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Abstract
The paper presents a multiple criteria model for the evaluation of the sustainability of projects for the economic re-use of historical buildings in Venice. The model utilises the relevant parameters for the appraisal of sustainability, aggregated into three macro-indicators: *intrinsic sustainability, context sustainability* and *economic-financial feasibility*. The model has been calibrated by a panel of experts and tested on two reuse hypothesis of the Old Arsenal in Venice.

Keywords
multiple criteria valuation, economic reuse, historical building conservation

JEL Codes
Z1- Cultural Economics, R52 - Land Use and Other Regulations

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1. Evolution of the concept of cultural heritage

Mapping out the guidelines for the sustainable economic re-use of historic buildings cannot leave out of consideration the complexity of the objectives and methodologies for safeguarding of cultural heritage. The historic, aesthetic and artistic characteristics of cultural assets make it difficult to apply a solely qualitative approach. The complexity of the investigation is also due to the public nature of these goods, not necessarily as far as the property right is concerned – many are privately owned – but rather those relate to historic, artistic and cultural value [Brosio 1993]. The evolution of the concept of cultural heritage in Italian laws and regulations is very interesting. An important law for this matter passed in 1939[1] deals with "moveable and immovable assets which are of artistic, historic, archaeological or ethnographic interest", as objects which are aesthetically pleasing and, as such, should be safeguarded by appropriate legislation. Article 9 of the Constitutional Charter refers to these concepts and states: "The Republic […..] safeguards natural landscape and the historical and artistic heritage of the Nation", affirming the central Government's sovereignty over the cultural heritage and the values of national identity [Giannini, 1976].

Italy's post-war cultural debate developed new views by proposing innovative laws and Commissions, including the Franceschini[2] Commission, which first used the term "cultural heritage" to describe "material evidence of civil value". The cultural heritage assets are no longer simply aesthetically pleasing but also a palimpsest of a culture's history.

The cultural heritage and landscape is currently safeguarded by the "Codex of cultural heritage"[3], which, together with the prior law[4], defines cultural

[1] Law 1089 of June, 1st 1939.

[2] The Franceschini Commission operated from 1964 to 1966.

[3] Legislative Decree bearing the "Codex of cultural heritage", in accordance with article 10 of the Law no. 137 dated July, 6th 2002.

[4] In January 2000 the "Consolidated Law on natural and cultural heritage" (TU 490, 1999) came into force; article 4 takes up the idea of cultural heritage as a testimony to civil value.

heritage. According to this definition, cultural heritage are assets that also encompass the qualities and attributes of objects that have ethnic, anthropological, archivistic or literary value for past, present or future generations.

In recent years, there has been an increasing interest concerning the economic value of the cultural heritage, defining the economic value not only in monetary terms, but also in terms of a broader considerations, recognizing for instance the fact that the conservation of these assets also generates economic benefits to the society as a whole [Forte, 1977; Throsby, 2002].

Throsby defines cultural heritage as "an asset which embodies, stores or provides cultural value in addition to whatever economic value it may possess" [Throsby, 2001 and 2002]. The difference, however, between physical assets (from a strictly economic viewpoint) and cultural capital is indeed the concept of "culture" which bestows the historic goods with an added qualitative dimension. It is this cultural quality which must be maintained and not simply the materials with which the asset is built.

In the scientific literature [Randall, 1991; Stellin and Rosato, 1998], the economic and cultural value of a historic asset are to be distinguished in two macro-categories which refer to two spatial and temporal dimensions. The difference lies in the use and non-use value:

- The use value, linked to the benefits the consumer receives directly from the asset itself, is a contingent prerogative; it is the utility that the historic artefact offers the consumer from the very moment he comes into contact with it. For this reason synchrony must be created between the cultural asset and the user;
- The non-use value, instead, does not have the same contingent obligation of the above and, as a result, does not require such close synchrony (but rather a diachrony) as it refers to the utility that the consumers perceive from the conservation of the cultural assets for themselves and for the future generations.

2. The sustainability of the re-use of historical buildings

The valuation of the sustainability of the economic re-use of historical heritage is crucial on this discussion and helps to tailor safeguard and protection policies.

Starting with the well-known declination of the concept of economic, social and environmental sustainability, literature on the matter refers to a common premise according to which the ultimate objective of any type of intervention should develop local resources and, as a consequence, should contribute to enhancing the quality of life. This is a multi-dimensional concept in so far as “the quality of life” touches several different economic and social aspects [Fusco Girard, 1987; Howarth 1997].

The concept of sustainability was initially presented by the World Commission on Environment and Development [1987] with reference to the effects of development on environmental assets. Sustainable development was defined as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

As far as the cultural heritage and, in particular, architectural assets are concerned, the concept of sustainability is influenced by the environment and involves two main aspects: the sustainability of the material and formal transformation of the building and the sustainability of the new function that is to be installed therein. In other words the objective of sustainability requires an equilibrium between the economic re-use of the asset and its conservation [Nijkamp and Voogd, 1989].

Current debate on the theories of restoration philosophies, which is particularly active in Italy today, follows two lines of thought.

The first is defined as *critical restoration*, and stems from the conviction that each intervention project represents a case of its own. Restoration must also transmit the asset to the future by guaranteeing and facilitating its interpretation without loosing sight of the fact that it is a “non-verbal criticism expressed in concrete non verbal ways” [Carbonara, 1987, Marconi, 1993].

On the other hand we have the pure *conservationists* who support the conservation of each strata of material or matter that the building has accumulated over time. Under this approach the building becomes a sort of palimpsest where it is impossible to identify what exactly has to be conserved or removed: “The aim of restoration is to conserve both the matter and substance which represents an archive of what the building is actually made of” [Dezzi Bardeschi, 1977].

An economic re-use project, attributing a new function to the building, often involves transforming, consolidating, adding and removing and may alter the various strata of existing materials and structures.

The decision not to use an asset however, undermines the intrinsic value of the asset and use poses the threat of possible abandonment and subsequent loss of the asset on the whole[5].

