The Development of a New Methodology Based on GIS and Fuzzy Logic to Locate Sustainable Industrial Areas

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Abstract. The following research presents a new model of industrial areas location based on sustainable criteria. The model has been implemented on a Geographic Information System. It defines three complementary evaluation levels related to the geographical scale in which the analysis takes place. The first one is applied to a wide area, region or group of regions, to identify potential zones for the location of potential industrial areas. At the second level, the suitability of a specific municipality is defined considering several categories of variables. At the third level, exhaustive issues related to the existing industrial land in the potential industrial area are considered. As a result, a creative methodology and a new tool have been developed to facilitate decision making at urban and regional planning. Through a multi-criteria analysis methodology, spatial suitability for locating industrial areas is represented by cartographic outputs. Methodology can also be used to evaluate existing industrial areas.

Key words: Sustainability, fuzzy logic, multi-criteria analysis, expert system, geographic information system,

1 INTRODUCTION

The location of industrial areas is a key factor in regional planning due to the social, economic and environmental impacts that this kind of decisions have on any territory. A proper location must attend to a wide range of factors in order to coordinate socio-economic benefits and environmental sustainability. Access to transport and communication infrastructures, work force availability, proximity to main market and to the raw materials are nowadays still the main factors (Leitham et al., 2000) (Somlev, 2005) (Figueiredo et al., 2002). Nevertheless, sustainable development requires new formulas to design and locate industrial areas in such a way that negative impacts produced by its creation and exploitation will be minimized. Previous research has proposed new location models in which integrate basic sustainable development principles (De Juan et al., 2005). From a scientific

point of view, the development of new theoretical models and their implementation on real problems in the basement of the basic and applied research.

The present paper proposes a conceptual model in which traditional factors related to industrial location are considered and moreover, extra environmental issues have been added. The proposed suitability evaluation method is modeled on three different stages associated with the geographic scale. First stage is applied to a broad area with the intention of identifying those potential areas with a high aptitude for industrial development. At the second stage, several factors related to regional and municipal scale are set out the evaluation process. Finally, at the third stage, specific aspects related to the existing industrial areas are also considered. Diverse criteria are used throughout the evaluation procedure. In this sense, spatial analysis and representation of the variables have been considered to help the regional and local politicians in making final decisions. Modeling and designing of evaluation methodologies in urban and regional planning is a clear example of a field where the use of geographic information technologies has become increasingly relevant in recent years (Peña, 2006) (Hernández et al., 2004). The present research uses a Geographic Information System (GIS) to store and present the information but the main aim of this work is related to the integration of spatial analysis in a much more complex evaluation methodology.

In order to reach this aim, an expert system based on fuzzy logic (Netweaver software) and the ArcGis EMDS extension (Ecosystem Management Decision Support) has been implemented. As a result, a new tool has been designed to help in the process of making decisions related to locating industrial areas through a multi-criteria evaluation methodology. The tool permits us to generate digital suitability maps and can also be used to evaluate existing industrial areas from a sustainable point of view.

2 METHODOLOGY

2.1 Basic of the model for location sustainable industrial areas

The variables that form conceptual model are more than 200. They have been grouped on a hierarchical structure. A brief scheme of this conceptual frame is shown on Figure 1. More detailed information about the list of variables can be found in the previous work (De Juan et al., 2005). In this sense, the conceptual model is derived from three levels according to the geographical scale in which analysis takes place.

At the fist level, the selection of a specific area is explained by the socio-economic need, the opportunity for environmental business development, the existing regional planning framework and the accessible transport and communication networks.

The model at the second level is concerned with physical and environmental factors and with a detailed analysis of infrastructures, services and urban considerations in order to define more accurately potential sectors for locating industrial areas.

Finally, during the third stage, very particular criteria at specific zones are considered to make a final decision.

For each level in which the conceptual model is structured, evaluation methodology is divided in four stages: (a) Criteria selection (b) Scoring of each criteria (c) Scoring of each category (d) Final score. An analytic hierarchy process (AHP) and lineal fuzzy logic functions have been considered for the evaluation model stages. The AHP allows weighting of both qualitative and quantitative aspects of decisions reducing complex decisions to a series of one to one comparisons while the fuzzy logic permits a more gradual assessment of factors (Saaty, 1994), (Campos & De Mello, 2006).

