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GIS Based Multicrteria Analysis in Integration of SEA Process Into Planning, Case Study: South West Region, Republic of Ireland

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ABSTRACT: Strategic Environmental Assessment can be viewed as a process to integrate the concept of sustainable development into planning. In this context, SEA can be regarded as a method that regulates the planning process to a state of sustainable development. However, to reach that goal it is necessary to achieve full integration of planning and the SEA process.Therefore this paper considers the integration of SEA into the planning process based on GIS multicriteria analysis. The paper is an attempt to introduce the concept of environmental protection in the planning process on the principle of dynamic modelling with the aim of identifying potential impacts of planned activities on the environment and determining the optimal alternative development. Moreover, the paper will introduce *the model of integration* of SEA process into planning as one approach to reach the goal of full integration of the two processes and therefore will assist the planner and decision maker to achieve a more sustainable decision.

Key words: Planning, SEA,GIS, Multi-criteria Analysis, Analytic Hierarchy Process

INTRODUCTION

The approach in this paper is an integration of the SEA process into planning through the *"integration model"*. The integration model represents a set of GIS-oriented multicriteria procedures to integrate environmental considerations with the planning process in order to reach sustainable development principles. The model consists of two sub-models: cumulative environmental sensitivity sub-model and expected development pressures sub-model.

The cumulative environmental sensitivity sub-model can be regarded as evaluation of all geographically mappable environmental factors that could be affected by planned development activities. The development pressure submodel reflects development indicators as the main cause of possible negative environmental impacts. The cumulative environmental sensitivity submodel is universally applicable in all planning systems, but with using the local indicators, while the expected development pressures sub-model universally is applicable at the strategic level but not at the local level. Local level planning is much more focused on local conditions and the local planning system, particularly in land use; therefore this model requires the necessary calibration according to specific local conditions.

According to research of Malczewski (Malczewski, 2006) almost 70% of all published papers on GIS-MCDA have been published in the last five years. That suggests that we can expect increased application of the GIS-MCDA concept in the future. Also, according to stated analysis of the most used MCDA techniques, the Boolean overlay technique is the most applicable with nearly 40% of all published literature referring to this technique, while the Analytic hierarchy process defined by researchers (Saaty, 1980, 2008; Saaty and Ozdemir, 2005; Saaty and Forman 1993) is represented with approximately 10% in published GIS-MCDA literature.

On the other hand, Malczewski (Malczewski, 2006) found in his research that GIS-MCDA concept was used in urban and regional planning in 10% of published papers, while the concept of environmental protection (environment / ecology) is the most common with 17%.

After analysing the literature about the possibilities of applying GIS-MCDA in environmental

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planning, it can be concluded that in most cases GIS-MCDA is oriented to assessment of impact to one receptor, like aero pollution (Makowski, 2001). On the other hand, an assessment could be based on one source of impact, like the construction of new road (Patrono, 1998).

Nevertheless, the question is can we employ GIC-MCDA in achieving cumulative environmental sensitivity of observed area?

Gonzales Del Campo (2008, 2009) applied that concept in the Kilkenny County Development Plan and she has also suggested this principle in GIS-SEA Guidelines (Gonzales Del Campo, 2008). She used *weighted-overlay mapping technique* in combinatin with MCDA and GIS for producing the Cumulative Environmental sensitivity map.

The main difference between the concepts of Gonzales Del Campo and the approcah for determining Cumulative Environmental Sensitivity map (Cumulative environmental sensitivity submodel) in this paper is the applied MCDA techniques in indicators assessment. In Gonzales Del Campo (Gonzales Del Campo, 2008) methodology, all relevant indicators are grouped into two groups with an assigned "weight" of 5 and 10 points. A group of indicators which are assigned to 10 points is more important from the standpoint of the environment.

On the other hand, within the Cumulative Environmental sensitivity submodel Analythic Hierarchy Process (AHP) was applied in the indicators assessment. Using the AHP, the indicators are structured in hierarhy order with the assigned "weight" obtained from the "pairwise comparrison" technique. In this way all indicators have been assessed in correlation with others and their weights have come from the mathematic model of organized hierarchy structure (AHP). With the AHP the level of subjectivity in assessment has been reduced on the base of validated mathematic theory.

The integration model, as centrepiece of this research, has been defined and tested in Ireland at three different levels of planning: the regional level, county level and local level. However, this paper will represent model application on the strategic level of planning – South West Regional Authority Regional Planning Guidelines and particularly in the Cork Area Strategic Plan (CASP) area.

MATERIALS & METHODS

The model was developed to integrate SEA into the planning process and, in general, it is one segment within a more comprehensive Spatial Decision Support System. The models primary purpose is to assist planners in understanding and recognising the complexity of the problem and to provide decision makers with a proper basis in decision-making.

The model (Fig. 1) is a GIS-MCDA application that analyses the conflict of two sub-models: *Environmental sensitivity submodel* and *Development pressure submodel*.

Applying the model, the concept of sustainable development was actively involved in the planning process through interaction between environmental sensitivity and planning indicators with the aim of identifying potential conflict zones.

In general, the model intends to assist decision makers in recognising potential negative impacts of planned activities on the environment. The model has an advisory rather than executive function. It simulates the potential conflicts on the basis of the adopted indicators. By changing the inputs, or by changing indicator weights, the sensitivity map would be changed and therefore conflict zones would be allocated. Due to the simulation characteristic, the model may be useful for planners in selecting the most suitable alternative scenario. Therefore we can say that model has also an optimization role.

The environmental sensitivity sub-model aims to generate a cumulative environmental sensitivity map. This is a synthesis map of environmental elements observed in terms of the degree of their sensitivity to planned activities. The sub-model aims to determine the most sensitive areas from the standpoint of the environment and to guide decision makers to the most optimal (sustainable) direction for future development in order to achieve new development demands. This sub-model can exist independently and out of the more comprehensive Spatial Decision Support System. As a standalone module, the sub-model represents a very useful source of information for both planners and decision makers regarding cumulative environmental sensitivity.

The development pressure sub-model is based on population and employment indicators. The population data came from the Census where we analysed population growth in two census periods: 2002 and 2006. Employment data may be within the general census data or may arise from separate studies. In our case the employment data came from the POWCAR data source, which analysed information from the Census.

The model is defined under the SEA terms that relate to the Republic of Ireland. Nevertheless, the model could be applicable universally, but it's necessary to calibrate it to local conditions. Since the SEA regulations are unique at EU level (SEA Directive), calibration is more related to local planning systems rather than to local SEA systems.

