plans (DP), Local Area Plans (LAP) and Area Action Plans (AAP) reveals that 65% of the plans contained an environmental assessment as required under the Planning and Development Act 2000. The reports indicate that the totality of these assessments have an EIA-based or a matrix-based approach (Figure 1). Therefore, and despite the clear spatial basis of all CDPs and LAPs and the spatial data available, they do not avail of the visual and analytical benefits of assessing information in GIS.

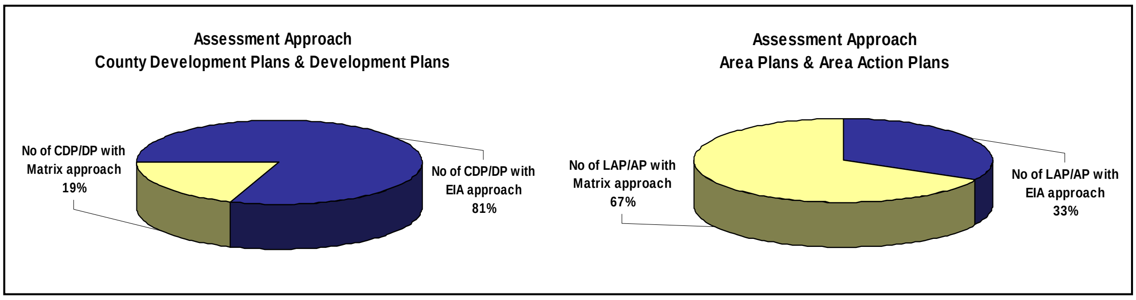

Figure 1. Methodological approach of non-statutory environmental assessment of CDPs and LAPs.

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[1] Bibliographic database for the Earth, Geographical and Ecological Sciences; Published by Elsevier.

[2] Electronic collection of science, technology and medicine full text and bibliographic information by Elsevier. Available at: http//www.sciencedirect.com (Last accessed: 10th January 2006)

[3] Only internally available.

Similarly, the majority of the CDPs, DPs and LAPs subject to the statutory requirement of an SEA are based on a matrix assessment approach (Table 2). In a number of limited cases, spatial data is used to extract the environmental baseline information; a singular case has been reported where spatial data has been applied during the environmental assessment of alternatives. This could be indicative of data availability and accessibility issues, as well as the poor GIS usage in the country.

Name of the Plan / Programme	Methodological Approach
North Ballymun LAP 2005 (Fingal Co.Co.)	Reporting
Fingal DP 2005-2011, Lands at Cruiserath 2005 (Fingal Co. Co.)	Reporting
North Drogheda Environs, Masterplan 2006 (Louth Co. Co.)	Matrix
Dundalk South West LAP 2006 (Louth Co. Co.)	Matrix
Greystones/Delgany LAP 2006 (Wicklow Co.Co.)	Reporting + Matrix
Greater Dublin Water Supply 2006 (Dublin City Co.)	Reporting + Baseline Mapping + Matrix
Carrigtwohill Special LAP 2005 (Cork Co. Co.)	Matrix
Skibbereen LAP Ammendment (Cork Co.Co.)	Reporting + Baseline Mapping
Meath Draft CDP (Meath Co. Co.)	Reporting + Baseline & Spatial Assessment Mapping
SEA Pilot on Midlands Regional Waste Management Plan 2005-2010 (EPA & County Councils)	Reporting + Baseline Mapping + Matrix
Clare Ennis & Environs LAP 2003, Variation No.4 2005 (Clare Co.Co.)	Matrix
Kilrush DP Variation No. 3 2005 (Clare Co. Co.)	Matrix
Limerick CDP Variation No. 1 2005 (Limerick Co.Co.)	Reporting + Baseline

Table 2. Methodological approach of statutory environmental assessment of CDPs and LAPs.

5. Basic Data Layers for SEA

The benefits of using GIS in SEA arise from the use of standardized sets of spatial data layers. Where baseline data is not created in-house, obtaining such data can be time consuming and costly. Furthermore, data gathering can be hampered by the lack of data sharing measures, legal boundaries or political will (Section 6).

Therefore, an effective GIS application for SEA is reliant on the existence of a central body with the necessary resources available for the set-up and maintenance of spatial data from source organisations. This is promoted by the INSPIRE proposal, where a number of environmental spatial themes are required to be collected and maintained in a central repository, each data producer being responsible for data quality and updating. In Ireland, the Irish Spatial Data Infrastructure (ISDI) – based on INSPIRE principles - would set the 'ground rules' and arrangements to enable spatial data from separate digital data bases to be combined seamlessly without undue difficulty and for such data to be widely available and used.

