A Spatial Decision Support Tool to Study Risks and Opportunities of Complex Environmental Systems

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1 Introduction

Territorial transformation projects are affected by a great deal of uncertainty and refer to long-term perspectives. It has been noticed that scenario analysis can be applied in this domain in order to support the decision-making process for the definition and assessment of future development strategies for a certain area (Torrieri and Nijkamp, 2009). In fact, scenario analysis attempts to develop and judge a set of hypothetical policy or development alternatives for a compound and complex decision-making system, in order to generate a rational frame of reference for evaluating different alternatives (Nijkamp et al., 1997). Scenarios studies have usually an experimental nature and have assumed a strong position in the field of spatial planning and analysis (Nijkamp and Rienstra, 1998).

The use of scenario analysis in decision-making process related to spatial planning is based on the assumption that the future is not predetermined, but it consists in the product of causal chains of events that are determined from exogenous or endogenous elements of the spatial system (Torrieri and Nijkamp, 2009). Planning actions aim to guide these events toward achieve political objectives.

An important problem arising when assessing territorial systems comes from their complexity. This requires a complex multidimensional approach for the evaluation in order to obtain concise final judgments. In this sense, there is a need of quantitative methods that are able to synthesize the full range of aspects involved in the transformation, from the impacts of the project on the environmental system to the effects in

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terms of mobility and accessibility, from the social and economic consequences of a certain strategy to the outcomes with reference to landscape and cultural heritage (Bottero, 2011). Moreover, when dealing with territorial systems, the analysis of the geographical patterns of the elements under investigation plays an important role.

In the current debate regarding sustainability assessment and integrated approaches, Multicriteria-Spatial Decision Support Systems (MC-SDSS) (Malczewski, 1999) play a fundamental role by solving semi-structured spatial problems through the integration of Geographic Information Systems (GIS) and Multicriteria Decision Aiding (MCDA) techniques.

Starting from a real case related to a mountain area in Northern Italy (Ferretti et al., 2014), the present paper proposes an application of the MC-SDSS methodology for exploring future transformation scenarios. In particular, the objective of the study is to investigate the role of the methodology for providing an assessment of the opportunities and the risks for the area under investigation.

2 Scenario analysis and Spatial Decision Support Systems

2.1 State of the art

Scenario analysis has been developed as a scientific tool for supporting policy-making processes under uncertainty conditions. According to Kahn and Wiener (1967), a scenario can be defined as a possible, often hypothetical, sequence of events constructed in an internally consistent way for the purpose of focusing attention on casual processes and decision points.

Following this first definition, several attempts were made in the scientific literature for better clarifying the concept of scenario. Warfield (1995) defined the scenario as "a narrative description of a possible state of affairs or development over time. It can be very useful to communicate speculative thoughts about future developments to elicit discussion and feedback, and to stimulate the imagination. Scenarios generally are based on quantitative expert information, but may include qualitative information as well".

Ratcliffe (2000) states that "the principal objective of scenario analysis is to enable decision-makers to detect and explore the full range of alternative futures so as to clarify present actions and subsequent consequences".

According to Godet (1987), "scenarios should aim to detect the key variables that emerge from the relationship between the many different factors describing a particular system, especially those relating to the particular actors and their strategies". Moreover, Schwartz (1996) highlights that scenarios "provide a context for thinking clearly about the otherwise impossible complex array of factors that affect any decision; give a common language to decision-makers for talking about these factors and encourage them to think about a series of 'what-if' stories; help lift the 'blinkers' that limit creativity and resourcefulness; and lead to organisations thinking strategically and continuously learning about key decisions and priorities".

The purpose of scenario analysis is not just about constructing scenarios, but it is about informing decision-makers and influencing and enhancing decision-making, thus creating a learning process.

The methodological base of scenario building, as with all future studies, is broad, diverse and comprises a wide range of approaches and techniques. It has been noticed that the integrated use of scenario analysis and Multicriteria Analysis can efficiently support decision-making process (Stewart et al., 2013; Montibeller and Franco, 2007).

With specific reference to the context of spatial planning, many applications exist in the literature related the use of Spatial Decision Support Systems in the domain of scenario analysis. Table 1 syntheses the main scientific papers, highlighting the field of application, the objective of the analysis and the methodology applied. As it is possible to see from Table 1, the sphere of the researches is very vast, including application for environmental risk analysis and energy planning. The principal aim the studies is the creation of a suitability map with the projection of effects produced by the considered scenarios.

Table 1 Examples of applications of SDSS for scenario analysis in land use planning and management

Author	Field of application	Objective of the evaluation	Methodology
Volk et al. (2007)	Management of water resources	Analysis of different land use scenarios from the point of view of the ecological and socio-economic effects	FLUMAGIS (GIS-based integrated ecological-economic model)
Duzgun et al. (2011)	Evaluation of seismic vulnerability	Map of the seismic vulnerability index of an urban area with 3D visualizations	MC-SDSS where the MCA module is based on a set of indicators obtained by means of a series of questionnaires to DM and key actors
Zerger and Wealands (2004)	Hydrogeological risk management	Map of the effects of different potential risk scenarios	Integration between GIS and hydrodynamic models
Scholten et al. (1998)	Hydrogeological risk management	Ranking of alternative management scenarios	SDSS developed through the IDRISI software
Brody et al. (2006)	Management of energy resources	Suitability map for the identification of the best sites for the production of oil and gas in Texas (USA)	MC-SDSS based on a set of statistical indicators
Volk et al. (2010)	Management of landscape and river basins	Critical review of different SDSS approaches	FLUMAGIS Elbe-DSS CatchMODS MedAction

2.2 Spatial Multicriteria Analysis

Scenario analysis plays a crucial role particularly in the field of sustainability assessments and territorial transformation processes, both at the urban and rural scale. These contexts give rise to complex decision problems due to the presence of different and often conflicting objectives to be pursued, the public/private nature of the goods under investigation, the existence of several values (historical, naturalistic, cultural, economic, etc.) and the presence of different actors (e.g. public government representatives, technicians, citizens, developers and owners).

