Interactive Multicriteria DSS for Spatial Planning Analysis

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Abstract

This paper builds up on previous work entailing, in a first stage, the development of a geographic information system (GIS)-based environmental modelling approach; in a second stage, it entailed the development of a stand-alone more generic integrated spatial decision support system. The latter system was designed to address general spatial decision problems in such a way that enables interactive definition of mathematical models, the spatial entities involved and their attributes. This manuscript focuses primarily on a further development that implements a multicriteria modelling framework supporting sophisticated evaluation and comparison of hypothetical alternative scenarios in the context of spatial decision problems. Typically several conflicting generally incommensurable criteria are involved which derive from the multidimensional nature of most of the decision problems. In such circumstances, multicriteria techniques are recommended to be used in the analysis process. Overall, at the very beginning, the decision maker (DM) is not fully aware of the whole problem in hands and hence an effective learning process needs to be undertaken. Operating interactively with the methods above, either simultaneously or following up a given sequence, the DM may become effectively acquainted with the whole problem by investigating possible coherences among results obtained; also, by analysing sensitivity of variations in input data.

Keywords: Decision support systems; multicriteria modelling; interactive decision making.

1. Introduction

1.1 The decision process

The multidimensional nature of most of the decision problems typically leads to a rather complex context where several conflicting – generally incommensurable – criteria and objectives are involved and have to be taken into consideration in the decision process towards the finding of possible solutions for the problem (Vincke, 1992). The decision, or decision support, process is a learning interactive mechanism that derives from the evolution of different comparisons and interactions between all the parameters involved, which in turn is regulated by formal models specifically developed for the purpose (Roy and Bouyssou, 1993). In the decision process, several alternatives are usually considered for evaluation using adequate methodologies. Under such complex circumstances, models for decision support where distinct evaluation aspects are explicitly taken into account become more representative of the actual decision context. According to some authors (including *e.g.* Alçada-Almeida *et al*., 2009; Chenoweth *et al*., 2004; Cohon *et al*., 1980; Coutinho-Rodrigues *et al*., 2011, 2012, in press; Current *et al*., 1990; Hakanen *et al*., 2011; Natividade-Jesus *et al*., 2007; Olazabal *et al*., 2010; Tralhão *et al*., 2010), both multicriteria and multiobjective models are of great importance for the purpose as they enable to capture the diversity of conflicting aspects to be evaluated providing decision makers (DM) and/or planning bodies a better perception of the nature of the trade-offs to be made.

Furthermore, when decision problems relate to spatial phenomena, the use of multicriteria methods makes even more sense, as some authors (including *e.g.* Chakhar and Martel, 2003; Laarabi *et al*., 1996; or Malczewski, 2004; Olazabal *et al*., 2010) have argued that this kind of methods perfectly fits in the spatial context of the decision support. Besides the quantitative evaluation of spatial decision problems, both the translation and representation on virtual maps of the figures computed may well be a powerful tool to help DM in identifying hot spots and in strengthening or weakening their own convictions and judgments about a particular case; indeed, given the spatial component of these kind of phenomena, they can be geographically located and hence are susceptible of being mapped. The flexibility in representing and analysing spatial information is particularly pertinent as it is assumed that about 80% of the data used by DM in decision processes are geographically interrelated (Worrall, 1991).

A wide variety of multicriteria methods has been proposed over the past decades. The different methods currently available in the literature vary in multiple aspects, in terms of theoretical fundaments, type of approach, and kind of results (Hobbs and Meier, 1994). The main aim common to all of them is their ability to analytically compare different alternatives, which have different levels of performance in relation to certain criteria, and hence to provide a formal decision methodology. Nevertheless, none of the methods can be considered beforehand applicable to any decision support situation. Therefore, before such a variety of different methods and their inherent characteristics, the overall assessment of the problem in hands and the identification of its nature are absolutely crucial. Indeed, the selection of the most suitable multicriteria method for the evaluation of a particular problem is a complex task and constitutes a multicriteria decision problem in itself (Al-Shemmeri *et al.*, 1997).

The integration of different methods in the multicriteria analysis process has been object of research and in fact has been proposed by some authors. For instance, Belton and Stewart (2002) emphasised how relevant the synergetic potential of the knowledge of various methods is. Above all, the DM must be acquainted enough with all the methods already applied within the field where the decision problem in his/her hands fits in, as to be able to choose the multicriteria method which best suits the decision problem. Secondly, the DM can apply more than one method, following a given sequence or simultaneously. This way, the decision process may benefit from the merits of each method which may well complement one another's weaknesses and therefore contribute to a wider decision support basis (Belton and Stewart, 2002). Kangas and Kangas (2005) confirmed that integrated multicriteria methods were a potential avenue worth of further research.

