Building reuse: multi-criteria assessment for compatible design

Maria Rita Pinto[1] Stefania De Medici[2] Carla Senia[3] Katia Fabbricatti[4] and Pasquale De Toro[5]

[1] University of Naples "Federico II", Department of Architecture, Napoli, Italy. Email: pinto@unina.it
[2] University of Catania, School of Architecture, Syracuse, Italy. Email: sdemedi@unict.it
[3] University of Catania, School of Architecture, Syracuse, Italy. Email: c.senia@tin.it
[4] University of Naples "Federico II", Department of Architecture, Napoli, Italy. Email: katia.fabbricatti@unina.it
[5] University of Naples "Federico II", Department of Architecture, Napoli, Italy. Email: detoro@unina.it

The paper presents the results of a research on the impact of the reuse of heritage building. The aim is to help in selecting the most appropriate design solution among several compatible alternatives. The method integrates AHP and EVAMIX multi-criteria approaches to assess design alternatives capable of maintaining and improving a building's performances while preserving heritage identity. This requires defining the users' needs to be met by the new function assigned to the building and identifying structural and cultural constraints to its transformation.

This assessment should allow designers to choose the best reuse project, achieving an optimum balance between conservation and usability. The selected project should offer flexible technological solutions allowing for reuse reversibility, both in terms of future changes of destination and, if need be, to bring the building back to its initial state. This strategy can generate a process that fosters safeguard and effective management of heritage buildings over time.

Keywords: reuse, cultural heritage, design solution, reversibility, multi-criteria assessment

1 Introduction

Reuse assigns new functions to obsolete buildings by adapting them to the requirements of new activities. Any existing building may have an economic, social, cultural, functional, or environmental value that makes it worth reusing. It is a strategy to preserve, safeguard and enhance buildings and the neighbourhoods they stand in [3, 19]. An appropriate approach to adaptive reuse reinforces and maximises people's understanding of the cultural significance of buildings, revitalizes their historical significance, rediscovers their history, and preserves their structural characteristics [59]. Adaptive reuse prolongs the "from cradle-to-grave" life of a building by retaining all or most of its structure, finishing and decorations [34].

There are different benefits to reusing existing buildings. The location value and quality of old buildings often make them preferable to new ones [5]. This is partly explained by the high quality of the construction of old buildings (including characteristics such as thick walls, windows that can be opened, high ceilings etc., not found in new buildings), by craftsmanship and materials which cannot be duplicated in today's market, and by their reliance on natural light and ventilation, which make them natural energy savers [23]. Building reuse also produces socio-economic benefits by conserving resources and employing proportionally greater numbers of workers. Furthermore, adaptation always requires testing of new techniques and materials, and calls for a skilled workforce; it thus constitutes an economic challenge for the building industry [43]. The literature on the subject highlights the potential large-scale positive effects of adaptive reuse, as it can increase property value and promote the social and economic development of urban areas [50].

In this regard, reuse carries a strategic role in sustainable development policies. The goal of “sustainable development” links together the idea of transformation and that of conservation, preventing decay and guaranteeing continuity. In this perspective, a building is a “resource” to be safeguarded and its reuse a means of preserving the cultural identity of an area.

In the Western world, adaptive reuse is becoming an increasingly common practice, but transformation of buildings is often of poor quality due to the absence of clear and shared rules. In the adaptive reuse business, developers face many legislative, financial, and physical obstacles. Regulations concerning building safety, comfort, and usability - usually conceived for new buildings - discourage rehabilitation [21, 26]. Thus, many old buildings that would be well worth preserving remain unused and, conversely, old buildings that are reused are excessively transformed, the requirements of conservation taking a back seat to those of profit [3, 37]. More specifically, in the case of buildings with cultural value, we see the following opposite approaches: either heritage conservation concerns prevail over user needs, or the adaptations required by the new function cause substantial changes, altering the identity of the buildings. The lack of a reflection on ways to harmonize the original building – the way it functions, the material it is made of, and the stories it has to tell – with the functional demands of the new activity it is to house often lead renovators to follow one or the other of these two approaches. There are many cases of reuses that have undermined the integrity of a building, and just as many that do not take proper account of the needs of the users. The objective of guaranteeing certain use requirements may lead to extensive demolition, in the worst cases involving the entire interior of a building, retaining only its shell to allow the implementation of a project regarding the building as a mere container. Conversely, concern for the safeguard of historic buildings has led to the implementation of projects that do not create adequate conditions for housing the new activities planned in these buildings and thus lead to their rapid obsolescence.