INSPIRE promotes data availability and sharing (EC, 2005) but does not tackle the economic implications of accessibility. To ensure wide distribution and use, these data should, in accordance with the Freedom of Information Act and 'state collected spatial data is public property' premise[4], be made available to Local Authorities, Government organisations and stakeholders free of charge.

For SEA and environmental policy a number of layers are considered necessary to be included in a spatial data repository such as the one promoted by the ISDI, these include:

5.1.Cartography: Digital Mapping

Digital cartography (i.e. raster maps, satellite imagery, LIDAR[5] radar images and aerial photographs or orthophotographs) provide a framework for the spatial assessment of environmental and planning issues. These include some spatial data themes listed in Annex I, II and III of the proposed INSPIRE Directive.

5.2. Mapping of environmental resources (ecological designations, soils, geology, aquifers, wells, protected sites, etc.) and infrastructure (industrial sites, health centres, land boundaries, etc.) facilitates further analysis and modelling procedures. These include thematic layers listed in Annex I, II and III of the proposed INSPIRE Directive and are provided by the public and private organisations (EPA; GSI; Duchas, DoEHLG, DCMN etc).

A number of key European mapping and research projects also provide relevant information for land management in Ireland. These include CORINE, an inventory of biophysical land cover based on the analysis of high resolution satellite imagery, and MOLAND (Monitoring Land Cover/Use Dynamics) a detailed database on the extent, characteristics and sustainability of the expansion (past, current and likely future) of land use development in major European cities – including Dublin city (McCormick *et al.*, 2003). Innovative approaches include the integration of GIS with Lidar radar imagery and Global Positioning Systems (GPS) in motor vehicles which has lead to accurate mapping of road features (Winstanley, 2006) relevant to road network and transportation studies. Similarly, using sonar radar in conjunction with GIS has allowed mapping of the Irish seabed topography - the first use of GIS in a non-terrestrial context (Coveney, 2006).

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[4] Open Knowledge Foundation & Public GeoData manifesto.

[5] LIght Detection And Ranging. It measures distance, speed, rotation or chemical composition and concentration of a remote target where the target can be a clearly defined object, such as a vehicle, or a diffuse object such as a smoke plume or clouds.

6. Spatial Data Management Requirements in SEA

Geographic information (i.e. spatial data) is being increasingly used for planning and environmental assessment related decision-making. The lack of standards or geographic data preparation and management guidelines create a risk of providing false or misleading spatial information. The quality of spatial data can be low even for scoping purposes (Haklay *et al.*, 1998). For it to be useful, data must be largely complete in terms of its spatial coverage and quality of information. Digital datasets may, in some cases, contain errors. Moreover, the lack of clear understanding of data validity and limitations may lead to inappropriate GIS and data applications which could derive in inconsistent or inaccurate results. Consequent lack of accuracy in final results will not only affect the end decisions but also the credibility of agencies and organisations involved in the process.

In SEA related GIS processes multiple data entry is required as a result of the variety of environmental factors generally to be considered. These geographical datasets are generally acquired through a string of successive sources (e.g. OSIreland; GSI; EPA; Local Authorities, etc.), which are consequently edited and manipulated to suit the purpose of the study. Primary data producers may provide quality documentation in accordance with ISO9000 quality accreditation (Hunter, 1999). However, provision of data quality statements for secondary and private data is not common (Rybaczuk and Mac Mahon, 1995). Errors and gaps are likely to be contained in any practical database. Furthermore, no general-purpose datasets will ever be complete for all potential purposes and nor will data accuracy meet the needs of all uses (Onsrud, 1999). Thus, the quality of the overall information can be significantly affected unless standardisation of raw data specifications and data management is undertaken. Adoption of initiatives such as INSPIRE (EC, 2005) are intended to assist the implementation of any effective GIS-based SEA system at a national level.

A number of key aspects need to be considered in spatial data management:

Accuracy and Definition**:** Measurements, location on a map and feature boundary definition must be precise to ensure spatial meaning. Non-spatial information associated to the represented features/objects must be correct, complete and truthful to ensure reliability of results.

Availability and Accessibility: Data may be available (i.e. gathered, compiled or created) but may not be accessible. Copyright and political constraints may limit data sharing. Access to and use of existing data may also be restricted by licensing and/or high costs.

Validity and Classification: The classification of data can be problematic in multiple source situations. Further problems arise when classifications change over time as a result of changes in research methodology. Standardised classes/groups are required to avoid confusion with different data sources.