Moreover, when dealing with territorial transformation processes, an undeniable important role is played by the spatial distribution of the characteristics and consequences of each option under analysis.

The availability of analytical frameworks able to support spatial planning and decision-making processes is thus getting more and more important.

Within this context, a fundamental support may be provided by spatial Multicriteria Analysis (Malczewski, 1999) which combines Geographic Information Systems (GIS) and Multicriteria Decision Aiding (MCDA) in order to provide a collection of methods and tools for transforming and integrating geographic data (map criteria) and Decision Maker's preferences and uncertainties (value judgments) to obtain information for decision-making and an overall assessment of the decision alternatives.

Spatial Multicriteria Analysis is an increasingly popular tool in decision-making processes and in policy making, thanks to its significant new capabilities in the use of spatial or geospatial information. In recent years there has thus been a growing interest towards the development and application of spatial Multicriteria Analysis across many scientific fields for solving different decision problem typologies (Ferretti, 2013), thanks to the ability of this integrated approach to both generate alternatives during the strategic planning phase and to compare them during the evaluation phase.

In particular, spatial Multicriteria Analysis is most commonly applied to land suitability analysis in the urban/regional planning, hydrology and water management and environment/ecology fields and is usually based on a loose coupling approach and on a value focused thinking framework (Ferretti, 2013).

Within these fields, an emerging trend seems to focus on the application of spatial Multicriteria Analysis for scenarios generation and evaluation, thanks to the ability of combining both qualitative and quantitative data representing the spatial consequences of different future courses of actions.

From the methodological point of view, the steps needed for the development of a spatial Multicriteria Analysis to specifically support planning and decision-making processes are summarized in Figure 1.

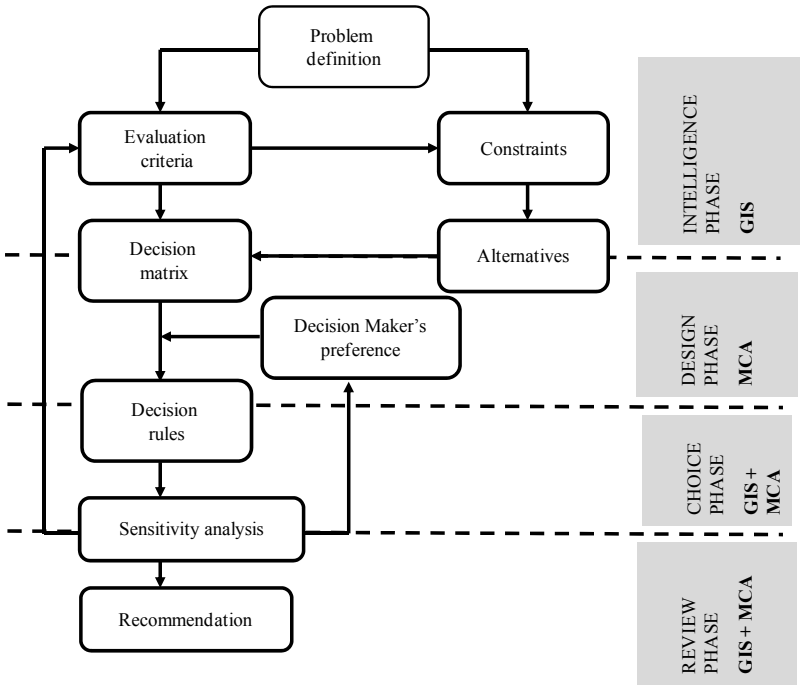


Fig. 1. Framework for planning and decision-making processes (Source: adapted from Malczewski, 1999)

In this model, there is a flow of activities from intelligence to design to choice phase, as well as steps in each phase.

In particular, the intelligence phase refers to the examination of the environment in order to identify problems or opportunity situations and includes the structuring of the problem, during which the system under consideration is defined and the objectives to pursue are explored. One or more criteria, or attributes, are then selected to describe the degree of achievement of each objective.

The design phase involves the development and analysis of possible courses of action. During the choice phase alternatives are evaluated and a selection of specific courses of action is performed; furthermore, detailed analyses, such as the sensitivity analysis, are deemed appropriate in order to obtain useful recommendations.

Finally, evidence is defined as the total set of data, information, and knowledge at disposal of the planners, Decision Makers and analysts.

3 Application

3.1 Description of the case study

The case study considered in the application refers to a small town in Northern Italy named Ormea[1]. The town

[1] The material used to illustrate the case study application is based on the thesis work performed by Elisa Piolatto at the Architectural and Landscape Heritage post-graduates specialization school at the Polytechnic University of Turin (Italy).

has a population of 1750 inhabitants and is located in the Alpine territory of the Piedmont Region, on the border with the Liguria Region and with France (Figure 2).

