An evaluation model for adaptive reuse of cultural heritage in accordance with 2030 SDGs and European Quality Principles

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Abstract
Cultural heritage can play a strategic role in achieving the sustainable development goals, as widely recognized worldwide by the United Nations, UNESCO, ICOMOS, as well as by many regional and national institutions. It is needed to implement the principles stated in international and national recommendations in new approaches and tools, both to preserve the historical assets and revitalize them in a circular economy perspective. The paper discusses the challenges of assigning new uses to abandoned historic buildings that still retain values to be protected and passed on to the future. Specifically, the research proposes an innovative analysis model based on the algorithms of the Analytic Hierarchy Process (AHP) and the employment of evaluation indicators established in accordance with 2030 Sustainable Development Goals (SDGs) and European Quality Principles. The model is applied to the case study of Villa Venusio, an 18th century noble house built in Metropolitan Area of Naples (Italy), which is currently in an advanced state of decay and abandonment, awaiting architectural, functional, and technological restoration. This study demonstrates that the proposed model can be an essential decision support for the most effective use of historic buildings, by respecting any social, economic, and cultural value. This has important policy implications in the processes of allocating public funding for the rehabilitation of architectural heritage.

Keywords: Cultural Heritage, Rehabilitation, Quality Principles, Highest and Best Use, Multi-Criteria Decision Methods, Analytic Hierarchy Process.

1. Introduction

The importance of cultural heritage for the economic and social development of settlements is particularly relevant in Europe, where a significant quota of architectural asset is made up of historic buildings and sites, including those abandoned or undervalued.
Current urban environmental policy and architectural redevelopment strategies aim to achieve healthier natural and built environments and to extend the buildings life through multiple uses, while respecting the principles of integrity and authenticity of cultural heritage. In this scenario, 'heritage economics' considers cultural assets as an integral part of cultural capital in urban and architectural conservation context, where adaptive reuse becomes a primary strategy for the protection and enhancement of cultural goods (Foster and Saleh, 2021). The allocation of new resources will activate, over time, a flow of goods and services, useful for the empowerment of territorial communities (Ost, 2018, 2021; James, 2006; Bullen, 2011).
The number of actors involved in the processes with potential direct or indirect impact on cultural heritage has grown, in an increasingly multidisciplinary approach in which architecture, archaeology, geography, art history, town planning, engineering, economics, environmental science, sociology, and political action collaborate for public benefit.
Nowadays, any approach on cultural heritage have to merge the architectural conservation principles with the economic and environmental values in a methodological 'unicum', within the international agenda in which the 2030 SDGs play a significant role (United Nations, 2015). Concerning the field of investigation relating to the links between cultural

heritage and sustainable development, any program or project must reach high level of performance, both to preserve the tangible and intangible civilization legacy and to enhance its attractiveness, through successful strategies, in circular economy scheme.
Together with the SDGs framework, the recent ICOMOS Essay "European Quality Principles for EU-funded Interventions with Potential Impact upon Cultural Heritage" is essential to share quality principles in cultural heritage conservation and management, improving the quality of each intervention and avoiding the risk of erasing precious testimonies of the past eroded by insensitive modernization and urbanization (Powell, 1999; Ribera and Cucco, 2019).
Thus, this research is fitting in the international context in which SDGs and ICOMOS Essay, together with any doctrinaire text by United Nations and UNESCO, play a key role, and it is based on a critical and interpretive application of the principles contained therein.
The Sustainable Development Goals (SDGs) provide a framework for national and international sustainable development until 2030. It is made up of 17 goals, 169 targets and 232. The SDGs request a better balance between economic, social, and environmental dimensions of sustainable development (Allen et al., 2018; Costanza et al., 2016). By starting its beginning in 2016, there was a rich production worldwide of reviews, assessments, guidelines, applications, and scientific publications. Research and implementation have included indicator-based assessments (Campagnolo et al., 2016; United Nations, 2016), systemic approaches to analyse any connection between targets (Collste et al., 2017; International Council for Science, 2017; Le Blanc, 2015), drafting of guidelines to support SDGs implementation (Institute for Global Environmental Strategies, 2015; Sustainable Development Solutions Network, 2015).
In the architectural and engineering practice it is needed to have an integrated approach to the SDGs, to ensure that these goals are properly understood and managed.
The strategic Essay "European Quality Principles for EU-funded Interventions with Potential Impact upon Cultural Heritage" was developed by ICOMOS International with the support of the European Community, during the European Year of Cultural Heritage 2018, then revised in 2020 (ICOMOS, 2020). This text provides guidelines for observing shared quality principles in cultural heritage conservation and in its management projects. They are the following: 1. Knowledge-Based, 2. Public Benefit, 3. Compatibility, 4. Proportionality, 5. Discernment, 6. Sustainability, 7. Good Governance.
Application of the principles is strongly recommended for public or private authorities, as well as planners, who have decision-making power in heritage actions.
The paper is structured in five sections. Section 2 describes the aim of the research. Section 3 provides first a literature review on the Multi-Criteria Decision Methods (MCDMs) for the enhancement and reuse of historic buildings, then the characterisation of an innovative evaluation model based on the Analytic Hierarchy Process (AHP) using a set of seven sustainability indicators. Section 4 presents a case-study, implementing the model to define the Highest and Best Use of Villa Venusio, a noble house in Southern Italy (Campania Region). Section 5 draws concluding remarks and discusses policy implications.

2. Research aim

This research aims to characterize a model for evaluating adaptive reuse strategies of historic buildings that succeed in ensuring Highest and Best Use (HBU). The issue is complex: on the one hand, it is necessary to consider a plurality of economic, cultural, and social effects (Morkunaite et al., 2019; Nadkarni and Puthuvayi, 2020, Li et al., 2021;

Alhojaly et al., 2022); on the other, it is essential to identify intervention strategies capable of preserving and enhancing the architectural heritage. The use of multi-criteria approaches becomes a key tool for decision-makers who must choose sustainable strategies for the recovery and rehabilitation of abandoned and ruined historic buildings (Kutut et al., 2014; Arfa et al., 2022).
Thus, we define an AHP-based model, using a new set of indicators concerning the dimensions: (a) social, considering the number of users and new employees; (b) cultural, expressed through specific indicators recalling the ICOMOS Quality Principle and SDGs; (c) financial, in terms of Return On Investment (ROI). The model is applied to the project of rehabilitation and enhancement of Villa Venusio, a XVIII century noble house located in the Municipality of Mugnano di Napoli (Italy). The aspects that characterize the third-level criteria are developed from the recommendations contained in the ICOMOS document. The House is currently privately owned, but negotiations are underway for its acquisition by the public authority. The Municipality, in fact, intends to acquire it both to preserve a part of its history, redevelop a whole portion of the city and thus enhance the profitability of public assets. The declared cultural interest of this work (legal protection imposed in 1996 under Law 1089/1939) calls for institutional cooperation through the involvement of several competent actors, at national and international level, with the consequent access to greater financial resources.

3. Materials and Methods

3.1. Clarification of terms

The expressions such as ‘adaptive reuse’, ‘rehabilitation’, ‘conservation’ or ‘restoration’ recur several times in the text. For the correct interpretation of these terms, it is useful to report the main definitions shared by the scientific community, to facilitate reading and remove potential ambiguities.
Conservation is the set of community attitudes aimed at making heritage and its monuments last (Krakow Restoration Charter, 2000). Restoration is “the complex of technical-scientific interventions intended to guarantee, within the framework of a critical-aesthetic methodology, the temporal continuity of a work of art” (Portoghesi, 1969). Recovery and rehabilitation are the “combination of all the technical, administrative and organisational actions, including analytical activities, that intervene on the built environment, aimed at maintaining or increasing the residual performance of the asset” (Standard UNI 10914/1, 2001). Reuse is the shared redefinition of a renewed role to be given to a building. The term ‘adaptive reuse’ is often used to describe processes of change in use. However, it refers not only to the change in function but also to “accommodate evolving demands of its context, thus maximising value through life” (Schmidt III et al., 2010). Adaptive reuse implies, due to its multidisciplinary nature, the focusing of attention on economic, functional, and cultural aspects, knowing how to manage social impacts on local communities (Conejos et al., 2017). There are multiple definitions that summarise this issue from different perspectives (patrimonial, economic, administrative). According to (Latham, 2000) it is a “process that retains as much as possible of the original building while upgrading the performance to suit modern standard and changing user requirements”; for (Langston et al., 2008) “building adaptive reuse is a viable alternative to demolition and replacement in order to minimize energy and the cost of new construction works”; for (UNESCO, 2015) it is a challenge of “finding new uses suitable for a place that respect its form, character, structure and historical integrity, often requiring some site-conscious changes”.