Often, however, historic architectural complexes are used for purposes which are completely different from those for which they had originally been built and the interventions required (especially in terms of standards and building regulations that need to be respected) might not always be compatible with the typology and structure of the architectural asset on which works are being carried out. Over-use or incompatible use can have similar consequences to those of abandonment and can gradually reduce the cultural value and historic evidence of the artefact.

Literature does not deal with the definition of what is, or is not sustainable as far as work carried out on historic buildings are concerned. Ono of the reasons for this silence might be sought in interdisciplinary character of the issue. In this paper a multiple criteria valuation model is proposed which is

[5] The European Charter of Architectural Heritage adopted by the Council of Europe [European Council 1975] introduces the social and economic issues related to restoration and formalises the concept of “integrated conservation”, or rather the integration of heritage into the “context of public life”, by means of restoration and appropriate use. In the same year, the Declaration of Amsterdam stated that the attribution of new functions should respect architectural characteristics and guarantee their survival; the conservation effort “must be based on the cultural and utilisation value of the building”. Carlo Forte, on the other hand, claims that the conservation of the cultural heritage aimed at its integration into modern day life “constitutes a true and proper productive activity” and an essential priority. The limited funding available do not allow conservation to be the sole finality of the intervention, but make it necessary that the building be put to compatible use. By so doing the cultural capital will generate assets and services which will increase its social function and its accessibility.

able to tackle interdisciplinary problems of valuation. The model is founded on a set of parameters measuring the performances of the reuse project.
From the information codified in parameters, a set of indicators can been developed representing the different points of view with which the concept of “sustainability” may be implemented in the case of restoration and reuse of historic buildings. These indicators should gear to the aim of identifying the limit of transformations, helping to identify the point at which the new use ceases to enhance the asset, and begins to consume and erode the original value. In the following paragraph, the quantitative framework utilised to implement such a model is presented.

3. The Method

Many methods have been proposed in the literature to approach multicriteria problems. Following [Vincke 1989], a commonly used classification distinguishes

- Approaches derived from Multi Attribute Value Theory (MAVT);
- Outranking approaches, like the ELECTRE family and its derivates;
- Interactive approaches,

The MAVT methods compute a score for each alternative, using Aggregation Operators (AO), see [Klement 2000, Kolesarova 2001]. Many of the MAVT methods are based on common sense rules, tailored for not quantitative skills of the majority of the Decision Makers (DM). In this contribution, we propose a mathematically founded MAVT approach, which is at the same time easily to be understood by any DM given a suitably designed interface.
The most common aggregation operator is the (simple) Weighted Averaging approach (WA), which, for each alternative, computes the weighted average of the criterion score. It is a simple and intuitive compensative method, but no interaction among the criteria can be admitted, since it is based on the Independent Preference axiom. For this reason, many other methods were proposed. We limit to quote the Geometric Averaging (GA) which

computes the geometrical averaging of the criterion scores. It can be usefully applied in *strong* conservative cases, since it gives a null global score if at least one criterion is null (thus impeding compensation). Another class of Aggregation Operators consists of the Ordered Weighted Averaging operators (OWA) introduced by Yager [Yager 1988, 1992]. It includes, as particular cases, the weighted averaging, and, as extreme situations, the Max and the Min operators. If the weights are obtained by a *non monotonic quantifier* [Yager 1993], the OWA operator implements linguistic statements as “at least”, “at most”, “at least the half” and so on. The *compensation operator* introduced by Zimmermann [Von Altrock 1995], uses a tuning parameter, representing thus more or less conservative situations. A different approach is obtained using a Fuzzy Expert System, but its design is not a simple task, since many effort needs to be devoted to the inference rules definition [Von Altrock 1995].

More recently, the introduction of methods based on non additive measures (NAM) helped to solve many theoretically cumbersome problems, and at the same time offers a wide range of possibilities of aggregation. Up to now, the multicriteria community considers these methods the most complete and mathematically well founded MAVT approach. Roughly speaking NAM consists in assigning a suitable weight to *every possible* coalition of the state of the criteria, and not only to a single criterion, as the WA approach. So the importance of a coalition of criteria can be greater, equal, or less than the sum of the importance (weights) of each criterion included in the coalition. Both *synergic* and *redundancy* interactions among the criteria can be modelled in this way. If the importance of the coalition for each them is equal to the sum of weights of the included criteria, the operator simplifies to the WA approach. In the other cases, a simple algorithm computes the score of the alternatives, considering the interactions among the criteria given by the non additive measures. Moreover, some indices can be computed showing the tendency towards pessimism or optimism reflected in the valuation of the set of alternatives. It should be remembered that the NAM can be directly obtained by experimental data, or implicitly elicited from expert's judgements. In this contribution, we propose an implicit approach. The price to be paid with respect to WA or to OWA consists in an increase in the number of parameters, which are equal to the number of all possible coalitions of criteria. For example using only two possible states for each criteria, 4 criteria request 16 parameters, with 5 criteria 32 parameters, and with 6 criteria 64 parameters are needed. Verifying the absence of interaction between higher order coalitions, we can use a *reduced order* model where the number of parameters is strongly reduced [Grabish, 1997].

3.1 Non additive measures

Let $N = \{1,2,3,....,n\}$. A *non additive* measure, [Marichal 1998, 1999-a, 1999-b], is a set function $m: S \subseteq N \to [0,1]$ $m: S \subseteq N \to [0,1]$, so that, $\forall S, T \subseteq N$ the following conditions hold:

$$m(\emptyset) = 0, \qquad m(S) \le m(T), \forall S, T \subseteq N : S \subseteq T, \qquad m(N) = 1$$

Such a measure is able to represent interactions among the criteria, giving a different weight to every possible coalition of them, and not only to a single one as in the case of the WA operator. The first and the third conditions limit the variability inside the domain $[0,1]$, while the second condition is a monotonicity constraint, namely, if more criteria are satisfied, the global satisfaction cannot decrease[6].

A non additive measure will be named as:

additive if: $m(S \cup T) = m(S) + m(T),\ S \cap T = \emptyset$

sub-additive if: $m(S \cup T) < m(S) + m(T),\ S \cap T = \emptyset$

super-additive if: $m(S \cup T) > m(S) + m(T),\ S \cap T = \emptyset$

[6] Violations of this constraint are accepted only in the case where a criterion is a benefit for one coalition, but a cost for another one. *Non monotonic* measures can capture this effect, but we will not this quite uncommon case.