In the past, the city used to be very important from the point of view of the industrial activities concerning the production of wool and paper. Moreover, thanks to the presence of the railway line, the town was an important tourism centre with tourists coming from many European countries.

Nowadays, due to the phenomenon of the abandon of mountain areas, many economic activities have been relocated; also the tourism sector is suffering and the trends of the presences have been decreasing since the last decades. As a result, the town is experiencing a deep crisis and new strategies for the development of the area are needed.

The objective of the paper is to support the creation of future development scenarios for the area, with particular reference to analysis of the opportunities and the risk characterizing the town under investigation.

Fig. 2. The location of the area under investigation

3.2 Structuring of the decision problem

Starting from the overall objective of the analysis, which is the definition of the opportunities and risks of the territory of Ormea, a comprehensive set of evaluation criteria that reflect all the concerns relevant to the decision problem has been identified according to a value focused thinking approach, which assumes the values as fundamental elements in the decision analysis and, based on the values and criteria structure, develops and evaluates feasible options (Keeney, 1992).

Due to the presence of different interrelated factors and to the intrinsic spatial nature of the problem, the method of the Analytic Network Process (ANP, Saaty, 2005) has been coupled with GIS. The ANP represents the evolution of the Analytic Hierarchy Process (AHP, Saaty, 1980) in order to take into account interactions and feedbacks among the decision elements. According to the ANP, the problem structuring phase involves identifying groups (or clusters) constituted by various elements (nodes) that influence the decision. All the elements in the network can be related in different ways since the network can incur feedbacks and complex inter-relationships within and between clusters, thus providing a more accurate modeling of complex settings.

In the present application the model has been developed according to the complex network structure (Saaty, 2005). The problem has thus been divided in four clusters (namely, natural system, historical and cultural heritage, economic aspects, territorial system) that have been organized according to the categories of Opportunities and Risks. In this case, the opportunities and the risks have been considered, respectively, as positive and negative aspects of the transformation in the long time period, for which it is difficult to make

any prevision

According to the ANP methodology, once the network has been identified, it is necessary to represent the influences among the elements (Saaty, 2005). Moreover, a raster map was linked to each criterion, within which each pixel has a suitability value. These maps were derived from basic raster GIS operations (map overlay, buffering, distance mapping, spatial queries, etc.). Table 2 presents the criteria identified for the analysis while Figure 3 represents the Opportunities and Risks subnetworks of the ANP model.

Table 2. The ANP model for the problem under investigation

O/R	Cluster	Elements	Description	Source map	Criteria mapping method
OPPORTUNITIES	Natural system	Naturalness index	The index ranks from a maximum of 10 (natural systems) to a minimum of 0 (artificial systems). This index allows the evaluation of the environmental quality of the territory, according to the physical and structural features of the vegetation	Corine Land cover map	Raw data were reclassified assigning different values within the 0-10 domain where 0 corresponds to artifical systems and 10 to the natural systems
		Natural elements	Specific natural elements, such as caverns	Map of the natural elements	Distance map
		Viewpoints	Viewpoints identified by the Landscape Plan of the area	Map of the Landscape Plan	Distance map
		Protected areas	Areas constituting natural parks as Sites of Community Importance (SCIs) and Special Protection Areas (SPAs) (European Commission, 2001)	Map of the natural protected areas (Natura 2000)	Distance map
	Historical and cultural heritage	Historical monuments	Archaeological sites and historical monuments such as castles, towers, churches, industrial archaeology buildings, etc.	Map of the historical monuments	Distance map
		Historical settlements	Important settlements identified in historical sources	Map of the historical settlements	Distance map
		Cultural events	Cultural events such as feasts, religious events, etc.	Map of the cultural events	Distance map
	Economic aspects	Accommodation structures	Hotels, bed & breakfast, mountain dews, etc.	Map of the accommodation structures	Distance map
		Sport pathways	The elements is related to the paths destined to the practice of trekking and other sport activities	Map of the sport pathways	Distance map
		Sport facilities	Facilities for climbing, sport fishing, skiing, hand gliding, etc.	Map of the sport facilities	Distance map
		Picnic areas	Areas for the temporal stop of tourists	Map of the picnic areas	Distance map
	Territorial	Accessibility	Infrastructural roads for	Map of the road	Distance map

	systems		arriving at Ormea from Piedmont, Liguria and France	network	
		Local roads	Local roads for reaching the different parts of the town of Ormea	Map of the road network	Distance map
	Natural system	Water bodies	Areas which are characterized by an high level of hydrogeological risk	Map of the hydrographic system	Distance map
		Avalanches	Territorial areas subjected to avalanches	Map of the hydrogeological risk produced by the Regional Environmental Protection Authority	Distance map
		Landslides	Territorial areas subjected to landslides	Map of the hydrogeological risk produced by the Regional Environmental Protection Authority	Distance map
	Historical and cultural heritage	Abandoned historical pathways	This elements is related to the presence of pathways that were used in the past for the transhumance or for reaching seasonal settlements (i.e. mountain pastures)	Historical map of the road network	Distance map
RISKS		Tracks of ancient vineyards and productive activities	The element concerns the risk of loosing the historical rural activities that nowadays are disappearing (for example, terraces for vineyards, mill runs, etc.)	Hsitorical map of the agricultural areas	Raw data were reclassified assigning different values in the 0-4 domain where 0 indicates absence of risk and 4 a very high risk
	Economic aspects	Power lines	Network infrastructure for the transportation of the electric energy	Regional Technical map	Distance map
		Quarries	Presence of quarries for the extraction of the marble	Map of the active quarries	Quarries areas are assigned the value 1 and all the other areas are assigned the value 0 according to a Boolean map
		Abandoned industrial areas	Former productive areas which now are abandoned (for example, the building of the paper mill)	Map of the abandoned industrial area	Distance map
		Distribution of the population	This elements concerns the different distribution of the population in the centre of Ormea and in the small outlying suburb hamlet	Map of the population in the Municipality of Ormea	Distance map

