Deliverable 4.17

Report on: Manual describing the SDSS structure and its use for on line training courses

DOCUMENTATION FORM

DISSEMINATION LEVEL PU (Public)	DISTRIBUTION Partners	OBSERVATIONS This report has been prepared by University of Trieste

TITLE

Deliverable 4.17
Manual describing the SDSS structure and its use for on line training courses

KEYWORDS

Spatial Decision Support Systems, GIS, Multi-Criteria Analysis, models, MATEDIT

ABSTRACT

This report deals with the development of SDSS taking into account the case study of Santos Bay

Project Leader

UNITS – University of Trieste
Department of Biology, via E.Weiss, 2 - Trieste ITALY

Funding

This project received research funding from European Commission’s Six Framework Programme – Contract nº INCO-CT-2004-003715 (Dec2004-Nov2007)

AUTHOR(S)

Enrico Feoli*, Mauro Scimone*, Rossella Napolitano*, Paola Almeida Guerra*, Massimo Dragan*, Marcela Torres**
* University of Trieste (UNITS)
** Universidad de Chile

Verification

Enrico Feoli

DATE	NUMBER OF PAGES	REFERENCE NUMBER
8/06/2008	13	

Table of contents

1 Introduction to Spatial Decision Support Systems

Spatial Decision Support Systems (SDSS) are special cases of Decision Support Systems (DSS). They are meant to optimally locate in space human activities (e.g. cropping, logging, selling, etc.) and structures (buildings, infrastructures etc.) that can be called for our purposes "land uses" according to some specific objectives. The application of SDSS should follow a decision making process that already selects the type of land use among different alternatives. Since the application of SDSS should always follow the application of a DSS, the following definitions for DSS and SDSS should be adopted:

- DSS (Decision Support System) is a combination of information, technology and tools designed to rank possible alternatives in order to choose the most suitable ones.

- SDSS (Spatial Decision Support System) is a combination of information, technology and tools designed to optimally locate the alternatives chosen with the help of a DSS.

The concept of suitability is very important for DSS and SDSS applications. According to this concept, the choice done is not the best in absolute terms, but just the best in the relative context in which DSS and SDSS are applied. For this reason, the ultimate objective of a computer based decision support system (DSS or SDSS) is merely to improve the decision making processes by providing useful and scientifically based information to the actors involved in these processes, and tools that can flexibly and easily deal with such information in an iterative and recursive way. DSS and SDSS belong to the "domain of decision making" that is given by a network of actors (stakeholders) whose main nodes are: decision and policy makers, investors, entrepreneurs, the "general public" and the scientific/ technical institutions that can offer knowledge and tools to support the decision making (Figure 1).