1.2 Aim & objectives

Because of the merits pointed out above of multicriteria analysis of different hypothetical alternatives, different alternatives possibly generated with a spatial decision support system may well be taken eventually to be evaluated and compared to one another within a multicriteria analysis framework. Further to this, the authors sought to design and implement a system capable of handling the challenging requirements mentioned above.

The ultimate aim of the work described in the present manuscript is therefore to provide decision aid by enabling the rationalization of comparisons between possible alternative scenarios within a multicriteria decision analysis framework. In order to accomplish this, the following objectives are pointed out:

(1) To implement some of the most widely used multicriteria methods;

(2) To create a map-based dynamic interactive interface;

(3) To interactively analyse, in such map-based interface, the alternative scenarios in hands and simultaneously visualise the decision aid results both in the geographical and objectives' spaces.

1.3 Paper structure

The remainder of this article is structured as follows. Previous work undertaken by the authors is reviewed in section 2; in particular, two GIS-based systems upon which the multicriteria decision support framework hereby proposed builds on are described: an environmental modelling system, and a generic integrated spatial decision support system. Section 3 covers the architecture and functionalities of the multicriteria decision support framework developed; in addition, the models related to the multicriteria methodologies implemented in the system are briefly revisited; at the end of section 3, three alternative solutions for a real-world decision problem are presented and analysed within in the criteria space aiming to test the proposed framework. Finally, section 4 summarises the most pertinent aspects of the work carried out, some conclusions are drawn and possible future work outlined.

2. Previous work undertaken

2.1 A GIS-based environmental modelling approach

A first stage of our work entailed the conception and implementation of a computerised environmental impact modelling approach for atmospheric dispersion that would enable authorities to perform a rapid, intuitive, and comprehensive evaluation in the immediate aftermath of a natural or man-made disaster scenario. With such a system, the authors sought to simulate and foresee the impact on territory and population of a hypothetical environmental disaster related to hazardous industrial waste (HIW) incineration.

A well established mathematical model representing impacts related to pollutants dispersed in the air, the Gaussian plume model, and its linkage to a GIS were implemented - for the purpose, the simplest formulation of the Gaussian plume model was used as an example scenario (for further details, the reader is referred to de Almeida and Coutinho-Rodrigues, 2011). Such a combination proved to profit from the capabilities of graphical visualisation of impacts on virtual maps. To accomplish this, a communication interface between a high-level programming language, supporting the model, and the GIS was developed. The numerical values obtained with the Gaussian formulation were automatically translated by the system into graphical metaphors based on coloured classes of values. This enables a rapid visualisation of the plume's footprint in meaningful intuitive gradient virtual maps. (Dykes, 1997; Dykes *et al.*, 2005; MacEachren, 1995).

Our case study covered the simulation of a fortuitous malfunctioning in the co-incineration plant of Souselas - where incineration of HIW is accomplished - located approximately 7 km north of Coimbra, a medium size city in the west-centre of Portugal's mainland. Under particular simulated circumstances, the authors sought to foresee who would be affected and where and also provide global indicators of the impact magnitude, such as people affected, maximum and minimum concentration values, or impact over particular facilities, irrespective of the type of pollutant considered. A particular attention was paid to more vulnerable segments of the population (*e.g.* patients, children, elderly people), and hence certain urban facilities, such as hospital units and pre-primary schools that serve particularly sensitive segments of population. Results obtained and their visual metaphors were overlaid over both digital cartography of the area affected and the spatial distribution of population (Figure 1-left). Results calculated for impacts over communities can be obtained by the system combining both the spatial distribution of the pollution and population (Figure 1-right, where coloured polygons correspond to populated urban areas and the grey scale tone, in monochromatic representation, is proportional to the pollutant concentration x nr. People affected). A zoom in to the most proportionally affected areas, in terms of population, is depicted in Figure 1-middle where some of Eiras statistical subsection[2] areas are highlighted in red circles.