For an additive measure, no interaction is possible among the criteria and the linear superposition holds. For a sub-additive measure a redundant effect is modelled, while the contrary holds for a super-additive effect (synergic effect).

3.2 The Choquet integral

Given a non additive measure m, let $(x_1,...,x_n)$ be the criteria values for a particular alternative, normalized in a common scale. We suppose that all the criteria are benefits (higher scores are more preferable than lower). As usual, cost criteria can be transformed into benefits by means of suitable value functions. The Choquet integral of the vector $(x_1,...,x_n)$ with respect to the measure m is defined as follows:

$$C_M(x_1,...,x_n) = \sum_{i=1}^{n} \left(x_{(i)} - x_{(i-1)} \cdot m\,(A_{(i)})\right)$$

being $(.)$ an index permutation so that: $x_{(1)} \le ... \le x_{(n)}$, and $A_{(i)} = \{i,...,n\}$, $A_{(n+1)} = \varnothing$.

It can also be written as:

$$C_m(x_1,...,x_n) = \sum_{i=1}^{n} x_{(i)} \cdot [m\,(A_{(i)}) - m(A_{(i+1)})]$$

This operator satisfies the following properties [Marichal 1999-a]:

a. it coincides with the WA operator if the measure is additive with:

$$m(A) = \sum_{i \in A} w_i, \forall A \subseteq N$$

being w_i the weight of the i-th criterion,

2) every OWA operator is a Choquet integral if every subset of the same cardinality has the same measure:

$$m(A) = \sum_{j=0}^{i-1} w_{n-j}, \quad \forall A \subseteq N : |A| = i$$

For an intuitive explanation of the Choquet integral, see the example in [Murofushi 1989].

3.3 The Möbius trasform and the dual values

Given a non additive measure m, its dual values can be obtained from the following biunivocal Möbius transform [Grabish 2003, Marichal 1998]:

$$\alpha(S) = \sum_{T \subseteq S} (-1)^{s-t}\, m(T), \quad \forall S \subseteq N$$

The inverse transform is given by:

$$m(T) = \sum_{S \subset T} \alpha(S), \quad \forall T \subseteq M$$

To be the dual of a non additive measure, the 2^n coefficients $\{\alpha(S) | S \subseteq N\}$ need to satisfy[7]:

$$\alpha(\emptyset) = 0, \ \sum_{T \subseteq N} \alpha(T) = 1, \quad \sum_{T \in P(S)} \alpha(T) \geq 0, \quad \forall S \subseteq N$$

It can be verified that the Choquet integral can be written in the dual space as:

$$C_m(x_1, x_2, .., x_n) = \sum_{T \subseteq M} \alpha(T) \cdot \min_{i \in T} \{x_i\}$$

Moreover, if $\alpha(T) > 0$, the coalition T is synergic, if $\alpha(T) < 0$, it is redundant, if $\alpha(T) = 0$, there is no interaction and the Choquet integral collapses into the WA operator [Marichal 1998, 1999-a, 1999-b].

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[7] $P(S)$ is the power set of the set S.

From a computational point of view, given n criteria, a non additive measure requires the assignment of 2^n coefficients, and this is very large as soon as n is greater than 5,6. In order to avoid this, the *k*-order models were introduced, which assume interactions between subsets of cardinality less or equal to k, usually the second order models are considered, that is, k=2. Even though in many applications it can be reasonably assumed that there no interactions between subsets with cardinality higher than 2, this hypothesis needs to be tested a priori.

3.4 Andness and orness measures

Given a non additive measure, it is possible to compute an *andness* measure together with its complementary *orness* measure. If the *andness* measure is close to 1, it means that the measure set tends to the MIN operator, that is to the logical conjunction of the criteria value, showing a conservative tendency of the Decision Maker (*pessimistic* behaviour). Conversely, if *orness*=1 we obtain the MAX operator, the logical disjunction, a totally compensative operator, corresponding to an *optimistic* behaviour. The computation of the *orness* index in the dual space is given by:

$$\text{orness}_m = \frac{1}{n-1} \sum_{T \subseteq N} \frac{n-t}{t+1} a(T)$$

Moreover:

$$\text{andness}_m = 1 - \text{orness}_m(i)$$

Both indices can be easily computed given the dual values of the measure.

3.5 Non additive measures and the multi-linear operator

In the dual space, the Choquet integral computes, for each coalition, the minimum of the criteria values of the coalition. The MIN operator belongs to a wide class of operators, the *triangular norm* (T-norm), which satisfies a set of rationality properties and are widely used in the field of MCDA analysis, especially in the fuzzy logic applications [Klement 2000]. Since the MIN is not compensative at all, some Authors proposed to substitute the MIN operator, in the dual space, with a smoother T-norm, [Kolesarova 2001, Klement 2000, Despic 2000, Fujimoto 1997]. A natural choice can be the product of the values, that is a differentiable and partially compensative operator. We obtain the so called *multi-linear* operator [Grabish 2001]. In the dual space, substituting the MIN operator with the product, we obtain:

$$V(x_1, x_2,.., x_n) = \sum_{i=1}^{n} a_i x_i + \sum_{i_1=1}^{n} \sum_{i_2=i_1+1}^{n} a_{i_1 i_2} x_1 x_2 + \sum_{i_1=1}^{n} \sum_{i_2=i_1+1}^{n} \sum_{i_3=i_2+1}^{n} a_{i_1 i_2 i_3} x_1 x_2 x_3 + \\ + ... + \sum_{i_1=1}^{n} \sum_{i_2=i_1+1}^{n} .... \sum_{i_n=i_{n-1}+1}^{n} a_{i_1 i_2 ... i_n} x_1 x_2 .... x_n$$

In the measure space the multi-linear operator has the following formulation [Marichal 1992-b]:

$$V(x_1, x_2,.., x_n) = \sum_{T \subseteq N} a(T) \prod_{i \in T} x_i (1 - x_i)$$

which represents a pseudo-Boolean function.