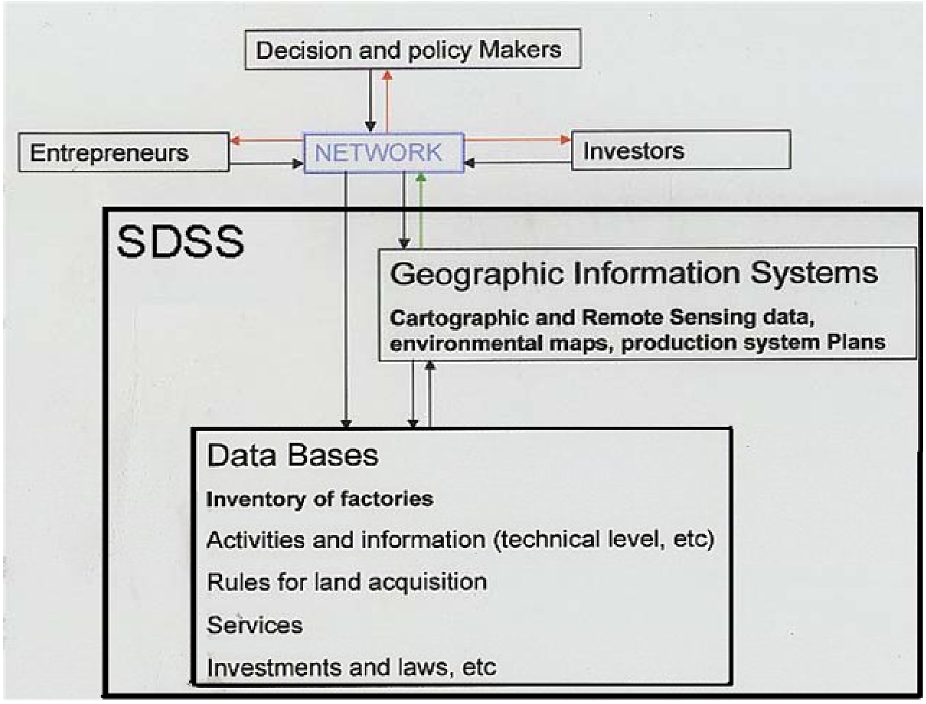

Figure 1: Network where SDSS is an essential component.

According to Fedra and Feoli (1998) in this network where "problem owners and various actors in the decision making process have a central role; supporting their respective tasks, requires man-machine interfaces that are easy to use and easy to understand: the paradigm of the thematic map offered by GIS is a powerful tool for this purpose…" an effective decision support system must first of all provide a common, shared information basis, framework and language for dialogue and negotiation. The network requires that information provided by SDSS is adequate for and acceptable to the broad range of users "needs" involved in the respective assessment and decision making processes. Fedra and Feoli (1998) stated also that "an information system that can cater to all these needs must be based on more than good science and solid engineering". It should consider the problems related to the complexity of the environmental systems such as the availability and quality of data, uncertainty of data and models and the limits of predictability inherent in the study of complex systems. For this reason Fedra and Feoli (1998) suggest that decision support systems must address and communicate this uncertainty to make it a useful component of decision making strategy rather than a problem. They conclude their paper with the following sentences: "The need for better tools to handle ever more critical environmental and resource management problems is obvious, and the rapidly developing field of information technology can provide the necessary machinery. ….…The biggest challenge, however, seems to be the integration of new information technologies and more or less mature formal methods of analysis into institutional structures and societal processes, that is, putting these tools to work in practice".

1.1 A unified view of DSS and SDSS

The theoretical and technical description of DSS and SDSS have been extensively and adequately covered in the literature (Geoffrion 1983, Craig & David, 1991, Densham, 1991, Goodchild & Densham, 1990, Moon, 1992, NCGIA, 1992, Paruccini, 1994, Malczewski 1999 and references therein). Concerning the technical aspects, DSS and SDSS have in common the following components: Data bases, Data analysis, Modelling and Expert systems, Simulation and Optimisation, Multicriteria Evaluation (MCE) and User Interface. However SDSS requires one more component that is known as Geographic Information System (GIS).

1.2 DSS and definition of alternatives

The word "alternative" is the key word in the domain of decision-making. A decision may be defined as a choice between alternatives. The alternatives may represent different options of action following different hypotheses among which a choice is desirable based on some specific criteria. Establishing alternatives is the first step in a decision making process. Even if a scenario of socio-economic development is delineated the scenario may present a set of possible alternatives that are difficult to be objectively evaluated and ranked according to the needs of the people. The ranking of alternatives is a procedure that requires comparative analysis in terms of costs and benefits. The questions: who pays the costs and who receives the benefits are fundamental to be answered within the "domain of decision making". The evaluation and ranking of the alternatives follows always a hierarchical process that can be logically and scientifically codified (Saaty 1980, 1999). An example of a hierarchical process is given in Table 1. Different scenarios can be built to describe the possible socio-economic development of a given area on the basis of different alternatives: e.g. development based on industrial sector (industry) or development based on tourism (tourism). A first application of DSS could be done in order to rank the scenarios as alternatives. Once a rank is obtained for "industry " or "tourism", a set of alternatives considered within each scenario (e.g. converting existing industries, building a new industry etc.) have to be ranked .

