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DEVELOPMENT OF A MODEL TO LOCATE SUSTAINABLE INDUSTRIAL AREAS: CORE FACTORS

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Abstract: Industrial parks location is a strategic decision which will determine its integration and operation within a new sustainable development model. Long-established factors have been reviewed in order to propose a new methodology to design a location model of industrial parks, implemented in a geographic information system (GIS). The main step of the model is the attainment of core factors and criteria which have to be fulfilled. These factors have been grouped by a hierarchical structure according to spatial and temporal scale of the decision making process. The classification and attainment of the factors have been based on the integration of land, environmental and economic planning aspects. This model will allow the selection of an industrial location which maximizes the territory capacity and reduces the adverse effects over the environment in the whole park development process.

Key-words: sustainable industrial area, location factors, decision making tool, location model

1 Introduction

An industrial park is a set of firms which arrange common services. Industrial areas are a basic part of urban arrangement plans, especially in developed countries. However, they have a substantial environmental risk, due to the concentration of environmental problems of individual companies in a relatively small space.

Diminution of the absorption capacity of impacts over the environment is a fact that entails a new model of actuation based on a sustainable development. Industrial Ecology is one of its tools, whose main target is to improve the environmental behaviour of the industry. This discipline, applied to a industrial state, establishes an analogy between industrial and natural systems by creation of matter and energy interchange networks between companies. As it happens in nature, what a link of the chain considers waste, is used as food for the following one [1]. The concept of eco-industrial park is born in this frame, trying to increase its economic and environmental efficiency as a group, greater than the individual sum of each company.

Some experiences have been gathered all over the world on the development of eco-parks in last years [2-4]. However, its establishment is not widely extended yet. In a recent study about the current development of eco-industrial parks at world-wide level, it is concluded that the most remarkable projects are situated in Europe and North America, as well as the collaboration between institutions of these countries with developing countries to set the eco-industrial parks in last ones [5].

There is a lack of a common methodology for the design of eco-industrial parks. However, some documents collect recommendations for future projects based on the experiences of eco-parks already implanted. A document edited by United Nations Environment Programme (UNEP) [6] gives environmental strategies of designing for the creation of new industrial parks and for the application on already existing ones. These strategies can be applied to all the phases involved: selection, design and planning of the location, design of the physical structure, construction and operation. So, the location of the new industrial activity must accomplish the requirements on transport communication and operating labour availability, but environmental criteria must be taking into account too, in order to design the location according to a suitable direction of the buildings, reduce the destruction of natural areas and avoid traffic jam during operation.

The location for the new industrial area is one of the most important stages at the beginning of the

project. Long-established factors are emphasized by several theories [7-9]. Some of these factors are proximity to communication nodes, availability of labour, proximity to raw materials or potential markets. However, according to current development, an industrial park has to be located where the capacity of the territory is maximized and the adverse environmental effects are minimized.

Land, urban and environmental planning tools are considered to manage the soil as natural resource and human activities support. Integration of these instruments in the earliest phases of the project, in agreement with European Directive 2001/42/EC guides [10], will make possible an optimal use of the soil. The goal of this Directive is the integration of environmental aspects in plans or programs to reach a sustainable development. This integration will be carried out making an environmental evaluation in the conceptual phase of the plan. Therefore, the concept of "strategic environmental assessment" is introduced, as a prevention methodology to evaluate potential environmental effects in plans and programs during the design process. This technique complements the Environmental Impact Evaluation tool in the earliest phases of a project development.

Also, local organizations must fulfil the necessary requirements to obtain an acceptable economic development in harmony with the environment. In this way the goals of local Agenda 21, introduced in the Earth Summit of Rio de Janeiro and developed in the Aalborg Charter, will be accomplished [11]. The promotion of a sustainable development by municipal commitment necessarily includes the creation of industrial areas which must be conceived under a new model of socioeconomic development.

The general aim of this work is to create a decision making tool of industrial parks location that fulfils the principles of sustainability. The application of this tool will evaluate and select the most acceptable location of an industrial area in a defined geographic area. This paper summarizes the stages followed to create the tool and particularly explains the main factors and variables which constitute the location model.

2 Methodology to create the location model

The proposed methodology to create the decision making tool of industrial location is shown in Fig. 1. Each stage is explained individually.

