Decision making and cultural heritage: An application of the Multi-Attribute Value Theory for the reuse of historical buildings

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Received 15 May 2013
Accepted 24 December 2013
Available online xxx

1. Research aims

The objective of the study is to investigate the use of the Multi-Attribute Value Theory (MAVT) in decision problems related to cultural heritage. MAVT is a particular Multicriteria Analysis technique and it can be used to address problems that involve a finite and discrete set of alternative actions that have to be evaluated on the basis of conflicting objectives. For any given objective, one or more different attributes or criteria, are used to measure the performance in relation to that objective.

In this research, MAVT has been applied to a real-world problem where a decision has to be taken about the reuse of a set of industrial historical buildings located in the metropolitan area of Turin (Italy). Particularly, the present study leads the choice of the best performing building to be reused for touristic purposes. In particular, seven buildings are compared on the basis of different attributes, namely quality of the context, presence of economic activities, flexibility of the building, pedestrian accessibility and conservation level. The research also explores the adoption of a decision support process, which makes use of a panel of experts for the implementation of the evaluation model.

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2. Introduction

Decision-making processes in the context of cultural heritage projects are affected by several characteristics.

To start with, they can be described as complex decision problems with many dimensions to be included in the analysis, taking into consideration historical and artistic value, economic constrains, environmental impacts and so on [1].

Secondly, multiple actors with different and conflicting objectives have a role in the decision arena, such as public government representatives, architects, architectural historians, developers and owners.

Thirdly, it is possible to mention the existence of factual information (for example, the degradation of an historical building) and value information (for example, the people's willingness to accept the risk of degradation) to be incorporated in the process.

Moreover, the evaluation must consider not only quantitative data, but also probabilistic variables and qualitative judgments, such as, for example, the landscape quality of a certain area.

Finally, the evaluation tools must be able to guarantee the transparency of the decision process and to communicate in an easy way the results of the choices.

It has been generally agreed that Multicriteria Decision Analysis (MCDA, [2,3]) can offer a formal methodology to deal with such decision problems, taking into account available technical information and stakeholders values.

Generally speaking, MCDA methods, are used to make a comparative assessment of alternative projects or heterogeneous measures. These methods allow several criteria to be taken into account simultaneously in a complex situation and they are designed to help decision makers (DMs) to integrate the different options, which reflect the opinions of the involved actors, in a prospective or retrospective framework. Participation of the DMs in the process is a central part of the approach.

Cultural heritage projects and, more generally, urban and territorial transformations can be defined as processes that produce direct effects in the physical environmental system of a given area and indirect effects in the social and economic system. According to the legislative framework, this kind of projects are made object of specific evaluation procedures such as, among the others, feasibility studies, Cost-Benefit Analysis [4] and Strategic Environmental Assessment [5].

The evaluation is a crucial point in the overall transformation process because it allows the project proposal to be decomposed and a series of fundamental information to be produced that can support the decision-making process. In this sense, it is possible to say that the evaluation plays a constructive role (and not resolutive) and it is not a form of decision-making but a support to the decision-making [6].

In the past, the evaluation used to be considered as a set of procedures and techniques finalized in defining the link between causes and effects. More recently, the scientific literature in the domain of environmental and planning evaluation agrees in considering the evaluation acts a social learning process [7] where reflecting and interpreting complex situations are the basis of the overall assessment. According to the latter approach, a primary role is played by public policies analysis. In fact, traditional approaches based on financial and economic feasibility analysis are not able to help the comprehension of such complex phenomena because they consider few quantitative variables and a limited group of experts and are not able to deal with environmental uncertainty, social risks and inter-generational equity factors. Moreover, a fundamental part in urban and territorial decision-making processes is played by the population and inclusive approaches that enhance public participation and collective learning processes among different actors, with different perspectives and objectives, are central in the creation of new responses in territorial transformation processes.

For the aforementioned reasons, MCDA is a valuable and increasingly widely-used tool to aid Decision making in the domain of sustainability assessment and urban and territorial planning, where a complex and inter-connected range of environmental, social and economic issues must be taken into consideration and where objectives are often competing, making trade-offs unavoidable. It is possible to highlight that MCDA gives not only a toolbox, but, overall, a well-developed methodology to support decision-making processes.

This paper considers the problem of sustainability assessment in cultural heritage projects using the Multi-Attribute Value Theory (MAVT, [8]), a particular kind of MCDA method. MAVT can be used to address problems that involve a finite and discrete set of alternative actions that have to be evaluated on the basis of conflicting objectives. For any given objective, one or more different attributes or criteria are used to measure the performance in relation to that objective.

Starting from a real case concerning the reuse of historical buildings in the metropolitan area of Torino (Italy), the paper aims at exploring the contribution of MAVT for decision problems in the field of cultural heritage. In the application, several buildings are considered on the basis of different attributes, such as environmental quality, accessibility, flexibility of the structures, and so on. The evaluation takes into consideration the opinions of different experts for the definition of the value functions of the attributes as well as their importance. In the result of the approach a ranking of suitable buildings to be reused is provided.

The research has an innovative value because only few applications of MAVT exist in this specific decision context.

3. Cultural heritage evaluation

3.1. Background and definition

Cultural heritage can be considered as a dynamic category in a constant evolution and the definition has varied through the years.

According to the World Heritage Convention [9], the term cultural heritage refers to single monuments, such as architectural works, works of monumental sculpture and painting, as well as groups of buildings and sites, considering for example areas including archaeological sites.

This initial definition has been enlarged and nowadays in the characterization of cultural heritage it is possible to include also territorial systems, landscapes, itineraries and intangible heritage.

Following this description, it is clear that the environment wherein cultural goods are ideally defined can be represented by the following elements [1].

Firstly, cultural heritage is a multidimensional issue, because it belongs to the economic categories of public and mixed goods. Secondly, cultural heritage is a multi-attribute problem considering that heterogeneous flow of services and functions characterises cultural markets. Thirdly, cultural heritage is a multi-value problem because it concerns a wide spectrum of personal and inter-personal value benefits.

According to the scientific literature, the economic and cultural value of cultural heritage must be addressed through the Total Economic Value paradigm, which allows the overall value to be decomposed in two macro-categories: the use value and the non-use value [10–12].