Table 1: Example of a hierarchical structure to be submitted to DSS in order to rank the different alternatives.

Scenario level	**Industry**	**Tourism**
Alternatives	(1) Converting existing industries (2) Building new industries (3) Improving infrastructures etc…	(1) Improving existing resorts (2) Building new resorts (3) Improving infrastructures etc…

1.3 DSS and definition of criteria

In any DSS application criteria are the factors that act positively or negatively in favour of a specific alternative. The ranking of alternatives is conditioned by the choice of criteria and by the weight given to them. For that reason the participatory approach is necessary to ensure the democratic discussion and the respect of the equity principle. It is obvious that the criteria are determined on the basis of the objectives to be achieved. If for example the objective is sustainable development, criteria are to be chosen within socio-economic and ecological parameters (indicators). In theory, there is no limit for the choice of the criteria. In terms of the DPSIR model the criteria are based on the State – Impact indicators. They are always determined by experts who act on the basis of their experience with or without the analysis of available data and/ or modelling and in consultation with stakeholders and interested public. Also the choice of the criteria is always based on cost-benefit considerations and has always a strong component of subjectivity.

1.4 DSS and the effects/alternatives matrix

Once a set of criteria is defined, they have to be evaluated or measured in terms of the effects the different alternatives have on the state of the corresponding indicators. For example, if biodiversity is a criterion to be used, the effects, negative or positive (costs and benefits) and the alternatives that may have on it have to be measured. The estimated number of species loss that each alternative may cause can be a measure of the effect (cost) of the alternative on biodiversity. When scientific/technical reports, databases, indicator tables, etc. are available, or when it is possible to apply models (e.g. predicting soil erosion, biomass productivity, etc.), for some criteria the effects may be measured by ratio/interval scale, however for the majority of the effects expert judgement in ordinal scale is the only possibility. The first step in any decision process is the construction of the matrix effects/alternatives. This matrix should be built once all the alternatives and effects have been well defined. The matrix consists of m effects and n alternatives, where the x(i,j) scores represent the effects of the j-th alternative on the i-th criterion (variable). There are several ways to attribute the scores, for example:

- direct knowledge (e.g. size of an area to be restored, amount of pollutants to be removed);
- response functions (e.g. correlation curves between ecological factors based on experimental campaigns);
- statistical models (e.g. probability of events based on data sets or historical series);
- complex models (e.g. dynamical / deterministic multi-factorial responses to ecological variables);
- evaluation by experts (e.g. knowledge by experience, literature);
- approximate estimation (e.g. common sense when nothing is better or available).

Table 2 represents such a matrix. This is the basis to compare the alternatives and the effects using matrix algebra.

Table 2: The matrix effects/alternatives for three alternatives

	Alternative 1	**Alternative 2**	**Alternative 3**
Effect a	X(a,1)	X(a,2)	X(a,3)
Effect b	X(b,1)	X(b,2)	X(b,3)
Effect c	X(c,1)	X(c,2)	X(c,3)
etc…	…	…	…

1.5 SDSS and definition of the alternatives (Operational Geographic Units, OGUs)

Once chosen the best scenario the question to answer with SDSS is: Where to optimally locate the selected “land uses” (that were alternatives defined and selected in a previous DSS).

For this, it is essential to use a geographic information system (GIS) where all the necessary cartographic information is stored. The first step in the use of GIS for the SDSS is the definition of the operational geographic units (OGU) of the territory where to locate the selected “land uses” (industries, markets, roads, airports, harbours, hotels etc.), these OGUs are then the alternatives to be ranked in SDSS. According Feoli and Zuccarello (1996) OGUs can be of different nature and size: pixels of remote sensing images (Landsat, SPOT etc.), administrative units, land cover patches or arbitrary cells of a net (grid, triangulated network, quadtree pattern, hexagonal mesh, thiessen polygons, etc., see Peuquet 1984; Skole et al. 1993) that are superimposed to a map of a given territory.