Territorial systems	Slope	This element is related to the slope of the ground which constitutes an obstacle for the accessibility	Regional Technical Map showing the level curves	According to the sloped of the ground raw data were reclassified in the 0-4 domain assigning the value 0 to a very flat ground and the value of 4 to a very steep ground
	Soil consumption	The element concerns the progressive soil consumption, comparing the actual situation with the situation registered in the historical maps	Map resulting from the difference between the current map of the urban areas and the historic map (beginning of the XX century) of the urban areas	Areas resulting from the difference between the two maps were given the value 1, all other areas were given the value 0.

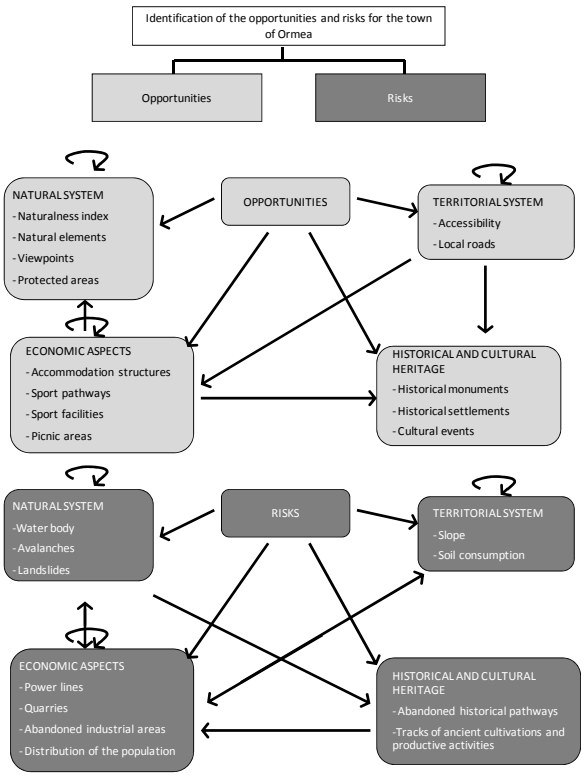


Fig. 3. The Opportunities and Risks subnetworks of the ANP model

3.3 Standardization of the criteria maps

For decision analysis the values and classes of all the maps associated with each considered criteria should be converted into a common scale. Such a transformation is commonly referred to as standardization (Sharifi and Rodriguez, 2002; Beinat, 1997; Eastman, 2006).

Through standardization the original factor scores (each expressed in its own unit of measurement) are converted into dimensionless scores in the 0 (worst situation) or 1 (best situation) range.

In the present study standardization was performed by means of specific interviews to the experts in their specific fields of expertises (economic evaluation, environmental engineering, history of architecture and landscape ecology) The training of a panel of experts allows to overcome some difficulties and biases which characterize the decision processes based on a single expert. In the present application, a close attention was devoted to the formation of a group of experts having a balanced background composition.

Through the active participation of all the experts, the control points used for the standardization of each criterion have thus been discussed and selected. With the aim of providing an illustrative example, Figure 4 shows the initial row map (Fig.4a), the intermediary source map (Fig.4b), the standardization function (Fig.4c) and the standardized map (Fig.4d) for the factor "panoramic viewpoints" under the Opportunities subnetwork.