Within the environmental sensitivity sub-model, the process begins with the establishment of indicators. Indicators are based on the cooperative work of SEA team (in this particularly case) and external experts (EPA in our case) and methodologically indicators came through the application of the Delphi technique. After the final list of indicators has been established, the indicators were organised within the AHP and assessed through pairwise comparison technique.
It's important to acknowledge that AHP procedure is mainly used to compare alternatives in order to get the most appropriate one. In this case the alternatives are the final level of the hierarchical process.

In our case, we applied a different approach. The AHP method was chosen as it is very useful for evaluating and comparing various types of data and their restriction to unambiguously defined hierarchical structure. In this case the aim is not selection of the best suitable alternative, but to obtain an attribute (indicator) value that represents the importance of attributes within hierarchical structures. The total attributes value ("weight") is relative attribute weight multiplied by the weight obtained through the hierarchical structure. The output from the process is "Criterion map" with the corresponding weight, which is an input for GIS "overlay" process.
Looking from the single criterion point of view, we could represent the process with three main phases:

1. Standardisation
2. Weighting
3. Aggregation

The "Criterion map" is a grid with accompanied "weight" obtained from the "pairwise comparison" technique and AHP structure. Criterion grid is going to add to other criterion grids and thus becomes an integral part of cumulative sensitivity map(fig.2).

The development pressure sub-model, as we noted, was based on two basic indicators: population and employment. Those two indicators could be assessed throughout two approaches: "conflict zone management" and "land allocation".
Conflict zone management represents a concept which is applicable on a regional level of planning and