1.6 SDSS and definition of the criteria

In SDSS the criteria are not “effects” but just factors that act in favour of the suitability of a given OGU to host the selected “land use” and constraints that deny the suitability. The most important key-word in SDSS is *suitability* and the most important tool is the *suitability map*. The GIS component of SDSS is essential to produce suitability maps. Criteria on which to rank the OGUs are spatial variables: topographical, geo-morphological, geographical, ecological etc., and they are expressed by values of distances (e.g. distance by the rivers, by the roads, by urban areas etc.), degrees of inclination of slopes, aspect, by meters above the sea level etc. or by the quality of the position (e.g. within a valley, on the top of a mountain etc.), or by measures of risks of various nature (soil erosion, water flooding, fire, etc.).

1.7 SDSS and the matrix spatial variables/OGUs

SDSS deals with the matrices describing the OGUs with the factors. Table 3 gives an example of this kind of matrices. Two situations may occur when ranking OGUs: the rank is done on a selected set or the rank can be done for all the OGUs in the map. In both cases a suitability map is obtained.

Table 3: The matrix factors/OGUs as n alternatives

	OGU 1	**OGU 2**	**OGU 3**	**OGU j**	**OGU n**
Factor a	X(a,1)	X(a,2)	X(a,3)	………….	X(a,n)
Factor b	X(b,1)	X(b,2)	X(b,3)	………….	X(b,n)
Factor c	X(c,1)	X(c,2)	X(c,3)	………….	X(c,n)
etc…	…	…	…	…………..	

2 An example of MATEDIT application

The following are the necessary steps to obtain a matrix of criteria-alternative on which to apply MATEDIT (Burba et Al. 2008) in order to rank the OGUs. For the example we consider a given set of OGUs.

2.1 Selecting the factors

Each SDSS variable (criterion) should be spatially defined and GIS mapped (territorial indicators). As an example we consider the problem of urbanisation in Santos Bay where approximately 60,000 people are living in the mangrove areas of the Santos Bay. New settlements are to be found on proper areas therefore to move the people outside the mangrove area.

Let us consider just for showing the use of MATEDIT the following maps of a GIS (in this case based on ArcMAP 9.0) with which it is possible to calculate the scores of criteria in terms of suitability:

- Land cover / land use (Landsat tm 7- October 2000)
- DEM (slope map)
- Rivers and water bodies
- Industries (CETESB database)
- Limits of conservation and protected areas
- Erosion maps (RUSLE model)

The criteria chosen as factors are presented in Table 4:

Table 4: Criteria for ranking locations for new urban settlements in Santos Bay

land cover/land use	Each land cover/ land use type was given a different degree of suitability (increasing) into a scale from 0 to 5 as follows: Mangroves, Spare mangrove and mud, Urban areas, Industrial areas, Water: 0 Mata Atlantica de Versante Primaria: 1 Mata Atlantica de Versante Secundaria: 2 Low vegetation and restinga: 3 Bare soil: 5
slope	If slope >= 30°, suitability=0, otherwise suitability decreases from 1 to 0 between 0° and 30°. Three classes are considered
Distance from water bodies	The high proximity is not considered suitable. Two classes are considered 1 less than 100 metres 2 more than 100 metres
Distance from the main roads	Three classes are considered, the most closed is the most suitable.
Distance from industries	If distance <=500 m, suitability=0; If distance >=1500 m, suitability=1; Otherwise, suitability increases from 0 to 1 between 500 m and 1500 m. 4 classes are considered
Distances from protected area	Suitability decreases in function of the proximity. 4 distance classes are considered 0, less than 50 metres, 1 more than 200 metres, 2 more than 400 metres 3 more than 600 metres, 4 more than 1km.
erosion degree	Min and max levels of erosion were calculated on the area by raster band statistics. If erosion is max, suitability=0; If erosion is min, suitability=1; Otherwise, suitability increases from 0 to 1 between min and max levels, according to standardised values (4 classes are considered).