Projection: The spatial reference system defined for data plays a significant role in any GIS project. Data in different projections do not adequately overlap and slight inaccuracies may be obtained when changing from latitude and longitude to another projection.

Scale: The scale or resolution of the data used in a GIS is a crucial quality factor having significant effect on the end result. The smaller the scale, the less detailed and more generalised the data. Digitised data may contain much more or not enough information for a specific purpose depending on the scale. Furthermore, using data at different scales in the same GIS project can be problematic as measures and positional accuracy may be affected.

Temporality: The age and currency of maps and data vary and their validity depends on their purpose or on when they were updated last. Data updates largely depend on data type and organisation in charge.

Technical issues also include ***transferring data*** from one format to another (e.g. dxf, ascii, shp, tif, dwg, dbf, etc.). This may lead to errors or compatibility problems. A common case is illustrated by *dxf (AutoCAD) files, where topology and attributes are lost when transferred to GIS and these need to be redefined. Similarly, ***sheet edge-matching*** may be a common technical problem. The comparison and graphic adjustment of features that cross adjoining map sheets to ensure that the features intersect the boundary at a common, coincident location. A "seamless" database is thereby created. Joining individual maps in a digital environment can often produce problems at map edges.

These issues can be significant and need to be further explored from an SEA perspective to understand potential practical problems that can be encountered when applying GIS to the various SEA stages. The effective use of GIS is ‘closely tied with understanding the nature of spatial data and how data quality might affect the end results’ (Joao, 1998 pp. 157).

6.1. Data Availability and Accessibility

The quantity and quality of the information in digital format has significantly grown in recent years, creating an important digital georeferenced database infrastructure. Major agencies and local authorities of EU Member States currently have a GIS repository. However, access to these data sources is often limited. Data accessibility depends on legislative and institutional frameworks and is country-specific. There are social and political pressures limiting the access to information, and public right to use and view geographic information significantly vary around the world (Chrisman, 1999). Generally access to data entails issues in relation to availability of metadata and pricing (Van Loenen and Onsrud, 2004). In some countries baseline or framework data is public and freely available (e.g. Spain, Slovakia, Slovenia), while in others the data is in the public domain but generally at cost (e.g. UK, Ireland, Canada). In Ireland, framework data (e.g. 1:50.000 base maps, aerial photography, geology, etc.) are subject to high pricing costs. Although data clearinghouses have been developed in the USA and other countries[6] for free data sharing, only data search and purchase mechanisms have been developed in Ireland[7]. It has been observed that current data accessibility issues can only be improved with political will by making data (particularly environmental data) freely available.

Data accessibility largely depends on the project and on the willingness of organisations and administrative bodies involved to share information. It is advocated that GIS data should simply be another adjunct of public information as provided under the Aarhus Convention (1998) and other international and national laws. These propose that GIS data should be open to the public; made publicly available and accessible for public consultation and inspection as part of the overall information process.

On the other hand, gaps in availability of datasets and sources remains an issue. Certain relevant data for EIA and SEA type studies are currently being prepared or have just been released (e.g. the recently launched flooding information[8] and the ongoing landslides information project[9]). However, availability of some other critical information (such as erosion data, surface water quality data, landscape textures, soil capacity, etc.) is not yet available in digital form for its integration in GIS projects.

6.2. Data Quality and Accuracy

Spatial data accuracy and reliability are key elements for informed, deliberated and successful land use management. System inputs significantly impinge on the validity of assessment outputs. Data measurement, input and analysis processes must be, therefore, monitored to ensure that information is fit for its purpose. To help determining the usability and characteristics of a dataset and its quality, every GIS layer should be complemented with *metadata* (i.e. ‘data about data’): overview information on data quality that contains descriptions of the purpose, the usage, the reference system, the

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[6] See for example: USA - http://www.fgdc.gov/clearinghouse/clearinghouse.html
http://edcsns17.cr.usgs.gov/EarthExplorer/
Basque Country - http://b5m.gipuzkoa.net
Europe: http://biodiversity-chm.eea.europa.eu/

[7] See for example: http://www.ordnancesurvey.co.uk/oswebsite/products/index.html
http://mida.ucc.ie/

[8] http://www.floodmap.ie

[9] http://www.gsi.ie/workgsi/geohazards/myform.htm

lineage of the GIS layer, etc. (EEA, 2003). In addition, the GIS datasets should include information on completeness, logical consistency, positional accuracy and thematic accuracy.