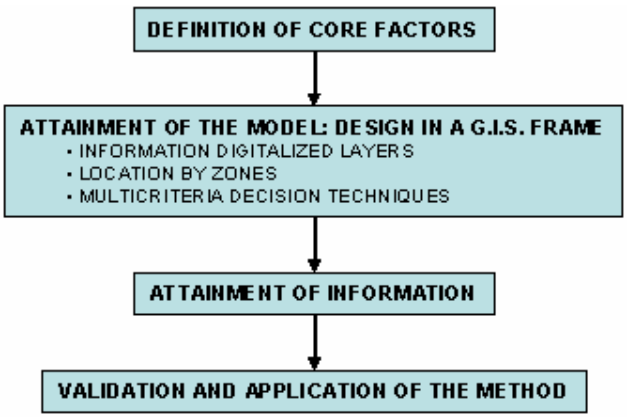

Fig. 1: Methodology for designing a model to locate industrial states

Definition of core factors

Initially, the main location factors are analyzed and defined: socioeconomic and infrastructure factors, from traditional theories of location, as well as physical and environmental factors, from new sustainability models are linked in this method. This stage is extensively developed in the third section of this paper.

Attainment of the model: design in a geographic information system frame

Factors are now defined and structured. Then, they are implemented on a geographic information system (GIS), in order to get the geographic reference to the location factors on the territory. So, each one of these abstract indicators will constitute a layer of digitized space information. Zones within the selected territory, which fulfil some key criteria, will be defined by the composition of these layers. Several multicriteria decision techniques will be used to select the most suitable areas to locate the industrial activity.

Attainment of information

A previous step of information attainment will be necessary to apply and validate the model. This information collection consumes most of the time and is the most laborious to carry out.

Many sources have to be asked because of the decentralization of the information. Normally, most of general data will come from municipal and regional organizations, as well as private companies that manage services like water, electricity, gas... Nevertheless, they will not have the complete information in small municipalities.

As physical information concerns, it could be obtained either by cartography or by in-situ inspection. Other possible sources of information will be Internet, books or magazines, or by own elaboration, considering the relation quality-cost and the time to obtain it.

Validation and application of the method

Finally, the model will be applied and valued with specific data. So, the most appropriate area to locate the industrial activity within will be selected. The municipality of Camargo (Cantabria), which is located on the north of Spain, has been selected to validate the model.

3 Definition of core factors

Elaboration process and structure of the factors and variables system is detailed in this section.

3.1 Process to obtain factors system

Systematic to define the set of influential variables to locate industrial areas is shown in Fig. 2.

First of all, most of general categories and subordination sequence are defined: main groups are identified and ordered by basic necessities, from the most general to the most specific ones.

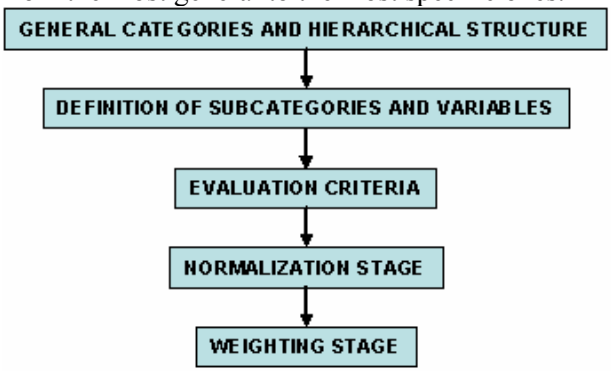

Fig. 2: Methodology to define the variables

The subcategories and their corresponding variables and indicators are clearly defined within each great group. Their existence and position inside the group must be justified.

Every indicator must be expressed on its specific units. However, a normalization stage becomes essential since the target is to obtain a score based on the fulfilment of the defined necessities.

On the other hand, it is obvious that all the indicators have not the same degree of importance. Some of them are basic, since they gather primary necessities for the establishment of an industrial area. Nevertheless, the other ones contribute to make the zone more attractive and interesting, but they are not strictly necessary by themselves. For this reason a stage of weighting is considered.

3.2 Structure of the factors system

The structure of factors and variables comes from a hierarchical and linear model, from the most general exigencies to the most specific ones. The area to analyze has to fulfil minimum requirements in every step. If not, the process stops and it is not necessary to continue in the compilation of information.

The selection process of industrial areas can be done in different space and temporal scales. Two phases are established in the proposed methodology, as Fig. 3 shows. The first one is the geographic area selection, which is obtained and justified on a great scale. The specific location is selected in the second one.