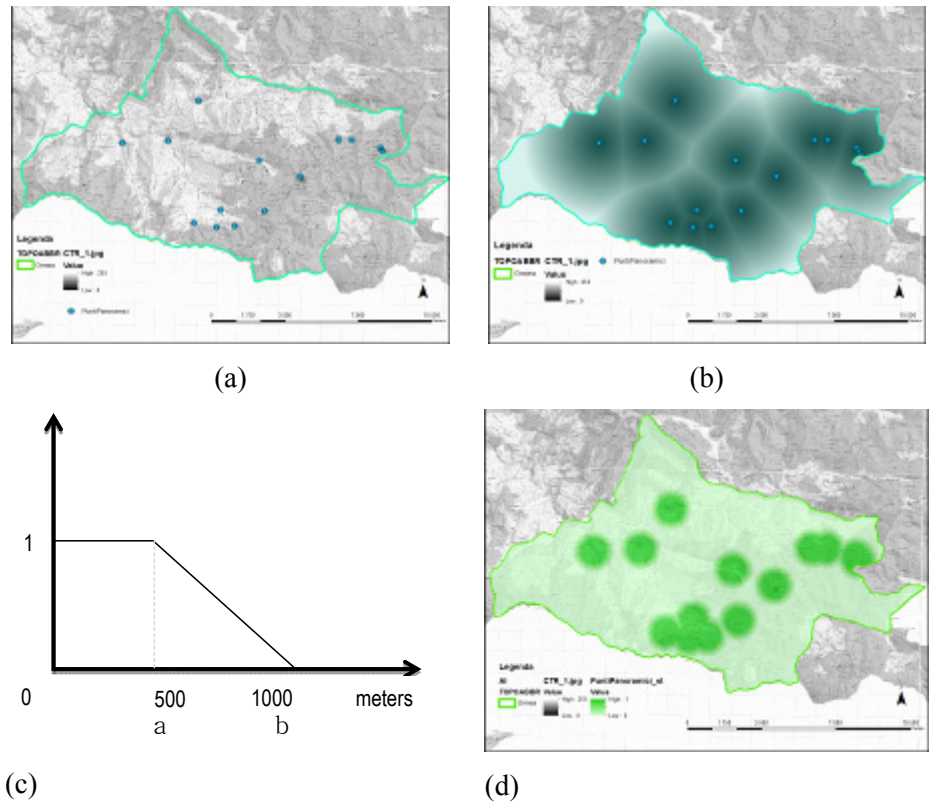


Fig. 4. The initial row map (Fig.4a), the intermediary source map (Fig.4b), the standardization function (Fig.4c) and the standardized map (Fig.4d) for the factor "panoramic viewpoints"

In particular, control point *a* and control point *b* in Figure 4c are the points that govern the shape of the standardization function. In this case, the first control point (*a*) indicates the value where the membership function starts to decrease. This is due to the fact that during the focus group the experts and the stakeholders agreed that after 500 meters the perceived utility of being near to a panoramic viewpoint starts to decrease. The second control point (*b*) in this case indicates the point at which the function reaches membership 0, since the focus group result was that a distance greater than 1,000 meters is not worth being covered to reach a panoramic viewpoint.

The same kind of reasoning has been repeated for all the considered factors inside the Opportunities and Risks sub-networks.

3.4 Weighting and aggregation

Once all the maps have been standardized in the 0-1 range, the next step of the decision process consisted in

weighing all the factors according to the pair-wise comparison approach underpinning the Analytic Network Process methodology. In paired comparisons, the smaller element is used as the unit, and the larger element becomes a multiple of that unit with respect to the common property or criterion for which the comparisons are made. A ratio scale of 1-9, that is, the Saaty's fundamental scale, is used to compare any two elements. The main eigenvector of each pair-wise comparison matrix represents the synthesis of the numerical judgements established at each level of the network (Saaty, 2005).

The comparison and evaluation phase is divided into two distinct levels: the cluster one, which is more strategic, and the node one, which is more specific and detailed.

At the cluster level, the numerical judgments used to fill the pairwise comparison matrices were derived by a specific focus group. The focus group was made up the mayor of the Ormea Municipality, a representative of a local foundation for the study of the history of Ormea, a representative of the local tourist bureau, a local entrepreneur in the field of tourism, an expert in history of architecture and landscape. The participants of the focus group worked together in order to achieve a consensus with reference to the weighing of the elements involved in the decision. In particular, the participants in the focus group evaluated the different aspects that characterized the problem with respect to the overall objective in order to reach a consensus decision on weights and priorities. The result of this phase is represented by the so-called cluster matrix.

Considering for example the cluster of the alternatives as parent node in the opportunities sub-network, the questions that had to be solved by the focus group were of the type:

With reference to the valorisation of the area under analysis, which of the following aspects can better enhance the opportunities of the territory? And how much more?

Economic aspects	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	*Historical and cultural heritage*
Economic aspects	9	8	7	6	5	4	**3**	2	1	2	3	4	5	6	7	8	9	*Territorial system*
Economic aspects	9	8	7	6	5	4	3	**2**	1	2	3	4	5	6	7	8	9	*Natural system*
Historical and cultural heritage	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	*Territorial system*
Historical and cultural heritage	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	*Natural system*
Territorial system	9	8	7	6	5	4	3	2	**1**	2	3	4	5	6	7	8	9	*Natural system*

The expressed judgments were used to fill in the related pairwise comparison matrix (Table 3).

Table 3 Pairwise comparison matrix at the cluster level for the Opportunities subnetwork

	Economic aspects	Historical and cultural aspects	Territorial system	Natural system	**Priorities**
Economic aspects	1	3	3	2	**0.467**
Historical and cultural aspects	1/3	1	1	1	**0.171**
Territorial system	1/3	1	1	1	**0.171**
Natural system	1/2	1	1	1	**0.191**

Table 3 shows the pairwise comparison matrix and the main eingenvector which represents the priorities of the different aspects in the Opportunities subnetwork with respect to the overall objective. This result highlights that from the Opportunities point of view the economic aspects are the most important ones. According to the ANP methodology, the final priority vectors, that result from the comparison matrices at the cluster level, determine the columns of the cluster matrix. Table 4 shows the cluster matrix for the Opportunities subnetwork. The priorities of the element that had previously been compared (Table 3) are shown.