The use value, linked to the benefits the consumer receives directly from the cultural asset itself, is the utility that the historic artefact offers the consumer from the very moment he comes into contact with it; the non-use value, which refers to the utility that the consumers perceive from the conservation of the cultural assets for themselves and for the future generation.

Moreover, speaking about cultural heritage evaluation, it is worth pointing out that a strong link exists between the cultural goods available in a given area and the active production of material culture. This link ascribes a particular importance to economic development and it suggests to separate two fundamental moments concerning:

- the estimation of the values of the site;
- the creation of value by means of economic activities.

It has been generally agreed that these two moments represent the basis of the historical identity of the site and of the vitality of the culture expressed by the site. In this sense, the evaluation must consider not only the historical and emblematic aspects of the site, but also the opportunities provided by the site to the overall community.

3.2. Cultural heritage and Multicriteria Analysis: state of the art

For the background presented in Section 3.1, decision problems related to cultural heritage can be addressed through a formal multicriteria analysis. Table 1 summaries the main scientific works available in the literature considering the application of MCDA in cultural heritage decision problems, putting in evidence the field of application, the objective of the evaluation, the MCDA technique used and the scientific journal in which the work was published.

Table 1
Main works available in the literature concerning MCDA applications in cultural heritage.

Authors	Fields of application	Objectives of the evaluation	MCDA method	Journals
Wang and Zeng [13]	Reuse of historical buildings	To rank different reuse alternatives (office, museum, hotel and shopping mall) for historical sites in Taiwan	ANP and Delphi method	*Expert Systems with Applications*
Bryan et al. [14]	Management of natural capital and ecosystem services	To identify management priorities for ecosystem services (including cultural services such as cultural diversity and heritage, sense of place. . .) in Australia	AHP	*Ecosystems*
Thórhallsdóttir [15]	Energy planning	To rank several hydroelectric and geothermal developments in Iceland on the basis of their impacts (including impacts on cultural heritage)	AHP	*Environmental Impact Assessment Review*
Hamadouche et al. [16]	Biodiversity preservation	To rank archeological site in a park in Algeria on the basis of the priorities for conserving biodiversity	GIS + MCDA (ELECTRE and PROMETHEE)	*Arab Journal of Geoscience*
Palmas et al. [17]	Energy planning	To spatially optimize residential development in Italy according to different energy potentials and paying attention to the distance from historic/cultural facilities	GIS + MCDA (AHP)	*Energy, Sustainability and Society*
Giove et al. [11]	Reuse of historical building	To rank alternative scenarios for the reuse of the historic Venetian Arsenal in Italy	Choquet integral	*Journal of Multicriteria Decision Analysis*
Di Bitonto et al. [18]	Mobile recommender system in the tourism domain	To calculate users' similarities and to rate predictions on items to be recommended (including cultural sites, historic itineraries. . .)	Specific algorithm for Multicriteria rating	*Lectures Notes in Artificial Intelligence (LNAI)*
Paolillo et al. [19]	Urban planning in historic centres	To create a suitability map for change and to rank alternative transformation scenarios for the historic centre of Como (Italy)	Multivariate analysis	*Lectures Notes on Computer Science (LNCS)*
Tarragüel [20]	Environmental planning	To evaluate the vulnerability of cultural heritage objects to landslides in Georgia	GIS + MCDA (AHP)	*Journal of Cultural Heritage*
Cerreta et al. [21]	Territorial transformation strategies	To rank alternative scenarios for the reuse of an historical railway line in Italy	GIS + MCDA (AHP)	*Lectures Notes on Computer Science (LNCS)*
De Toro et al. [22]	Spatial planning	To create suitability maps for the location of different functions (industrial areas, residential areas. . .)	GIS + MCDA (AHP)	*Lectures Notes on Computer Science (LNCS)*
Fuentes [23]	Reuse of historical buildings	To assess the potential reuse of vernacular architecture objects in Spain	Weighted sum	*Journal of Cultural Heritage*
Dutta and Husain [24]	Reuse of historical buildings	To grade different heritage sites in order to find priorities for conservation	Weighted sum	*Journal of Cultural Heritage*

MCDA: Multicriteria Decision Analysis; GIS: Geographic Information System; AHP: Analytic Hierarchy Process; ANP: Analytic Network Process.

As it is possible to see from Table 1, many applications of MCDA exist in the domain of cultural heritage. From the point of view of the field of application and the objective of the evaluation, the analysis shows that there is a presence of works in different research domains, such as energy planning, spatial planning, ecosystems valuation, where the preservation of cultural heritage is a criterion of the evaluation model. It is possible to say that only few works exist for the evaluation of cultural assets with reference to the strategies for the reuse. As far as the MCDA method is concerned, many studies consider the application of Analytic Hierarchy Process, often combined with GIS, while the use of outranking methods is less diffused. It is possible to affirm that works based on Multi-Attribute Value Theory or Multi-Attribute Utility Theory are limited. Finally, most of the researches were published on the *Journal of Cultural Heritage*.

4. Multi-Attribute Value Theory: methodological background

The theoretical concepts of MAVT were described by Fishburn [25], Raiffa [26] and Keeney and Raiffa [8]. Different techniques to assess a general value function can also be found in Von Winterfeldt and Edwards [27] and French [28].

MAVT can be used to address problems that involve a finite and discrete set of alternative options that have to be evaluated on the basis of conflicting objectives. For any given objective, one or more different attributes or criteria, which typically have different measurement scales, are used to measure the performance in relation to that objective [8]. MAVT can handle quantitative as well as qualitative data. If quantitative data are not available, expert judgments can be used to estimate the impacts on a qualitative scale.

The intention of MAVT is to construct a means of associating a real number with each alternative, in order to produce a preference order on the alternatives consistent with the decision maker value judgments. To do this, MAVT assumes that in every decision problem a real value function exists that represents the preferences of the decision maker. This function is used to transform the evaluation of each alternative option on considered attributes into one single value. The alternative with the best value is then pointed out as the best [29].