3.6 Identification of the measures

As said above, one of the most critical point in the evaluation is the assignment of the numerical values of the non additive measure. Many methods were presented in literature, but most of them are based either on quite complex optimization algorithms, or on data mining techniques. In this case study, we preferred a user friendly approach, and adopted a method based on a suitable questionnaire [Despic 2000]. Let us suppose that the DM(s) judgements are in the scale [0, 100], with the usual meaning for the numerical values, i.e. 0= WORST, 50= MEDIUM, 100= OPTIMAL, and so on. For each criterion two particular extreme cases are enhanced, the OPTIMAL and the WORST ones, conventionally indicated with 1 and 0 respectively from now on. An *edge* is a (fictive) scenario formed by a combination of (only) WORST and OPTIMAL evaluation. Each edge is nothing else that a question that is asked to the DM(s), which will assign his/(their) evaluation in the scale [0,100]. The edges are the vertex of an hyper-polyhedron in the criteria space. It is sufficient to define the values only in all those vertex to obtain the values of the measure, and this is the minimum amount of information. This simplification causes a poor statistical robustness, since it corresponds to the minimum number of interpolating points in an *n*-dimensional space, but given the unavoidable uncertainty, which is implicit in every human decision process, this does not seem to be a serious obstacle, considering the information gain that should be obtained explicitly considering all the possible interactions among the criteria. The advantages with respect to the WA approach are evident.

Figure 1 reports an instance of the questions that needs to be formulated in the case of 3 criteria. Referring to the case study, we are considering the node in the Sustainability Tree which evaluates the Sustainability starting from Intrinsic Sustainability, Economic-Financial Sustainability, and Context. The fourth column reports the DM evaluation (only one DM is here simulated). For a better comprehension, the third row implements the question:

"How would you score an hypothetical case where the Economic-Financial Sustainability is OPTIMAL, and the two other criteria, Intrinsic Sustainability and Context are WORST?"

After having fulfilled all the answers, a simple algorithm computes the dual values and passes such parameters to a procedure that implements the computation of the multi-linear aggregator for a real case. Moreover, the *andness* and the *orness* degrees can be computed and the behavioural nature of the DM can be obtained.

Assume, for the previous example with three criteria represented in Figure 1., the "weight" of the first criterion to be equal to 30, the second to 20 (the second and the third empty cells in the last column of the Table), while the "weight" of the coalition formed by the two criteria together to be equal to 70 (the last empty cell in the last column). Then a synergic effect can be observed, since the "weight" of the coalition is greater than the sum of the weights of the single criteria.

SUSTAINABILITY			
Intrinsic sustainability	**Context sustainability**	**Economic & financial feasibility**	**Evaluation**
Worst	Worst	Worst	
Optimal	Worst	Worst	
Worst	Optimal	Worst	
Worst	Worst	Optimal	
Optimal	Optimal	Worst	
Optimal	Worst	Optimal	
Worst	Optimal	Optimal	
Optimal	Optimal	Optimal	100

Figure 1: The valuation table

Evaluation in intermediate points would increase the statistical robustness, but the numerical complexity of the algorithm would increase significantly either. We feel that the edges evaluation and the multi-linear operator are a good compromise choice between theoretical complexity and operative usefulness. Other solutions, see for instance [Fujimoto 1997], are difficult to be implemented and require a strong computational effort. Moreover, the same approach can be used in the case of multi-person decision scenario, where many Experts or Decision Makers cooperate in the assignment of the "weights" of the criteria coalitions, and a measure of consensus could be easily defined and computed [Kacprzyk 1987, 1988, 1982].

4. Evaluation of sustainability of re-use projects.

In the previous paragraphs, we illustrated that integrated conservation is defined as the best possible compromise in dealing with conflicting objectives. Therefore the operative phase of the study concentrated on the definition of indicators for the evaluation of sustainability of alternative re-use projects for historic artefacts.

The design of a hierarchy model for the evaluation of the sustainability was based on the definition of criteria synthesizing the main characteristics, which could influence the evaluation of sustainability. This initial phase was completed by consulting experts in urban re-qualification and the re-use of historic buildings. The resulting, proposed indicators take into consideration the effects of the intervention on the artefact by using three main points of view: the impact on the historic building (defining future re-use – and relative standards – to be hosted in the historic building); the social impact; the economic and financial feasibility (Figure 2).