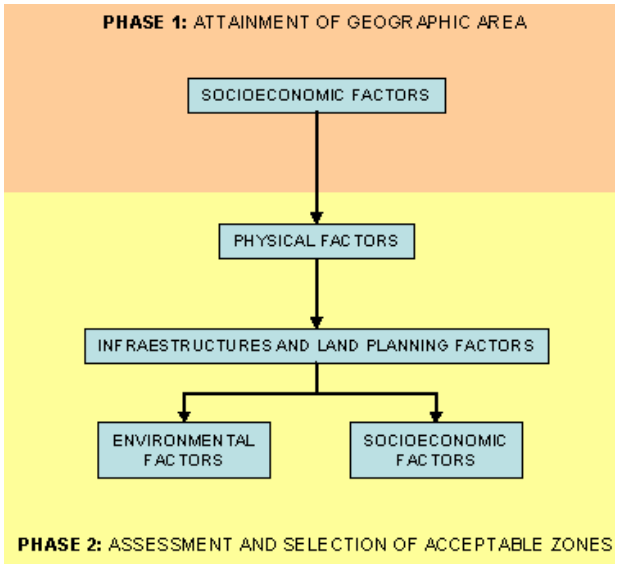

Fig. 3: Hierarchical structure of the factors

3.2.1 Phase 1: Attainment of the geographic area

Firstly the necessity of establishment of new industrial activities is analyzed by socioeconomic parameters in a specific geographic area.

These indicators try to collect general information, which will be detailed in the second phase of location selection. Therefore, some indicators are similar in the two stages of analysis, but the application scale is different and consequently the aim and information too. Structure and justification of these factors are shown in Table 1.

3.2.2 Phase 2: Assessment and selection of acceptable zones

In the second phase, specific location is evaluated. The hierarchical structure arises as answer, from the most to the least basic features, to the question *what is needed to locate a sustainable industrial*

park?. Initially, the knowledge of the physical medium is considered essential. Later, it would be necessary to know general services of the zone and its territorial legal frame. Finally, the integration of the environmental, social and economic aspects of the specific scope of the location.

Physical factors

As Fig. 3 shows, physical factors occupy the first place within the hierarchy. That is because these factors must verify the capacity of the soil to support the establishment of an industrial area, prioritizing the spaces whose productive uses do not have any other socioeconomic interest. Therefore, and as Table 2 details, physical features are defined in great sets: climatology, soil, water and risks. Evaluation of risks is the most determining one, since the detection of a soil with some physical risk will reject the zone.

Table 1: Structure of socioeconomic factors

CATEGORY	JUSTIFICATION
SOCIALS	Definition of social state
Demography	Demographic tendency
Academic formation	Definition of graduation and cultural level of the population
Work occupation	Distribution of the working population by sectors and unemployment index
ECONOMIC	Definition of main economic activities and costs assessment of the industrial sector
Economic activity	Economic distribution by sectors and, particularly, secondary sector, analyzing the location and occupation of consolidated industrial states
Costs	Costs of goods and services of industrial activity

Table 2: Structure of physical factors

CATEGORY	JUSTIFICATION
CLIMATOLOGY	Specific climatic characteristics of the zone and the particular area. Climatic and microclimatic comfort
Climatic comfort	Climatic comfort given by various indices
Microclimate	Influence of the climatic parameters over the particular area
SOIL	Characteristics of the soil to verify the availability of supporting industrial activity
Specifications of construction	Basic properties of the ground as support of the industrial activity
Productive aplications	Potential and implanted uses of the soil to evaluate if industrial use is feasible
WATER	Identification of the natural water sources to evaluate potential impacts of industrial activity
Superficial water	Existence of superficial waters
Underground water	Existence of underground waters
Hydrographic river basins	Existence and location of the hydrographical river basins
RISKS	Existence and type of risks for the industrial activity
Risks derived from fluvial processes	Existence of possible risks derived from the fluvial processes
Risks derived from gravitational processes	Existence of possible risks derived from the gravitational processes
Risks derived from other processes	Existence of possible risks derived from seismic, volcanic processes...

Land planning and infrastructures

Factors related to infrastructures and land and urban planning are evaluated in next step. It will be determined if the zone has necessary infrastructures to locate the industrial activity, and if the land and urban legal framework are adapted to the industrial necessities. It means if the technical and legal requirements are fulfilled to implant the industrial area in a sustainable city-planning model. Table 3 shows the factors proposed in this group.

Environmental and socioeconomic factors

Last group are environmental and socioeconomic factors, which are described in Table 4 and Table 5 respectively. Environmental factors evaluate the availability of resources and infrastructures, environmental quality and present and future practices of environmental management. As a general criteria, it is prioritized the guarantee in quality and amount of necessary resources and public domain and availability of services that allow to operate as a sustainable park. Socioeconomic factors characterize the specific area in which the industrial activity is going to be implanted. Social services available, which express the quality of life of the zone, and specific costs are evaluated.