Following this reasoning, it becomes clear that MAVT aggregates the options' performance across all the criteria to form an overall assessment and is thus a compensatory technique. This means that the method does allow compensation of a weak performance of one criterion by a good performance of another criterion. It is interesting to notice that the compensatory approach is crucial in the field of sustainability assessment. Sustainability is often considered in terms of the three pillars of environmental, social and economic considerations and a critical issue is how to combine the different dimensions in the evaluation framework [30]. In this context, it is worth recalling that there are two competing theories about sustainability, one referring to the weak sustainability approach and the other to the strong sustainability approach [31]. The central element, which distinguishes the two theories, is the assumption that human-made capital can effectively substitute for natural capital and the services provided by the ecological system. This is the perspective supported by the weak sustainability theory. On the other hand, the strong sustainability approach calls for maintaining human, human-made, and natural capital separately [32]. Being a compensatory method, MAVT thus supports the evaluation process under weak sustainability assumptions and complete substitution between man-made capital and natural capital is allowed.

From the methodological point of view, the process to be followed to build a MAVT model consists of the following five fundamental steps [33,34]:

- defining and structuring the fundamental objectives and related attributes;
- identifying alternative options;
- assessing the scores for each alternative in terms of each criterion;
- modeling preferences and value trade-offs: elicitation of value functions associated with objectives and attributes and assessment of their weights;
- ranking of the alternatives: a total score is calculated for each alternative by applying a value function to all criteria' scores.

An appropriate statement of decision objectives is the first logical step in a decision problem. Objectives are "statements of something that one desires to achieve" [35] and they depend on the problem to be analyzed, on the actors involved in the decision process, and on the environment in which the decision process takes place. The degree to which objectives are achieved is measured through a set of attributes, which may be natural (they follow directly from the definition of the objective), constructed (they specify a finite number of degrees to which objectives are met), and proxy (they are only indirectly linked to the definition of the objective) [35].

The second step in the process consists in the identification of alternatives, which are the potential solutions to the decision problem.

In the third step the performances of each alternative specify for each attribute the outcome of the alternative. In some cases, the performances are readily available, in some other cases they have to be computed or estimated ad hoc for the problem at hand [36].

In the development of a MAVT model it is of crucial importance to express the perceived values on the impact that the options under consideration can have, measuring the relative worthiness of each impact. The way of modeling such preferences is via a value function [33]. Value functions are a mathematical representation of human judgments. They offer an analytical description of the value system of the individuals involved in the decision and aim at capturing the parts of human judgments involved in the evaluation of alternatives. In particular, a value function translates the performances of the alternatives into a value score, which represents the degree to which a decision objective (or multiple decision objectives) is achieved. The value is a dimensionless score: a value of 1 indicates the best available performance and a high objective achievement, while a value of 0 indicates the worst performance and a low objective achievement [36].

Since people do not naturally express preferences and values in this way, value functions have to be estimated through a specially designed interviewing process in which the relevant judgments for the decision are organized and represented analytically. In this sense value functions are at best an approximate representation of human judgments and are constructed or produced [36].

It is important to underlie that different strategies are available for the development of a MAVT model. The holistic scaling and the decomposed scaling strategies are the most used in practice [36]. According to the former, an overall value judgment has to be expressed of multi-attribute profiles, which can be either the real alternatives or artificially designed profiles. Weights and value functions are then estimated through optimal fitting techniques (e.g. regression analysis or linear optimisation) and are the best representation of the assessor's judgments. According instead to the decomposed scaling technique, the multi-attribute value function is broken down into simpler sub-tasks (the marginal value functions and the weights), which are assessed separately. The aim of decomposed scaling is to construct the multi-attribute model for evaluating decision alternatives while the aim of holistic scaling is to make an inference about the underlying value functions and weights [36]. The following paragraphs provide a brief overview of the methods and techniques that can be used to assess value functions and weights within the decomposed scaling strategy, which is the one followed in the case study proposed in the present paper.

Concerning the value functions construction, the most commonly applied approaches refer to the following [36]:

- Direct rating technique. In this method, the respondent is asked to estimate the strengths of preferences for different levels of an attribute on a numerical scale. First, the most and least preferred levels are identified and valued with 100 and 0, respectively. The remaining levels are then rated between the two endpoints. The relative spacing between the levels of the attribute reflects the strength of preference of one level compared with another [27];
- Curve fitting. In this case a curve is selected directly by the assessor from a set of functional forms;
- Bisection. In this method it is necessary to identify midpoints of value given two anchoring levels within the range of the attribute. Bisection can be applied only for quantitative attributes;
- Standard differences. The reference standard sequence technique aims at dividing the score range into equal value-spaced subintervals. This approach is very simple, but also sensitive to random error magnification;
- Parameter estimation. In this case, the assessor is first asked to evaluate the marginal rate of substitution of an attribute, starting from a specific point. Knowing the rate of change of the marginal rate of substitution at different points, the value function can be deduced analytically;
- Semantic judgment. In this case, decision alternative scores are first marked on the attribute range and then the assessor expresses judgments on the difference of attractiveness between each pair of points. The value function, which represents these judgments, is then computed through linear optimization, selecting the curves most consistent with the revealed preferences. This technique offers a bridge between the ability to make sensible judgments and the numerical specifications of the value model.

A detailed discussion of the characteristics of these techniques is beyond the scope of this paper but the interested reader is referred to [36] for a complete overview.

Dealing with value functions, mentions has to be made to the fact that the applicability of value functions relies to a large extent upon the possibility of assessing value function models easily and reliably [36].

One of the greatest strengths of the MAVT approach is that it can deal with a large number of alternatives without an increase of the elicitation effort compared to a study with a smaller number of alternatives. This is due to the fact that value functions are elicitated from the decision maker or stakeholder independently of the alternatives, based on his or her preferences about the fulfillment of the different objectives. The preference elicitation step is indeed based simply on the range of variation of each attribute over all alternatives, i.e., the best- and worst-possible level of each attribute. Once the value function has been constructed by means of one of the aforementioned approaches it becomes possible to evaluate the different alternatives. Therefore, the elicitation procedure is independent from the number of alternatives and any additional alternative can be introduced at a later stage as long as the extreme levels of its attributes stay within the ranges defined for preferences elicitation [37]. However, eliciting preference functions for complex decisions with many objectives is intellectually challenging and time consuming.