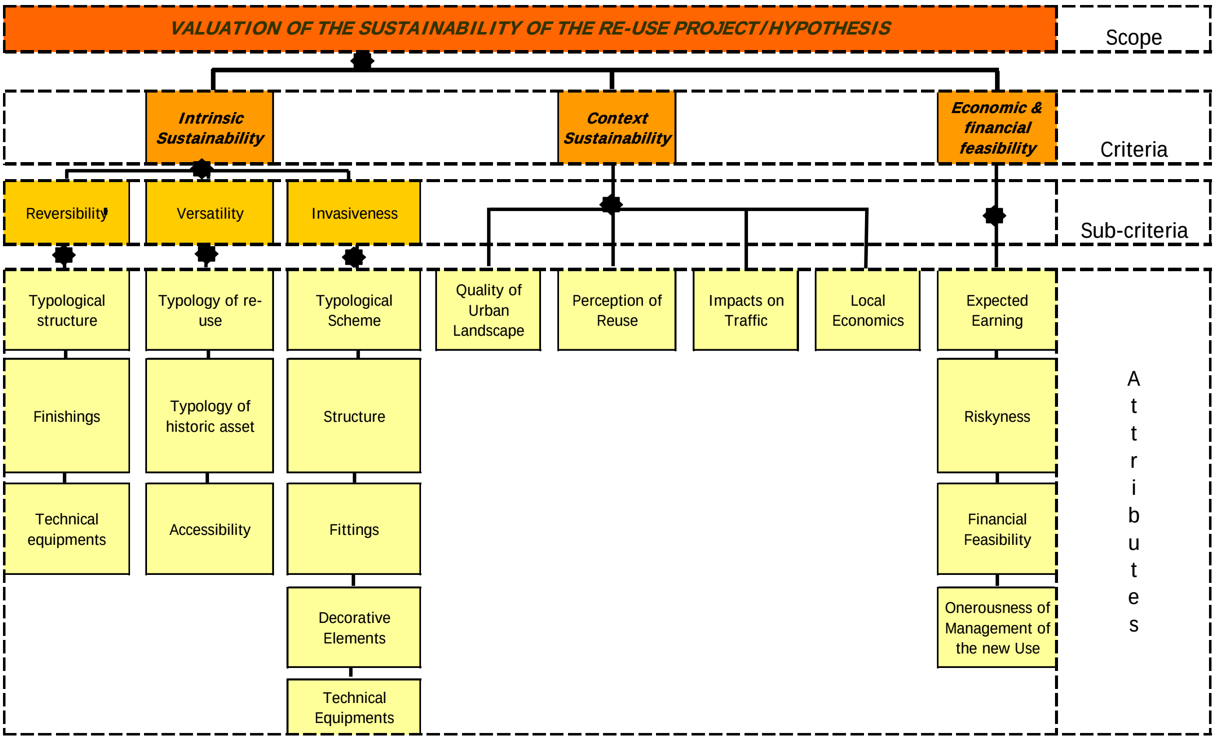

Figure 2: Hierarchic structure (simplified) of the evaluation model (* nodes).

Intrinsic sustainability*:* or the respect of the materials and typology of the building. This criterion is the synthesis of three sub-criteria:

- *Reversibility* or the opportunity to restore the building to the state it was in before the modifications carried out with the re-use project;
- *Versatility* or the possibility to eventually modify the function of the building proposed by the re-use project without major works;
- *Invasiveness* or the degree to which the project interferes with the materials the historic building is made of.

Context sustainability, which refers to the extent to which the reuse project enhances the social, economic and environmental context of the building and its contribution to the local identity. The re-use project must, where possible, rebuild a relationship between the building and its environmental setting. The local community's reaction to the project must induce the local authorities to view it positively. It is also hoped that the project will produce positive externalities on circulation and bring economic advantages to the territory.

Economic and financial feasibility which evaluates the project according to economic and financial principles. The model implies that the objective of sustainable re-use also depends on the project's financial efficiency of the economic activity. Moreover, the risk concerning the investment must also be taken into account.

After evaluation model structuring, to each criteria, sub-criteria and attribute was given a weight which defines its contribution towards sustainability. In order to calculate the weight of each single characteristic, a questionnaire was prepared applying the edge's method described in the previous paragraph.

The questionnaire had a page for each of the nodes of the hierarchical tree, so that to each leave belonging to the node would be given a weight. The questionnaire was compiled by 11 experts.

Figure 3 presents the average score of the evaluation given by the experts, their standard deviation and variation coefficient for the "sustainability" node and for the extreme scenarios[8].

Scenario	*SUSTAINABILITY*			Average score	Standard Deviation	Variation Coefficient (%)
	Intrinsic Sustainability	*Context Sustainability*	*Economic & Financial Feasibility*			
1				0,0	0,0	-
2				29,5	11,7	39,7
3				24,7	19,3	78,1
4				20,0	14,3	71,6
5				65,2	10,0	15,3
6				57,7	10,3	17,9
7				48,2	25,5	53,0
8				100,0	0,0	0,0

Figure 3: The scores attributed to the "sustainability" node.

Figure 3 shows some interesting data. First of all it evidences that the experts place at the first level the intrinsic sustainability of the re-use project (Scen. 1), the coherence with the social context is placed in the second step (Scen. 2) and, finally, they consider the economic aspects (Scen. 3). Another interesting results is that the importance given to the intrinsic sustainability is quite stable across the experts' valuations (V.C. 40%), but they gave quite different evaluation scores for the indicators regarding the "context sustainability" criterion and the economic-financial feasibility (V.C. 70-80%).

Analysing the scores given to scenarios (5, 6 and 7), where "optimal" judgements are given contemporarily to two criteria, it emerges that a "optimal" judgement given to the "intrinsic sustainability" criterion is sufficient to realize a good (approx. 60) and stable (V.C. 10%) score.

[8] It should be noted that the average of a set of non additive monotonic measures is a monotonic measure, too.

Furthermore, in the other case the overall score is low (48) and variable across the experts (V.C. 25%).
The following equation illustrates the value function derived from the scores presented in fig. 3 for the Sustainability nodes:

$$I_S = 0{,}295SI + 0{,}247C + 0{,}200FEF + 0{,}109SI \cdot C + 0{,}082SI \cdot FEF + 0{,}035C \cdot FEF + \\ + 0{,}032SI \cdot C \cdot FEF$$

where:

I_S = Sustainability;
SI = Intrinsic Sustainability;
C = Context Sustainability;
FEF = Economic & Financial Feasibility.

For each node of the hierarchical tree illustrated in Fig. 2 a questionnaire was compiled and a value function estimated.
Once the model has been calibrated with the value functions, the technician responsible for evaluating the sustainability of re-use projects expresses a judgement (0,100) for each parameters in which the various attribute of Fig. 2 has been disaggregated. This score is multiplied by the weight attributed to the parameter and by the weights assigned to the nodes higher up. In other words, giving a technical evaluation to each parameters associated with the project under examination, a comprehensive evaluation of the sustainability of the re-use project is realized.
The model is useful when there are several alternative projects to choose from, as it supplies a final sustainability score for the project and intermediate scores which refer to the criteria, sub-criteria and attributes. As described above, in order to assign weights to criteria, sub-criteria, attributes and parameters, the experts filled out a questionnaire and gave scores ranging from 0 to 100 to hypothetical scenarios.
The experts shared cultural knowledge in at least two fields: the *conservationists* were architects operating in the material restoration of historic buildings; the *designers* and *planners* were specialists in analysing

and identifying the function that the historic building should be given and the economic evaluation of re-use.

It was thus useful to establish indices which would evaluate the attention toward conservation shown by each expert's judgement.