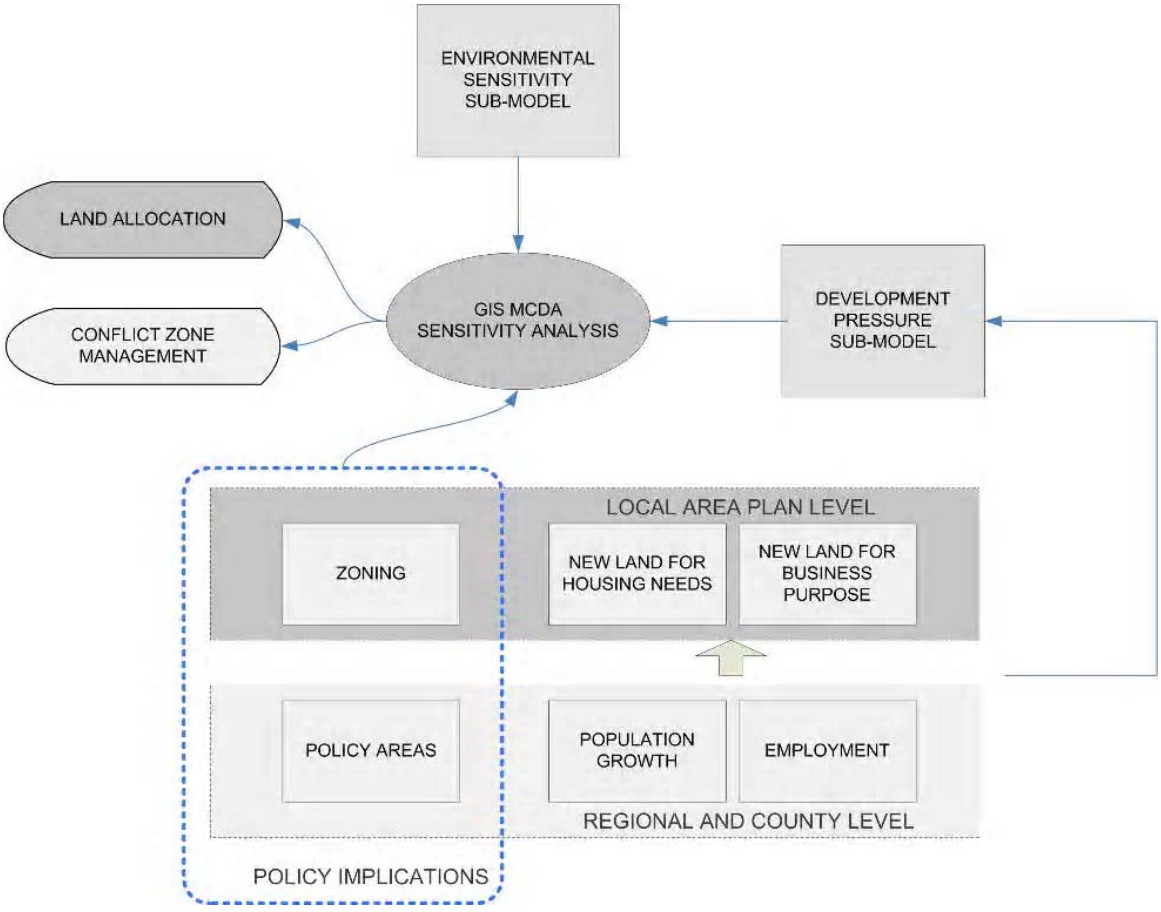

Fig. 1. Concept of the Model

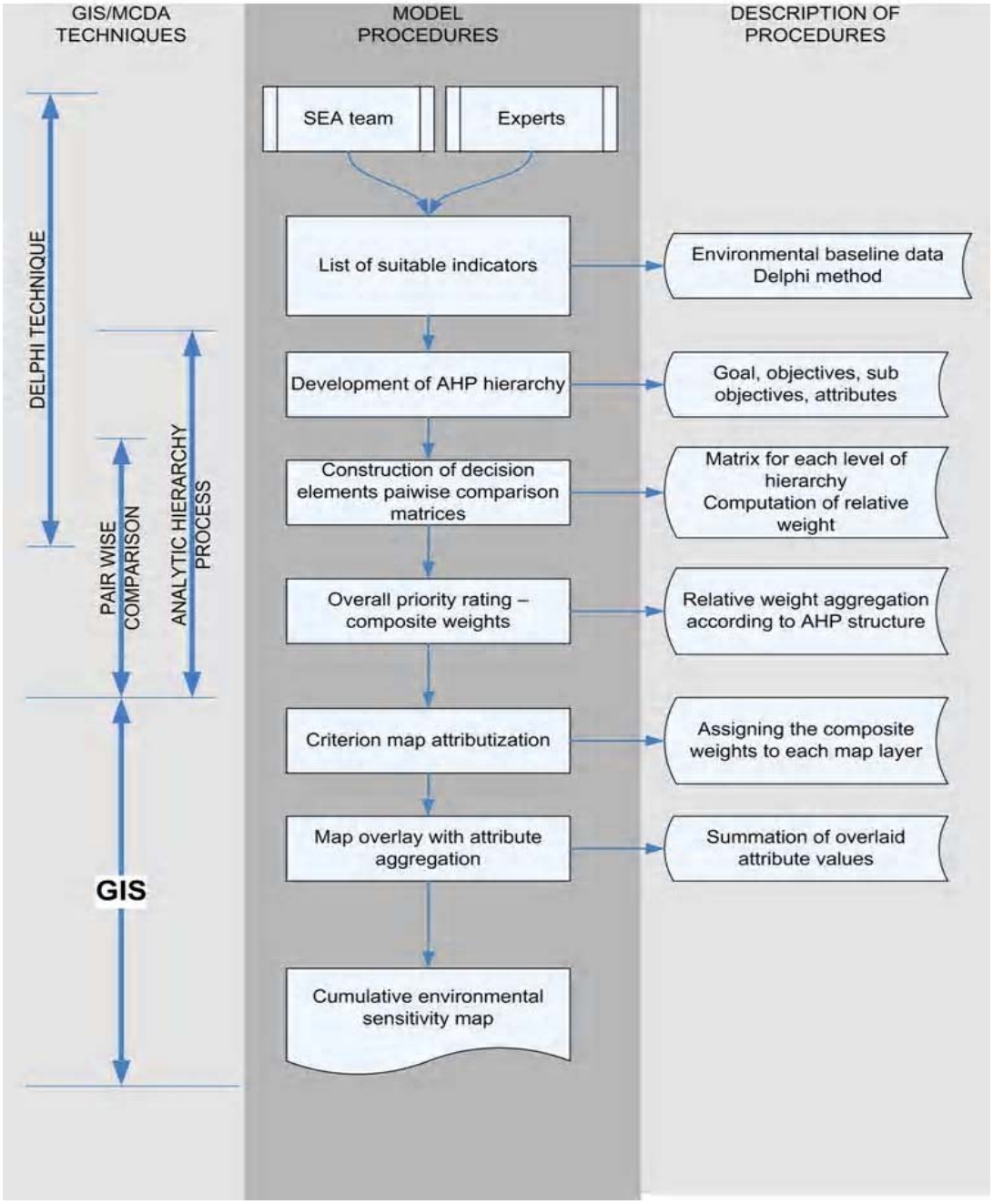

Fig. 2. The Model procedures and applied GIS-MCDA techniques

population and employment are categories which link with the planned development scenarios. In other words, at regional level the link between "development pressure zones – development scenarios" has been established through population and employment indicators. Within this link, development pressure zones are connected with development scenarios and changes in development scenarios would mean changes in development pressures zones and furthering addition, the conflict zones would also change. Therefore, the indicators get different values depending on the scenarios that represent strategic plan objectives.

In applying the above approach, the model seeks to integrate the Plan scenarios with environmental sensitivity and to simulate potential future conflicts between future development (represented with population growth and higher employment concentration) and environment. It is up to decision makers to take responsibility for the scenario selection having regard to the potential impact on the environment that the selected scenario may cause.

RESULTS & DISCUSION

SW *Regional Planning Guidelines* is a strategic document for southwest region development for the period 2010-2022. It is prepared by the Southwest Regional Authority. The guidelines should ensure the successful implementation of the National Spatial Development Strategy at the regional level.

The Southwest region includes the geographical area of Cork City, Cork County and County Kerry. Administratively, those areas are incorporated into Local Authorities which taken together form the south-west region.

The SEA methodology applied in SW regional planning guidelines Environmental Report contain all the phases (screening, scoping, etc) suggested by SEA Guidelines, but we will focus on the environmental baseline phase where the Model was applied.

„Environmental baseline" phase of *„Environmental Report"* has identified the main existing environmental problems and how they will be affected by RPG.

Within the section of Environmental baseline we applied the integration Model as correlation between environmental sensitivity sub-model and development pressure sub-model.

The environmental sensitivity sub-model was based on AHP and pairwise comparison technique, as stated in model definition. The SEA team prepared a questionnaire with the preliminary ranking of main indicators (Delphi technique). After the few phases of a ranking process the final list of indicators were established with their preliminary ranking. Indicators were organised in hierarchy structure and with pairwise comparison technique every pair of indicators was assessed in order to get their weight in the overall hierarchy system. The graph below (Fig. 3) shows the hierarchical structure of assessed indicators. The main indicators pairwaise comparison matrix is shown in Table 1 while Table 2 represents the main indicators with the corresponding weights. The total sum of all weights according to AHP theory is equal to 1.

Table 1. The main indicators pairwise comparison matrix

	BIODIVESITY	POPULATION AND HUMAN HEALTH	SOIL AND GEOLOGY	WATER RESOURCES	AIR AND CLIMATE	CULTURAL HERITAGE	LANDSCAPE	MATERIAL ASSETS	FLOODING
BIODIVESITY	1	6	4	3	3	5	4	9	7
POPULATION AND HUMAN HEALTH	1/6	1	1/3	1/5	1/5	1/2	1/3	5	3
SOIL AND GEOLOGY	1/4	3	1	1/3	1/3	3	1	7	5
WATER RESOURCES	1/3	5	3	1	1	4	3	7	5
AIR AND CLIMATE					1	4	3	7	5
CULTURAL HERITAGE						1	1/3	5	3
LANDSCAPE							1	7	4
MATERIAL ASSETS								1	1/3
FLOODING									1

Table 2. The main indicators weight

INDICATOR	WEIGHT
BIODIVESITY	0.3
POPULATION AND HUMAN HEALTH	0.05
SOIL AND GEOLOGY	0.1
WATER RESOURCES	0.17
AIR AND CLIMATE	0.17
CULTURAL HERITAGE	0.06
LANDSCAPE	0.1
MATERIAL ASSETS	0.02
FLOODING	0.03
SUMMARY	1