Another crucial step consists in the prioritization of the different objectives. Many different methods have been proposed in the literature for assessing criteria weights, which are then used explicitly to aggregate criterion specific scores. It has been generally agreed that the meaning and the validity of these criteria weights are crucial in order to avoid improper use of MCDM models and the procedures for deriving criteria weights should not be independent of the manner they are used [38–40]. As far as MAVT is concerned, it has to be noticed that weights in the additive model are scaling constants, which allow marginal value functions to take on values in the same interval. The meaning of weights can be stated in terms of the end point of each attribute range: the value improvement obtained by switching an attribute from its worst to its best score corresponds to the attribute weight [36]. In MAVT method, the most common assessment techniques for weights are [36]:

- swing-weights. This technique is based on the direct analysis of the value advantage associated with swinging between the end points of each attribute range;
- rating. In this case, the assessor simply assesses the importance of each attribute by implicitly considering their ranges. The first point is usually the classification of attributes in classes of importance, then comes the ranking of the attributes and finally their numerical rating;
- pairwise comparison. This method requires importance ratio judgments between each pair of attributes. Redundant judgments are used to average our inconsistencies in such a way that a single set of weights can be computed [41];
- trade-off. This method requires indifference judgments among multi-attribute profiles;
- qualitative translation. Starting from ordinal weights, these methods provide numerical weights either by selecting an arbitrary, consistent, numerical representation or by exploiting assumptions of statistical regularity.

Again, a detailed discussion of the characteristics of these techniques is beyond the scope of this paper but the interested reader is referred to [36] for a complete overview.

Among the aforementioned approaches, one of the most used methods for eliciting weights is the Swing-weights procedure, which explicitly incorporates the attribute ranges in the elicitation question. In particular, the method asks to value each improvement from the lowest to the highest level of each attribute [33]. The Swing method uses a reference state in which all attributes are at their worst level and asks the interviewee to assign points to states in which one attribute at a time moves to the best state. The weights are then proportional to these points. One of the most important advantages of the Swing method is that it only requires to know the attribute ranges and is thus independent from the shape of the value functions of the objectives. On the other hand, the disadvantages are that the technique is based on direct rating, it does not include consistency checks, and the extreme outcomes to be compared may not correspond to a realistic alternative, which makes the questions difficult to answer [37].

Finally, MAVT includes different aggregation models, but the simplest and most used one is the additive model [42] as it is represented in equation (1):

$$V(a) = \sum w_i \cdot v_i(a_i) \qquad (1)$$

where V(a) is the overall value of alternative a, $v_i(a_i)$ is the single attribute value function reflecting alternative a's performance on attribute $_i$, and w_i is the weight assigned to reflect the importance of attribute $_i$.

A closely related theory to MAVT is Multiple-Attribute Utility Theory (MAUT, [8]). MAUT is based upon expected utility theory and requires stronger assumptions to ensure additivity. The advantage of MAUT is that it can take uncertainty and the decision maker's attitude to risk into account and represent it directly into the decision support model. However, the associated level of difficulty obviously increases.

5. Case study application

5.1. Description of the case study and presentation of the alternatives

This case study concerns the application of MAVT for the reuse of historical buildings.

In particular, starting from an analysis of the former industrial buildings located in the municipality of Caselle (which is near the city of Torino in northern Italy), our study aims at finding the most suitable building to be recovered for touristic purposes.

Indeed, a strong interest toward the recovery of the industrial and cultural heritage of this small municipality has been raised by several stakeholders, as for instance local public authorities, private entrepreneurs, local practitioners and inhabitants.

Starting from all the former woolen and paper mills and silk factories located in the municipality of Caselle, we identified the decision alternatives by excluding those buildings that have already been reused for other purposes and those buildings that do not exist anymore.

As a result of this screening procedure, we identified the 7 alternative highlighted on Figs. 1 and 2.

The reasons for choosing MAVT in the present application refer to some important properties of the method that are summarized in the following paragraphs. To start with, the elicitation of value functions forces the DM to carefully reflect upon their project priority approach and thus generates a learning effect (since preferences are constructed rather than discovered [33]). Secondly, the method can deal with a large number of alternatives without an increase of the elicitation effort compared to a study with a smaller number of alternatives. Finally, MAVT does not require probability distribution in contrast to MAUT.

5.2. The decision support process

The decision support process that we decided to follow in the present application can be structured according to Fig. 3.

As previously anticipated, we started from the definition of the decision context and the identification of the real alternatives.

The next step consisted in the definition of a panel of experts for the development of the evaluation. The use of experts' panels expands the knowledge basis and may serve to avoid the possible

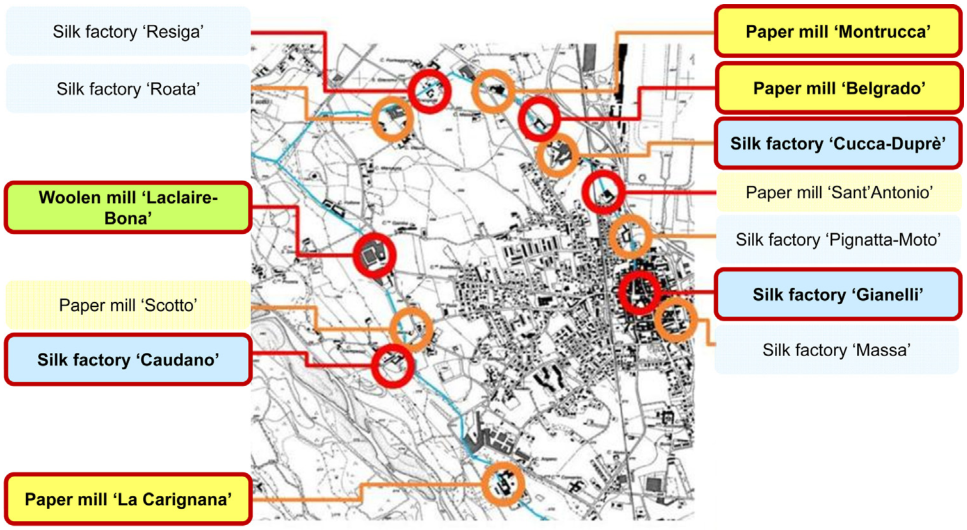


Fig. 1. Identification of the alternatives.