Insert FIGURE 1 about here

2.2 A generic integrated spatial decision support system

Further to the recommendation of some authors, such as Turban *et al.* (2007), the approach and system described above in section 2.1 was further extended entailing the conception and implementation of a more generic and fully integrated spatial decision support system. The advantages of such a spatial decision support system (SDSS) – where components like, spatial data, GIS software, a model solver, and a database, are really integrated within a single system – are widely recognised (Carlsson and Turban, 2002; Turban *et al.*, 2007): the what-if and the goal-seeking options must be easy to perform; in addition, it facilitates the generation of different scenarios; furthermore, it supports the interactive analysis of sets of interdependent problems that may totally or partially share the same data, and whose output of a certain problem

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[2] Corresponds in Portugal to a 2nd-level non-administrative subdivision of local civil parishes, for statistics purposes.

may well be in turn the input of others. This is particularly relevant at the planning stage of facilities as alternative scenarios have usually to be generated and analysed.

In order to illustrate the system integrated capabilities, this was applied to the same real case study as that mentioned in section 2.1 and similar circumstances were simulated.

The model editing interface

The initialisation procedure consists of the definition of a new entity “Problem” by inputting general attributes: *e.g.* geographical area extension, measure units, or accuracy. Spatial objects are specified by a hierarchical definition of their categories using sets of hierarchical attributes of their characteristics (generally referring to static physical aspects) and properties (generally referring to dynamic aspects, thus typically associated to mathematical functions). Functions that describe the pollutant diffusion model being used are implemented in the system through an embedded generic editor for mathematical expressions.

This editor is structured in three pages: “Function Arguments”, “Function Algorithm”, and “Function Test”. The type of model defines whether it is a step-by-step user defined expression, a table-based model returning data stored in the database associated with entry keys, or a model integrated and embedded in the system binary code. Any type of model can be defined in the second page of the editor. Any model stored in the system may be called by other mathematical expressions. The sort of model compilation to be carried out can be defined by the user. Functions can be tested in the third page by returning the results for any set of parameters previously inputted. As far as our particular test is concerned, both the Gaussian models and the respective components were defined and stored in the system using its model editor.

Defining spatial objects

The test aimed to visually show the impacts of punctual source atmospheric emissions, both in terms of concentrations and population affected. A digital map of the area, the location of the spill source (location and physical attributes), and the spatial distribution of population and facilities must be taken as fundamental input data. The system may calculate and represent population densities in colour gradients that can be visualised and overlaid (making use of the "intersection" or "union" GIS operations) over other spatial information, *e.g.* the Gaussian plume's footprint.

The spill source is defined by creating in the system a spatial object with the appropriate geometric primitive (typically a "point") along with the specification of the respective attributes (*e.g.* planimetric coordinates on the ground, height, emission flow rate, temperature of the flow, hole's diameter). Any other particular entities to be considered must also be defined along with their attributes – in our particular simulations, a large hospital unit was considered.

After the definition of the model along with the associate spatial objects, the DM is able to perform simulations and visually evaluate the corresponding results. If several emission sources are defined and activated in the problem, the global results may be automatically obtained as a cumulative procedure performed by the system.

Results obtained and their analysis in the geographical space – different alternatives

As noted above, a particular situation was simulated under similar circumstances as that of our previous work. In this specific simulation described in section 2.1 – which constitutes our scenario #1 – a 2800×2400-cell rectangle (each cell corresponds to a 10×10 m^2), representing our case study area (672 km^2), was considered. Maps illustrating both pollution concentration and number of inhabitants at each single location of the geographical space considered can be generated (*vd*. Figure 1). Usually, a measure of impact is given by: pollutant concentration × #people affected (Dykes and Mountain, 2003).

In addition, same data can be observed numerically in a 2-variable diagram generated and displayed by the system, as shown in Figure 2 where the vertical axis represents the number of inhabitants affected, and the horizontal axis represents several classes of pollution concentration. This combination of the environmental and social dimensions gives more precise information about the distribution of the actual impact, enabling equity comparisons between different solutions.

Insert FIGURE 2 about here

In what concerns environmental studies, the Portuguese law explicitly requires the consideration of alternative scenarios, and hence the reason for us to take into account in our case study three different scenarios. Given the multidimensional nature of environmental decision problems, this implicitly appeals for a multicriteria analysis framework. Within this context, several simultaneous emission sources, and associate impacts, may be simulated in this kind of problems, as shown in Figure 3 where another alternative scenario was considered: scenario #2 – consisting of two new smaller dedicated incineration units in different locations from the above offering an increment of about 10% in terms of total joint capacity, when compared with the existing cement plant. This allows, for example, to verify whether the total impact over the population (measured as the total sum of pollutant concentration × #affected people) is possibly smaller when the emissions are distributed by several smaller sources, corresponding to feasible candidate sites (*e.g.* where population density is lower). In spite of representing higher costs, this new solution would affect less people and would have lower maximum and average pollutant concentration values. Besides, the dedicated solution could eventually have a lower psychosocial impact.