3.2. Multi-criteria decision-making for cultural heritage conservation and development

To determine the historic buildings HBU requires a rational study approach that can employ Multi-Criteria Decisional Methods (MCDM). Such methods allow to consider not only the economic performance of the restoration and valorisation intervention, but also the wide range of effects it will have on the territory, such as involving the community in the new functions, job opportunities, and the project's ability to promote cultural growth while respecting historical-architectural values.

A literature overview shows that MCDMs are used to address different issues related to the field of cultural heritage (Egusquiza et al., 2022; Guerriero et al., 2022). There are several works from research areas such as ecosystem assessment, energy planning, spatial planning, where cultural heritage conservation is a criterion of the multi-criteria assessment model (Ferretti et al., 2014). Just to name a few, Thórhallsdóttir (2007) defines a model to identify the best among several hydroelectric and geothermal projects in Iceland, including impacts on cultural heritage among the evaluation criteria. Bryan et al. (2010) establish management priorities for ecosystem services in Australia by prioritising diversity and cultural heritage. Tarragüel (2012) assesses the vulnerability of cultural heritage to landslides in Georgia. Hamadouche et al. (2014) rank archaeological sites in a park in Algeria based on priorities for biodiversity conservation. Vodopivec et al. (2014) use Analytic Hierarchy Process (AHP) to select useful projects to preserve the cultural heritage of castles in Slovenia and to help decision-makers identify the buildings with the highest priority for renovation. Nicu (2016) implement AHP to assess cultural heritage sites in the Valea Oii catchment area in north-eastern Romania. Jajac, Rogulj, and Radnić (2017) employ both AHP and Preference ranking organisation method for enrichment evaluation (PROMETHEE) to guide the decision-making process regarding a historical bridge rehabilitation project. Özdemir Işık and Demir (2017), instead, employ both AHP and ELECTRE to rank historical-cultural structures on the coastline of Trabzon.

However, there are still few studies that aim to evaluate the most effective intervention strategies for the reuse and valorisation of cultural property. Wang and Zeng (2010) use the Analytic Network Process (ANP) and the Delphi Method to identify the most effective reuse alternative for historical sites in Taiwan. Specifically, the authors first identify evaluation criteria from expert opinions using fuzzy Delphi. These are a series of criteria grouped into cultural aspect, economic aspect, architectural aspect, environmental aspect, social aspect and continuity aspect. Then, based on these criteria and an ANP-based selection model – which allows for the interdependencies of the criteria to be taken into account – they obtain the final priority of the alternatives.

Dutta and Husain (2009) evaluate various cultural heritage sites in Calcutta (India) to identify priority conservation actions using an additive linear multi-attribute model. The criteria selected are: historical value, architectural value, socio-cultural value, signs of deterioration, accessibility, integrity, public opinion, local response and usability. Fuentes (2010) suggest employing the weighted sum method to analyse the potential reuse of vernacular farm architecture in Spain. Giove et al. (2011) characterise a multi-criteria model for the sustainability assessment of economic reuse projects in the Arsenale Vecchio in Venice. The model uses the relevant parameters for assessing sustainability, aggregated in three macro-indicators: intrinsic sustainability, contextual sustainability and economic-financial feasibility. Ferretti et al. (2014) examine the sustainability of cultural heritage projects using the Multi-Attribute Value Theory (MAVT) approach. They apply MAVT to choose the reuse of a set of historic industrial buildings located in the metropolitan area of Turin (Italy). In particular, seven buildings are compared on the

basis of different attributes, such as the quality of the context, the presence of economic activities, the flexibility of the building, pedestrian accessibility and the level of preservation.

Several authors favour the use of the Analytic Hierarchy Process (AHP) for the evaluation of refunctionalisation strategies of historical heritage. Ribera et al. (2019) propose an AHP-based assessment model to identify the HBU for historic buildings, taking into account both their social, cultural and economic identity and the preservation of their integrity and original image. Haroun et al. (2019) intends to select interventions for adaptive reuse of heritage buildings. They select the following criteria to assist in the process of evaluating reuse alternatives in order to achieve an effective adaptive reuse of a heritage building: heritage value; architectural value; economic performance; social value; environmental impact. Della Spina (2021) combines two methods according to a multi-phase design for the selection of adaptive reuse strategies for historic buildings: (i) a multi-criteria analysis to identify the highest and best use among alternative reuse scenarios on the basis of nine criteria pertaining to social value, historical and cultural value, and economic and financial value; (ii) a discounted cash flow analysis to support the verification of the financial feasibility of the investment. Recently, Dell'Ovo et al. (2021) use the Novel Approach to Imprecise Assessment and Decision Environments (NAIADE) to define the most suitable function for adaptive reuse of Castello Visconteo in Cusago (Italy). Since the project will impact both the building and the context, the authors propose to divide the assessment framework into two main dimensions, on-site and off-site. These dimensions are then further classified according to social, technological, economic, environmental and political aspects.

The literature review firstly shows that different MCDMs have been used to identify the most suitable reuse strategy for historic buildings and studies comparing different methods or defining whether some MCDMs are more suitable than others are rare. However, we can highlight some crucial aspects that may be decisive in the choice of the MCDM. Some methods such as AHP and TOPSIS allow the return of a priority list, with a corresponding score. In contrast, outranking methods such as ELECTRE provide only the winning alternatives and can be used with a limited number of criteria and alternatives. Compromise ranking methods (VIKOR) only score alternatives if specific acceptability criteria are met. In contrast, they only return acceptable alternatives and not a priority list.

A common limitation of most methods is the assignment of weights to the criteria. Weights are estimated by means of pairwise comparisons between the evaluation criteria. However, it should be noted that in the case of AHP, different weights can be assigned to criteria that are on different hierarchical levels. In most other methods – e.g., ELECTRE, TOPSIS and VIKOR – the criteria must all be on the same level and then compared with each other in pairs. It follows that AHP is among the most flexible multi-criteria methods. It can be used to solve even complex decision-making problems with evaluation criteria arranged on several hierarchical levels (Nesticò and Somma, 2020).

Another shortcoming found in the literature concerns the choice of criteria used to define multi-criteria schemes. The indicators are almost always qualitative and are chosen with reference to the specific case study. Instead, the present research proposes a set of seven criteria that have also been chosen considering the principles of sustainable development and the guidelines of international bodies for the protection of historic buildings and sites, and therefore may have general validity. These criteria are expressed where possible through quantitative indicators or, where this is not possible, through indicators based on a qualitative rating scale.

3.3. The Analytic Hierarchy Process to identify the most effective use for historic buildings: methodological background

Based on the framework outlined in the previous subsection, we intend to define a new AHP-based model for identifying the Highest and Best Use of historic buildings. We believe that AHP is the most suitable for solving the decision-making problem related to the identification of the most effective functional use of assets with high historical and cultural value. This is a hierarchical multi-criteria technique, which is termed: (i) 'analytical' because it breaks down the complex decision-making problem into its fundamental elements (Saaty, 1980; 1984); (ii) 'hierarchical' because the decomposition of the problem itself takes place on different levels of increasing detail (Forman, 2001). Indeed, at the top of the hierarchy is the goal to be achieved. At the next level are the criteria, which in turn can be decomposed into further sub-criteria. Finally, at the last level are the alternatives to be evaluated (Saaty, 1980; 1996; 1999; Tzeng and Huang, 2011). Since some criteria may conflict with each other, the most effective option is not the one that optimises each individual criterion, but rather the one that achieves the best compromise considering all the criteria selected for comparison, whether social, cultural and economic (Basak, 2019; Nesticò and Somma, 2019).
The logical-operational steps on which the multi-criteria model is based are:

i. Identification of the goal and selection of project alternatives.
ii. Choice of evaluation criteria and sub-criteria to evaluate the alternatives.
iii. Evaluation of the weights and the scores and consistency checks.
iv. Calculation of overall score and ranking of alternatives.