Once the clusters comparison has been conducted, it is necessary to study the problem in depth through the analysis of the elements. At the nodes level, in order to fill in the pairwise comparison matrices, the values were derived from the judgments expressed by technical experts in the field of economic evaluation, environmental engineer, cultural heritage and history of architecture. We submitted to each expert a detailed questionnaire containing pairwise comparison questions in his own field of expertise. With the aim to better

clarify the explanation, an example of the question submitted to a technical expert in the history of architecture field is shown:

Table 4 Cluster matrix for the Benefit sub-network

	Opportunities	Economic aspects	Historical and cultural aspects	Territorial system	Natural system
Economic aspects	0.467	0.333	0.000	0.545	0.000
Historical and cultural aspects	0.171	0,.333	0.000	0.182	0.000
Territorial system	0.171	0.000	0.000	0.273	0.000
Natural system	0.191	0.333	1.000	0.000	1.000

With reference to the opportunities arising from the valorization of the area under examination, which element is more important from the historical and cultural aspects point of view? And how much more?

Historical monuments	***9***	*8*	*7*	*6*	*5*	*4*	***3***	*2*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*Cultural events*
Historical monuments	*9*	*8*	*7*	*6*	*5*	*4*	***3***	*2*	***1***	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*Historical settlements*
Cultural events	*9*	*8*	*7*	*6*	*5*	*4*	*3*	***2***	*1*	*2*	*3*	*4*	*5*	*6*	*7*	***8***	*9*	*Historical settlements*

The expressed judgments were used to fill in the related pairwise comparison matrix (Table 5).

Table 5 Pairwise comparison matrix for the elements of the cluster "Historical and cultural heritage" (Opportunities sub-network)

	Historical monuments	Historical settlements	Cultural events	**Priorities**
Historical monuments	1	1	9	**0.481**
Historical settlements	1	1	8	**0.056**
Cultural events	1/9	1/8	1	**0.463**

Table 6 Unweighted supermatrix for the Opportunities sub network

		Opp.	Economic aspects				Historical and cultural heritage			Territorial system		Natural system			
			Picnic areas	Sport facilities	Sport path.	Accom. Struct.	Hist. mon.	Cultural events	Hist. settl.	Access.	Local roads	Natural elements	Nat. index	Viewp.	Protected areas
Opportunities		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Economic aspects	Picnic areas	0.187	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.750	0.000	0.000	0.000	0.000	0.000
	Sport facilities	0.138	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Sport pathways	0.070	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Accom.	0.606	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000
Historical and cultural heritage	Historical mon.	0.481	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.250	0.000	0.000	0.000	0.000
	Cultural events	0.056	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000
	Historical settl.	0.463	0.000	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.750	0.000	0.000	0.000	0.000
Territorial systems	Accessibility	0.833	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000
	Local roads	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Natural system	Natural elements	0.370	0.000	0.000	0.250	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Naturalness index	0.066	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Viewpoints	0.434	0.000	0.000	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Protected areas	0.131	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000

Once all the pairwise comparison matrices were compiled, all the related vectors together formed the unweighted supermatrix. In this case, two supermatrices were obtained, one for each subnetwork. Table 6 represents the unweighted supermatrix, with reference to the Opportunities sub network. The priorities of the elements that had previously been compared (Tables 5) are shown.

Finally, according to the ANP methodology, the cluster matrix was multiplied by the initial supermatrix as a cluster weight. The result was the weighted supermatrix, which was raised to a limiting power in order to

obtain the limit supermatrix, where all columns were identical and each column gave the global priority vector. In this case, four limit supermatrices were obtained, one for each subnetwork.

Each column of the limit supermatrices obtained from the two subnetworks provides the final priority vector of all the elements being considered (Table 7).

The results of the complex ANP model highlight that the most important elements in the decision problem are: the accommodation structures for the opportunities subnetwork (0.230 in the final priority list) and the abandoned industrial areas for the risks subnetwork (0.352 in the final priority list).

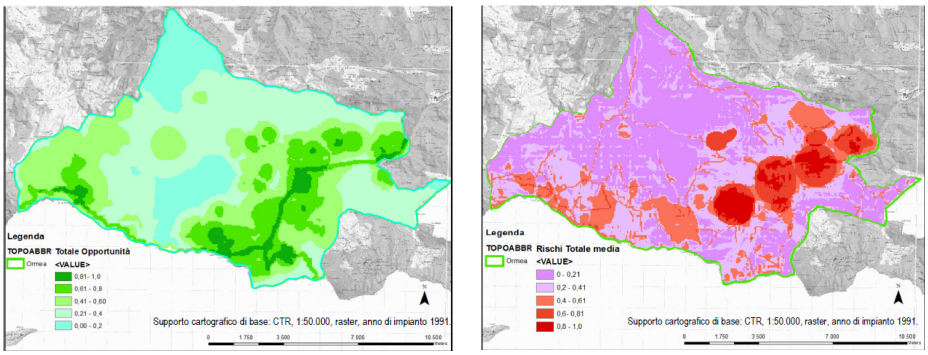
In order to obtain the final opportunities and risks maps, a weighted linear combination was then used, combining the respective factor maps according to the following formula:

$$S_j = \sum W_i X_i \tag{1}$$

where S_j represents the overall value of pixel j, W_i represents the weight of factor i, and X_i represents the standardized criterion score of factor i.