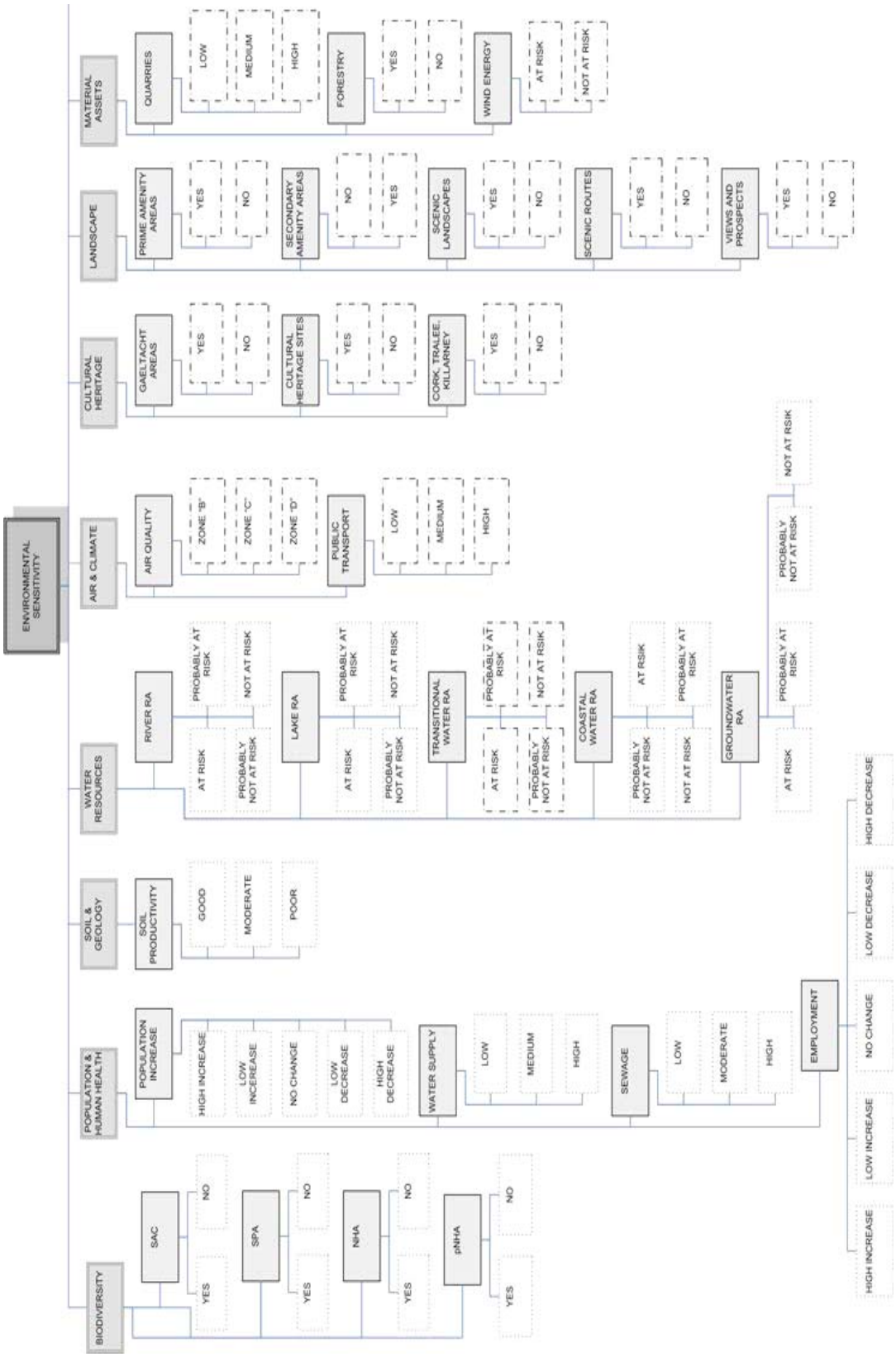

Fig. 3. Indicators AHP structure

After the main indicators weights were defined, all sub-indicators weights were calculated following the pairwaise comparison and AHP rules. For all other sub-indicators and criteria's we followed the same principle in order to obtain their relative weights.
The list of indicators, criteria and their relative weights can been seen on the graph (Fig. 4) below.
The final phase in the assessment process was to normalise relative weight to the weight of higher level in hierarchy structure in order to summarise all weights in the system to 1. In the graph below (Fig. 5) you can find final weighs.

The obtained weights from AHP we assigned to criteria grids and through aggregation process (GIS overlay) we got a Cumulative Environmental Sensitivity Map (Fig. 6) as a synthesis grid of all criterion grids.
Within the Development pressure submodel, on the basis of Census data, the population change was calculated through the following criteria: high population increase ED's, low population increase ED's, no change in population, low population decrease ED's, high population decrease ED's. The population change was based on Electoral division (ED) population census data for the period 2002 and 2006. The ED based population criteria were converted to grid with corresponding class of calculated population change.

The employment data was based on POWCAR data source where the job density was calculated applying the GIS point density tool. The development pressure zones are classified by the level of pressure, where the highest development pressure zones overlap with high population increase or with the highest concentration of jobs. So, development pressures zones are represented as zones with high population increase or strong employment zones.

Grid cell size depends of research area characteristics. In metropolitan area (Fig. 7) we chose very small grid cell size of 250 m. The reason for this is that we used POWCAR data source for the analysis and under the methodology they summarise jobs in squares 250x250 meters. So in addition, the applied analysis was also very useful for the employment strategy and RPG's planners used the results of this analysis for developing local economic strategies.
Areas of conflict are regarded as location where development pressure areas and high vulnerable land overlap.

The development pressure zone is connected to development scenarios which mean that development scenarios will determine the level of development pressure zones. If the development scenario prefers strong development and further urban sprawl that means that development pressure zones will spread and possibly more overlap with high environmental sensitive areas.
In the RPG the three scenarios were explored:

1. Continuation of current trends
2. High urban growth
3. Moderate urban growth

The stated three scenarios were analysed by 5 main strategic planning areas (Fig. 8):

1. Cork Gateway
2. CASP strategic planning areas
3. Tralee- Killarney strategic planning areas
4. West strategic planning areas
5. North strategic planning areas

Scenario 1: Continuation of urban trends
Continuation of urban trends has the following main characteristics:

- High population growth in villages and rural areas surrounding the Cork Gateway and Tralee-Killarney Hub,
- Decline in population growth within Cork City and Tralee-Killarney Hub areas
- Mallow Hub and other regional main towns will increase in population
- Increased number of commuters to Cork City and Tralee-Killarney Hub
- Rural communities will continue to decline

Scenario 2: High urban growth
Main characteristics:

- New development will be primary focused to Cork gateway and Tralee-Killarney and Mallow Hub
- Population in Cork City will increase rapidly especially in northern suburbs of Cork City
- Moderation of the rate of population growth in villages and rural areas within Gateway and Hub areas
- Low rate of population growth in countryside in line with local employment opportunities

Scenario 3: Moderate urban development
Main characteristics:

- Moderate population growth in Cork City, Hubs and main towns where insufficient infrastructure would be a highest restriction to reach the targeted population
- Investment in Brownfield sites within Gateway and Hubs

Because of the size limitations of this paper we will only explain the assessment of CASP area scenarios.
In the CASP area scenarios we explored development possibilities following the context of Atlantic Gateway initiative, where the development corridor Cork-Limerick-Galway-Waterford was highlighted, as well as an importance of Hub towns.