Our aim is to define a model that: (i) is exportable and applicable to different case studies; (ii) is based on criteria and sub-criteria rigorously identified according to 2030 SDGs and European Quality Principles; (iii) use indicators that are easy to estimate and use readily available data, so that it can be widely employed by policy-makers and planners.
The main innovations concern the rationalisation of the phases, the selection of evaluation criteria according to international references for cultural heritage conservation disciplines and the economic evaluation of the projects, and finally the formalisation of the calculation schemes. Below we go into the details of the phases of the model, which retrace the four AHP stages already mentioned.

i. Identification of the goal and selection of project alternatives
Having defined the goal, which concerns the determination of HBU for a historic building, this step translates into the preliminary selection of possible functional destinations. In accordance also with the Dictionary of Real Estate Appraisal (The Appraisal Institute), such destinations are to be chosen among those that are:

a. technically feasible,
b. urbanistically admissible,
c. economically viable,
d. and architecturally compatible (Ribera et al., 2020).

In this stage, the public and/or private operators have the prerogative to select alternative functions after careful social, cultural, and economic analysis of the context in which the building is located, and after hearing the opinions and feedback of stakeholders and thus of the community, associations and administrations. Statistical data on the composition of the population, the prevailing market, the types of immediately related functional destinations, the level of education, tourist flows, etc. are all helpful.

ii. Choice of evaluation criteria and sub-criteria to evaluate the alternatives

At the first level of the hierarchy, we consider the social criterion (S), the cultural criterion (C) and the financial criterion (F).

The social criterion includes the following sub-criteria:

- community involvement (S_1);
- level of employment (S_2).

These two criteria are expressed through indicators considering the Quality Principles and the 2030 Sustainable Development Goals. In particular, for estimating the values related to the social sub-criteria, a series of quantitative data must be evaluated using statistical assumptions. For each functional alternative, it is possible to hypothesise the dimensional availability to be assigned to each room and consequently calculate the maximum number of users to be accommodated, according to the minimum requirements of the regulations and the suggested comfort parameters. Following that, the indicators *average daily number of users* (S_1-indicator) and the *number of new employs* for each functional proposal (S_2-indicator) can be estimated using affluence data and socio-economic analyses conducted in the context in which the building is located.

The cultural criterion (C) is stated through the following two sub-criteria:

- impact on the community (C_1);
- impact on the asset (C_2).

The sub-criterion impact on the community (C_1) summarises all aspects related to the impact that the various re-functioning alternatives could have on the local community, both in terms of benefit that each individual function could bring from a socio-cultural standpoint and in terms of the perception generated in the community regarding the historic building's new appearance. It is essential, therefore, that the approach to recovery is prudent and careful, to enhance the characteristics of the work while avoiding losing or distorting its original spirit. The new function must, therefore, reflect the needs and interests of the community, assisting in the reintroduction of the disused or undervalued historic building into a renewed vital circuit.

This sub-criterion (C_1) is expressed through two third-level sub-criteria:

- public benefit (C_{11});
- sustainability (C_{12}).

Public benefit (C_{11}) is a function of cultural impact on the community, fulfilment of local needs, and achievement of SDG Goals. Sustainability (C_{12}) depends on three main factors: usefulness of the function, enhancement of the building, and building management.

The sub-criterion impact on the asset (C_2) is intended to assess the material repercussion of the proposed functions on the structure in terms of the quantity and quality of interventions. The latter must be evaluated in the context of their level of invasiveness, considering how much and how they are grafted into the historic material, and tend to be limited to a minimum. In this context, the potential reversibility of such interventions is critical in order to ensure greater flexibility in acting on the recovered asset, eliminating, if necessary, additions and re-evaluating design choices that are no longer effective. The proposed functions are also evaluated in relation to how they can be installed in accordance with the original layout of the structure, with the goal of minimising design distortions that risk distorting the building's main historical characteristics.

C_2 in turn is expressed through two third-level criteria:

- compatibility (C_{21});
- proportionality (C_{22}).

C_{21} summarises respect for the criterion of minimum intervention, invasiveness of interventions and reversibility of interventions. C_{22} is a synthesis of architectural aspects

such as coherence with the characteristics of the structure, respect for the original conformation, and spatial flexibility.
The aspects that characterize the third-level criteria are developed from the recommendations contained in the ICOMOS document. They attempt to answer the initial questions that the international institution poses for each individual Quality Principle, accompanied by considerations made in accordance with the universally recognized principles that ensure compatible interventions on the historic built environment (respect for cultural heritage and its significance, adequacy, preventive care, precaution in designing, minimum intervention, efficacy, inclusiveness, maintaining authenticity and integrity, community involvement in public interest, and so on).
The financial criterion (F) is introduced to summarise the financial performance of the project (F_1) and, therefore, the profitability of each alternative for the investor. F is expressed through the *Return On Investment* (ROI) index, which is understood as the rate of return on a company's investment.
The ROI of each alternative is approximated to the average ROI of the sector in which the investment falls. Since we are dealing with *ex-ante* financial evaluations, the indicator can be estimated on the balance sheet data of similar companies. These data are provided by databases such as Bureau van Dijk's ORBIS and AIDA, which respectively give information on global and Italian companies to optimise decision-making processes.
Table 1 provides a detail of the hierarchical structure of the decisional problem, evaluation criteria and sub-criteria and related indicators. Table 2 focus on the third-level criteria.

iii. Evaluation of the weights and the scores and consistency checks
Once the hierarchical structure of the problem has been defined and the alternatives have been identified, it is necessary to estimate: (a) the weights of each criterion and sub-criterion; (b) the score of each alternative against each evaluation criterion.
With reference to point (a), all criteria of the same order are compared with each other in pairs to establish their importance in relation to criteria of a higher order. Accordingly, a matrix of pairwise comparisons is constructed for each group of sub-criteria belonging to the same criterion. Every matrix is of a square type with the number of rows and columns corresponding to the number of criteria at the same level pertaining to the same higher-order criterion. This matrix is*:*

- positive, i.e. all major minors are positive, where major minor means the determinant of the square submatrix formed by the first *n* rows and *m* columns (with $1 \leq m \leq n$);
- reciprocal, since $a_{ij} = 1/a_{ji}$ and therefore the elements on the principal diagonal are all unitary ($a_{ii} = 1$). This reciprocal relationship arises from the need to ensure symmetry of importance judgements;
- consisting of finite elements, since for each criterion C considered we have $a_{ij} \neq \infty$.

The attribution of judgements in pairwise comparisons is a crucial stage of the AHP because it is often conditioned by the panel of decision-makers conducting the evaluation (Aczel and Saaty, 1983; Yang, Li, and Yao, 2010; Nesticò and Maselli, 2020). Therefore, at an early stage of the analysis, it can be assumed that all criteria of the same hierarchical level have the same importance, thus limiting subjectivity of judgement.
Once the weights of each criterion have been defined, we proceed to estimate the scores of each alternative with reference to each evaluation criterion (b), starting from the lowest level of the hierarchy. Then, the alternatives are compared in pairs against each criterion. It follows that as many matrices of pairwise comparisons are constructed as there are criteria at the last level.

