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A GIS Tool for Modelling and Visualizing Sustainability Indicators Across Three Regions of Ireland

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ABSTRACT

This project uses a Geographic Information System (GIS) as a tool to visualize and model Sustainable Development Indicators for 71 settlements across three regions of Ireland. Tools for simulation models within the GIS are developed to project the effects of policies over time on the sustainability indicators of an area. This project further develops the database created over the last two years at the Centre for Environmental Research (CER) University of Limerick within the Irish Environmental Protection Agency-funded project, Sustainability and Future Settlement Patterns in Ireland. It contains data on 175 environmental and socio-economic indicators for each of the 71 settlements in the Sligo, Midlands and Limerick regions of Ireland.

A Geodatabase data model was used to store and spatially reference the sustainability indicators and indices. Database schema was created using Microsoft Visio and Universal Modelling Language (UML), and generated using Environmental Systems Research Institute's (ESRI's) CASE Tools. This method enables the database and framework to be more easily shared, modified and updated.

A combination of graduated symbols, diagrams and hyperlinks are used to display the indicators and indexes. A visualization tool for these data facilitates comparison of sustainability across regions, identification of regional tradeoffs between certain indicators, and highlights sustainability issues, including 'hotspots' where policy and resources will be most effectively targeted across the study areas.

Key words: Sustainability Indicators, GIS, Visualization, Policy Scenarios

INTRODUCTION

Sustainable development indicators are pieces of information that summarise or typify characteristics of complex systems and are designed to make perceptible trends which are not otherwise immediately apparent (Hammond et al., 1995; Pagina 2000). Sustainability is, of course, a very complex concept. It includes environmental, social, economic and institutional dimensions, as well as numerous actors, interests, and groups (see, for example, Spangenberg 2002). Indicators have been recommended as a practical and reasonable vehicle for making sustainability manageable for stakeholders (Pannell and Schilizzi 1999; Pannell and Glenn 2000). Such indicators have been developed by many researchers and agencies, including the Irish Environmental Protection Agency (EPA 1999; EPA 2002). Ireland is also a Member State of the European Union (EU). EU policy is to adopt indicators as tools in assessing progress towards sustainable development. Reports of EU-wide progress are published within EU *Signals* publications.

Economic growth in Ireland has resulted in accelerated development and increasing environmental pressures over the last ten years. The Irish government's *National Development Plan* (NDP, 1999) and *National Spatial Strategy* (NSS, 2002) emphasize the importance of sustainable development and define goals and general guidelines to achievement. Both the NDP and the NSS call for more balanced regional development. Dublin is the capital city of Ireland and has experienced rapid population and economic growth. Currently approximately 30 percent of Ireland's population lives in the greater Dublin area (NSS, 2002). The rapid development in and around the city has put enormous pressures on infrastructure and the environment. The current scale and pattern of development has made provision of services such as public transportation extremely difficult. One means identified to alleviate this pressure is more balanced development for the country as a whole. The NDP and NSS call for further development of existing towns in less populated areas of the country, including the Sligo, Midlands, and Limerick regions. These already have appropriate infrastructure and can likely accommodate population growth more sustainably than the greater Dublin area can at present.

The sustainability of settlements varies across these regions. Researchers at the Centre for Environmental Research (CER), at the University of Limerick have developed numerous sustainability indicators for the recently completed study *Sustainability and Future Settlement Patterns in Ireland*. The resulting database includes environmental and socio-economic indicators for 71 settlements across the Sligo, Midlands, and Limerick regions of Ireland. It includes raw environmental and socio-economic indicators compiled for sustainability research and information collected directly by CER researchers through questionnaires administered in each of the study settlements. It also contains developed indicator data, such as Sustainable Development indices and Ecological Footprint (EF) analyses results. This database

presents the unique opportunity to spatially explore the relative sustainability of settlements across the study region.