Table 3: Structure of infrastructures and land planning factors

CATEGORY	JUSTIFICATION
LAND PLANNING	Legislative limitations for the development of industrial activities
Legal frame of soil planning	Restrictions and ordination of the zone by its legal frame
Public domain	Identification of public domain
Historical patrimony	Identification of historical patrimony
INFRASTRUCTURES	Existence of services and necessary acquiments for the industrial activities
Availability and accessibility to transport	Existence of infrastructures for different means of transport
Energy supply	Existence of networks for energy supply
Water supply	Existence of networks for water supply
Water cleaning	Existence of networks for water cleaning
Recovery, reusability and recycling	Existence of recovery, reusability and recycling installations
Waste treatment managers and installations	Existence of facilities for the treatment of wastes
Garbage dumps	Existence of different types of garbage dumps
Communication and information technologies	Availability of technological services
URBANISM	Urban structure of the zone
Management and planning	Current qualification and property of the soil
Urbanizeable soil	Current model of soil occupation for industrial activity
Urban and interurban transport	Current model of urban and interurban transport

Table 4: Structure of environmental factors

CATEGORY	JUSTIFICATION
NATURAL RESOURCES AVAILABILITY AND ENVIRONMENTAL QUALITY	Environmental situation of natural resources and basic parameters of availability and quality
Air	Air quality
Water	Availability and quality of superficial and underground water
Noise	Acoustic quality
Soil	Soil quality
RESOURCES AND SERVICES OF INFRASTRUCTURES AVAILABILITY	Availability and quality of the resources and services by existing basic infrastructures
Transport	Availability of existing infrastructures of transport
Electrical energy	Electrical energy availability
Natural gas	Natural gas availability
Water	Availability and quality of supplying and cleaning water networks
Waste	Capacity of garbage dumps and facilities to recover, reuse and recycle
ENVIRONMENTAL MANAGEMENT	Systems of environmental management and municipal organization
Functional structure of municipal environment	Environmental municipal performances
Systems of environmental management	Existence of environmental management in public and private organizations
ENVIRONMENTAL IMPROVEMENT PRACTICES	Techniques, technologies and practices which reduce natural resources consumption and environmental pollution
Efficiency in resources consumption	Practices for reducing the natural resources consumption
Reduction of residual stream	Tendency of residual stream production
Reusability, recovery and recycling	Degree of reusability, recovery and recycling
Waste and by-products interchange	Existence of waste and by-products networks
Use of renewable energies	Types of renewable energies and power produced by them
Mobility and urban transport	Sustainability transport
City-planning management	Sustainability in the urban plan

Table 5: Structure of socioeconomic factors

CATEGORY	JUSTIFICATION
SOCIAL SERVICES	Quantitative description of the more common social services in the municipality to valuate the quality of life
House	Type of arrangement of house (property, rent, etc.)
Education	Existence of sufficient educative services to cover existing necessities
Medical and social assistance	Existence of sufficient medical and social services to cover existing necessities

Table 5: Structure of socioeconomic factors (Cont.)

	Culture and leisure	Existence of sufficient culture and leisure services to cover existing necessities
	Commercial services	Existence of stores for basic supplying of food and other products
	Technical attendance services	Existence of engineering and consultancy services
COSTS	Costs of specific goods and services associated to the industrial activity	
	Specific costs	Costs of goods or specific services at the location
	Additional costs	Possible additional costs by lack of certain goods or services

4 Conclusions

This paper introduces a new model of industrial parks location, which integrates instruments of land, urban and environmental planning, leading to a positive evaluation of the project in its earlier phases according to Directive 2001/42/EC.

A methodology to design the model, implemented in a GIS, has been set out in this work. The most appropriate zone within a delimited geographic area will be selected by techniques of multicriteria decision.

A fundamental stage of the model is the obtaining of the core factors and criteria that must be fulfilled. These factors have been grouped in a hierarchical structure, according to the space and temporary scale of the decision making process.

Basic features have been considered initially. First phase of the model evaluates the real necessity to implant a new industrial area in a determined zone. Its justification will come mainly given by socioeconomic factors. When the geographic area have been delimited, it is time to assess different locations from a more detailed scale in the second phase, according to a sequence in three stages.

In the first stage of the second phase, the main characteristics of the physical medium are analyzed as well as the minimum criteria which the establishment of the industrial activity has to fulfil. Later, factors related to infrastructures and land and urban planning are defined. Basic infrastructures and protection of sensible zones protection are high-priority. In the third stage, environmental and socioeconomic factors are defined and integrated. Environmental factors define the quality and availability of natural resources and services of infrastructures, as well as environmental practices established. In socioeconomic factors, current social services and potential costs of the specific zones are valued.

To sum up, it is important to emphasize that a suitable planning implies a continuous feedback of the model. For this reason, it is necessary to redefine the influential factors and criteria which have to be fulfilled according to the scientist-technical and legal advance in territory arrangement and sustainability.

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