For both (a) and (b), the pairwise comparisons return the terms a_{ij} of the evaluation matrices, where a_{ij} is given by the ratio w_i/w_j. The pairwise comparisons are made according to the semantic scale of Saaty (1989). It is a comparison scale based on nine values of mutual importance, of which 5 are main values and 4 are intermediate values (Table A.1 in Appendix). Therefore, by comparing two criteria *i* and *j*, the value of 1 is attributed if the two criteria are considered of equal importance; while a progressively increasing value is attributed as the importance of *i* grows with respect to that of *j*.
Once the matrices of the pairwise comparisons have been defined, it is necessary to derive the weight vector *w* which returns the 'absolute' weight of each criterion. The same procedure is also followed to derive the scores of each alternative with respect to each criterion.
In general, to estimate the vector of weights (and of scores), we can use the method of eigenvalues, usable also if you only have an estimate of the w_i/w_j ratios. The matrix of pairwise comparison W has its order *n* as its only eigenvalue and the vector of the searched variables as its corresponding eigenvector. Therefore, the maximum eigenvalue λ_{max} is close to the value *n*, which can be used as an estimate of *w*. Furthermore, according to Basak (2019), the values found will be closer to the exact values the more consistent the estimates provided for the w_i/w_j ratios are. In formula:

$$W \cdot n = \lambda_{max} \cdot w \qquad \text{with} \qquad \lambda_{max} \geq n \tag{1}$$

Alternatively, the vector *w* can be determined assuming that its *i*-th element is equal to the geometric mean of the elements present on the *i*-th row of *W*, normalized with respect to the sum of the geometric means of all the rows. However, it is necessary to have the value of λ_{max} for the consistency measurements.
λ_{max} is calculated by multiplying the row vector, obtained by adding all the elements of the matrix *W* placed in the same column, by the column vector *w*.
Finally, the vector *w* can also be calculated first by normalizing the matrix *W* through the ratio of each of its elements to the sum of the elements in the same column and then by calculating the arithmetic mean of each of its rows (Fishburn, 1967).
Once weights have been assigned to the criteria and scores to the alternatives, it is necessary to verify the mutual consistency of the weights attributed, estimating the Consistency Ratio (CR):

$$CR = \frac{CI}{RCI} \tag{2}$$

In (2), the Consistency Index (CI) measures the consistency of the values given to the ratios w_i/w_j and it is worth:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{3}$$

The Random Consistency Index (RCI) is a function of the number *n* of variables (see Table A.2 in Appendix). Each RCI value is obtained as a mean consistency random index

based on a sample of 500 randomly generated binary comparison matrices with CI less than 10%.
Finally, from the value of CR we check the consistency of the binary comparisons. These comparisons are adequately consistent with each other if: CR < 5%, for n = 3; CR < 9%, for n = 4; CR < 10%, for n > 4.

iv. Calculation of overall score and ranking of alternatives
The last step allows to calculate the overall score of each alternative. This score is obtained by adding the scores of each alternative with reference to a specific criterion, multiplied by the respective weight. This weighted sum is conducted starting from the lowest level of the hierarchy up to the goal. The winning alternative is the one with the highest score. The output is therefore a score ranking of the alternatives to be evaluated.

4. Case study. Application of the model to the project of rehabilitation and enhancement of Villa Venusio, a XVIII century noble house in Mugnano di Napoli (Italy)

The reuse of historic ruined constructions, unlike well-conserved buildings, involves a different number of technological, functional, aesthetic and structural criticalities, such as:
1. Old-new balance. The boundary between respecting the past and the new design is not always well defined.
2. Generic reuse. It is impossible to indiscriminately reuse all ruined works; many artefacts must be preserved as a monument of themselves in their fragmentary image. Many of them (castles, fortresses, towers, palaces, archaeological remains, etc.) were born with a defined use that characterises their architectural, technological and structural system. It is therefore not always easy to guarantee a change of use clearly compatible with the original layout.
3. Environmental conditions. Abrupt changes in environmental conditions make it difficult to intervene in these buildings: infiltrations, structural micro shocks, and environmental shocks can lead over time to new and more dangerous mechanisms.
4. Location. The position of these works often doesn't encourage wide and comfortable accessibility.

On the other hand, reuse reveals some potential:
1. Conservation actions. Continuous maintenance and technological improvement.
2. Territorial cohesion and enhancement. Reuse leads to a revitalization of the urban environment, creating a new network of social and economic relations; in peri-urban or rural contexts, it also activates new touristic and cultural routes.
3. Architectural addition. The planimetric layout of some buildings often allows the creation of new independent structures and the use of the most modern reversible technologies.

The origins of Villa Venusio in Mugnano di Napoli date back to the late 18th century. It was most likely built at the request of Antonio Capece Minutolo, Prince of Canosa, a prominent member of one of the Kingdom of the Two Sicilies' oldest noble families. The Capece Minutolo family had been in Mugnano di Napoli for about a century, living in the then-adjacent noble palace, which was later demolished during the Fascist era. In the following years, ownership of the Villa passed to Ottavio Venusio, who had already attained the title of baron in 1752 with the purchase of the fief of Turi, in the current province of Bari. The Villa was thus named after the family that would inhabit it over the

next two centuries (Gargiulo, 1982). The Villa is an outstanding example of Neapolitan Baroque architecture. Its original structure was articulated in a longitudinal body developed on two levels and built with typical Neapolitan yellow tuff. The aristocratic chapel in the centre of the building is dedicated to Saint Blaise, the patron saint of the city, and was later enlarged in 1872, as evidenced by a marble panel still in the Villa, certifying its blessing by Vito d'Ardia on commission from Cardinal Riario Sforza.

This first addition included the construction of a rectangular room with three altars surmounted by round arches. In 1873 there was a second and final enlargement that provided for the demolition of the central altar for the construction of the apse, with a semicircular dome roof that is still preserved today, although in an advanced state of disrepair. In addition, a small bell tower was built in the same year. The villa was inhabited until the 1950s by the last descendant of the family, Emma Venusio. It was later sold to third parties and has now been neglected for several decades.

From the entrance gate towards the main courtyard, two volumes separate from the main building, which once housed the servants' quarters, can be seen to the right and left. In front, the front façade of the Villa is majestic and imposing, with a series of irregular openings. On the left is the bell tower, which houses the main staircase, and on the right is a loggia with a balcony serving the main floor and characterised by a series of polycentric and lowered barrel arches.

Figure 1 summarises the history of the villa and shows its architectural survey. Figure A.1 in Appendix returns General Regulatory Plan, Municipality of Mugnano di Napoli (1987) showing the current boundaries of the historic centre and the lot where Villa Venusio is located.

Most of the doors and windows have completely or partially lost their frames and the piperno cornices that adorned them, and the originally sloping roof has collapsed. Several other major collapses, as well as a portion of the mezzanine floor, the floors of the west wing and the east end, currently characterise the building's state. In the north-western part of the garden, the semicircular wall of the chapel is characterised by the presence of a unique gooseneck staircase, which sinuously allows direct access from the outside to the first floor. The Villa is clearly neglected and abandoned, with advanced deterioration of the surfaces and structural components that comprise it. Furthermore, weeds have completely engulfed the structure, causing detachments, cracks, and biological growth on the surfaces.

The decay and precariousness of the structures can still be seen when entering the interior, where one can admire all the evocative splendour of this traditional example of late 18th-century local architecture. The chapel is structured on the succession of three main rooms, the first surmounted by a lowered barrel vault, the second by a false coffered ceiling and the third by an extra-domed dome, evidence of progressive extensions of the structure. The second room is characterised by the presence of two arched niches, opposite each other on both sides, housing sacred altars, while the semicircular apse of the dome features a central marble aedicule, once housing the votive image of the patron saint. The room adjacent to the dome led to a women's gallery, located on a mezzanine floor jutting out over the apse, characterised by slender columns figuratively echoed on the opposite side of the dome by decorative pilasters. This chamber leads to the hypogeum, which contains the burial crypt where the remains of the Venusio family were once kept.

The structure contains numerous architecturally significant elements, particularly in the chapel, such as the gable of the entrance door, window frames, column capitals, arched shutters, and stuccoes decorating the dome's surfaces. Part of the flooring is still preserved, and it is distinguished by the so-called "riggiole", hand-decorated majolica

ceramic tiles typical of the Campania coastal area. Figure A.2 in Appendix shows images of the interior, exterior and decoration of the Villa in its current state of decay.
Large and spacious rooms follow one another in the west wing of the structure. As evidenced by the presence of what remains of an oven, these most likely housed service functions such as stables and kitchens. In the east wing, however, several barrel-vaulted rooms connect until they reach the area now affected by the extensive collapse. The noble floor is accessible from a single stairwell inside the bell tower, the ramps are covered by rampant barrel vaults while the landings by ribbed vaults. The first landing provides access to a balcony that connects the staircase with the mezzanine floor of the women's gallery (Figure 2). The rooms in the west wing are completely inaccessible due to the total collapse of the floors, which were originally made of girders and bricks; the rooms to the east and the subsequent flights of stairs are also inaccessible due to the numerous debris caused by the collapse of the roof (Figure 3). Construction details of the hypogeum and chapel are in the Appendix (Figure A.3).