To date, scientific research in the field of reuse has developed methods for assessing the compatibility of new functions with the morphological and dimensional characteristics of existing buildings and with the goals of urban development and revitalisation to be pursued [e.g. 31, 56, 24]. The purpose of these methods is to determine the most compatible use, in the programming stage and the preliminary design. However, a method for making detailed design choices to minimize transformations - in a perspective of preservation, safeguard and enhancement of existing heritage – has not yet been developed.

In the programming stage, the evaluation of compatibility allows the planners to identify the most appropriate use for a building, a use that will bring benefits such as the improvement of the building’s market, use, environmental, cultural and social value [50, 56]. In the preliminary design stage, such methods encourage reuses making the most of the building’s potential [14].

However, even a compatible use requires the adaptation of some of the building’s elements and spaces. The need to split or join rooms, to improve the building’s performance in terms of light, ventilation, room temperature, etc., and to improve access by adding lifts, staircases, etc. can lead to transformations of the building’s plan and inner layout, and of its cultural, structural, and environmental features, to the detriment of the conservation of cultural heritage value.

The present paper sets forth a comprehensive decision-making method to control and predict the results of reuse in detailed design. The compatibility evaluation method outlined here allows the choice of a suitable solution among several technological and/or functional design hypotheses in order to achieve effective preservation of historical buildings.

2 Review of relevant literature

2.1 The issue of building reuse: preservation and adaptation

In the western world, the reuse of town areas and buildings is an issue that involves citizens, professionals, businesses and public institutions. Over the years, the relative percentage of built heritage rehabilitation actions versus ex novo building has considerably increased in the construction market [e.g. 5, 7, 11, 13, 25, 32, 8, 51, 57, 9]. For example, in Italy a report published in 2014 by the Centre for Social and Economic Research on the Construction Market (CRESME) shows that in the construction industry, from 2006 to 2013, investments for maintenance and recovery have considerably grown (from 56% to 67%) and investments in new construction have decreased (from 44% to 33%).

The practice of reuse as a programmatic activity began to spread in the 1970s, as a result of the abandonment of industrial areas – most notably in Britain, France, Germany and the United States – and the simultaneous urbanization and saturation of cities. This reuse also concerns cultural heritage insofar as it constitutes a strategy to ensure its conservation.

Since the 1970s, several guidelines for reuse have been set forth, in the form of conventions, recommendations or declarations, with the aim of converting theories of building reuse into design practice. Specifically, the widespread reuse of town centres required the adaptation of ancient buildings to the needs of the tertiary sector.

In 1975, the European Charter of Architectural Heritage declared that heritage buildings are “a capital of irreplaceable spiritual, cultural, social and economic value” and stressed that their use saves community resources (Art. 3); in this perspective, architectural heritage is an economic resource. The Charter defines “integrated conservation” as a joint result of “the application of sensitive restoration techniques and the correct choice of appropriate functions” (Art. 7). This requires planners to take into account both the cultural value and the use value of buildings in restoration projects.

During those same years, in the United States the study Adaptive Use: a survey of construction costs (1976), performed by the Advisory Council on Historic Preservation, points out that between the late 1960s and early 1970s, due to growing concern for the natural environment, building reuse took on a new meaning by extending the principles of safeguard from nature to the man-made environment. The study recognized that in urban renewal the rehabilitation of decayed buildings has a socio-economic impact that is less devastating than demolition and reconstruction. The ACHP study also argued that, although adaptive use is not always cheaper than new construction, its cost is not much higher.

In 1985, the Granada Convention for the Protection of the Architectural Heritage of Europe sanctioned the adoption of integrated conservation policies by the member states of the Council of Europe. The Convention encourages the adaptation of old buildings – when appropriate – to new uses to meet the needs of contemporary life. Only two years later, the Washington Charter for the Conservation of Historic Towns and Urban Areas proposed a new approach to building reuse. Article 8 affirms that “new functions and activities should be compatible with the character of the historic town or urban area; adaptation of these areas to contemporary life requires the careful installation or improvement of public service facilities”. For the first time, the Washington Charter stated that building reuse should be compatible with the identity of architectural heritage, and that conservation concerns should prevail over the requirements of the new use.