Elaboration from [47].

Fig. 2. Pictures of 4 former industrial buildings still existing (from the top left: silk factory Caudano; paper mill La Carignana; paper mill Belgrado; paper mill Montrucca). *Elaboration from [47].*

bias, which characterizes the situation with a single expert. On the other side, the use of experts' panels has a range of problems associated with it, such as the panel composition, the interaction mode between panel members and, above all, the aggregation of panel responses into a form useful for the decision [36]. In our case, particular attention was dedicated to the panel composition in order to have it balanced. Therefore, we involved an historian, an expert in the field of cultural heritage, a planner and an expert in the field of economic evaluation, by using the technique of the focus group. In particular, we used decomposed scaling as explained by Beinat [36] and thus marginal value functions and weights were assessed separately. The overall value model was then built by combining these parts through the additive combination.

With specific reference to the assessment of the scaling constants for all the attributes, we chose the Swing Weight approach because the discussion oriented towards value ranges seemed very promising in the context of cultural heritage evaluation. In particular, we first tried with face-to-face interactions among panel members in order to discuss opinions and estimates but it was impossible to achieve an agreement among the experts. Therefore, we interviewed each expert individually, we aggregated the results and we finally organized another joint meeting in order to share the final results and to search for consensus alternatives.

Finally, it is important to highlight that it has been an iterative process and that the discussion with the experts during the focus group provided useful insights for the definition of the attributes and their value functions. In particular, bringing together experts from different disciplines allowed to perform a preliminary screening of the proposed attributes and to better detail the characteristics of the relevant ones. Moreover, the discussion oriented towards values rather than towards alternatives during both the value function construction and the level of trade-offs

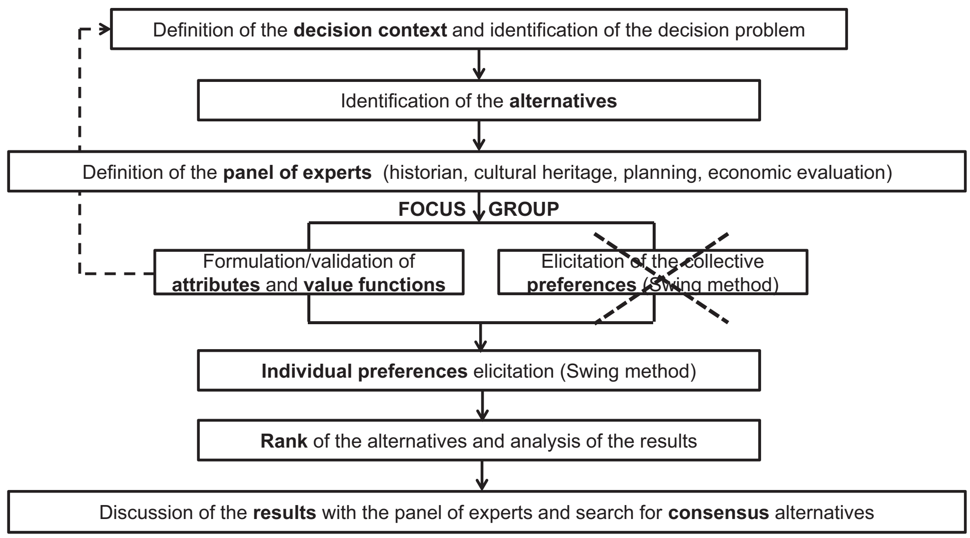


Fig. 3. Scheme of the decision support process.

Elaboration from [37].

elicitation facilitated a better understanding of the problem and of the relationships among the considered aspects.

5.3. Structuring of the decision problem

As previously mentioned, the first step of the process consisted in the structuring of the decision problem. A set of measurable attributes has then been identified for the evaluation of the alternatives and it has been organized according to the value tree approach (Fig. 4).

In this case, we used a top down approach for structuring the value tree meaning that we started from eliciting the ultimate objective and climbed down, asking how this objective could be achieved and thus looking for attributes.

As it is possible to see, the main objective of our model is to determine the suitability of the buildings to be reused for touristic purposes. To this end, 5 attributes have been considered. The first one is the quality of the context, which takes into account the quality of the surrounding buildings, the quality of the surrounding environment, the presence of a park and the proximity to the airport. The second one is the presence of economic activities in the 1500 m range, which can create positive synergies with the touristic recovery of the building. The third attribute is the flexibility of the building, which takes into account the possibility to maintain the readability of the building from both its original function and original structure point of view. The fourth one is the accessibility. Following the suggestions coming from the international literature and the sustainability paradigm, we considered the pedestrian accessibility, measured as walking time needed to reach each building from the station. Finally, the fifth attribute is the conservation level, which refers to both material conditions and economic considerations.

Table 2 provides the raw values of each alternative for all the considered attributes.

5.4. Elicitation of the value functions

The next step consisted in the elicitation of the value functions, which are mathematical representation of human judgments. Following the MAVT methodology, each attribute is described by a value function, which allows to scale the attributes between 0 and 1 in order to compare non-commensurable items. In particular, a value of 1 indicates the best available performance and a high objective achievement, while a value of 0 indicates the worst performance and a low objective achievement.

The construction of a value function for every evaluation criterion in the model is a task that can be accomplished through different numerical and non-numerical techniques [27,42,43]. In cases where discrete scales of performance were constructed, direct rating [27] is widely used [44].

For the assessment of marginal value functions we thus used the direct rating technique because, based on the type of information available for each attribute, it seemed the most appropriate approach. In particular, we first described the attributes and selected the score range, we then determined the qualitative characteristics of the marginal value function (monotonicity), we specified values for selected attribute scores and, finally, we interpolated the values. The resulting rating scales have thus been constructed in such a way that the difference between the scores of two performance levels reflects their difference of attractiveness

Table 2
Raw values of the alternatives.