Several metadata ‘standards’ are in widespread use around the world (Guptill, 1999), including the widely used International Standards Organisation’s (ISO) 19115:2003 (ISO/TC211, 2003) and the Open Geospatial Consortium’s Specifications[10]. They establish mandatory and conditional metadata sections, metadata entities, and metadata elements for data producer (both private businesses and public organisations).

Data quality and accuracy are subject to a number of factors. An international questionnaire[11] addressing data quality, validity and availability issues reveals that, in most cases, data accuracy can be enhanced by quality control, validation and verification of raw data. Ensuring that data is updated, complete, at an appropriate scale and comprehensive contributes to data quality.

6.2.1. Reference System

Geodetic datums define the reference systems that describe the size and shape of the earth. Similarly, coordinate projection systems define the latitude, longitude, and height of earth features (Universal Transverse Mercator coordinate system translates position to a bi-dimensional location: latitude and longitude). A coordinate system is vital for positioning – the act of determining and stating where something is. Referencing geodetic coordinates or projection systems to the wrong datum can result in position errors of hundreds of meters. The use of a common coordinate system for all positioning is crucial if information collected from different sources and at different times is to be seamless.

Many nations have defined grid systems based on coordinates that cover their territory. The Irish National Grid (ING) is administered by the Irish Ordnance Survey and is based on a Transverse Mercator projection since the 1920s. However, a new projection has been recently devised that is best suited for Ireland. It is a Transverse Mercator projection with a central meridian of 8° West and a scale factor of 0.999820 on the central meridian; it has been given the working name of Irish Transverse Mercator (ITM). The general form of the projection is very similar to the existing Irish Grid (i.e. it is one which minimises the distortions due to the mapping of three dimensions into two).

Translation of all existing data to the new Irish reference system presents temporary problems as a result of the spatial incompatibility between converted and Irish National Grid layers (see Figures 2 & 3)

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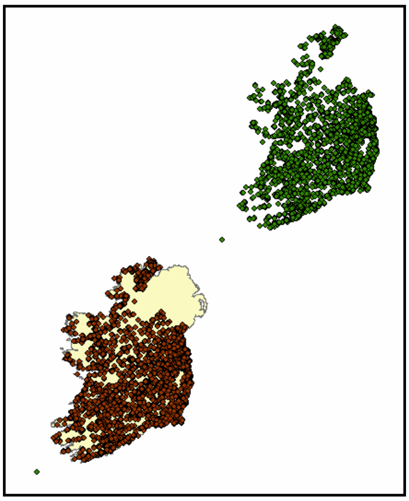
[10] http://www.opengeospatial.org/standards/

[11] “GIS-aided Participative Methods in Environmental Assessment: An International Perspective”. Gonzalez, A.; Gilmer, A.; Sweeney, J.; Foley, R. and Fry, J.



Figures 2 & 3. Left: Sample of Reference System (below ING, on top ITM). Right: Positional accuracy errors.

6.2.2. Scale and Positional Accuracy

The scale of digital data can be regarded as both, an indicator of spatial detail (the level of detail available for map making), and as an indicator of positional accuracy (the possible difference between the true real world coordinates and the coordinates of the data). The ‘spatial detail’ determines both the minimum mapping area and the number of coordinates used to describe an element. A particular geographic feature (e.g. a river) is presented in more detail (i.e. with more coordinate points) on a large-scale map (i.e. 1:250,000) than on a small-scale map (i.e. 1:1,000,000), at which adjacent features (e.g. springs) may not be visible.

Considering the variety of SEAs undertaken in the planning sector (i.e. the geographical extent varies according to the plan type, (i.e. CDPs will cover larger spatial areas than LAPs), the appropriate scale at which the SEA spatial analysis is carried out will differ. Care must be taken when deciding on the scale and consequent level of detail of the spatial data required. For SEA - where the potential impacts are assessed at a broad level - the detail required at this tiered stage of decision-making is often more qualitative than quantitative.

6.2.3. Spatial Identification and Definition of Features

Feature boundaries are often misinterpreted as being well defined, however, in the environmental arena these boundaries/limits are generally "fuzzy" (Burrough and Frank, 1996) - e.g. the geographical boundaries of geology, soils or landscape character areas can seldom be accurately mapped. Although this issue may not appear to be significant at SEA level, where the overall potential effect on the relevant environmental resources of plan/programme provisions is assessed, its implications must be taken into account when deriving policy responses – such as the definition of the boundaries of designations. Tiering in the planning process should be used to allow these potential issues to be further assessed in a more specific way at lower levels of planning or at EIA stage.