In 1987, a most innovative contribution to the topic of architectural reuse was provided by the Pontifical Central Commission for Sacred Art in Italy with its issuing of the Charter for the Reuse of Ancient Ecclesiastical Buildings. In its declarations (Paragraphs 1-3), this Charter states that continuous maintenance of ancient buildings ensures their preservation and transmittance to future generations; “maintenance is guaranteed when the building acquires a functional purpose, which […] must never conflict with the character and meaning of the building itself, especially if the aforesaid is of religious or ecclesiastic origin”. The document emphasizes that the guarantee of compatible uses for religious buildings requires joint actions of the State, local governments and ecclesiastical institutions, in order to define coherent programs.

In 1992, the Charter for the Conservation of Places of Cultural Heritage Value (ICOMOS New Zealand) set out principles to drive the conservation of cultural heritage in the spirit of the Venice Charter for the Conservation and Restoration of Monuments and Sites (1964). The New Zealand Charter stresses that “the conservation of a place of cultural heritage value is usually facilitated by its serving a socially, culturally or economically useful purpose” and that adaptations may be acceptable when they are essential to continued use.

In the same year, the Preservation Charter for the Historic Towns and Areas of the United States of America (US ICOMOS, 1992) extended existing guidelines for determining new uses while preserving urban sectors in a coherent and thorough manner. This Charter recommends that “new functions and activities proposed to take place within the historic town or district should be compatible with the overall character of the place. When historic places and buildings are adapted for contemporary use, it is essential that the design, installation, and maintenance of supporting public utilities and facilities be sensitive to the special character of the place”.

The need for the choice of new appropriate uses, compatible with the original layout and significance of heritage buildings and places, is emphasized and reaffirmed in the Charters of the twenty-first century (e.g., in the “Principles for Conservation and Restoration of the Built Heritage”, ratified in the Charter of Krakow, 2000, and in the Australia ICOMOS Burra Charter for Places of Cultural Significance, 2013).

Starting from 2008, the introduction of the principle of “sustainable use” for heritage buildings and sites has opened new scenarios in the field of adaptive reuse. The UNESCO Operational Guidelines for the Implementation of the World Heritage Convention (2008) indicate that sustainability goals should not threaten heritage preservation. Indeed, Article 119 declare that “World Heritage properties may support a variety of ongoing and proposed uses that are ecologically and culturally sustainable. The State Party and partners must ensure that such sustainable use does not adversely impact the outstanding universal value, integrity and/or authenticity of the property. Furthermore, any uses should be ecologically and culturally sustainable. For some properties, human use would not be appropriate". In 2015, the updated UNESCO Operational Guidelines for the Implementation of the World Heritage Convention point out that the reuse of heritage properties "may contribute to the quality of life of the communities concerned". This text introduces, as a further innovation, the role of legislation, policies and strategies affecting World Heritage properties in promoting and encouraging "the active participation of the communities and stakeholders concerned with the property as necessary conditions to its sustainable protection, conservation, management and presentation".

The contents of these charters, conventions, recommendations and declarations reflect the evolution of the approach to building reuse as an outcome of the international scientific debate.

Many researchers who have addressed the topic of building reuse consider a historic building as a resource whose values must be protected and enhanced. During the 1960s and 1970s, growing concern for the environment led the scientific community to start to discuss the issue of adaptive building reuse, widely regarded as a sustainable strategy for reducing the use and transportation of material, energy consumption and pollution by increasing buildings' life-cycle [12, 52, 53, 1, 33, 17]. However, the central concern of the scientific literature of this period is the search for a balance between conservation goals and the needs of transformation. In the case of heritage buildings, the choice of a new use entails a decision-making process aimed at preserving their cultural significance [36]. The practice of adaptive reuse requires architects to get in touch with the past, trying to understand how the building met its original users' needs and reading into ancient design choices before proceeding with renovation; in the words of Philippe Robert, "working on an existing building means coming to terms with it; such work involves juggling constraints additional to those arising from the program and from building regulations" [43, p. 4]. For instance, monumental, public and industrial buildings have the peculiarity of having especially large surfaces and room volumes, whose shape was dictated by symbolic requirements as well as usability and comfort. These features can be obtained with specific materials and construction techniques. Dimensions, proportions, and relationships between elements, as well as materials and construction techniques, determine the identity of a building and thus constitute constraints to its transformation.