Also, we considered the areas suitable for rural diversification in order to explore possibilities for local economy development. Following the principles of

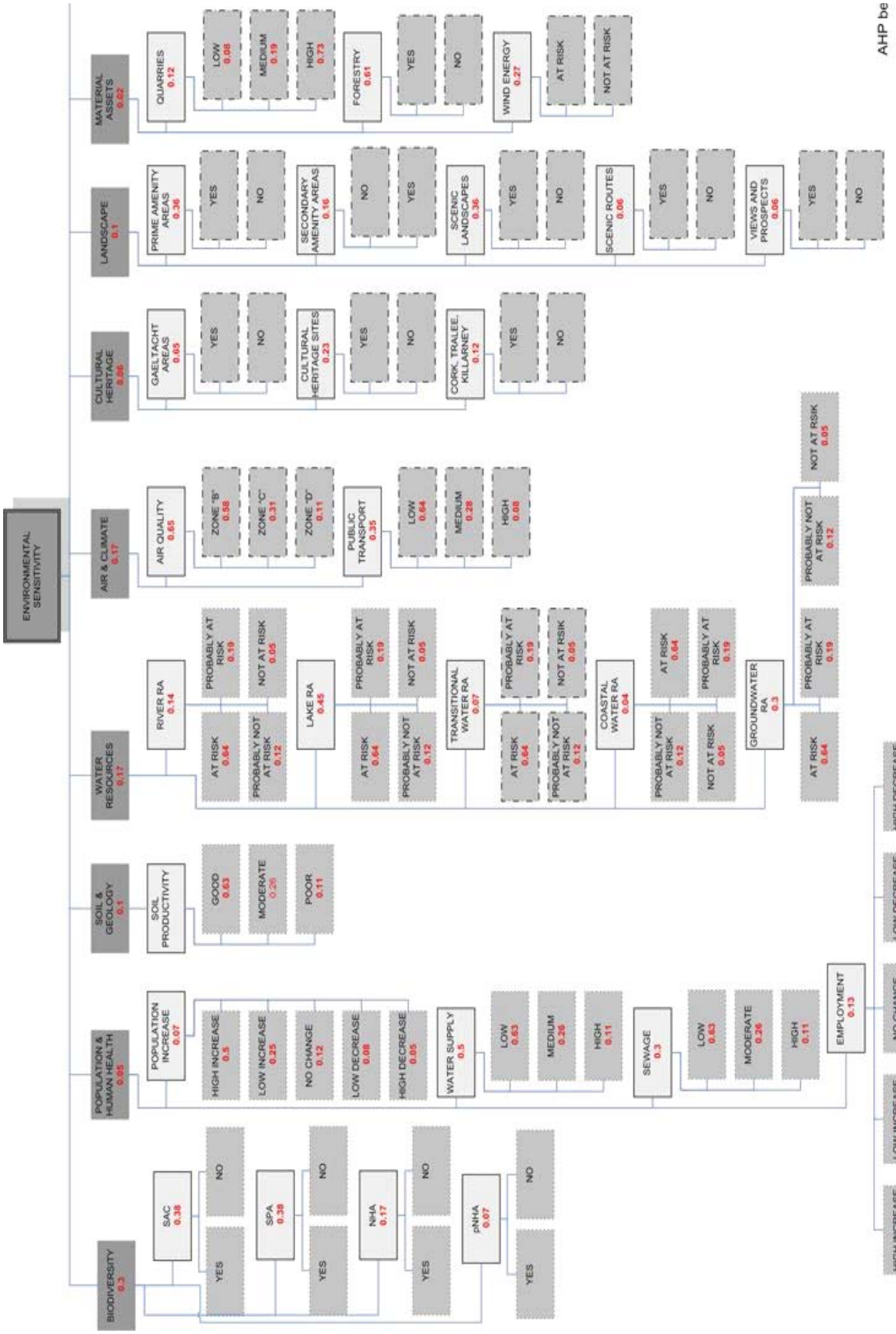

Fig. 4. AHP structure with indicators relative weights

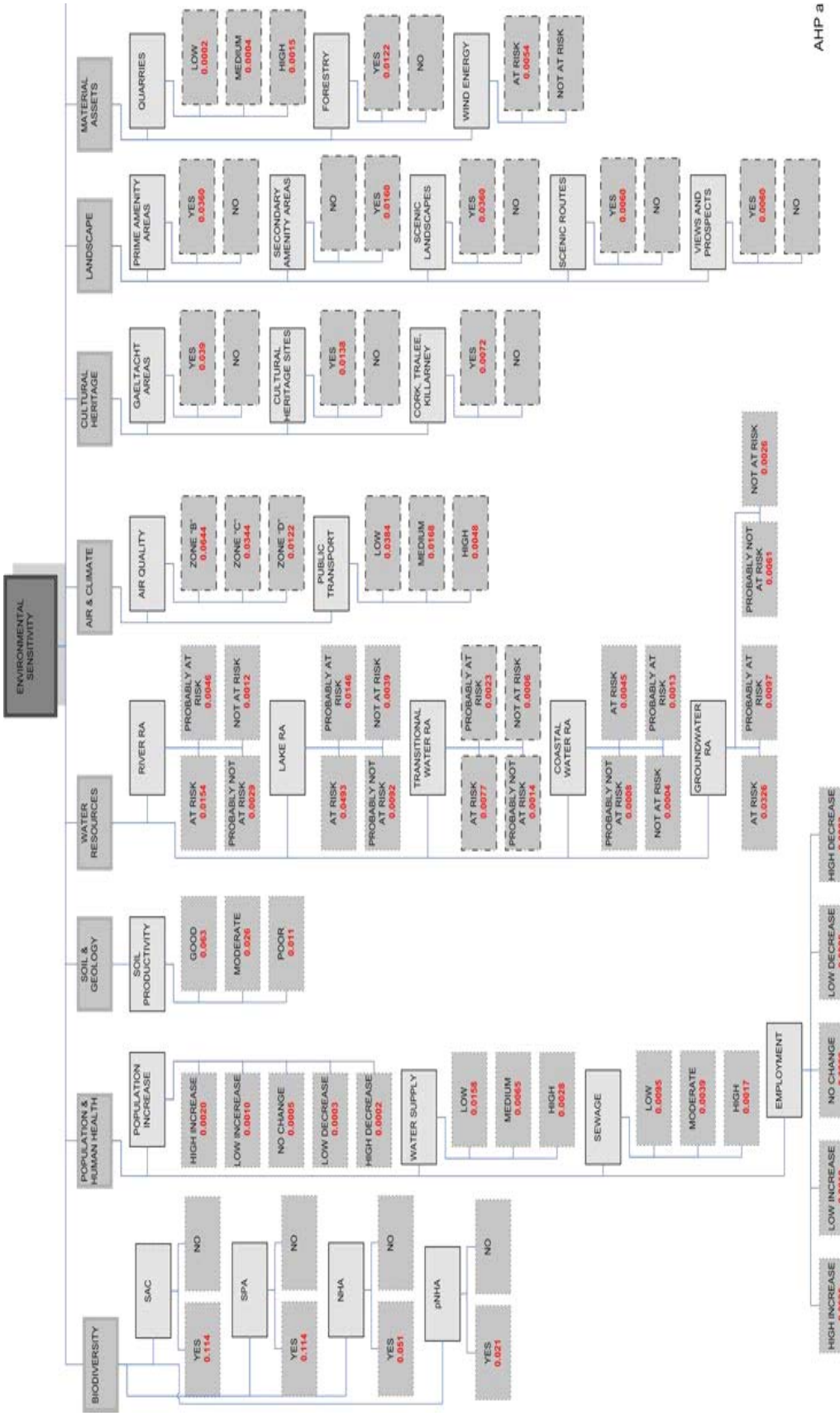

Fig. 5. AHP structure with final indicator weights

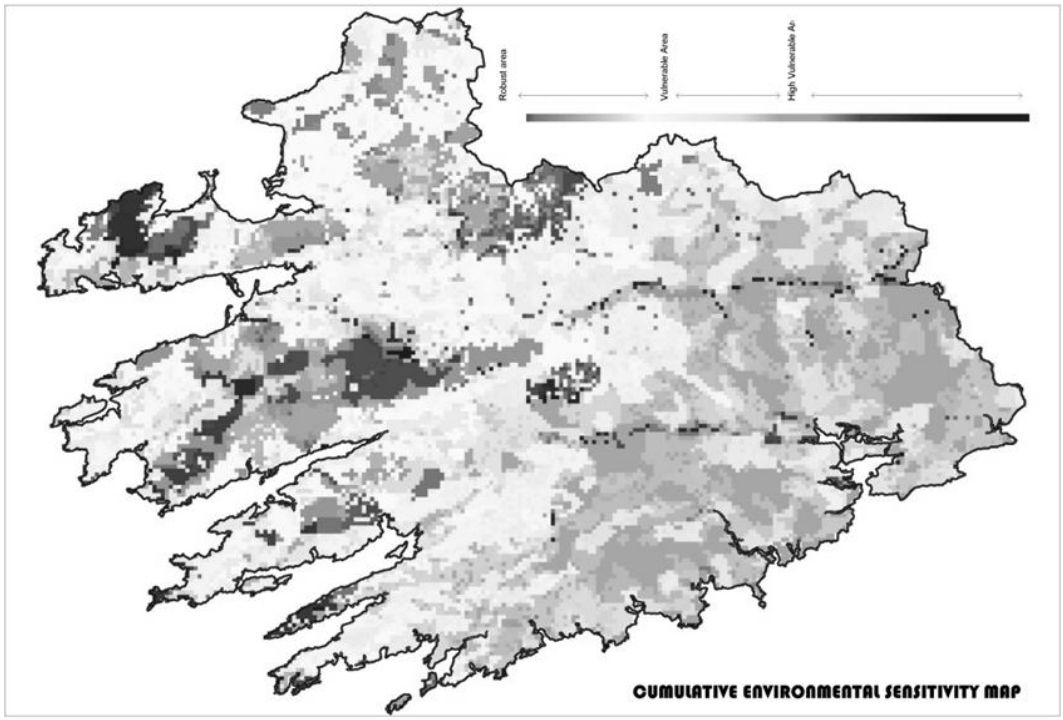

Fig. 6. Cumulative environmental sensitivity map

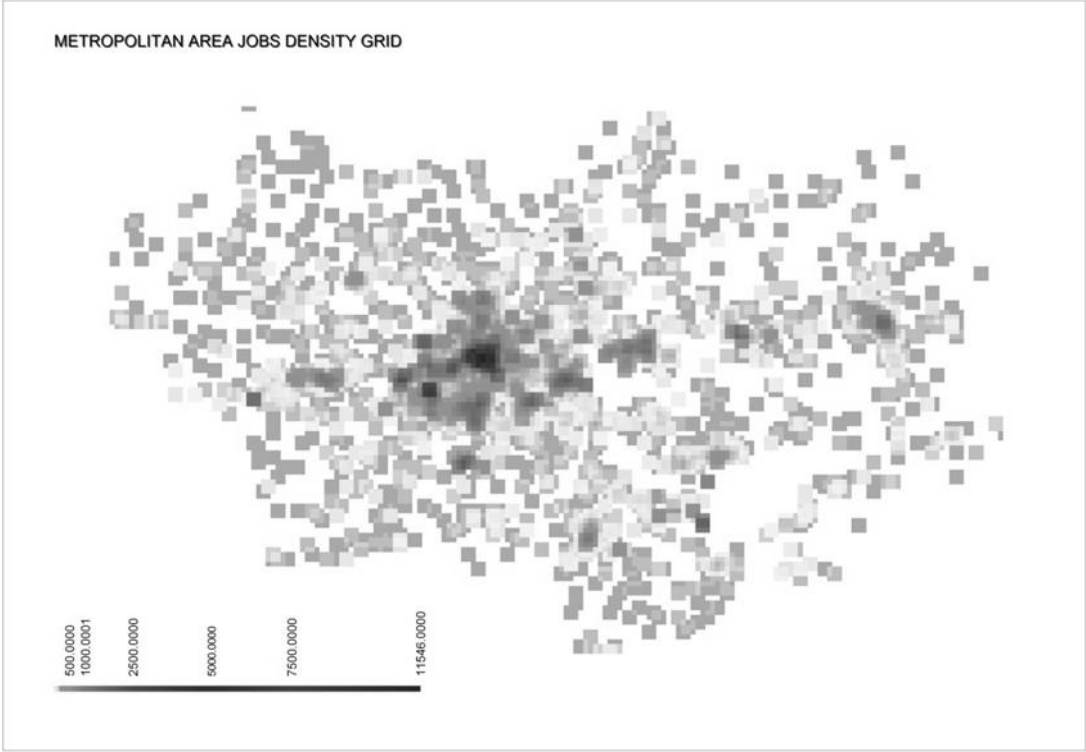

Fig. 7. Metropolitan area jobs density grid

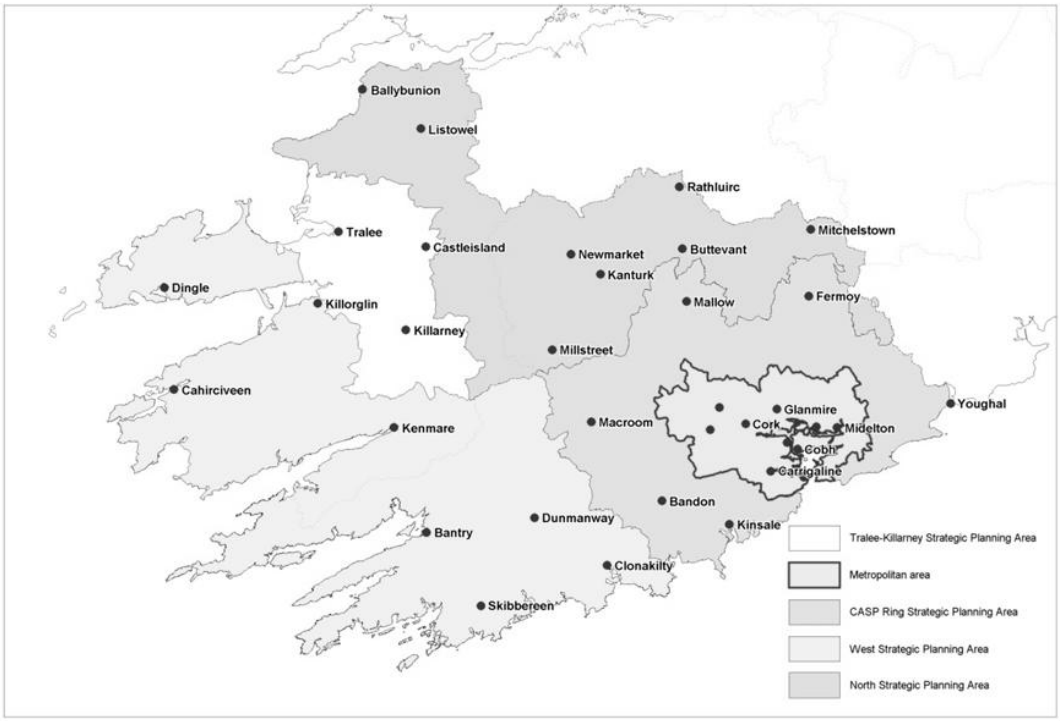

Fig. 8. RPG's main strategic planning areas

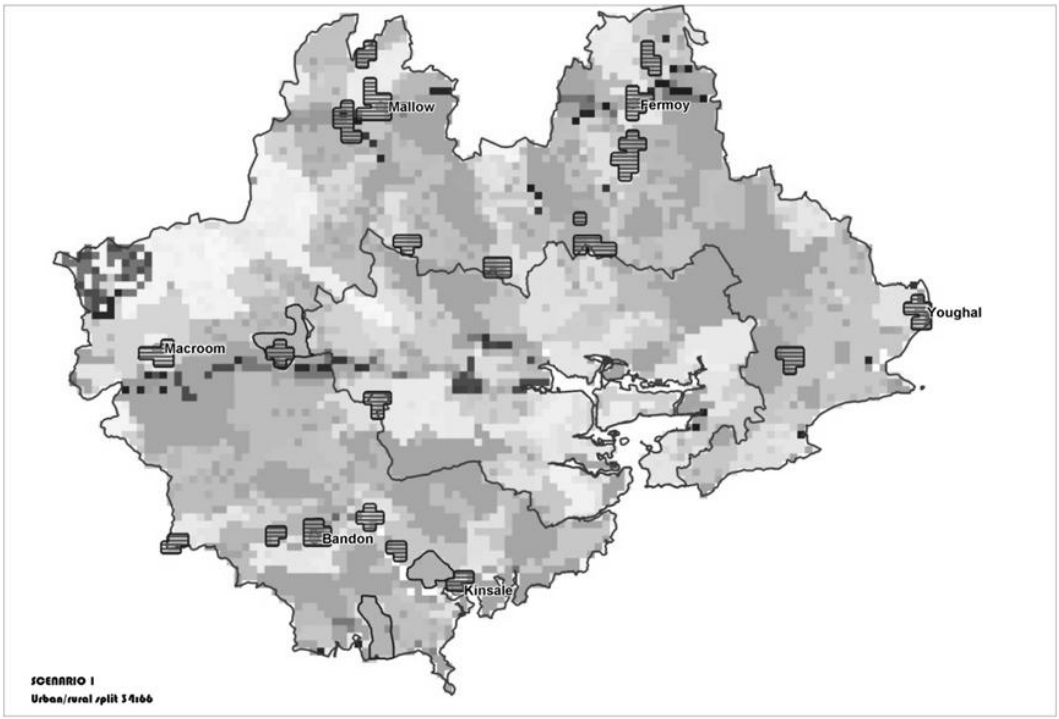

Fig. 9. Scenario 1

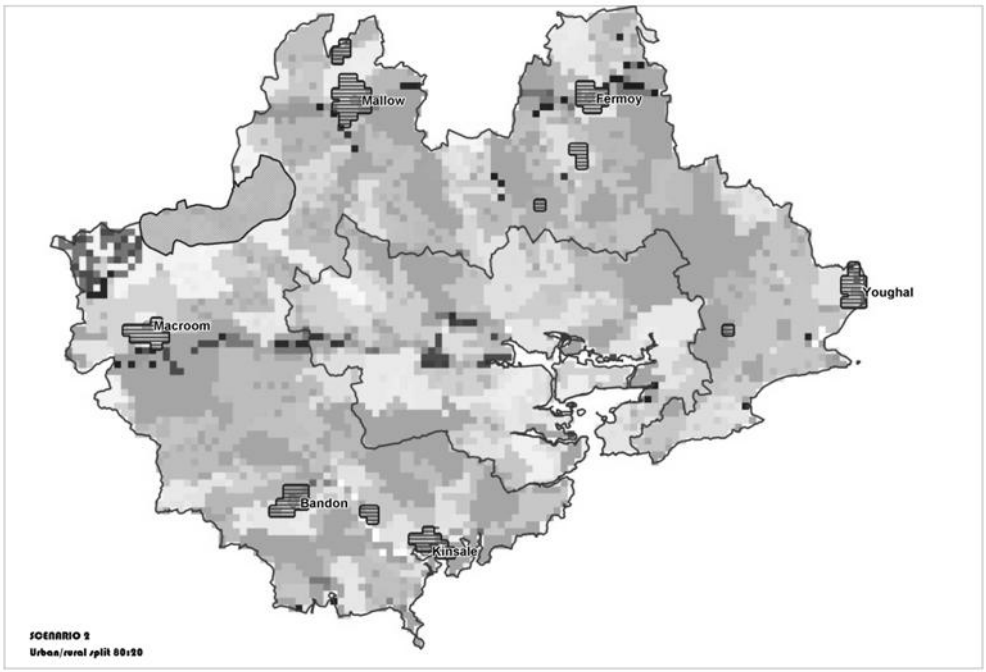

Fig. 10. Scenario 2

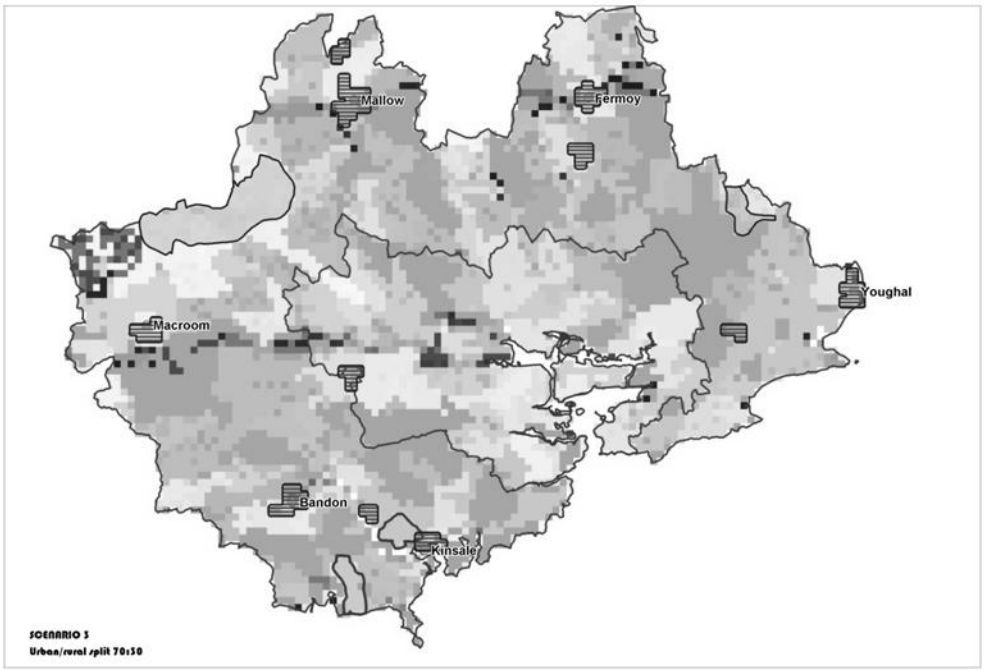

Fig. 11. Scenario 3

National Spatial Strategy, the three areas were designated:

- Village strengthening and rural area opportunities
- Diversifying areas
- Rural areas with string potential for diversification

Those areas are identified in the CASP area having regard to cumulative environmental sensitivity which means that rural diversification areas have to be designated in the low environmental sensitivity areas but also in areas with strong potential for agriculture and forestry.

With respect to the stated main development characteristics we applied the integration model to simulate expected development pressure zones in order to get possible conflict zones.