Alternatives	Quality of the context [qualitative judgment]	Economic activities [number]	Flexibility [qualitative judgment]	Accessibility [minutes]	Conservation level [qualitative judgment]
Carignana	Good	8	Good	18	Good
Caudano	Discrete	3	Discrete	18	Discrete
Bona	Good	1	Very good	21	Discrete
Montrucca	Discrete	1	Very good	19	Very good
Belgrado	Bad	4	Very good	19	Very good
Duprè	Bad	9	Good	15	Very good
Gianelli	Bad	12	Discrete	6	Bad

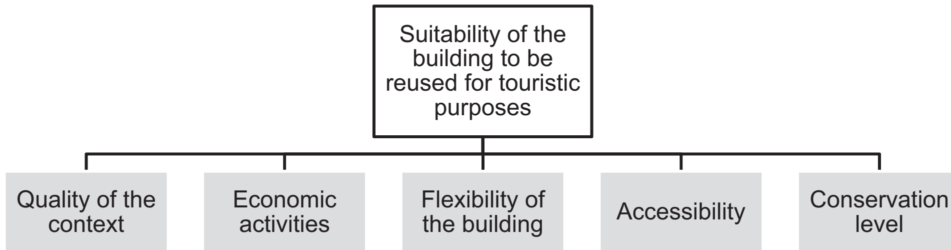


Fig. 4. The value tree for the decision problem under analysis.

for the evaluator. These preliminary function shapes have been showed to the panel of experts and thus validated through an iterative process.

Direct rating can be applied for both qualitative and quantitative attributes.

Mention has to be made to the fact that the application of classical models and techniques for cardinal measurement of values usually requires a person to answer quite difficult questions. For this reason, other methodologies have been proposed in the literature such as MACBETH [45] and aggregation-disaggregation methods [46]. In particular, MACBETH is a technique that enables the construction of value functions derived from qualitative (i.e. non-numerical) judgments about the difference of attractiveness between every two performance levels of the scale, thus avoiding the difficulty or cognitive uneasiness experienced by some evaluators when expressing their preference judgments numerically [44].

Table 3 describes the value functions that have been constructed for the attributes considered in the present application.

As a result of the value function elicitation procedure, we were able to determine the performance matrix of the alternatives under consideration.

As it is possible to see in Table 4, there is not an alternative that performs as the best one on all the considered attributes. It is therefore necessary to proceed with the determination of the levels of trade-offs among the attributes.

5.5. Weighting

With reference to the MAVT theory, once the alternatives have been evaluated, it is necessary to define the weights of the different attributes of the decision problem. In this case the Swing method has been used and the weights have been determined using a reference state in which all attributes are at their worst level and asking to the decision maker which attribute he would improve to the best level, assuming that only one attribute could be improved. The next step consists in asking to the decision maker to give a value to (e.g. in the range 0–100) to this swing in terms of worthiness. The weights are then proportional to these values. This implies that the criteria weights are proportional to the discriminating power of the criteria in MAVT [39].

The evaluation has been performed by individual experts in their proper field of expertise; in this case, four different experts in the context of urban planning, history of architecture, cultural heritage and economic evaluation have been questioned separately by means of a specific questionnaire which is based of the Swing method approach [37]. The questionnaire is given in the Appendix (p. 2).

As an example, the Appendix (p. 3) provides the questionnaire that has been submitted to the economic evaluation expert. The normalization of the scores provided by the expert led to the following set of weights: quality of the context (26.2% of importance), economic activities (24.6%), building flexibility (20%), accessibility (21.5%) and conservation level (7.7%).

Following a very similar procedure, it was possible to obtain the set of weights for the other experts. Table 5 represent the set of weights used for implementing the evaluation.

As it is possible to see from Table 5, all the experts agreed in considering the quality of the context as the most important attribute in the decision problem under examination. Also the flexibility of the building was judged as important from the full range of experts while the importance of the other attributes is more variable. These considerations are reflected in the mean set of weights, where the most important attribute is the quality of the context (27.7% of importance), followed by the building flexibility (22.7%), the conservation level (17.7%), the accessibility (16.4%) and finally the economic activities (15.5%).

5.6. Aggregation of the results

The single attribute value functions have then been aggregated using the obtained set of weights and additive assumptions to calculate the total value of the specific alternatives. Fig. 5 represents the overall values and the ranking of the alternatives. From the obtained results it is possible to say that the building "La Carignana" is the best alternative according to four sets of weights out of five and it ranks second in the remaining set. Also the building "Montrucca" has very good performances since it ranks as the very best alternative for one expert out of four and as the second best alternative for two experts as well as in the average model. Moreover, mention has to be made to the fact that the building "Caudano" is classified as the worst alternative in three cases out of five.

6. Discussion of the results

6.1. Sensitivity analysis

After obtaining a ranking of the alternatives and despite the coherence obtained in the results, it was considered useful to perform a sensitivity analysis on the final outcome of the model. The sensitivity analysis is concerned with a "what if" kind of question to see if the final answer is stable when the inputs are changed. It is of special interest to see whether these changes modify the order of the alternatives.

It has to be noticed that a distinction exists between the terms "sensitivity" and "robustness" analysis in MCDA literature. Generally speaking, sensitivity analysis indicates which parameters contribute more to the variance of the outputs while robustness analysis is based on the development of multiple model versions in order to identify a solution that can be accepted in any version of the model. In this sense, it is possible to state that sensitivity analysis occurs *a posteriori*; on the other hand, robustness analysis involves concerns that must be taken into account a priori, at the time that the problem is formulated [48].

Table 3
Elicitation of value functions for each attribute.