To redesign a heritage building for new uses, knowledge of its history and past uses is critically important. A careful identification of exterior and interior architectural elements is needed in order to define the building's identity and assess the impact of the changes required by the new function. According to Murtagh and Nelson, architectural integrity rests on several factors, such as style, workmanship, setting or location, materials, shapes, construction techniques, building type or function, and continuity [38, 39]. The "intactness of the building", its architectural integrity, implies the preservation of its plan, structural system, materials, finishes, and architectural features [2]. These elements should be incorporated as both constraints and resources in the new design. They act "as a stimulus to the imagination; they enable architectural solutions to be developed which would never have been invented from scratch" [43, p. 4].

The adaptation to new requirements imposes transformations to accommodate new activities in the building. Such activities bring with them new requirements in terms of usability, comfort, security and management, and are organized according to a new pattern of relationships.

Conservation goals are not restricted to safeguarding the building's exterior appearance, but are also taken on to spaces and interior elements. According to Francis Ching, interior spaces are defined by the combination of load-bearing elements and enclosures (floors, ceilings, walls, windows, doorways and stairways) [15]. These elements have both visual and functional purposes. Materials, construction and technology contribute to defining the building's identity [1]. L.H. Nelson considers that perceiving the character of interior spaces can be more difficult than dealing with the exterior, "because so much of the exterior can be seen at one time and it is possible to grasp its essential character rather quickly. To understand the interior character, it is necessary to move through the spaces one at a time" [39, p. 2]. According to Henry Ward Jandl, the interior of a building can be more important than its exterior in conveying the building's history and development over time, and is strictly related to the building's former function [30]. The visual qualities of the interior depend on the building's plan (the sequence of rooms and the passages from one to the other), spaces (rooms and volumes), individual architectural features, finishes and the materials that make up the walls, floors and ceilings. Therefore, these elements should be preserved in order to maintain the identity of heritage buildings [39]. Secondary spaces, often perceived as less important than the main rooms to the visual character of the building, can also be important elements of a building's identity, for aesthetical considerations or because of the historical importance of events that transpired in them.

The wish to protect the identity of a building induces planners to estimate the quantity and the import of the transformations required by each function in order to come up with the most compatible solution. Nevertheless, the choice of the new function must also take into account goals of economic and social enhancement, notably in terms of the effects of the reuse on the urban environment. Some researches have explored this issue, introducing the socioeconomic impact of the reuse project among preliminary assessment criteria. In 2007, the Architectural Institute of Japan defined a set of "Guidelines for building assessment, preservation and utilization" based on five criteria: historical value, cultural and artistic value, technological value, scenic/contextual value and environmental effects, and social value. According to Wang and Zeng, decision-making for reuse should simultaneously strive to preserve the original values of buildings and develop their environment and society.

The compatibility between a historic building and its new function should also be such in cultural terms, i.e., the symbolic value of the building should be preserved. Reuse generates a new identity for the building, arising from the encounter between the building's original features and the new use it is put to. Even when the new function is compatible with the original one, the design choices may still determine deep transformations of the building. Indeed, technical and architectural solutions do not always lead to positive results in terms of conservation (roofing of courtyards, partitioning of interior spaces, changing of the size of windows or replacement of window frames, removal of elements or materials, etc.). A building's character may be irreversibly damaged or altered by inappropriate transformations [39].

To protect and increase the intrinsic values of the reused building, it is therefore essential to perform an analysis of its aesthetic, spiritual, social, historical and symbolic values, as well as a survey of its technical structure, materials, residual performance and degree of preservation, as part of the decision-making process [59, 41]. The purpose of this investigation is to define the building's identity and its "constraints to transformation" [35, 58]. In order to achieve an effective preservation of historical buildings, the compatibility between buildings' original elements and the planned transformations should be evaluated both in preliminary design and in detailed design.