Besides the spatial variables factors have been defined also as space availability, cost for building and time to build.

2.2 Defining decision rules

A suitability index should be elaborated for each alternative, composing the different territorial indicators. This can be based on the index c proposed by the index suggested by Malczewski (1999): C= Dw/ (Dw+Di) (2), where Dw is the distance to the worst situation and Di is the distance to the ideal situation, or simple by the similarity with the best situation.

2.3 Definition of the alternatives

Table 5 shows an example of 5 alternatives of location of the new urban settlements. Table 6 shows the first step for MATEDIT application in ranking the alternatives. It consists of adding the worst and best alternatives as "ideal points" according to Malczewski (1999). Table 7 shows the similarity between the alternatives and the worst and best situation. This is the first rank of the alternatives that in our case suggests that the alternatives A3 and A2 are the best ones since they are more similar to the best ideal point. Table 8 presents the similarity between the alternatives and the worst and best situation after transforming the data in Table 6 according to he formula (x-xmin)/(xmax-xmin), that has the effects to standardize, or to give the same weight to all the factors.

Table 5: Matrix describing 5 hypothetical alternatives for localizing the new urban areas based on the factors defined in Table 4.

ALTERNATIVES (OGUs) ---------------------- **factors**	**A1**	**A2**	**A3**	**A4**	**A5**
1) land cover/land use	4	4	4	2	1
2) slope	3	3	3	2	1
3)distance from water bodies	2	2	2	1	1
4) distance from industries	3	3	3	1	1
5) distance from protected areas	4	3	3	2	1
6) distance from the main roads	2	3	3	2	2
7) Erosion degree	4	4	4	2	1
8) Space Availablity	1	2	3	2	2
9) Cost of Building	3	1	2	3	4
10) Time to Build	2	3	3	3	4

Table 6: Data of Table 5 in which the scores for the WORST and BEST alternative are added

	A1	A2	A3	A4	A5	WORST	BEST
1) land cover/land use	4	4	4	2	1	1	4
2) slope	3	3	3	2	1	3	1
3)distance from water bodies	2	2	2	1	1	1	2

4) distance from industries	3	3	3	1	1	1	3
5) distance from protected areas	4	3	3	2	1	1	4
6) distance from the main roads	2	3	3	2	2	3	2
7) Erosion degree	4	4	4	2	1	4	1
8) Space Availablity	1	2	3	2	2	1	3
9) Cost of Building	3	1	2	3	4	4	1
10) Time to Build	2	3	3	3	4	4	2

Table 7: Similarity ratio between the alternatives and the worst and best one (ideal points) according the data in Table 6.

	A1	A2	A3	A4	A5	WORST	BEST	
A1	1	0.912	0.916	0.737	0.523	0.691	0.759	A1
A2	0.912	1	0.978	0.733	0.517	0.688	0.798	A2
A3	0.916	0.978	1	0.769	0.573	0.719	0.807	A3
A4	0.737	0.733	0.769	1	0.875	0.825	0.677	A4
A5	0.523	0.517	0.573	0.875	1	0.773	0.5	A5
WORST	0.691	0.688	0.719	0.825	0.773	1	0.432	WORST
BEST	0.759	0.798	0.807	0.677	0.5	0.432	1	BEST

Table 8: Similarity ratio between the alternatives and the worst and best situation after transforming the data in Table 6 according to the formula (x-xmin)/ (xmax-xmin). In this way the factors have the same weight.

	A1	A2	A3	A4	A5	WORST	BEST
A1	1	0.734	0.704	0.323	0.083	0.304	0.537
A2	0.734	1	0.952	0.287	0.089	0.414	0.536
A3	0.704	0.952	1	0.339	0.153	0.427	0.573
A4	0.323	0.287	0.339	1	0.6	0.442	0.218
A5	0.083	0.089	0.153	0.6	1	0.381	0.074
WORST	0.304	0.414	0.427	0.442	0.381	1	0
BEST	0.537	0.536	0.573	0.218	0.074	0	1

The indices c of Malcewsky (1999) for the complement of matrix in table 7 are the following

A1	0.561	A2	0.606	A3	0.593	A4	0.351	A5	0.313

While for the complement of table 8 they are the following:

A1	0.601	A2	0.558	A3	0.573	A4	0.416	A5	0.401

Standardizing the factors with the index c gives a higher rank to the alternative 1, however the analysis clearly shows that the first three alternatives are to be preferred over the other two.