Insert FIGURE 3 about here

A third scenario, #3, was tested considering the co-incineration activity still in the existing cement plant, considering however an additional investment to build a higher chimney. This could be a compromise solution considering the trade-offs between costs and impact over population – due to the lower value obtained for the maximum impact over any individual (*vd.* Figure 4).

Insert FIGURE 4 about here

As stated in our previous work (*vd.* section 2.1), the impact of airborne toxic releases on vulnerable segments of population in urban areas is absolutely relevant for the generation of risk maps (Corburn, 2007; Coutinho *et al.*, 2006; Coutinho-Rodrigues *et al.*, 2011); in fact, this constitutes an important spatial component of the problem. Therefore, the evaluation of impacts in particular points representing urban facilities dedicated to more sensitive people, such as children, patients, or elderly people, may well be of great interest. For this sort of analysis, entities such as pre-primary schools, hospitals, and/or care houses should be of interest. Given its dimension and relevance within Portugal's national health system, one of the urban facilities specially considered in our case study was the Coimbra University central hospital, as it had been before.

As displayed by the system, the important hospital unit above happens to be located roughly on the straight line defined by the cement plant's chimney in Souselas and the general predominant wind direction (*vd.* Figures 1, 3 or 4 above). The concentrations calculated for this particular hospital in the context of the three scenarios simulated have also different values; this attribute may well be an important aspect in the analysis of this kind of decision problems. The maximum pollutant concentration in the hospital location occurs in scenarios #1 and #3 (co-incineration installed in the existing cement plant) – in fact, in those scenarios the hospital is located right on the straight line defined by the potential polluting source and the predominant downwind direction. In scenario #2 (dedicated plants) the concentration in the hospital location for the same amount of pollutant released would be significantly lower (about ¼), as readily obtained with the system.

Pertinent criteria to be considered in the analysis process

In terms of decision analysis, the scenarios specified above are clearly multidimensional and could well be evaluated under the consideration of different conflicting criteria. Aspects like, (i) the number of people affected, (ii) economic costs, (iii) maximum impact over an individual (equity criterion), (iv) average impact on communities, (v) the number of people affected above a given minimum safety threshold or (vi) the number of people affected above a maximum tolerable threshold (which may well mean unacceptable threshold values), or (vii) the impacts over a particularly important urban and sensitive facility (like the hospital unit mentioned), are different dimensions of the problem that should be considered simultaneously in this kind of analysis. They were indeed taken into consideration under a multicriteria framework as described in the section bellow.

3. A multicriteria decision support framework

3.1 Background

Cheng *et al*. (2002) and Farahani *et al*. (2010) have classified multicriteria location-allocation problems into two categories: multiobjective and multiattribute. The multiobjective methodology involves the search for the best solutions within a vast set of possible solutions identified beforehand; the main goal is to provide the infrastructure to support the generation of sets of feasible alternatives (Malczewski, 1999). According to Stewart (1992), the set of alternatives is implicitly defined through a mathematical programming structure generally referred to as "multiobjective optimisation". Overall, multiobjective optimisation consists of either the maximisation or minimisation of the objective functions, which cannot be grouped in a single mathematical expression. As to the multiattribute methodology, a relatively small set of possible solutions, a set of criteria under which the solutions generated are judged, and a set of both synthesis function-based methods and prevalence relation-based methods to evaluate those solutions, are considered (Vassilev *et al*., 2005).

There are in the literature some well established models related to the methodologies above which were implemented in the system and stored in a models base, namely: Simple Additive Weighting (SAW) (Yoon and Hwang, 1995), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) (Yoon and Hwang, 1995), and Elimination and Choice Translation Reality (ELECTRE) family (Roy, 1990; Figueira *et al.*, 2005). The system's decision support base offers a set of techniques that provide a coherent guidance throughout the decision analysis process. The methods above can be broadly categorised as compensatory or non-compensatory, being also different with regards to the preference information required from the DM and the type of output provided. Another difference refers to the relative *vs.* absolute judgment of alternatives. In the first case, alternatives are directly compared one to each other and the results are expressed using the comparative notions of "better" and "worse". In the second case, each alternative is considered independently from the others to determine its intrinsic value by means of comparisons to norms or references. In this case, results are expressed using the absolute notions: "assign" or "not assign" to a category; "similar" or "not similar" to a reference profile; or "adequate" or "not adequate" to some norms (Mousseau *et al.*, 2001).