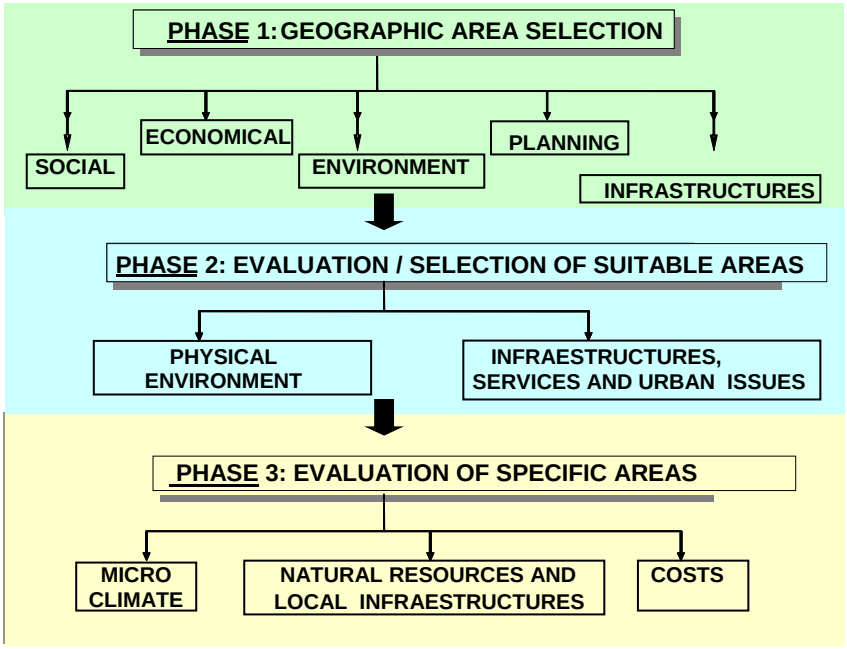

Figure 1. Conceptual structure of the localization model

2.2 Implementation of the model on a GIS platform

The implementation of the location model has been carried out via the integration of compatible tools on a GIS platform (Figure 2). ArcGis 9.1 provides spatial analytical functions. Through the Model Builder environment the user is able to create graphical geoprocessing models interactively, to include cartographic datasets, user defined parameters, other models… Using an expert systems environment, Netweaver, the hierarchical structure of the location factors and their logical relationships are built. Moreover, fuzzy functions are used to evaluate the attributes linked to the vectorial features on the maps. Fuzzy rules are mainly defined using linear, triangular and trapezoidal functions.

Analytical tasks and cartographic outputs are performed through the ArcGis EDMS extension that joins the model built on Netweaver with the geographical database. Final evaluation is obtained by the expert system and values are classified on seven categories attending to their veracity level, receiving the label of *no support* for the less suitable and *total support* the most suitable one. Final results are different maps that can help the decision makers to select a specific place to locate an industrial area, considering always the way in which different groups of criteria are valuated in the model.