4.1. Identification of the goal and selection of project alternatives

The three alternatives are chosen by statistical surveys on the number and qualification of inhabitants, on the functional needs as expressed in municipal and regional programs, and in strategies for inter-municipal collaboration and growth (Municipality of Mugnano di Napoli, 2018-2020). In addition, all three proposals fall under some of the SDGs: Goal 4: Quality education; Goal 8: Decent work and economic growth; Goal 9: Enterprise, innovation and infrastructure; Goal 10: Reducing inequality. They are as follow: A_1. Coworking Spaces, A_2. Advanced Formation School in Cuisine, A_3. Educational Pole.
The details of each, such as the objectives and functional distribution hypotheses are specified below.

Coworking Space (A_1)
Coworking is a working style that involves sharing a workspace while keeping each activity independent. It typically attracts remote workers, freelancers or people who travel frequently and end up working in relative isolation. Coworking is the social gathering of a group of people who share common values and artistic synergies while working independently.

Advanced Formation School in Cuisine (A_2)
The school aims to be a centre of excellence in local food and wine training. It can support courses aimed at both amateur chef and specialised professionals thanks to well-equipped classrooms, laboratories, and cutting-edge equipment. A didactic restaurant will have the role of providing students with an initial impact with the working world of quality catering, and special classrooms will allow them to meet entrepreneurs and consultants in the field, for a more rapid and efficient entry into the market. The presence of an urban vegetable garden highlights the significance of promoting regional products and culinary traditions.

Educational Pole (A_3)
The facility will house a nursery and a kindergarten, as well as workshops and classrooms equipped to meet children's educational needs. It will also be a facility of excellence for the treatment of children with special educational needs, with pre-planned activities and, most importantly, counselling and training for families. There will also be numerous green spaces with play areas and botanical gardens to encourage contact with nature and outdoor activities.

Table 3 returns goals and functional distribution of the alternatives A_1, A_2 and A_3.

4.2. Choice of evaluation criteria and sub-criteria to evaluate the alternatives

The selection of evaluation criteria, sub-criteria and indicators was carefully carried out in the previous section. The indicators are defined taking into account: the social impacts on the community; the cultural value of the historic building in accordance with the European Quality Principles and the SDGs; and the financial performance of the investment.
The hierarchical structure with criteria and indicators to be estimated is in Table 1.

4.3. Evaluation of the weights and the scores and consistency checks

In this research, we assume that all criteria have equal importance. In other words, we define a base scenario in which, for each level, equal weight is given to each criterion and, with reference to the individual criterion, equal weight is also given to each sub-criterion. Therefore, the dominance coefficients of the pairwise comparison matrices are all equal to 1. It results that the weights of each criterion and sub-criterion are those shown in Appendix (Table A.3).
This choice can be considered coherent for two main reasons: (i) for a correct and objective assessment of the most effective functional use for a historic building, it is not possible to consider any criterion predominant over the other, but all must be pursued at the same time; (ii) the assignment of weights to criteria and sub-criteria is often a political operation (Ribera et al., 2020).
A preparatory step in the construction of the scoring matrix against each criterion is to estimate the indicators in Table 1 for each functional alternative. The values attributed to each indicator for each use is detailed in Appendix (Table A.4). Table 4 returns the scalarized decision matrix, which summarises the value of each indicator for the three functional alternatives.
The next step concerns the pairwise comparison of alternatives against each evaluation indicator. Therefore, we derive seven matrices of pairwise comparisons, one for each indicator and with a number of rows and columns equal to the number of alternatives. Each element of each matrix – or dominance coefficient – is the result of the pairwise comparison performed based on Saaty's semantic scale. Table 5 returns the matrices of the pairwise comparisons. In this table, under the heading 'Rank', the ranking of the three alternatives is shown with respect to the individual indicator to which they refer. All matrices are consistent, as all CRs are below the acceptability threshold and the relative uncertainty ranges for each indicator are contained.

4.3. Calculation of overall score and ranking of alternatives

The implementation of the hierarchical analysis model returns the classification of the alternatives. Figure 4 shows: (a) the score of each indicator for each alternative; (b) the score of each alternative against the social, cultural and economic first level criteria; (c) the total score of each of the three use functions.

5. Results and discussion

The application confirms the relevance to use multi-criteria schemes to solve problems with conflicting criteria and, consequently, to make a consistent and objective choice.
In fact, as shown in Figure 5, the winning alternative Advanced Formation School in Cuisine scores higher than the other two alternatives in criteria S_1, S_2, C_{11}, C_{22}. While for criterion C_{12}, the Educational Pole predominates. Again, for C_{21}, the Co-working Space

far outperforms the other two alternatives. Finally, for criterion F_1, the Advanced Formation School in Cuisine and the Educational Pole win out over the Coworking Space. Table A.5 in Appendix shows the total priorities. In this table, the term w_{ci} represents the weight of the criterion. w_{Ai} is the score of the i-th with respect to each of the criteria. Priority represents the total score achieved by the i-th alternative, considering all the criteria and sub-criteria of the decision problem.
To provide a more complete range of results, three other scenarios have been implemented, each time being assigned a weight of 0.50 to a single macro-criterion and a weight of 0.25 to the other two. This is to evaluate any differences in results based on different choices in the decision-making phase.
Tables A.6, A.7 and A.8 summarize the results deriving from the implementation of the above scenarios.
Analysing the results, the Advanced Formation School in Cuisine emerges as the winning alternative, which, based on the indicators chosen and the values assigned, represents the most representative choice of the Highest and Best Use for Villa Venusio. It ranks first, among the three functions, in all preference scenarios, regardless of which criterion was privileged. In any case, the pre-eminence of this function is slightly higher than that of the Education Centre, which remains constantly at about ten percentage points from it; the Coworking Space, on the other hand, remains rather behind in all four simulations, confirming itself as the worst option among those considered.
However, it should be emphasised that giving a different weight to the sub-criteria could have resulted in a different ranking. Therefore, it is evident that assigning specific weights to the various indicators makes it necessary to consult a panel of experts on the different aspects of the problem (architectural, economic, socio-cultural), to avoid overlooking crucial aspects in the analysis. In other words, since this is a multidisciplinary problem, both the estimation of the evaluation indicators and the weights to be assigned to the different criteria should be chosen using focus groups, the Delphi method and questionnaires to be submitted to architects, engineers, art historians, conservators and sociologists. In this way, there is no risk of neglecting social, cultural, historical-architectural and financial aspects that would end up failing to valorise both the historic building and the area in which the public good is located in the most effective way.

6. Conclusion

The issue of reusing historic buildings is highly relevant because it reflects the vast number of abandoned or underutilised buildings that dot European territory. At the same time, it is a complicated process because it has a strong impact on communities from financial, social, cultural, and environmental point of view. Therefore, it requires an all-inclusive methodological approach that balances the society requests, the economic development, and the preservation of the historical asset.
In this scenario, the use of multi-criteria evaluation techniques, combined with the principles of sustainable development and the guidelines of international protection bodies for historic buildings and sites, makes it possible to direct the planner, and thus the decision-maker, towards optimal solutions for the most effective use.
When confronted with such architectures, the selection of the new intended use must consider a variety of parameters, useful for expressing the whole range of values involved: historical, architectural, social, economic, and so on. The attribution of new uses useful to the contemporary needs also implies the enhancement of urban and territorial contexts. Therefore, the architecture revitalization can become a driving force

in the dynamic contemporary context, even in circular economy approach (Ribera and Cucco, 2020; Foster, 2020).

The contribution of this research is to provide an AHP-based model applicable when the objective is to identify for historic buildings compatible uses at urban, social, economic, compositional, formal, technological, and structural levels. The application to the case study of Villa Venusio highlights the advantages of the method for decision-makers and planners: (i) the use of easily available data from project deliverables, databases, or secondary sources; (ii) simple calculation procedures; (iii) the possibility to adapt the model also to different case studies. A further strength of the model compared to what is proposed in the literature is that it is based on a set of social, cultural, and financial indicators, which are rigorously identified according to 2030 SDGs and European Quality Principles. Thus, we propose a multi-criteria scheme that can be repeated whenever the most effective use for a historic building is to be selected. Among the weaknesses, we can cite the presence of some qualitative and not quantitative indicators, a critical issue that can be overcome by involving a multidisciplinary team of experts with expertise in the recovery and conservation of historic buildings, economics, sociology, history of art and architecture in the assessment.