Andness and *orness* indices were used, where the index value may vary between 0 and 1 in both cases and takes on the following significance:

- total *andness*: the expert consulted considers that the sustainability of a project is guaranteed only if all the indicators are attributed the maximum score (*andness* index =1; *orness* index = 0);
- total *orness*: the expert consulted considers that the sustainability of a project is guaranteed if one of the indicators is given the highest (*andness* index=0; *orness* index= 1);
- mainly *andness*: the expert consulted considers that the sustainability of a project is guaranteed only if the majority of the indicators are attributed a high score (*andness* index > 0,5; *orness* index < 0,5);
- mainly *orness:* the expert consulted considers that the sustainability of a project is sufficiently guaranteed when one indicator rather than another receives a high score (*andness* index< 0,5; *orness* index > 0,5);
- *Additive* measure: the expert consulted considers that the sustainability of a project depends on the sum of the scores assigned by the indicators, without there being any synergy between them (*andness* index = 0, 5; *orness* index = 0, 5).

Criterion		Average	Std. Dev.	C.V.
Sustainability	orness	0,409	0,087	0,214
	andness	0,591	0,087	0,148
Intrinsic sustainability	orness	0,493	0,079	0,16
	andness	0,507	0,079	0,156
Context	orness	0,501	0,05	0,099
	andness	0,499	0,05	0,1
Economic and financial feasibility	orness	0,48	0,071	0,149
	andness	0,52	0,071	0,137

Figure 4: Indices of '*Andness*' and '*Orness*' for the most important criteria.

Figure 4 shows average *Andness/Orness* indices for the 11 experts consulted. The majority of experts tended towards *Andness* behaviour in all the nodes examined which means that a project can be considered sustainable if at least two or more criteria are deemed "optimal"; thus it is not enough for the project to respect the historic building, but it must also be economically sustainable, and its reference context must be carefully considered (Figure 5). Furthermore, the *Andness* behaviour is higher for the "Intrinsic Sustainability" criterion than in the other criteria.

5. Evaluation of sustainability of hypothesis for the re-use of the historic Venetian Arsenal

The model presented I the previous paragraphs has been used for the valuation of the sustainability of alternative re-use hypothesis of the ancient Arsenale of Venice.

The Venice Arsenale is owned by the Italian government and is currently used primarily by the Italian Navy. About 45 hectares in size, the Arsenale accounts for about 15% of the area of the city of Venice, and is located in the Castello district. Founded in 1104, in its heyday the Arsenale employed roughly 20,000 workers and was said to produce one ship a day.

The Arsenale started to decline after World War I, and continued to decline at an even faster rate after World War II, when its buildings were progressively abandoned. In 1983 the *Soprintendenza per i Beni Ambientali* *ed Architettonici* of Venice (local of office of the state authority for cultural heritage conservation) started a series of conservation works. At present, the Italian Navy continues to own and occupy a large portion of the Arsenale. Research activities, shipbuilding, museums and exhibitions occupy other areas, but many buildings and areas remain unutilized.

Out of the analysis of the political debate on alternative options for the re-use of the Arsenal two basic alternative directions could be extrapolated. The first one is pointing to installing "poor" functions in the ancient buildings without considering the historic significance of the area, but well compatible with the historic building structures. The functions to be introduced are small artisans activities (carpenters, electricians, masons, etc.) mostly already working within the historic centre but often under menace of expulsion because of pressings from the real estate market. The second option points to the introduction of "new" uses somehow connected to the Arsenal's historic function, a touristic marina. On the basis of these basic assumptions two hypothetic projects or scenarios have been created in order to evaluate their sustainability.

Figure 5: Aerial View of the historic Venetian Arsenal (CIRCE, 2000)

1st Scenario: Area for artisans

In the first scenario it is assumed to use the buildings of the Arsenale for craftsmen's activities actually dispersed in the historic centre. The surfaces of water of the main dock and some of the buildings will be used for laying up small boats owned by Venetian residents.

It is presumed that the whole surface and all buildings, except those actually occupied by the Navy, will be used by artisan's activities. The re-conversion will take place after a restoration programme managed by the municipality, which will adapt the buildings to the requirements of craftsmanship and small manufacturing activities. The industries which are going to settle within the restored buildings will pay a rent ruled by medium-long term contract (around 20 years). The surface of the big dock (Darsena Grande) will be used for mooring of Venetian boats. A limited number of buildings, including the covered docks, will be used for mooring and laying up of boats on high rise racks.

2nd Scenario: Marina

The second scenario refers to a proposal frequently presented in the past, to use the historic Arsenale as a touristic marina for permanent and temporary mooring. The activities to be introduced regard, beyond the berths themselves (approx. 220 places), supplementary facilities comprising high quality shipyards, boats repair and laying up services, shops and services necessary for tourism, as retail stores for nautical equipment.

In this proposal the area's original vocation is takes up, expecting the nautical tourism, to contribute to a revival of the traditions of this place in terms of boatbuilding. The berths of the main dock will be partly assigned on a permanent basis, 25% will be reserved for temporary mooring.

The historic buildings will house the facilities connected to the port such as marine shops, craftsmen activities and boatbuilding as well as a shipyard for the production of leisure time boats. A supermarket will be located in a position easy to access from the surrounding residential areas as well.

The open spaces, transformed in quays, are used as slipways for the marine activities and shipyards.

Some buildings on the southern front of the main dock will be transformed in reception area with restaurants and bars, a yacht club, and rooms for small events, sailing schools etc. as well as services offering assistance for guests.

Introducing productive activities into the historic buildings does not represent a particular problem from the conservation point of view. Some more problems may be represented by the introduction of commercial facilities and supermarkets, which might ask for divisions of the inner spaces, with consequently modification of the typologies of the historic buildings.

6. The assessment of sustainability of re-use projects

The evaluation of the scenarios described above requires the assessment of the state of the indicators of the model in each re-use hypothesis. This assessment must regard the technical parameters that define the attributes.

6.1. CRITERIA: Intrinsic sustainability

Sub-Criteria: Reversibility

Reversibility of the interventions is not a major concern for re-use projects for the historic Arsenale, as the typological scheme of the buildings is easy to be adapted to the needs of productive activities. The open spaces inside the buildings allows, up to a certain extend, for the insertion of internal structures. These structures have to remain detached from the main structures in order to allow for the perception of the original shape of the building. The transformation of the shipyard buildings, which were initially open towards the waterfront, into closed buildings has already taken place during the 19th and 20th century, and will be reconfirmed by the project for the artisan’s area. A problematic aspect of reversibility regards the lack of natural illumination of the original buildings, requiring thus transformation of parts of the coverage.