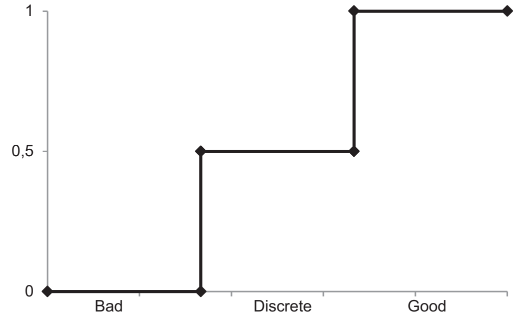
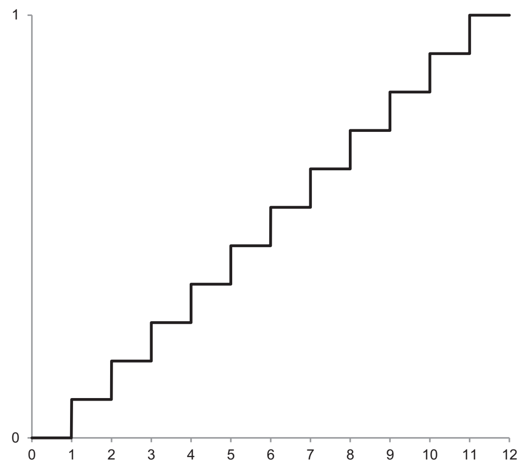
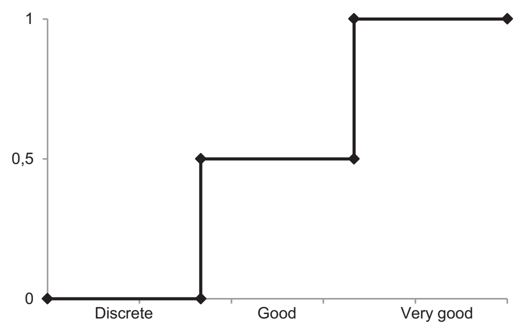
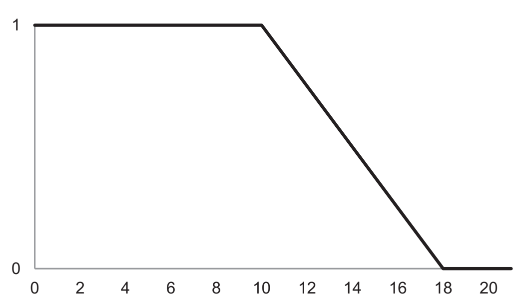
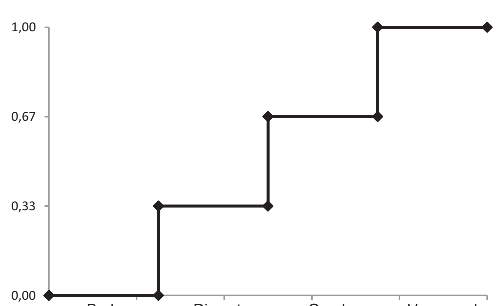
Attributes	Value functions
Quality of the context	
Economic activities	
Flexibility of the building	
Accessibility	
Conservation level	

Table 4
Standardized scores of the alternatives.

Alternatives	Quality of the context	Economic activities	Flexibility	Accessibility	Conservation level
Carignana	1	0.64	0.5	0	0.67
Caudano	1	0.18	0	0	0.33
Bona	0.5	0	1	0	0.33
Montrucca	0.5	0	1	0	1
Belgrado	0	0.27	1	0	1
Duprè	0	0.73	0.5	0.38	1
Gianelli	0	1	0	1	0

Table 5
Sets of weights provided by the experts.

	History of architecture	Spatial planning	Restoration	Economic evaluation	Mean
Quality of the context	0.290	0.292	0.264	0.262	0.277
Economic activities	0.065	0.083	0.226	0.246	0.155
Building flexibility	0.226	0.125	0.358	0.200	0.227
Accessibility	0.161	0.167	0.113	0.215	0.164
Conservation level	0.258	0.333	0.038	0.077	0.177

In the present study the sensitivity analysis has been performed with regards to the weights of the attributes. Particularly, the weight of one attribute at time has been increased until 40% while the weights of the other four attributes have been maintained equal to 15%. The evaluation model has been run considering the new weights and the final priorities of the alternatives have been recalculated. Fig. 6 represents the results of the performed sensitivity analysis. As it is possible to see, three alternatives (La Carignana, Montrucca and Duprè) have the best performances in the considered sensitivity scenarios while the alternative Caudano ranks worst in the most part of the scenarios. In this sense, it is possible to affirm that three best performing alternatives need to be studied in depth in order to better differentiate their priorities.

From the point of view of the decision process, mention has to be made to the fact that the results represented in Fig. 5 were presented during a final meeting where the four experts were invited and asked to discuss the outcomes of the evaluation model. It has to be noticed that even the experts had different concerns about the importance of the attributes (Table 5), they came to very similar final rankings (Fig. 5). In fact, "La Carignana" and "Montrucca" are the best alternatives according to all the set of weights while the building "Caudano" ranks last in most of the considered cases. Moreover, the experts agreed with the results of the sensitivity analysis, according to which the best performing alternatives are "La Carignana", "Montrucca" and "Duprè". As a conclusion, it is possible to say that at the moment the aforementioned buildings constitute consensus alternatives, which need further research in order to come to a final decision.

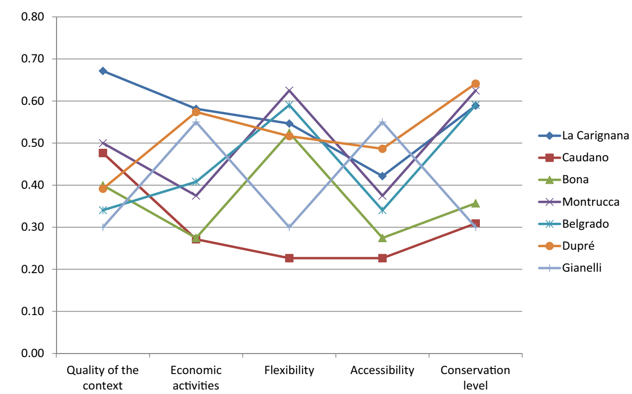


Fig. 6. Sensitivity analysis for the case under examination.