Thus, the study demonstrates that multi-criteria analysis can be a valid and scientific decision support with important policy implications in public funding allocation processes. Policymakers and public administrations should adopt appropriate decision-support tools as well as develop more expertise in these tools, especially when intervention strategies concern historical-architectural heritage. Indeed, a prudent and sustainable project becomes an opportunity for material care, economic investment and, nonetheless, community cohesion and affection for the artefacts in which generations of people have recognized themselves for centuries.

This paper is intended to be a contribution in the research concerning the choice of the most effective strategies for the reuse of historical-architectural heritage. Research perspectives may concern: (i) the empirical application to other case studies; (ii) the use of multi-criteria methods other than AHP and conducting a comparative analysis of the value judgments; (iii) involvement of experts in the different aspects of the topic to estimate specific weights of evaluation criteria and sub-criteria.

Author contributions

Antonio Nesticò and Federica Ribera have conceived and structured the article. Antonio Nesticò and Gabriella Maselli have deepened the study on the multicriteria economic evaluation model and have developed the elaborations through software. Federica Ribera and Pasquale Cucco have deepened the theme of reusing the abandoned buildings, the analysis on the characteristics of historical buildings and on the actions useful for their conservation and enhancement.

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Tables

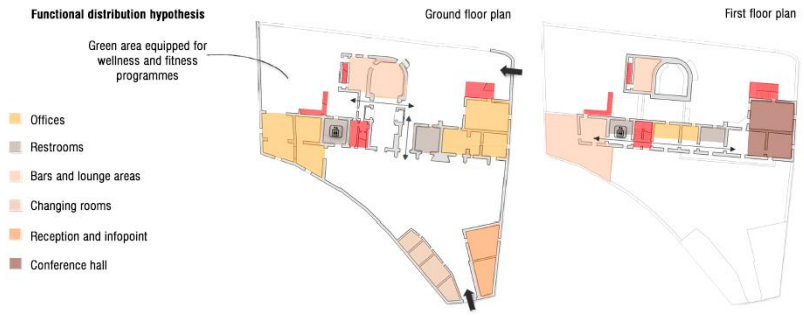
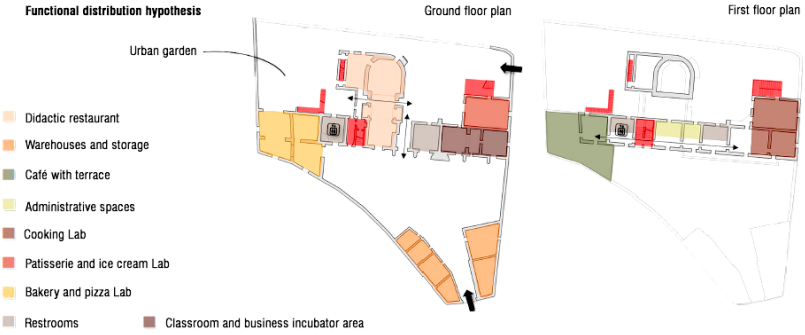
Goal	*I level Criteria*	*II levels Criteria*	*III levels Criteria*	*Indicators*
HBU of a historic building	Social (S)	Community involvement (S_1)		"Average daily number of users" (quantitative), estimated using attendance indices specifically identified for each proposed function.
		Level of employment (S_2)		"Number of new employs" (quantitative), calculated by estimating the number of new permanent workers the new structure needs in the various re-functionalisation alternatives.
	Cultural (C)	Impact on the community (C_1)	Public benefit (C_{11})	Qualitative indicator, evaluated through the drafting of a qualitative scale of preferences with values between 1 and 9, recalling the ICOMOS Quality Principle "Public Benefit" and related parameters.
			Sustainability (C_{12})	Qualitative indicator, evaluated through the drafting of a qualitative scale of preferences with values between 1 and 9, in accordance with the ICOMOS Quality Principle "Sustainability" and related parameters.
		Impact on the asset (C_2)	Compatibility (C_{21})	Qualitative indicator, evaluated by drafting of a qualitative scale of preferences with values between 1 and 9, in accordance with the ICOMOS Quality Principle "Compatibility" and related parameters.
			Proportionality (C_{22})	Qualitative indicator, evaluated by compiling a qualitative scale of preferences with values between 1 and 9, in accordance with the ICOMOS Quality Principle "Proportionality" and related parameters.
	Financial (F)	Financial performance of investment (F_1)		"Return Of lnvestment" - ROI (quantitative). Index estimated from balance sheet data provided by databases such as Bureau van Dijk's AIDA and ORBIS.

Table 1. Criteria, sub-criteria, and indicators to assess the HBU of a historic building.

Public Benefit	***Sustainability***
1. Cultural impact on the community 2. Fulfillment of local needs 3. Achievement of SDG Goals	1. Usefulness of the function 2. Enhancement of the building 3. Building management
It represents the set of objectives that the function is capable of pursuing, bringing a benefit to the local community and an interest that is not momentary and specific, but also able to meet future needs. With this in mind, the indicator is also to be assessed by taking into consideration which and how many of the SDG goals the function was able to achieve. Furthermore, the interaction that the function is able to create with the community in terms of public use of the asset can be investigated.	It indicates the capacity of the function to be able to last over time and to be subject to sustainable management that guarantees the best cyclical maintenance of the asset. This indicator is evaluated above all in the perspective that the proposed functions may or may not enhance the value of the building and also be considered suitable by the community to which it belongs, which therefore manages through the new use to still perceive the spirit and memory of the work alive.
Compatibility	***Proportionality***
1. Respect for the criterion of minimum intervention 2. Invasiveness of interventions 3. Reversibility of interventions	1. Coherence with the characteristics of the structure 2. Respect for the original conformation 3. Spatial flexibility
It indicates the degree of appropriateness of the function with respect to the historical-architectural characteristics of the asset. It is configured in the ability of the projects to pursue the criterion of minimum intervention,	It indicates the extent to which the function is pertinent to the original characteristics of the structure, its planimetric conformation, the arrangement of rooms and connectives, and the extent to which it succeeds in

minimum invasiveness and potential reversibility of the necessary planned interventions.	enhancing its spatial and architectural peculiarities without distorting its layout.

Table 2. Focus on the third level criteria.

Goals	Functional distribution hypothesis
	Coworking spaces (A_1)
- exploit the high incidence of employment in the noncommercial tertiary sector and in highly-medium specialised professions; - discourage work isolation and encourage sociability and aggregation; - promote physical activity in the workplace as a new means of improving individual well-being and productivity; - regenerate urban space and increase green areas, suitably equipped and usable; - facilitate young professionals to start autonomous and independent work activities.	
	Advanced Formation School in Cuisine (A_2)
- promotion and training of professionals in the gastronomic sector; - promotion and dissemination of local 0 km products and the slow food cult; - development of synergies with institutions, associations and relevant actors in the food and wine sector; - combating youth unemployment through the creation of privileged access channels to the world of work; - generation of high profitability.	
	Educational Pole (A_3)

- need to build support structures for school activities; - location as one of the 7 poles, identified in the Naples metropolitan area, within the 'Crescere insieme in Campania' project; - strengthening of access channels to childcare services, through tools and methodologies conducted by operators with specialised skills; - support and assistance to families, aimed at the identification, prevention and early educational intervention for pre-school children with special educational needs (SEN).	

Table 3. Goals and functional distribution of the alternatives A_1, A_2 and A_3.

	Co-working Space (A_1)	Advanced Formation School in Cuisine (A_2)	Educational Pole (A_3)
Average daily number of users	137	177	73
Number of new employs	18	30	27
Public Benefit	5	7	6
Sustainability	3	6	7
Compatibility	7	3	5
Proportionality	4	7	5
ROI	8.87%	9.71%	10.00%

Table 4. Scalarized decision matrix.