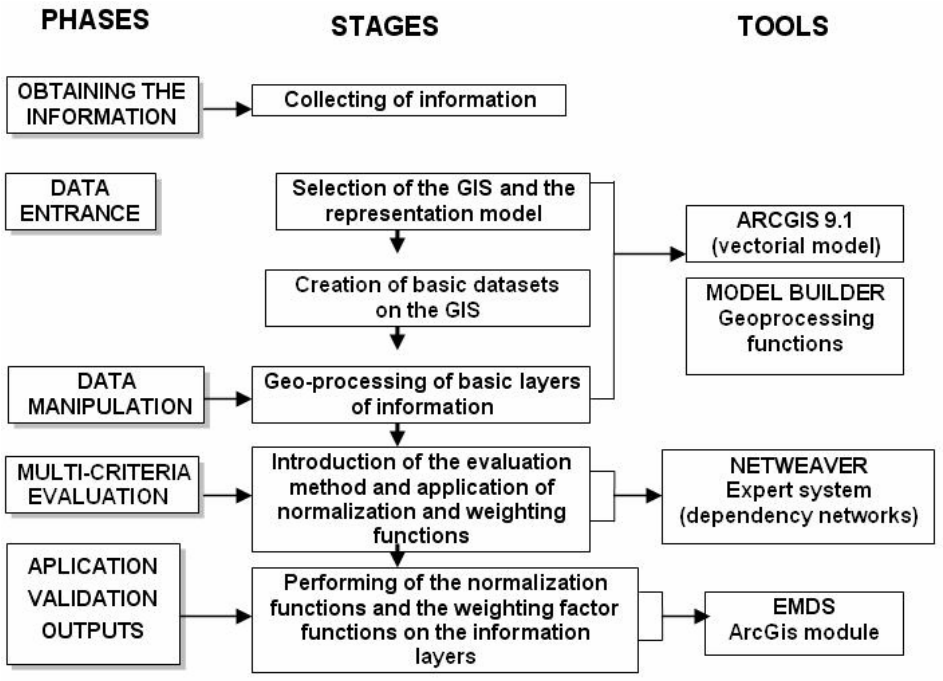

Figure 2. Methodological approach for the location model implementation

3 APPLICATION

The implementation of the whole model requires a huge amount of information. In this sense, model validation has been done only at the second level. Model has been applied to Camargo municipality, located to 8 kilometers from Santander, the capital of the Autonomous Community of Cantabria in northern Spain. Camargo's surface is about 36.6 Km^2 and its population is around 30.000 inhabitants. Results presented here are just a basic approach. The main aim of this research is to demonstrate the GIS platforms potential of helping to make decisions under a complex multi criteria environment such as the one that can be found at regional and urban planning.

Figure 3 presents the result of the evaluation of physical and environmental factors. There is a predominant background where suitability to locate an industrial area is low and it gets worse closer we are to the most populated areas in the region. According to this group of variables, there would be a limited number of places whose evaluation is very favorable. Figures 4, 5 and 6 show the partial evaluation for infrastructures, services and urban considerations respectively. The existence and capacity of infrastructures to develop new sustainable industrial areas is considered deficient by the model. The model valuation is very low all over the municipality at this level (Figure 4). On the other hand, services related to industrial activities are assessed as very positive in the whole area (Figure 5).

When we attend to the urban issues in the area, heterogeneity is the main characteristic. In this case suitability is extremely low in the southwest and center of the municipality. Only those areas that surround most populated urban areas present a higher suitability rate (Figure 6).