Within the project for the Marina, the problems raised by the transformation are similar to those mentioned above, as the complex was created as a productive structure, and is relatively easy to be adapted to new uses of the same type. Within some limits the same can be said about the insertion of commercial services and restaurants, which might be practiced in a similar way to the productive activities, using detached structures inside the original buildings, emphasizing the technical and productive character of the context. The realization of support structures for the marina seems to be more complicate as the buildings have no lateral openings. It will thus be necessary to accurately distribute the functions inside each building. In no case an irreversible transformation of buildings is foreseen. As in the case of Scenario 1, the problems will be raised by the introduction of sanitary services in both scenarios.

With regards to finishing, no particular problems of conservation are to be expected given the industrial character of the buildings. In the case of the Marina the lack of finishing can be transformed in added value, evocating the historic character of the area.

The introduction of new technical equipments will cause some problems as transformation of roofs and/or openings will be required. In both cases, technical structures will be distributed and designed according to the requirements of the single enterprise, although the concentration of some facilities and some support services (reception, administration, canteen) in separate structures is planned.

		Score	
Criteria	Intrinsic Sustainability	Artisan's area	Marina
Sub-criteria	**Reversibility**	**89,2**	**76,6**
Attribute	**Typological structure**	**90,8**	**73,3**
Parameter	Demolitions	90,0	80,0
	Subdivisions	85,0	60,0
	Conservation of characterizing elements	90,0	70,0
	Walls	90,0	80,0
	Floors	85,0	60,0
	Roofing	90,0	70,0
Attribute	**Finishings**	**97,5**	**92,5**
Parameters	Plasters and hangings	100,0	95,0

	Thresholds, benches	95,0	90,0
Attribute	**Technical equipments**	**77,5**	**65,5**
Parameters	Removable housings Compacting	75,0 80,0	70,0 60,0

Sub-Criteria: Versatility

The high grade of reversibility of both projects guarantees for a high grade of versatility, allowing eventually for the insertion of alternative productive uses. This is assured by inserting new structures and vertical connection as independent elements respect to the historic building, both from the static and the visual point of view. The Marina project, where the internal divisions to be introduced for restaurants, reception etc. might require more important transformations, results in a lower grade of versatility respect to alternative uses. In no case irreversible transformations of relevant parts of the existing structures are planned.

The adaptation of the buildings of the Arsenal to the necessities of small enterprises does not present particular problems for what regards the insertion of adequate technical structures. In analogous way the Marina project allows for the adaptation of the historic buildings by insertion of independent structures detached from the historic elements. Major difficulties might arise in this case of the restaurants and commercial facilities.

With respect to the type of use chosen in the first scenario, the Arsenal would regain its original productive destination, although from the symbolic point of view the significance of these new uses is quite different from the original one. The production of ships was a crucial activities for the maintenance of the geopolitical role of the Venice Republic as one of the mayor commercial and political forces in the Mediterranean, the craftsmen activities represent a mere support to the every-day maintenance of the city itself, without any strategic role for its economic base.

The symbolic value of the new use in the second scenario is quite high, and is consistent with the historic function of the complex. Similar to the period of the venetian republic, the use of the Arsenal as Marina is coherent to the economic identity of the city, based today mainly on tourism.

For both scenarios, accessibility for pedestrians is determined by the original asset of the complex oriented to a maximum of control of the access to a strategic area for the military security of the Republic. Some new accesses have already been created during the transformations in the past two centuries, and only few further access points can be created if heavy transformations should be avoided. Furthermore the area is situated in a peripherical location with respect to the city centre – and towards the principal accesses to the mainland. The accessibility within the complex is determined by the location of the single building with respect to the nearest access point, and can be in some cases very poor.

With respect to the accessibility by boat from outside for the first scenario, there are two accesses from public transport lines: one from the north and one from the south, which both connect to the pedestrian accesses to the area. The access for private boats can be considered very good.

Circulation inside the main dock may be made difficult by the presence of landing stages for the mooring of Venetian boats for both scenarios; access for boats to the port is optimal for the second scenario as the north-eastern opening of the main dock is easy to be reached from the lagoon. The entrance into the main dock is possible also for small ships.

		Scores	
Criteria	Intrinsic Sustainability	Artisan's area	Marina
Sub-criteria	**Versatility**	**75,0**	**74,0**
Attribute	**Type of re-use**	**87,7**	**78,3**
Parameters	Rigidity of installations	80	80
	Poss. surface removal	90	85
	Prevision of vertical connections	90	70
Attribute	**Congruity of technical installations with the standards required**	**98,3**	**93,3**
Parameters	Dedicated rooms	100	100
	Comfort	95	95
	Number of terminals	100	85
Attribute	**Typology of the historic complex**	**65,0**	**75,0**
Parameters	Historic character	70	80
	Congruity of technical installations	98	93

	with the standards required Dedicated rooms Outdoor spaces	 100 60	 100 70
Attribute	**Accessibility**	**50,0**	**50,0**
Parameters	Public transport Parking spaces Access for disabled	40 100 10	40 100 10

Sub-Criteria: Invasiveness

The invasiveness of the structures under the first scenario is rather low, due to the concept of detached structures to be introduced into the buildings guarantees for a good visibility of the original typological scheme. Albeit the convergence among traditional and new uses, not in all cases the coherence with traditional functions is assured, which may result in difficulties in re-establishing the original orientation of the buildings towards the water. The same can be said for the second scenario, although a stronger orientation towards the water surface is guaranteed by the specific functions foreseen. In the case of commercial services some important modifications of the distributional schemes will be necessary.