In *scenario 1* (Fig. 9) the development pressure zones and possible conflict zones are located in line with the main road corridors: Fermoy-Cork and Mallow-Cork.

Therefore we can expect high commuting in the areas which could result in decreasing of quality of life and also a decrease in the quality of air. Moreover, it's expected to have conflict with the archaeological heritage and biodiversity in Greenfield sites.

In *scenario 2* (Fig. 10) the development pressure zones are more concentrated in Mallow Hub and main towns. With this scenario it's likely to expect more sustainable commuting because the main development will be oriented towards urban centres, i.e. centres of work. The rural areas will experience population growth as they have strong potential for rural diversification, especially in area between Mallow and Macroom (Figure 10). In applying this scenario we could be faced with infrastructure problems so it's necessary to make important investment in infrastructure in order to achieve targeted population.

In *scenario 3* (Fig. 11) moderate population growth was predicted because of infrastructure limitations and restrictions in further infrastructural investments. We could expect moderate population growth in the Mallow Hub and main towns. Because of the limited investment in infrastructure, and particularly in wastewater treatment, we can also expect important impacts on the water quality of the River Lee and Blackwater. In this scenario few areas suitable for rural diversification were designated.

In general, 40% of CASP area is regarded as high vulnerable. The development corridor, based on Atlantic gateway corridor and hub towns, could be strongly effected with new development which could have a significant impact on the environment.
In the Environmental Report it was stated that "the main environmental considerations in the CASP area is the protection of agriculture productive lands, the protection of site integrity and the environmental conditions necessary to support the site integrity of Natura 2000 sites, achieving the Water Framework Directive River Basin management objectives and increasing sustainable commuting." (Environmental Report, page 132).

Therefore, analysing the RPG's main development objectives we could say that *Scenario 2* is the most preferable scenario from an environmental point of view, but also from the RPG main objectives point of view.
As the RPG supports the ER preferred scenario (Scenario 2) for CASP area all individual objectives were assessed in the assessment matrix in order to ascertain their environmental effect.

CONCLUSION

The presented model has tried to give one more perspective in the integration of the SEA process into planning. Unlike other methods the SEA process is actively involved in the planning process. The model enables simulation of results and therefore can be very useful for planning simulations.

An important feature of this model is the planning basis. The model is not a separate expert system for evaluating the environmental impact, instead it's an active model guided by planning principles in considering the impacts of the planned activities to the environment. Therefore, this model is seen as a tool developed for planning purposes.

The model and the presented approach is an attempt to involve GIS-MCDA concept into environmental planning. The critical segment of the research is how to reduce subjectivity in preliminary ranking? In the model the Delphi method was used and, in general, the Delphi method could reduce the level of subjectivity but still all individual ranking was based on subjectivity judgement. Also, within the development pressure sub-model the employment indicator was based on POWCAR data source, with "place of work" data, which could be a problem in the cases where we don't have "place of work" data within the Census. Because of this restriction the sub-model could not be universally applied.
To conclude, the model has pasted several developmental stages and the presented one is certainly not the final. As planning and SEA are processes in their essence - the presented MCDA-GIS-oriented model is a process that will improve with the improvement of planning theory and SEA.

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