Table 7 Final priorities for the elements under analysis

O/R	Elements	Final priorities
OPPORTUNITIES	Naturalness index	0.009
	Natural elements	0.054
	Viewpoints	0.067
	Protected areas	0.118
	Historical monuments	0.067
	Historical settlements	0.069
	Cultural events	0.037
	Accommodation structures	0.230
	Sport pathways	0.025
	Sport facilities	0.055
	Picnic areas	0.130
	Accessibility	0.118
	Local roads	0.021
RISKS	Hydrogeological risk	0.142
	Abandoned historical pathways	0.123
	Tracks of ancient cultivations and productive activities	0.114
	Power lines	0.072
	Quarries	0.009
	Abandoned industrial areas	0.352
	Distribution of the population	0.109
	Slope	0.069
	Soil consumption	0.010



(a) (b)

Fig. 5. Overall distribution of the Opportunities (5a) and Risks (5b) for the area under analysis

The results of the proposed study are thus represented by two maps highlighting the spatial distribution of opportunities and risks within the area under examination. These maps represent a first synthesis of negative and positive aspects for the region under analysis (Figure 5a and Figure 5b, respectively) and allow to derive useful indications with reference to warning spots needing specific mitigation or monitoring measures.

As it is possible to notice from the results of the analysis, the Opportunities and Risks seem to concentrate in the South Eastern portion of the area under investigation, where the city centre is located.

4. Discussion of the results and conclusions

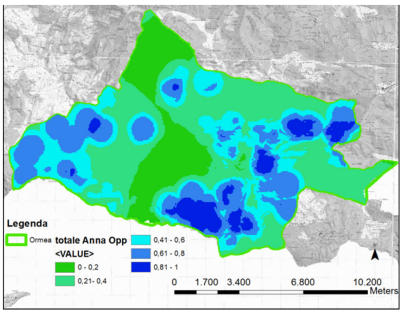
In order to test the robustness of the obtained results and to provide proper recommendations for the definition of requalification strategies for the study area, the individual perspectives expressed by the stakeholders participating in the focus group have also been considered and discussed. In particular, the individual points of view generated different scenarios (Figure 6) that allowed to understand the main uncertainties and controversies involved in the decision problem under analysis.

As it is possible to see from the comparison between Figure 5 and Figure 6, the stakeholders expressed quite different preferences with reference to the Opportunities for the development of the Ormea's area but agreed in evaluating the priorities of the risks elements. This is highlighted on one side by the variation in the distribution of the positive aspects across the different maps and, on the other side, by the homogeneity of the risks maps.

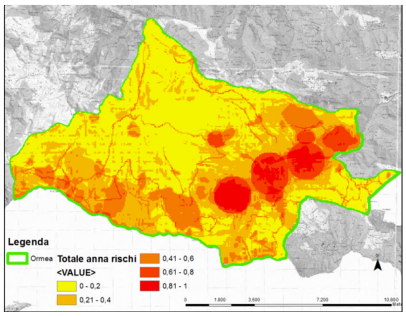
The subsequent steps of the study will allow to draw policy recommendations and to support the strategic planning phase in order to foster the opportunities and minimize the risks for the region.

This paper describes the development of a spatial multicriteria evaluation to identify future opportunities and risks for a specific region. The proposed methodology was illustrated with reference to a mountain area in the North of Italy which represents an environmental system characterized by multiple values.

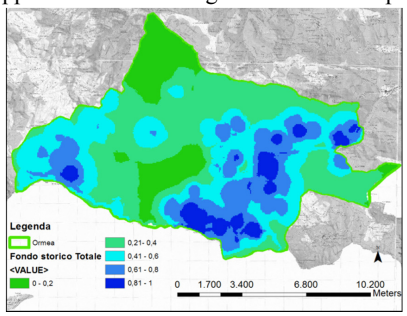
The methodology described in the present paper can be seen as an innovative approach in the field of decision making processes regarding cultural built heritage, since it considers the cultural and environmental resources as a system and it uses the evaluation as a cyclic activity aimed at finding out new development strategies. The value-focused thinking approach (Keeney, 1992) highlights the potentials of the constructive and explorative use of evaluation, which enable decision makers to catch opportunities instead of simply analyzing/selecting existing options. On one hand, the partial and the final evaluation maps represent an effort for clarifying the complexity of the reality in order to provide a rational basis for understanding complex information, on the other hand, they have played the role of a common knowledge platform. It must be noted that the definition of the maps, from the source to the value ones, has involved both experts and decision makers, who have shared the entire evaluation process. The decision makers engagement in the analytical phase is very helpful as the maps should be considered as dynamic picture to be updated according to the monitoring of territorial systems' change.



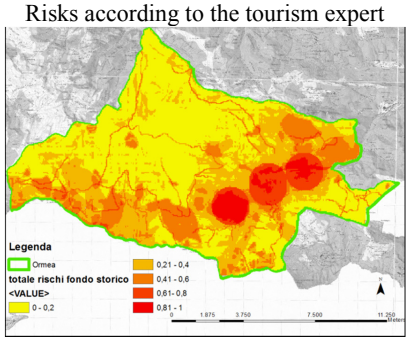
Opportunities according to the tourism expert