The compatibility between existing buildings and the new uses planned for them affects the cost of adaptation works. For any given project this cost will vary with the amount of work needed to adapt the building to the new activities; the more the project is compatible, the less it requires transformations. In reuse projects, the main costs are installations, because heritage buildings are usually not equipped with mechanical and electrical systems meeting present-day requirements [50, 48, 42, 21]. Thus, minimizing the transformation of the building increases the feasibility of its reuse, both in terms of cultural heritage protection and in terms of cost effectiveness. Use compatibility increases if adaptations to meet use requirements decrease. According to this principle, compatibility assessments for reuse must be based on an analysis of the existing performance that the building can provide with regard to the needs of the new function.

Performance-based building design is a key to the assessment of rehabilitation plans. It is "the practice of thinking and working in terms of ends rather than means. It is concerned with what a building or building product is required to do, and not with prescribing how it is to be constructed" [27, p. 4]. It evaluates a building's quality, transforming the relevant user requirements into performance requirements and quantitative performance criteria. By using reliable evaluation tools, it assesses whether proposed design solutions meet the stated criteria at a satisfactory level, through the "[...] quantification of the level of performance which a building material, assembly, system, component, design factor, or construction method must satisfy in order that the building meet the all goals established by society and the client" [4, p. 19]. In a performance-based approach (PBB), the focus of all decisions is on the required performance-in-use and on the evaluation and testing of building assets.

2.2 Multi-Criteria Decision Aid (MCDA) methods applied to reuse process

Multi-criteria evaluation methods can address reuse to minimise transformations and choose design solutions compatible with a building's characteristics. Multi-criteria analysis is a useful tool to evaluate different alternative options in the field of cultural heritage preservation. Many types of multi-criteria methods were developed over the last several decades [28] and tested in real-life cases (including cases of building reuse) in different sectors to support decision-making processes [18].

In the literature, we can find several examples of the application of Multi-Criteria Decision Aid (MCDA) methods [28] for the preservation and reuse of cultural heritage [22].

One of the aims of decision-making processes is to identify the consequences of different actions before they are implemented (ex-ante evaluation). In this perspective, "multi-criteria analyses" are useful tools for evaluating different options in order to determine and rank alternatives. Therefore, some multi-criteria evaluation methods have been developed that can be interpreted as "decision support systems": they do not automatically offer a choice but rather provide an aid to decision-makers faced with complex problems, characterized by a certain degree of uncertainty and information of different nature (quantitative or qualitative).

In general, the application of a multi-criteria evaluation method is articulated in several phases.

First, the planners determine the “objectives” to be pursued.

Second, when the objectives are defined, they determine alternative ways to pursue these objectives. These alternatives must be defined in detail, otherwise no comparison and identification of a preferable solution will be possible.

Third, a set of evaluation “criteria” is drawn up and these criteria are used for a comparative assessment of the alternatives. These criteria must be such as to make the assessment possible, using quantitative or qualitative information related to suitable “indicators”. In different approaches, evaluation criteria have different relative importance and are hence weighted differently.

Fourth, the criteria are applied and this yields a “ranking” of the alternatives.

Finally, a sensitivity analysis is carried out.

To support decisional processes, a “decision tree” (i.e. a hierarchical framework) is often built to highlight relationships between objectives and criteria. In the case of decision-making processes affecting cultural heritage, protection objectives take on a primary role in the evaluation of possible actions. It is also possible to consider “integration” (and not overlapping) of different methods.

In this perspective, a key problem is that of the prior identification of the most suitable evaluation methods for the decision problem at hand. To facilitate the selection of the appropriate method for a specific decision-making situation, a list of quality criteria was developed in De Montis et al. [18], which can be used to reveal strengths and weaknesses of MCDA methods with respect to three main aspects: 1) operational components of MCDA methods; 2) applicability of MCDA methods in the user context; 3) applicability of MCDA methods considering the problem structure.