3 On line training courses

Using the site of Ecomanage of University of Trieste **www.ecolab.it** MATEDIT is easily downloaded and it can be applied using the WEB-GIS of the site for on-line training courses with SKYPE or other e-conferences tools. Courses can be organized as follow-up of ECOMANAGE.

References:

- Burba N, Feoli E, Malaroda M, Zuccarello V., 2008. MATEDIT: a software tool supporting the application of similarity theory in community ecology. Submitted to Community Ecology.
- Carver SJ., 1991. Integrating Multicriteria Evaluation with Geographical Information Systems. International Journal of Geographical Information Systems 5(3): 321-339.
- Craig WJ, David MD., 1991. Progress on the Research Agenda: URISA '90. URISA Journal 3 (1): 90-96.
- Densham PJ., 1991. Spatial Decision Support Systems. In: Maguire DJ, Goodchild MF, Rhind DW, (eds) Geographical Information Systems: Principles and Applications. London, Longman 1: 403-412.
- Eastman JR., 2001. Idrisi 32, release 2. Guide to GIS and Image Processing, vol.2. ClarkLabs, Worcester, USA.
- Fedra K, Feoli E., 1998. GIS Technology and Spatial Analysis in Coastal Zone Management. EEZ Technology 3:171-179.
- Feoli E, Zuccarello V., 1996. Spatial pattern of ecological processes: the role of similarity in GIS applications for landscape analysis. In Fisher M, Scholten HJ, Unwin D (eds) Spatial Analytical Perspectives on GIS. Taylor and Francis, London. pp.175-185.
- Geoffrion AM., 1983. Can OR/MS Evolve Fast Enough? Interfaces 13: 10-25.
- Goodchild MF, Densham PJ., 1990. Spatial Decision Support Systems: Scientific Report for the Specialist Meeting, technical Report 90-5, National Centre for Geographic Information and Analysis.
- Gorry A, Morton MSS., 1971. A framework for information systems. Sloan Management Review 13: 55-77.
- Malczewski J., 1999. GIS and Multicriteria Decision Analysis. John Wiley and Sons, New York.
- Moon G., 1992. Capabilities Needed in Spatial Decision Support Systems. GIS/LIS '92 2: 594-600.
- NCGIA, 1992. A Research Agenda of The National Centre for Geographic Information and Analysis. Technical Report 92-7.
- Peuquet DJ., 1984. A conceptual framework and comparison of spatial data models. Cartographica 21 (4): 66-113.
- Paruccini M., 1994. Applying Multicriteria Aid for Decision to Environmental Management. Kluwer, Dordrecht.
- Rotmans J, van Asselt MBA, 2001. Integrated Assessment: Current Practices and Challenges for the Future. In: Costanza R, Tognetti S (eds) Ecological Economics and Integrated

Assessment: A participatory process for including equity, efficiency and scale in decision making for sustainability.SCOPE, Paris, USA.

- Saaty TL., 1977. A Scaling Method for Priorities in Hierarchical Structures. J. of Mathematical Psychology 15: 234-281.
- Saaty TL., 1980. The Analytical Hierarchy Process. McGraw Hill, New York
- Saaty TL., 1999. Decision Making for Leaders. RWS Publications, Pittsburgh.
- Skole DL, Moore III B, Chomentowski WH., 1993. Global Geographic Information Systems and Databases for Vegetation Change Studies. In: Solomon AM, Shugart HH (eds) Vegetation Dynamics and Global Change, Chapman & Hall, New York, London, pp.168-189.