The potential for ‘double counting’ of data also arises in this regard. The definition of the boundaries of many any large-scale environmental factors such as watersheds, aquifers, ecological designations, landscape characterisation and flooding potential for instance are all determined using interpretation of topographic and geological data. It is conceivable that the same area could appear to have many simultaneous environmental sensitivities because the same underlying geological feature was used to define the extent of a valued characteristic. Professional vigilance based on a fairly thorough understanding of a wide number of scientific and technical disciplines is required to anticipate and avoid the occurrence these types of issues.

In this case, the spatial definition of the geographic data may need to be questioned and addressed.

6.2.4. Validity and Relevance

The original purpose of data creation defines the level of detail and the attributes of the geographical features that are recorded and represented. Therefore, spatial data reuse must take account of its rationale to verify that it is fit for the new purpose. The quality of the resulting representation or analysis largely depends on the quality of the data used. To be valid for use in SEA data must be of an appropriate level of data resolution, relevance of associated attributes and data currency (i.e. updated boundaries and attributes in dynamic spatial datasets). In this context it also very important to avoid the problem of ‘spurious accuracy’ whereby demands are made for highly resolved data that are to be incorporated with coarse or low-definition material (for example requiring vegetation mapping [as opposed to habitat classification] to be used in conjunction with regional geological mapping).

Similarly, relevance of thematic data must be addressed in any SEA project. Some data derive from combining two or more sources of information to produce a completely new dataset (e.g. vulnerable aquifers derive from a combination of soils, aquifers and geology). In such case, the use of source data and duplicated layers should be avoided to prevent mistakenly overstating a potential issue – discussed above as ‘double counting’.

Spatial data is generated and stored in a range of formats. Differences in formats can cause difficulties when data from different sources needs to be used during for environmental assessment. This is of particular importance for current GIS practice in Ireland, where adoption of several GIS software packages has led to incompatibilities between data layers created by different organisations. Care must be taken when translating data formats to avoid errors and data disparities; particularly when converting to computer assisted design packages because topology and attributes can be lost.

Land use management decisions are commonly based on the spatial distribution and growth of cities and urban areas. In this context, combining updated raster maps and aerial photographs with historic maps is a widespread practice. Joining individual maps from different sources can often produce sheet edge-matching problems. Ensuring that the features intersect the boundary at a common, coincident location at map edges is fundamental to allow effective comparison of features that cross adjoining maps.

7. Conclusion

In recent years in Ireland the quantity and quality of the information in digital format has grown, creating an important digital georeferenced database infrastructure significantly contributing to the quality and effectiveness of natural resource analysis and planning. It is anticipated that implementation of standards and quality control for data creation and sharing – promoted by both the ISDI and the forthcoming INSPIRE Directive – will further contribute to the quality and effectiveness of digital information management.

However, it is important for all parties involved to be remain vigilant to the reality that GIS technology used to illustrate and analyse spatial information cannot guarantee either accuracy of inputs nor the validity of outcomes *per se*. Spatial data and associated mapping must be accurate if they are to fulfil their objective and aid effective decision-making. Spatial data and GIS are subject to uncertainty and will only support valid outputs based the understanding and acceptance of certain limitations. Residual uncertainty associated with data quality issues is inevitable and must not be ignored. The limitations of the reliability of the conclusions drawn from the information through the use of GIS must be communicated for effective and transparent decision-making. Uncertainty can also be tackled by accepting that GIS is best used to provide a tool for identification of indicative areas (which may or may not need further study depending on the end purpose of the assessment) rather than acting as a prescriptive planning instrument. Above all else, for the reasons of limitations outlined above, it must never be used to produce prescriptive land-use zonings.

Notwithstanding these limitations GIS has a valuable role to play in the Strategic Environmental Assessment of Plans because both planning and environmental considerations can be easily integrated and cumulative effects addressed. Similarly by linking various datasets in a spatial network, new and innovative insights are possible which could not be obtained through considering individual non-spatial databases. The benefits of using spatial data in SEA include: (1) evidence-based decision-making; (2) greater analysis and understanding; (3) improved information sharing; (4) increased effectiveness; and (5) better quality output.

Data quality and pricing are likely to remain as major constraints for SEA in Ireland because of the scale at which such plans are prepared. Furthermore data gaps, lack of use of standards (i.e. incompatible information, fragmentation, overlap); deficient coordination (across borders, between levels of government and data providers) and data policy restrictions (i.e. pricing, copyright, licensing) appear likely to continue to constrain spatial data use in SEA in Ireland with consequent loss of potentially improved effectiveness, speed and accuracy of results.

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