Average daily number of users	A_1	A_2	A_3	**Priority**	**Rank**	(+)	(-)
A_1	1.00	0.50	3.00	30.90%	**2**	1.90%	1.90%
A_2	2.00	1.00	5.00	58.20%	**1**	3.50%	3.50%
A_3	0.33	0.20	1.00	10.90%	**3**	0.70%	0.70%
CR = 0.4%							

Number of new employs	A_1	A_2	A_3				
A_1	1.00	0.25	0.33	12.60%	**3**	1.20%	1.20%
A_2	4.00	1.00	1.00	45.80%	**1**	4.40%	4.40%
A_3	3.00	1.00	1.00	41.60%	**1**	4.00%	4.00%
CR = 1%							
Public Benefit	A_1	A_2	A_3				
A_1	1.00	0.33	0.50	16.30%	**3**	1.60%	1.60%
A_2	3.00	1.00	2.00	54.00%	**1**	5.20%	5.20%
A_3	2.00	0.50	1.00	29.70%	**2**	2.80%	2.80%
CR = 1%							
Sustainability	A_1	A_2	A_3				
A_1	1.00	0.25	0.20	10.00%	**3**	0.70%	0.70%
A_2	4.00	1.00	1.00	43.30%	**2**	3.20%	3.20%
A_3	5.00	1.00	1.00	46.60%	**1**	3.50%	3.50%
CR = 0.6%							
Compatibility	A_1	A_2	A_3				
A_1	1.00	5.00	3.00	63.70%	**1**	12.40%	12.40%
A_2	0.20	1.00	0.33	10.50%	**3**	2.00%	2.00%
A_3	0.33	3.00	1.00	25.80%	**2**	5.00%	5.00%
CR = 4%							
Proportionality	A_1	A_2	A_3				
A_1	1.00	0.25	1.00	17.40%	**3**	1.70%	1.70%
A_2	4.00	1.00	3.00	63.40%	**1**	6.10%	6.10%
A_3	1.00	0.33	1.00	19.20%	**2**	1.80%	1.80%
CR = 1%							
ROI	A_1	A_2	A_3				
A_1	1.00	0.50	0.50	20.00%	**3**	0.00%	0.00%
A_2	2.00	1.00	1.00	40.00%	**1**	0.00%	0.00%
A_3	2.00	1.00	1.00	40.00%	**1**	0.00%	0.00%
CR = 0%							

Table 5. Comparison matrices in pairs between the alternatives with respect to each criterion.

Figure

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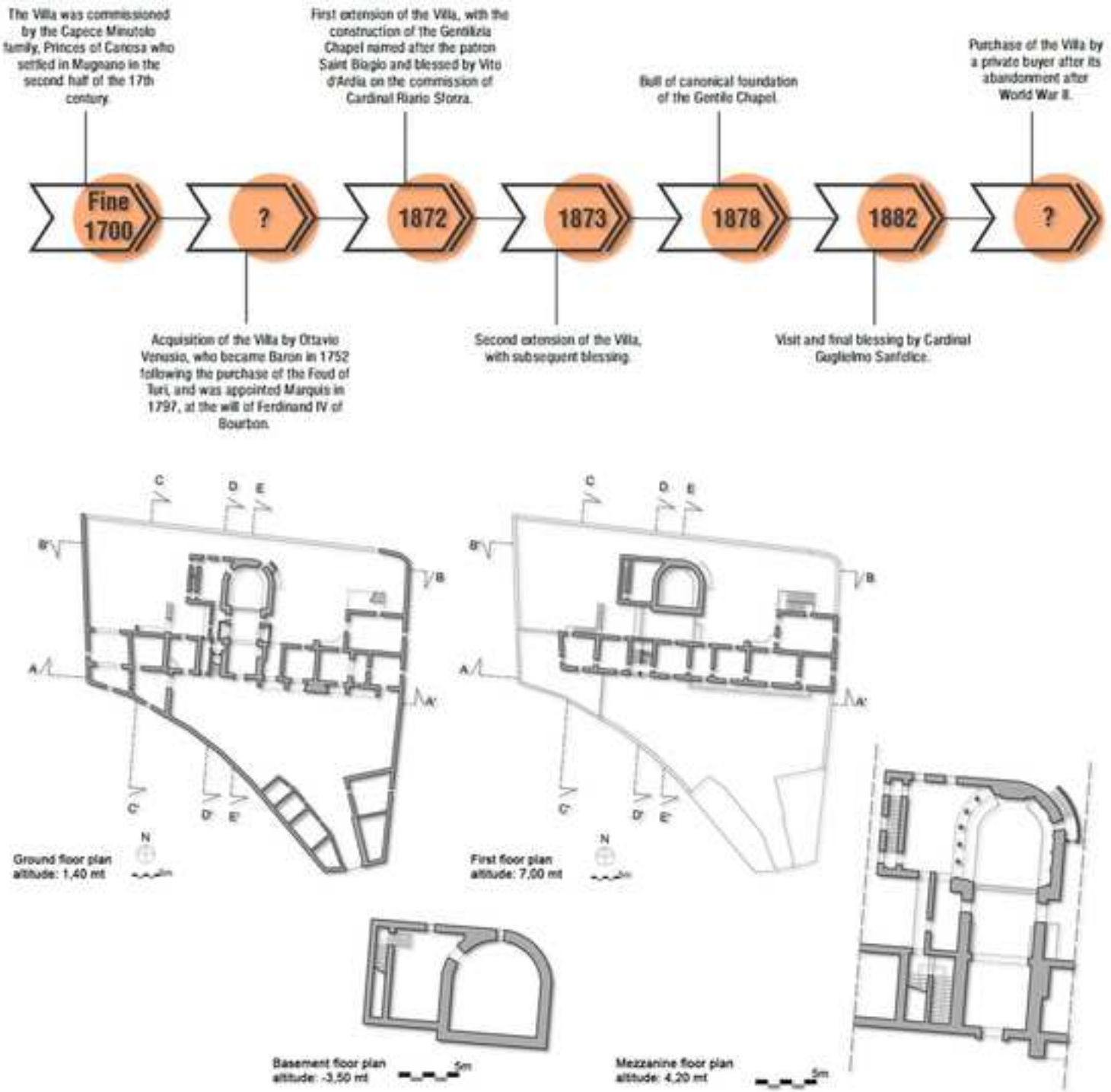

Figure

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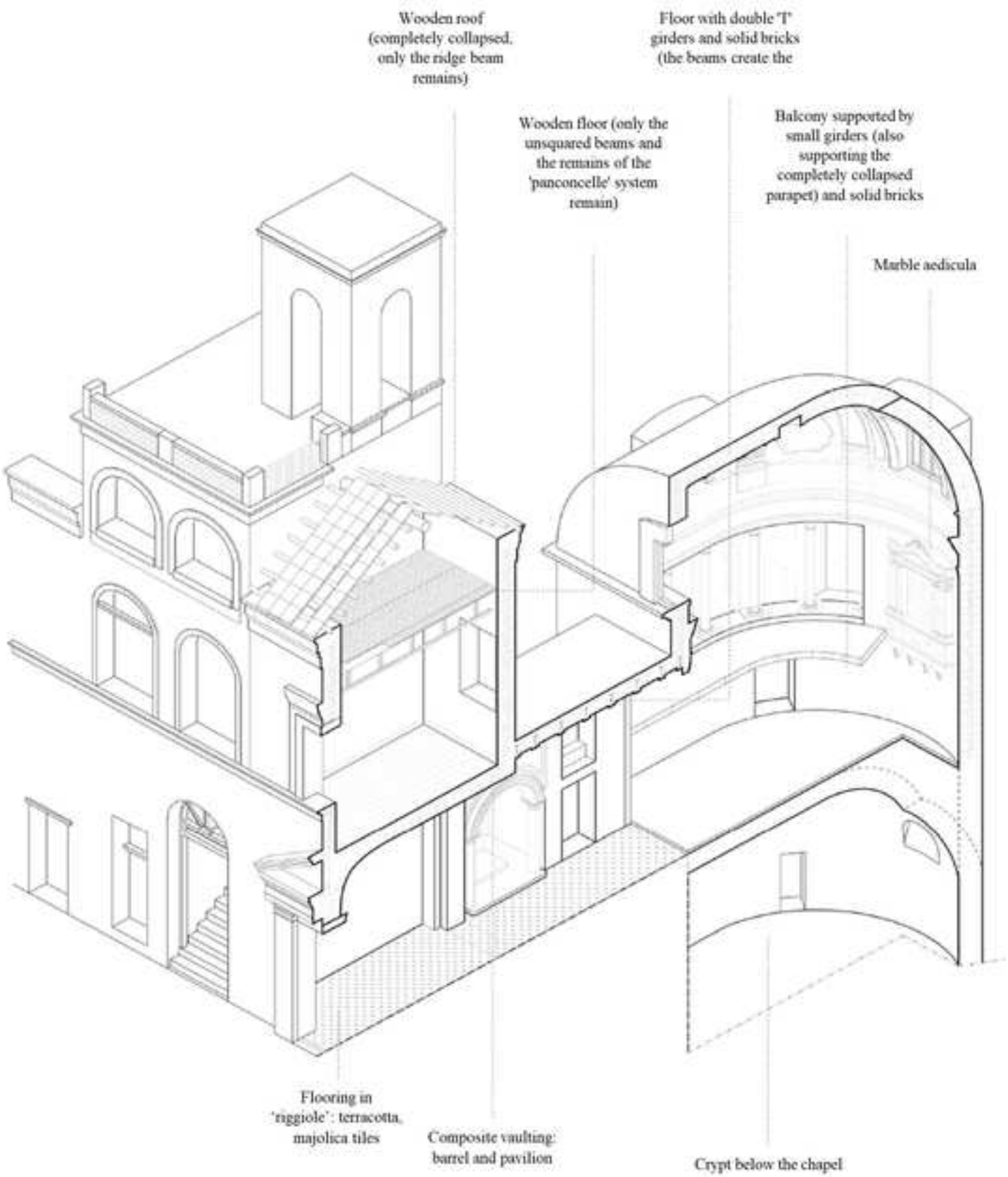