		Scores	
Criteria	Intrinsic Sustainability	Artisan's area	Marina
Sub-criteria	**Invasiveness**	**81,7**	**79,6**
Attribute	**Typological scheme**	**80,0**	**81,7**
Parameters	Visibility of the asset Functional coherence Changes in distribution	90 70 80	85 90 70
Attribute	**Structures**	**91,7**	**86,7**
Parameters	Substitutions can be recognized Similarity of materials Removal of decay	90 85 90	85 60 70
Attribute	**Finishing and decorative elements**	**100,0**	**100,0**
Parameters	Reconstructions can be recognized Conservation Removal of decay	100 100 100	100 100 100
Attribute	**Technical equipments**	**55,0**	**50,0**
Parameters	Visual impact Compacting	50 60	50 50

No substitution of structures is planned, but new structures may be necessary under both projects where the original buildings are lost. Technical equipments will be realised for both projects in a detached manner which results in an elevated visual impact. For the artisan's project a medium rate of compacting is expected, for the Marina project this rate will be medium – high.

6.2 Criteria: Context Sustainability

In the both scenarios, the scarce level of invasiveness will determine a substantial conservation of the urban landscape of the Arsenal. This is true for the buildings, but not for the outside areas and the water surface, which will be fragmented by the floating structures used for the mooring of small Venetian boats and for leisure boats in the second case. The impact of the re use on the surrounding area is limited, as no new uses will be introduced, and the area is substantially isolated towards the surrounding.

The decision to open the Arsenal to urban productive functions and to the moorings for the citizens will cerate a good level of consensus for the first scenario of the artisan's area.

Also under the marina project the Arsenal will be accessible to the citizens and to a somehow "noble" function, reconnecting to the area's original function. These aspects will promote a positive perception of the project, whereas critical voices will note that the weight of the tourism in the urban economy will be further fortified.

Judgements on the impacts on traffic foresee only scarce impacts for both scenarios.

The impact on the urban economy of the project described in the first scenario, will be rather scarce. New uses in the Arsenal might be able to develop the urban economy and, as described in the second scenario, might be used to qualify the predominant sector of urban economy, tourism.

In the second scenario some positive effects may be expected in terms of re-qualification of the tourism sector on the surrounding areas.

		Score	
Criteria	Context Sustainability	Artisan's area	Marina
Attribute	**Quality of urban landscape**	**80,0**	**96,7**
Parameters	Maintenance of landscape quality Maintenance of aesthetic quality Positive externalities on the built env.	100 90 50	90 100 100
Attribute	**Perception**	**85,0**	**52,5**
Parameters	Sharing of functions with the community Public use Maintenance perception in the community Increase in perception of cultural value	100 100 70 70	30 40 70 70
Attribute	**Impacts on traffic**	**97,5**	**92,5**
Parameters	Pedestrian Private transport Public transport Natural and cultural paths	100 100 100 90	100 90 100 80
Attribute	**Local economics**	**60,9**	**90,9**
Parameters	Benefits for the community New economic activities induced by re-use Diversification of economic activities Natural and cultural paths	100 100 100 90	100 90 100 80

6.3 Criteria: Economic & Financial Feasibility

The expected earning from the project described in the first scenario will be rather low, and public aid is needed for the restoration. These initial investments to be made by the municipality will only in part be covered renting the buildings. Also the moorings for residents will have a low return. On the contrary the attended earnings from the Marina project will be high as a high number of moorings for transit and of big boats is expected.

Under the Artisan's project mainly already existing functions will be transferred from other urban areas to the Arsenal. Consequently the level of risk is low, but also the marina has low risk level as tourist activities in the Venetian context generally prove to be a quite sure form of investment.

The initiative for Artisans activities requires a high level of external financing for the restoration works and has low return rates to be expected albeit low management costs, whereas the marina initiative will guarantee for financial feasibility also without initial subventions, although management activities required will be higher.

		Score	
Criteria	Economics	Artisan's area	Marina
Attribute	**Expected earning** **Riskiness** **Financial feasibility** **Onerousness of management of the new use**	**40,0** **90,0** **50,0** **90,0**	**100,0** **80,0** **90,0** **60,0**

This analysis shows that the evaluation of the sustainability of the hypothetical projects for the marina similar to the sustainability of the project for the artisan's area. The project for the marina would ask for mayor transformations of the original buildings, resulting in a score on intrinsic sustainability which is slightly less favourable than for the artisan's area. The score for the context sustainability is slightly more favourable for the marina project, as positive impacts on the local economy outweigh the negative impacts expected in terms of social consensus and large boat traffic.

The score on the economic sustainability is favourable for the tourist marina project, as it can be expected to produce a sufficient return to cover expenses for restoring and maintenance of the structures.

		Score	
		Artisan's area	**Marina**
Criteria	Intrinsic sustainability	0.641	0.589
	Context Sustainability	0.832	0.850
	Economic & Financial Sustainability	0.658	0.804
Sustainability (overall)		**0.649**	**0.675**

7. Conclusions

The aim of the paper has been to present a procedure for the evaluation of the sustainability of projects for the economic re-use of historical buildings in Venice. A multiple criteria model for the analysis of alternative projects for re-use and to support the choice was set up. The model adopts a hierarchical approach that identifies the relevant indicators for the appraisal of sustainability, and groups them into three criteria: *intrinsic sustainability, context sustainability* and *economic-financial feasibility*. The aggregation operator at each node of the hierarchical tree of the model computes a global evaluation based on non-additive measures and the multi-linear aggregation function. The measure values are implicitly obtained from a panel of experts who filled a questionnaire on hypothetical scenarios, allowing for the calibration of the value function with which to analyse the sustainability. The preference structure obtained permits the analysis of the conjunctive – disjunctive (andness – orness) behaviour of the experts.

Starting from the opinions expressed, indicators were then drawn up to estimate the level of conservativeness of the expert evaluations.

Operationally, the evaluation model was tested on two reuse hypothesis of the Arsenal in Venice. The evaluation model seems able to provide interesting results on the sustainability of the projects for re-use, correctly considering the environmental, social and economic components of the work and highlighting the strengths and weaknesses of the two type of re-use. Such analysis can be used in various ways.

Primarily, it can provide a useful support the identification the critical point, at the preliminary stage, of projects capable of combining conservation and economic improvement. Secondly, it can be a support for the selection of projects to be financed in that it allows the trade-off between economic use and conservation to be appraised and thus, implicitly, the cost of the conservation. Finally, it can provide a means of reading the projects for re-use, a kind of checklist of variables to be considered in the evaluation of the proposals.

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