Another research reviews the main works available in the literature concerning MCDA applications in cultural heritage [22], pointing out that in the field of application “reuse of historic buildings” an elementary method, viz., the weighted sum, has often been used [24]. As an alternative approach, Ferretti et al. propose the use of Multi-Attribute Value Theory (MAVT), a kind of Multicriteria Analysis that can be used with a finite and discrete number of alternatives. They tested this approach in the reuse of a group of historic industrial buildings located in the metropolitan area of Turin, Italy [22]. In this case study, the authors evaluated different alternatives on the basis of the performance of buildings for tourism purposes, considering five criteria: 1) quality of the context; 2) presence of economic activities; 3) flexibility of the building; 4) pedestrian accessibility; 5) preservation. The evaluation criteria were chosen according to the objectives, even though these were conflicting. In the construction of the value function, the MACBETH technique [6] was used, as it is able to take into account qualitative information (i.e. judgments about differences in attractiveness), avoiding having to express judgments by means of a numerical scale. Weights were assigned through the “swing method” [16]. In order to test the robustness of the results, a sensitivity analysis was conducted.

The integration of Geographic Information Systems into multi-criteria evaluation methods has resulted in the so-called Multi-Criteria Spatial Decision Support Systems (MC-SDSS), used to define enhancements strategies for cultural heritage, among other things. An important experiment employing this approach was conducted on a series of 13 castles in the Valle D'Aosta Region in northern Italy [40]. In this case-study, the spatial characteristics of each alternative of development were assessed simultaneously with an evaluation of their multi-dimensional impacts. The decision problem was categorized under several headings, all characterized as "wares": hard-ware (physical infrastructures), eco-ware (environmental impacts), soft-ware (logistics and informalities), fin-ware (financial arrangements and funding), org-ware (institutional and organizational setting), civic-ware (social capital). The evaluation method employed was the Analytic Network Process (ANP) [46] in which each "ware" is a cluster and the elements of the decision problem were grouped in the various clusters to assess opportunities and risks. For the identification of the main elements and the structuring of the problem, a SWOT analysis was used. In this case, too, a sensitivity analysis of the results was carried out.

In the reuse of two historic buildings in Taiwan [56] selected as case studies, the relevant evaluation criteria were identified by means of a Finite Difference Method (FDM) and the results was used to build an Analytic Hierarchy Process model [44], thereby capturing the interdependencies between the different criteria. Moreover, the authors of the study conducted some interviews with experts in order to identify criteria by means of a fuzzy Delphi method [29]. The proposed method comprises two phases: 1) construction of a framework for the initial screening of reuse alternatives; 2) an ANP-based approach for the final selection for reuse. The identified criteria are the following: cultural aspect; economic aspect; architectural aspect; environmental aspect; social aspect; continuity aspect. The weights assigned to each criterion were attributes in a pair-wise comparison using the 9 points Saaty scale, as in the case of the AHP approach [44].

Other examples of the use of multi-criteria decision aid (MCDA) methods in the literature include the PROMETHEE method for the renovation of the masonry of historic buildings in Algeria [47]; the revisiting of the Linear Additive Model for the grading of heritage sites in Calcutta, India [20]; the use of the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [55] – or of AHP [49] – to enhance the energy performance of existing buildings by applying retrofitting solutions.

3 Research approach: assessment method of detailed design for the reuse of cultural heritage

The aim of the method proposed here is to assess detailed design solutions for the reuse of cultural heritage applying multi-criteria evaluation tools in order to select the most appropriate transformation. Technical solutions should improve a building's performances while preserving its identity. This requires both determining future users' needs and identifying the "constraints to building transformation" posed by a building's cultural value.

The assessment should lead to a comparison of user requirements and performance requirements for each solution and make sure that the solution complies with constraints to transformation. Therefore, it is necessary to define control parameters for detailed design solutions, related both to the requirements of the new function and to the building's characteristics.

The feasibility of performance improvement should be evaluated on the basis of the constraints to transformation. These constraints influence the building's flexibility [31].

The method proposed here singles out the most adequate design solution for building reuse in four stages:

- Stage 1: determining the needs of future users;
- Stage 2: identifying the constraints to the transformation of the building determined by its historical and artistic characteristics;
- Stage 3: design of alternative solutions for the recovery of the building;
- Stage 4: evaluation of alternative design solutions in relation to the needs of preservation and adaptation to the new use.

In the evaluation phase, each user requirement is hierarchically ranked according to its role in preservation (e.g., reversibility has a high weight) and its importance for the activities that are to take place in the renovated building. For each design solution, the satisfaction of each requirement can be assessed through a set of indicators defined according to the aims of building preservation and adaptation to new use.