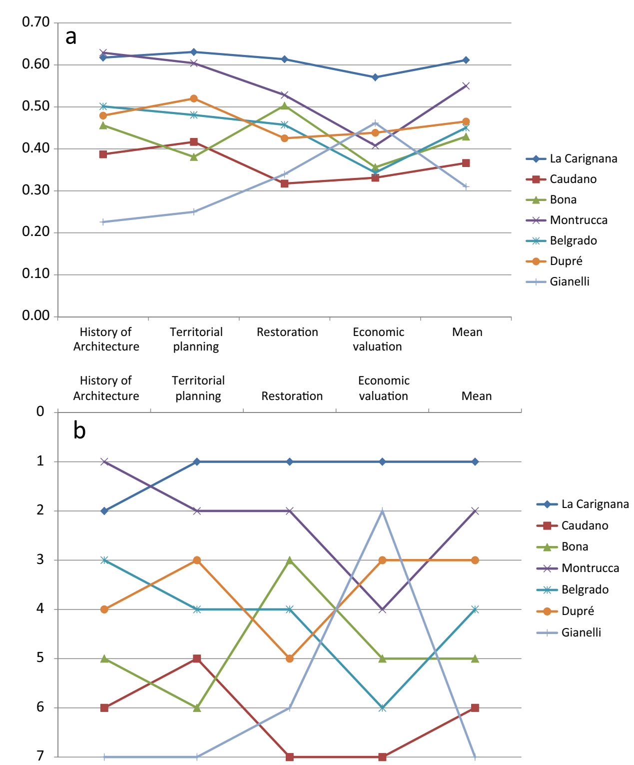


Fig. 5. Overall value (a) and ranking (b) of the alternatives for the different experts.

7. Conclusions

The study discusses the contribution of MAVT for decision problems in the field of cultural heritage. Particularly, the work illustrates the application of the MAVT for addressing the decision problem concerning the reuse of historical buildings in the city of Caselle (Italy).

To start with, we can affirm that the results of the performed analysis show that MAVT is efficient in representing the real problems of a territorial system. Particularly, using a structured participative process based on the use of an MCDA approach allows the decision makers and stakeholders to gain more awareness of the elements at stake while structuring the model and thus learn about the problems while solving them [49].

Secondly, a discussion oriented toward the value of the performance of each indicator forces the involved stakeholders to carefully reflect upon their project priorities approach. Finally, the method allows to include new alternatives at any stage of the procedure without the need of re-elicitating preferences and without changing the ranking of the alternatives.

Moreover, the discussion oriented towards values rather than towards alternatives facilitates appreciating other perspectives and opening new horizons for the discussion. In this sense, it is possible to affirm that MAVT supports the creation of consensus alternatives because the reasons for bad and good performances are revealed in the evaluation. Following this reasoning, MAVT, and in general MCDA techniques, are much more than procedures for ranking alternatives and they can be seen as a tool for supporting Decision making by stimulating a discussion among the stakeholders, with different perspectives, by identifying causes of disagreements and by inspiring the search for better alternatives [37].

With reference to the weights elicitation, the Swing method proved to be effective and the questionnaires were evaluated as very clear by the respondents. However, according to the experience carried on, the Swing method seems to be not suitable for supporting participated discussion among the participants because it does not allow a common set of weights to be found in case of disagreement among the involved participants.

The contribution of MAVT approach (and, more generally, of MCDA methods) in cultural heritage decision problems is particularly important for emerging countries. In this situation, given the limited financial resources, the renovation and maintenance of all heritage buildings is not feasible from an economic point of view. The application of the proposed method in such decision contexts would provide a checklist of elements able to support planners and DMs in understanding which buildings are worthwhile to be preserved and conserved. Given the rational basis of the method, the transparency of the procedure and the possibility of including visions and preferences of different stakeholders [50,51].

It has to be noticed that as far as decision problems related to cultural heritage are considered, different evaluation approaches are available. Considering the existing methodologies, a preliminary classification between monetary and non-monetary evaluation techniques can be made. With reference to the monetary methods, the evaluation is addressed from an economic point of view and the techniques aim at exploring the economic value of cultural and historical assets starting from the preferences of residents and tourists on the area. Among these methods, a very important role is played by the technique of Choice Experiments (CE). CE are statistical methods initially applied in commercial psychology and marketing literature and recently adapted to environmental assessment and cultural heritage evaluation [52]. Particularly, CE are stated preference techniques that ask respondents to state their preferences and opinions towards hypothetical scenarios. CE have the ability to obtain values for various elements of a good and to estimate multidimensional changes regardless of whether an entry fee is paid or not. This ability to investigate the “part-worths” of a good is well suited to the nature of environmental and cultural goods. Conducting a CE will allow the quantification of values for specific features of a site and the observation of trade-offs people are prepared to make [53]. With reference to the non-monetary methods, the techniques are based on MCDA methods and they aim at providing an holistic and integrated evaluation of the cultural-historical assets under investigation, including in the model the specific opinions of experts, stakeholders and policy makers. In our application we chose to follow the MCDA approach because of the following reasons:

- the objective of the evaluation was to choose the best performing building to be reuse;
- spatial and geographic attributes have to be taken into account in decision problem formulation.

For these reasons we believe that MCDA is particularly suitable for dealing with the problem under investigation. The main drawback of the MCDA approach in the present application is related to the use of expert panels for the development of the model. In this sense, as already recalled in Section 5.1, the use of experts’ panels affects the final results of the evaluation considering the composition of the panel and the way through which the response are aggregated and imputed in the model.

Future developments of the research will consider uncertainty of predictions and risk attitude of DMs switching values functions to utility functions. This is very important in public decisions where complex problems arise and the outcomes cannot be predicted precisely.

Given the spatial nature of the decision problem under consideration, further improvements of the work will refer to the integration of the model with Geographic Information Systems in order to develop a Multicriteria Spatial Decision Support System [54,55].

Finally, future developments of the analysis refer also to the use of different mathematical methods for panel aggregation as for instance the distance minimization and weighting schemes [36] and to the investigation of the stability of the results by carrying out a sensitivity analysis that focuses also on the value functions and on the uncertainty levels.

To this end, it is possible to conclude that the use of MAVT seems to be a very promising line of research for supporting decision-making processes in the context of cultural heritage and territorial transformation projects.

Acknowledgments

The contribution is the result of the joint effort of the authors. Despite the global responsibility for the work being equally shared between the three authors, Marta Bottero is responsible for paragraphs 2, 3, 5.5, 5.6 and 6 while Valentina Ferretti is responsible for paragraphs 4, 5.1, 5.2, 5.3 and 5.4. The abstract, paragraph 1 and paragraph 7 are the result of the joint work of the three authors.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version.

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