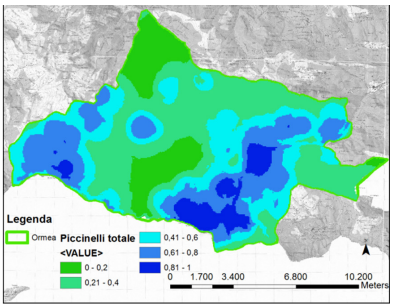
Risks according to the tourism expert



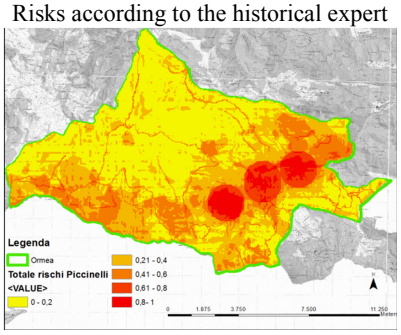
Opportunities according to the historical expert



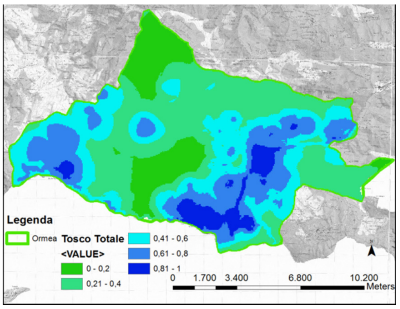
Risks according to the historical expert



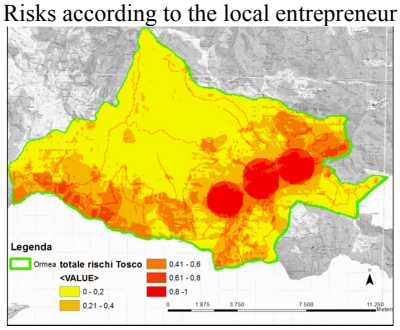
Opportunities according to the local entrepreneur



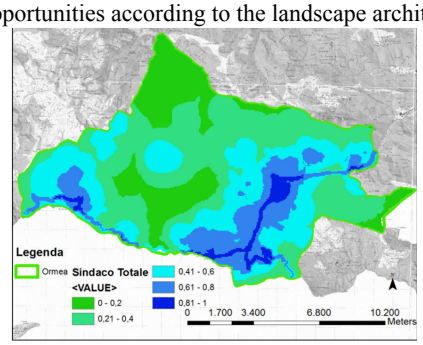
Risks according to the local entrepreneur



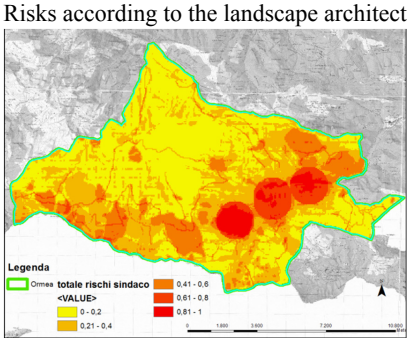
Opportunities according to the landscape architect



Risks according to the landscape architect



Opportunities according to the Mayor



Risks according to the Mayor

Fig. 6. Stakeholders' perspectives on the area under analysis

The obtained results show that spatial Multicriteria Analysis can handle heterogeneous information and provides a significant contribution in the strategic decision-making phase. Moreover, one of the most significant strengths of the adopted methodological approach is represented by the fact that the evaluation is organized in a learning perspective. The decision maker thus gains more awareness with reference to the elements at stake while structuring the model (by means of value functions and trade-offs elicitation) and thus learns about the problems throughout the decision process (Ferretti and Pomarico, 2013; Bottero et al., 2011).

By assessing the expectable opportunities and risks for the area under analysis, the adopted approach also allows to foresee different future strategies (scenarios) for the management and valorization of the entire area. Consequently, different policy strategies could then be studied and evaluated in order to select the most sustainable one.

Scenarios can thus assist decision makers in the selection of proper policy solutions which produce robust results under varying conditions, in the assessment of strategies to cope with threats from particular natural and socio-economic conditions, and in risk assessments of various uncertain future developments (Nijkamp and Vindigni, 2003).

However, there are still a number of opportunities for expanding research and for validating the results obtained herein. First, it will be interesting to develop the present model according to the fuzzy sets theory (Zadeh, 1965), which represents attribute values according to membership classes. As a matter of fact, uncertainty can be associated with fuzziness concerning the criterion weight assessment as well as the spatial attribute values. In order to take into consideration the imprecision and uncertainty (i.e., linguistic descriptive variables) as well as value judgment by Decision Makers (i.e., knowledge in relation to the problem), it would be of scienti.c interest to expand the application under examination through the use of the Ordered Weighted Average (OWA, Yager, 1988) for the combination of the evaluation criteria. This approach belongs to the family of the non-additive measures and allows the generation of a wide range of different solution maps and predictive scenarios through the consideration of the interaction among the criteria of the model.

In conclusion, the integration of decision aiding tools and spatial analysis constitutes a very promising line of research in the context of scenario analysis and sustainability assessments.

Acknowledgments

The paper is the result of the joint work of the three authors. Despite the overall responsibility being equally shared, Marta Bottero is responsible for paragraphs 1, 2.1, 3.1 and 3.2 while Valentina Ferretti is responsible for paragraphs 2.2, 3.3 and 3.4. The abstract and paragraph 4are the result of the joint work of the three authors. Finally, the authors would like to express a special thanks to Dr. Elisa Piolatto for the work done during her thesis at the Architectural and Landscape Heritage post-graduates specialization school of the Polytechnic University of Turin (Italy).

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