Both SAW and TOPSIS allow for compensation between criteria and are based on simple and intuitive principles, yet quite disputable ones mainly regarding the role of weights. However, in many situations, a very good performance in one criterion may not compensate a low score in another criterion. Other methods, such as the ELECTRE family, were developed to overcome this limitation.

TOPSIS in particular is based on the idea that the best compromise alternative is the one that has the minimum distance to the ideal solution (*i.e.* a solution unlikely to be feasible composed of the best possible values for all the attributes), and the maximum distance to the anti-ideal solution (*i.e.* a solution, usually not real, composed of the worst possible values for the attributes). This method belongs to the complete aggregation methods group that compute an aggregate performance for each alternative. Consequently, it provides a complete ranking of the alternatives based on those values of overall performance.

ELECTRE methods rely upon the construction and the exploitation of an “outranking relation” in face of the problem to be tackled (selection, ranking or assignment). To say that “alternative A outranks alternative B” means that “A is at least as good as B”. The main feature of ELECTRE methods is their intrinsic non-compensatory nature. That is, a very bad performance on a given evaluation aspect (criterion) cannot be compensated by good scores on other criteria. Furthermore, ELECTRE methods accommodate in a natural way the imprecision and uncertainty inherent to Human decision processes by relying on the use of thresholds: indifference, preference, and veto. ELECTRE methods also allow for incomparability between alternatives whenever, with the available information, there is no clear evidence in favour of one of them (which is not the same as indifference between the alternatives). The validity of the assertion “alternative A outranks alternative B” is verified using the concordance (a majority of criteria supports it) and non-discordance (no criterion is strongly opposed to it) principles. Weights in the framework of ELECTRE methods do not depend on the nature of the criterion scales. Therefore, these weights possess the true meaning of relative importance given to the distinct criteria. In this way, weights in the framework of ELECTRE are different of weights used in SAW and TOPSIS, which in these cases can be interpreted as rates of transformation into a common utility/value unit.

ELECTRE I (and its variants, like Is) is devoted to the selection problem. ELECTRE TRI is dedicated to the assignment problem, where the aim is to assign each alternative to one of a pre-defined set of (ordered) categories or classes. For the definition of the limits of these classes, standard or reference actions that the user can select within the information system may be used. Other important characteristic of ELECTRE TRI, for the analysis of this kind of problems, is that it comprises the concept of pseudocriterion. In the case of a real-criterion, action A and B are indifferent according to this criterion only if their performance is equal. In the case of a pseudocriterion, indifference is extended to a zone where the difference between A and B is below a given threshold; whereas, between the zone of indifference and the zone of strict preference, there is a zone of weak preference which indicates a hesitation between indifference and strict preference.

3.2 System's architecture

For the results' analysis, the system provides graphical illustrations of them aiming to minimise the cognitive effort required to the DM: global rankings of the alternatives (*e.g.* outputs of the SAW and TOPSIS methods in bar graphs – better classified alternatives have larger bars), or graphs (outputs of ELECTRE methods in directed graphs where the alternative in the tail node of an arc outranks the alternative in the head node) are represented in floating windows (*vd.* Figure 5). The user can interactively manipulate different features, such as:

- Scenarios generated may be activated *vs.* deactivated themselves;
- Criteria may be activated *vs.* deactivated;
- Multicriteria methods implemented may be activated (whose results are visualised simultaneously) *vs.* deactivated;
- Both global and local parameters of the active decision aid method(s), *e.g.* weights, indifference, preference, or veto thresholds in the ELECTRE methods, may be changed.

As the DM interactively changes parameters, corresponding results are obtained automatically; these are displayed simultaneously for all the active methods in the graphical interface of the so called "criteria space". Therefore, the DM can easily compare the outputs of the different active multicriteria methods displayed simultaneously; moreover, he/she can visualise the immediate output reaction to any modification imposed on a specific parameter. This interactive characteristic, which is transversal to all the system itself, may also enable sensitivity performance analysis (*e.g.* based on different sources of variation of the inputs) of the scenarios generated.

In adittion, other parameters referring to the numerical values obtained can be manipulated. For instance, the DM may choose a particular type of numerical scale out of three implemented: ordinal, interval, or ratio; attribute values may be either actual or normalised; furthermore, six types of attribute value normalisation are available: linear-ratio, linear-difference ratio, manhattan, euclidean, manhattan of differences, and euclidean of differences.