Figure

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Figure

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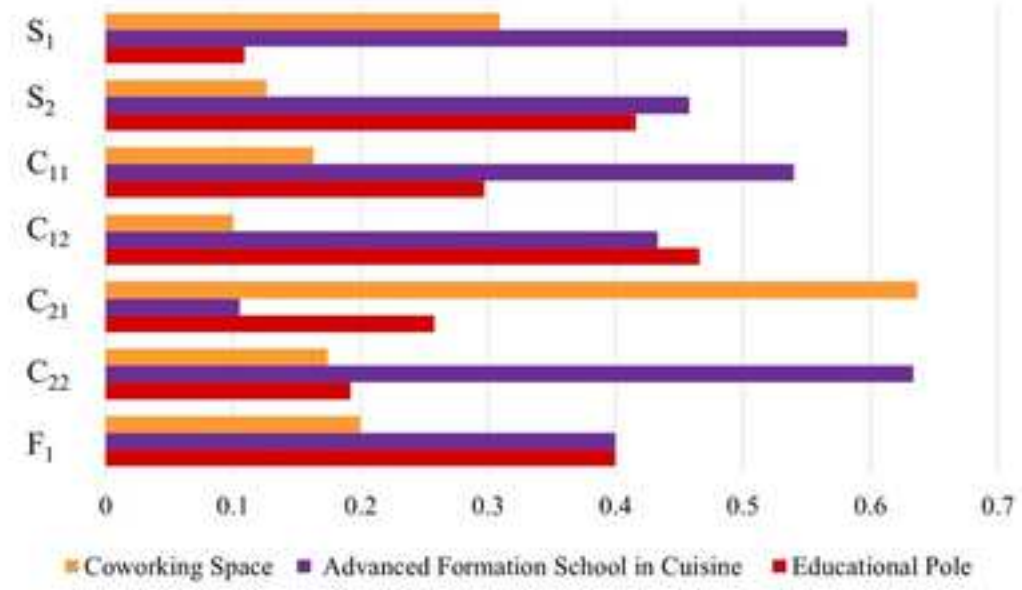

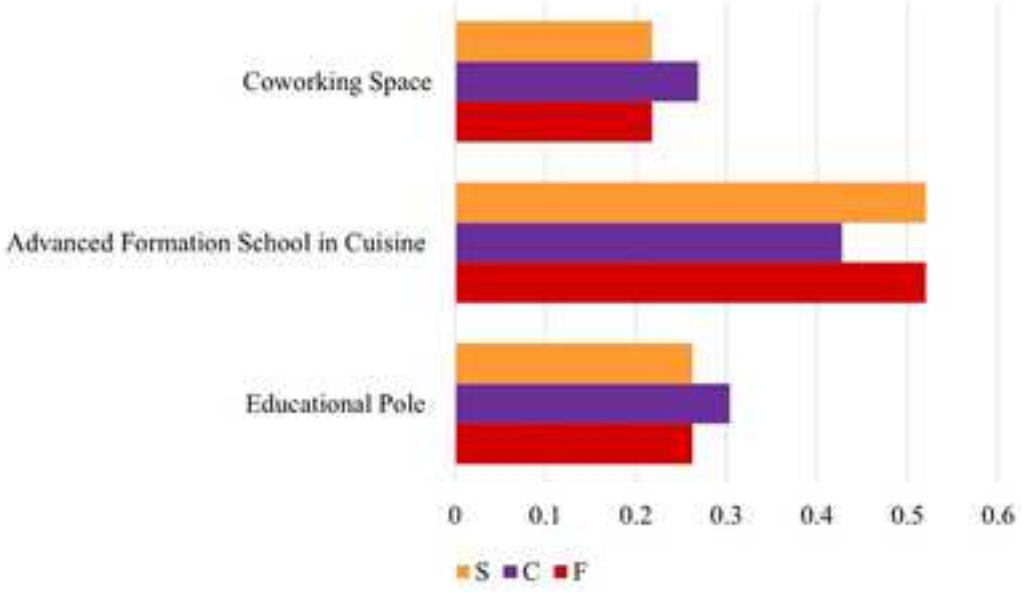

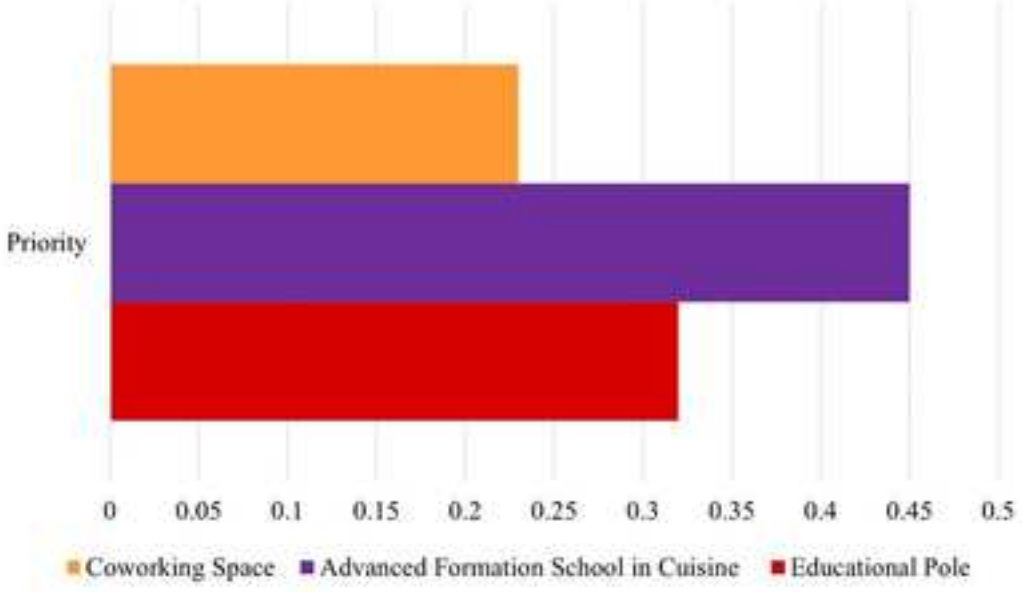

Caption for figures

Figure 1. Architectural survey of Villa Venusio.

Figure 2. Cross-section of the Villa in which the hypogeum and the Chapel can be appreciated.

Figure 3. Material survey and degradation analysis of the main façade.

Figure 4. Scores of indicators and criteria for each alternative.