The growing agreement on the importance of spatial data in policy development is resulting in many countries developing spatial data infrastructures (Craglia et al. 2005). It is often the case that there are ample data, yet a lack of access preventing its use. The European Commission Infrastructure for Spatial Information in Europe (INSPIRE) initiative is a proposed infrastructure framework for legislation to improve the efficiency of use and improve accessibility to Geographic Information (GI) (Annoni and Smits, 2003). INSPIRE addresses issues of disparate extents, availability, data quality, standards, missing documentation, and other obstacles to GI sharing and re-use (Craglia et al. 2005). INSPIRE would help support the growing interest in facilitating public participation in Union policy formulation (Annoni and Smits, 2003) by improving public access to GI.

Systems and tools at are needed to organize and manage data (often from various sources), also to display and model the information for optimal benefit for use in policy formulation. GIS as a graphic spatial media offers visualization tools and a framework for modelling and managing spatial data. Customizations to existing GIS software can provide a means of accessing and applying models to conduct and visualize the results of policy scenarios. Visualization of the sustainable development indicators and their relationships over space may help improve understanding of the sustainability of settlements at the regional level, and therefore assist in decision making.

METHODS

GIS is used as a tool for management, and visualization of sustainable development Indicators and policy scenarios. The Geodatabase data model by ESRI (the leading GIS technology designer and developer) is used to store and model the sustainability indicators and indices. ESRI Computer Aided Software Engineering (CASE) Tools is used to generate the Geodatabase structure (schema). Using this method, the database design schema was defined in Microsoft Office Visio using Universal Modelling Language (UML) format and an ESRI design template. The completed version of the schema was exported as an XML Metadata Interchange (XMI) file then imported into ArcCatalog as a geodatabase schema then populated with data from the Sustainable Development Indicator Database. Geodatabase design with this method allows the design and structure to be easily shared and modified as the project grows. The documentation of the database and the customizations within it are enhanced by this design method.

A combination of graduated symbols, diagrams and hyperlinks are used to display the indicators, indices, and EFs. The sustainable development Indicator database has been expanded to include additional data such as transportation networks. This adds the potential for further spatial analyses such as

accessibility/gravity modelling and aides in visualizing the indicator data by providing visual reference.

Simulation models within the GIS project the effects of policies on the sustainability indicators of an area. The scenarios include estimating the effect of policy changes on the input indicator data and recalculating EFs and their components, to reflect the policy scenario. The models are programmed in Visual Basic for Applications (VBA) and ArcObjects (the building blocks of ESRI software). The scenarios may be applied to a settlement, a group of settlements or an entire region by graphic selection. A user-friendly interface will allow decision-makers to enter new indicator values representing the effect of policy changes. EFs and component EFs are then calculated with the click of a button. The scenario results are automatically displayed spatially in the GIS.

DISCUSSION

These scenarios provide comparisons between the potential effects of various policies or policy mixes toward the goal of more sustainable development. This work facilitates the visualization of sustainability indicators across regions, the identification of regional tradeoffs between certain indicators, and the highlighting of sustainability issues including 'hotspots' where policy and resources will be most effectively targeted across the study areas. Visualization has great potential to assist decision makers and stakeholders in accessing and understanding the indicators, indices, analyses and simulation results.

There have been challenges to finding the most effective visualization methods for this data within the GIS software package. Information is available for each settlement. While it is easy enough to provide visualization for one indicator or index at a time within a GIS, in order for relationships and tradeoffs to be spatially explored, multiple indicators must be shown at once. A combination of graduated symbols, diagrams, and hyperlinks are used to display data. Additional visualizations, such as surfaces to display the relationships between indicators, will be added to these options as the project progresses.

CONCLUSION

The development of a database design that can be shared, updated and populated with additional data and simulation models, represents an important step towards utilizing existing data and analysis results for more informed policy making. Visualization of this indicator data and a user-friendly scenario tool offer further opportunities for understanding and utilizing this sustainable development indicator data.

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