Insert FIGURE 5 about here

3.3 Decision analysis in the criteria space

In order to perform a multicriteria analysis, the values for the seven pertinent criteria mentioned above, in section 2.2**,** were obtained by creating three scenarios: #1 - currently existing cement plant; #2 - two dedicated plants; #3 - currently existing cement plant with a higher chimney 180m high. They are represented in a decision matrix (Table 1) where the contrasts among solutions can be observed. In fact, some conflicts are evident: the cheaper solution (scenario #1) corresponds to overall higher environmental impacts (maximum, average, and over the hospital unit). Lower impacts over the hospital unit correspond to the most expensive solution (scenario #2). The lowest maximum impact over an individual corresponds to scenario #3.

Insert TABLE 1 about here

Both graphical and numerical results – some of which are indicated in Table 1 – were obtained for each scenario as input data for the multicriteria analysis module. In this module, the decision matrix in Table 1 was considered (only economic costs were edited by the user since, all the others are calculated by the system) and associate values used as input for a multicriteria analysis. The analysis process was carried out by applying the appropriate models implemented. As illustrated in Figure 5, for that particular set of parameters mentioned in section 2.1 (including the weights, at the bottom-center), scenario #3 was classified as the best by the three multicriteria active methods: SAW, TOPSIS, and ELECTRE III.

Nevertheless, the system also enables one to undertake sensitivity tests and analyse what the associate tendencies in the results of the methods above are. In fact, by applying continuous variations to the methods' parameters – principally those that are common to different methods – the DM may evaluate dynamically what the implications of such variations are on the global performance of the alternative scenarios. As an example, Figure 6 depicts an experiment carried out as follows: "Cost" criterion was deactivated – hence, more importance was given both to the average risk and to the impact on the hospital unit; in addition, all the alternative scenarios and SAW, TOPSIS, and ELECTRE III methods remained active; finally, indifference, preference, and veto thresholds – respectively 5%, 20%, and 40% – also remained the same. As it may be seen, scenario #2 was classified as the best option by both SAW and TOPSIS methods, whereas ELECTRE III considered equally scenarios #2 and #3 as the best options without ranking them out separately.

INSERT Figure 6 ABOUT HERE

4. Conclusions and further work

The integration of large bodies of knowledge with extensive datasets, and their re-use thereafter, is still generally considered in the literature to have emerged yet and to be awkward to be fully accomplished. Our ultimate goal was a step forward to assist the DM in keeping and structuring information, obtaining spatial and statistical analysis, and to provide decision aid by enabling the rationalization of comparisons between possible alternative scenarios.

The process of adequately evaluating different alternative scenarios depends not just on the quality and amount of information gathered but also on the system features offered to the DM. Coupling within the same software package analytical models with spatial data storage, geo-visualisation capabilities, and decision support methods is a promising area for providing sound decision support to decision and policy makers in a wide range of fields. The system proposed in this paper implements in fact a multicriteria decision support framework that supports the analysis and comparison of alternative scenarios previously generated. In addition, the system provides spatial visualisation of scenarios on maps (*e.g.* in urban, regional, transportation, or environmental planning), assisting the user to rapidly locate spatial occurrences on maps; this constitutes in fact a value-added for a quick perception of the spatial variation of qualitative and/or quantitative indicators is possible.

Overall, analysis of different alternative scenarios involves the consideration of conflicting generally incommensurable criteria that derive from the multidimensional nature of most of the decision problems. Technically, there is no optimal solution in the circumstances above and hence a considerable degree of subjectivity is intrinsic to the analysis process. It is believed that only an interactive system provides the DM – typically not fully aware of the whole planning problem in hands – with an effective learning process, which is clearly required in such circumstances. Our system enables in fact the manipulation of different features; in addition, the DM can visualise the immediate output reaction to any modification imposed on a specific parameter. This interactive characteristic also supports sensitivity tests; indeed, by applying continuous variations to some methods' parameters, the DM is capable of analysing what the associate tendencies in the results of multicriteria methods are, and also may dynamically evaluate what the implications of such variations are on the global performance of the alternative scenarios.

At the current stage of its development, our system constitutes an independent separate application from the generic decision support system previously developed (section 2.2). Further work will entail the implementation of that one embedded in the latter; this way, a proper fully integrated spatial decision support system will be obtained. It is strongly believed that such a system will be versatile enough to support territorial system modelling of a wide range of fields.

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