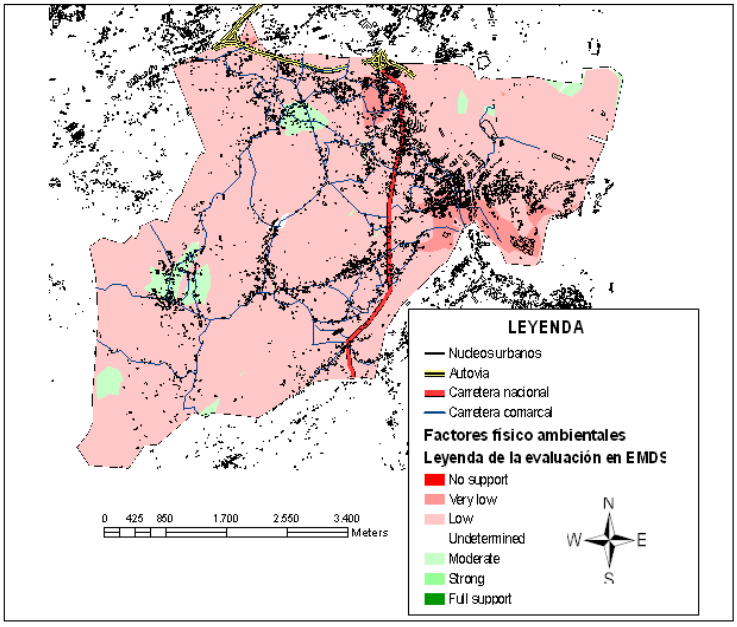

Figure 3. Results of environmental and physical assessing

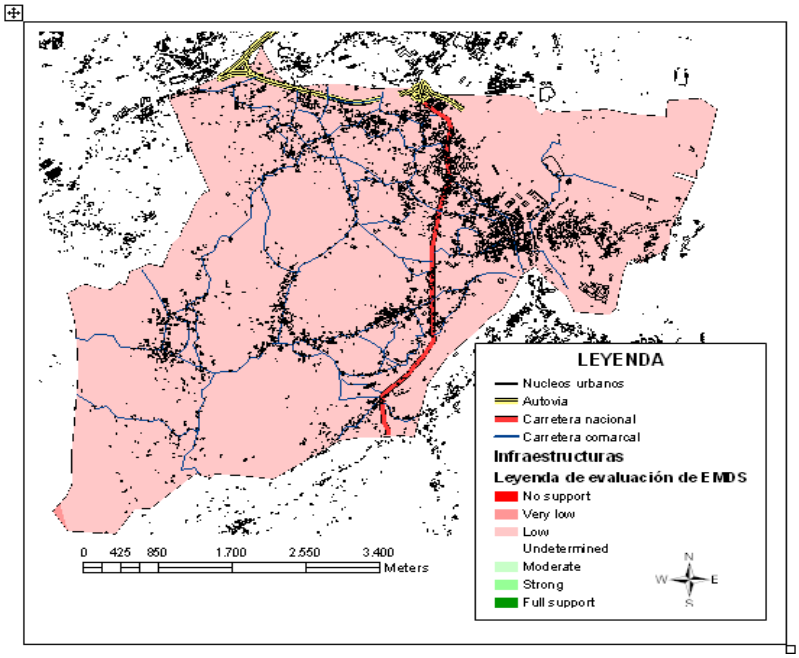

Figure 4. Results of infrastructural assessing

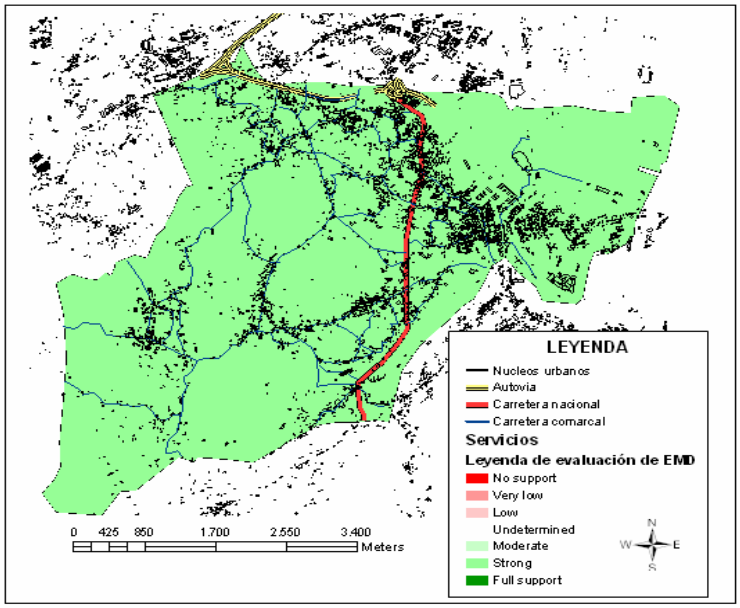

Figure 5. Results of services assessing

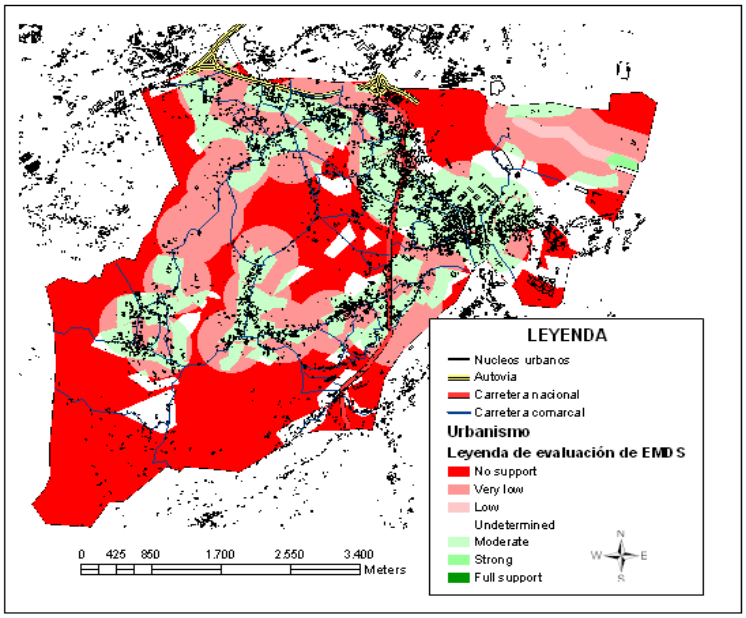

Figure 6. Results of urban issues assessing

Consequently, gathering partial evaluations, global one is generated and presented on Figure 7. Those spaces with a positive assessment are mainly located around less populated urban nucleus being clearly distinguishable from other zones. The conceptual model and the tools give user the chance to perform a detailed analysis previous to make a final decision.

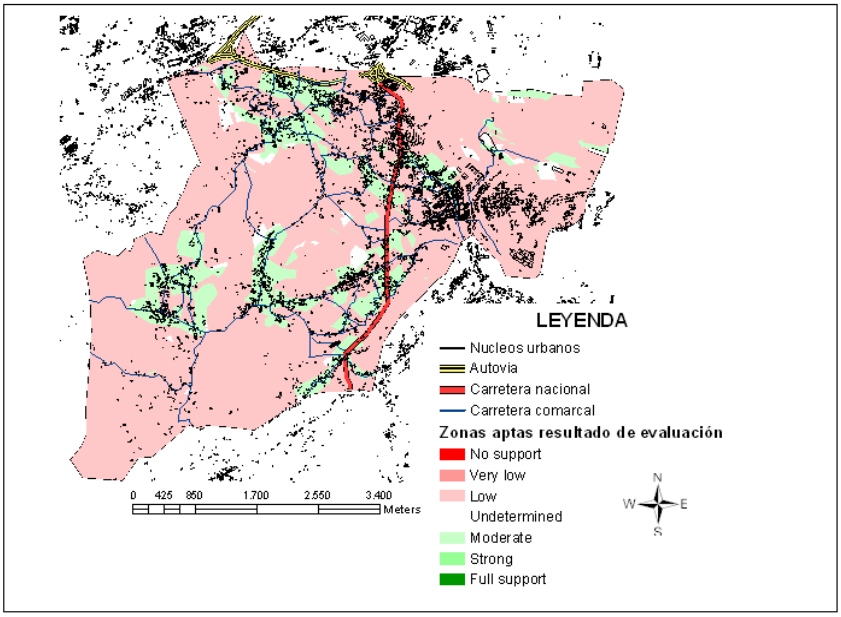

Figure 7. Results of final evaluation

4 CONCLUSIONS

Location of an industrial area is an extremely relevant decision that affects to the future sustainability of the industrial activities in the surrounding area and the whole sustainable development in the region. Increasingly awareness about the need of designing and performing new sustainable development models has made necessary the implementation of many more new factors and variables than those presented in traditional location models. This fact is causing a major complexity for the decision making processes. That is the reason why in this research a GIS platform has been used to spatially analyze the suitability of a municipality to locate an industrial area, bearing in mind hierarchical structure of the location factors and considering the fuzzy logic attributes. In this sense, the new proposed methodology gathers the necessary tools: ArcGis 9.1, to organize the datasets and to apply geo-processing functions on a clear interface; Netweaver, to define and execute the evaluation methodology; EMDS extension to carry out the evaluation process. The creation of an expert system based on Netweaver and the flexibility of ArcGis EMDS package allow the user to query the system using different groups of criteria. This makes the planning process for the decision makers easier. The fuzzy logic gives to the system a type of evaluation closer to the complex reality of regional planning. In this sense, obtained is a helpful tool based on a multi-criteria evaluation methodology that generates suitability maps to locate an industrial area from a sustainable point of view.

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