In the present study, the assessment has been conducted through the integration of two multi-criteria methods: Analytic Hierarchy Process (AHP) and EVAMIX. In particular, AHP, developed by Thomas Lorie Saaty at the University of Pittsburgh, structures the decisional process in a hierarchical form.

From a procedural point of view, this method consists of three steps [44, 45]:

1) the construction of a suitable hierarchy;

2) the definition of priorities between elements of the hierarchy by means of pairwise comparisons; and

3) the verification of the logical consistency of these pairwise comparisons.

Step 1 is based on findings that indicate how - when information is processed - the human mind recognises objects and concepts and identifies relations existing between them. As the human mind simultaneously perceives all the factors affected by an action and their connections, AHP helps to break down complex systems into simple structures. This simplification is made possible by a logical process that aims at the construction of suitable hierarchies.

The simplest model of hierarchy consists of three levels: the first level is that of the main objective (called "goal") of the decision-making problem; the second and third levels include criteria and alternatives. However, it is possible to develop more complex hierarchies (i.e., with more levels) including a certain number of sub-criteria. This means that factors affecting the decision are organized in gradual steps from the general, in the upper level of the hierarchy, to the particular, in the lower levels.

In the AHP method, pairwise comparisons (i.e., comparing elements in pairs with respect to a given criterion) are used to establish priorities (or weights) among elements of the same hierarchical level (step2). These elements are compared in pairs with respect to the corresponding elements at the next higher level. This comparison results in a matrix of pairwise comparisons.

To represent the relative importance of one element with respect to another, a suitable evaluation scale called "Saaty's scale", is introduced. It defines and explains the values 1 to 9 assigned to judgments in comparing pairs of elements in each level with respect to a criterion in the next higher level.

Pairwise comparisons are organised in adequate matrices, as each of them are relative "vectors of priorities" (expressed on a 0-1 scale) and, when aggregated, provide a complete ranking of alternatives. For pairwise comparisons, it is possible to use quantitative and qualitative data. As regards the third stage, it should be noticed that when comparing elements a certain degree of inconsistency can arise: in the AHP approach, a "consistency ratio" for each matrix of pairwise comparisons is computed to check the degree of inconsistency. A consistency ratio of 0.10 or less is considered acceptable; if this ratio is more than 0.10, it is necessary to reformulate the judgments using new pairwise comparisons.

The EVAMIX method, developed by Henk Voogd at the University of Groningen, structures an evaluation matrix for quantitative and qualitative elements. From a procedural point of view, it consists of five steps [54]:

1) distinction between ordinal and cardinal criteria;

2) calculation of dominance scores for all ordinal and cardinal criteria;

3) calculation of standardised dominance scores for all ordinal and cardinal criteria;

4) calculation of overall dominance scores; and

5) calculation of appraisal scores.

The first step is the construction of an evaluation matrix E, which is an m-by-n matrix characterised by m evaluation criteria and n alternative options. Its components are qualitative or quantitative entries, which express in rows the performance of each alternative with respect to a certain criterion.

The set of criteria is divided into two subsets that are designated as O and C, where O is the set of ordinal (qualitative) criteria and C is the set of cardinal (quantitative) criteria. They yield two distinct evaluation matrices: EO (ordinal criteria/alternative options) and EC (cardinal criteria/alternative options).

Thus, the differences between alternatives can be expressed by means of two dominance measures, the first based on ordinal criteria, the second on cardinal criteria. In particular, to construct the cardinal dominance score, the components of EC are standardised by a common unit; this allows all the quantitative criteria to be expressed on a scale from 0 to 1. Weights can be assigned to both quantitative and qualitative criteria.

In the second step, it is possible to calculate "dominance scores" for all ordinal and cardinal criteria; these scores reflect the degree to which one option outranks another.

Subsequently (Step 3), the dominance scores are standardised into the same measurement unit to make them comparable, resulting in two "standardised dominance measures" for all ordinal and cardinal criteria.

Then (Step 4) an "overall dominance measure" for each pair of alternatives is calculated - giving the degree in which one option dominates over another option.

Finally, (Step 5), starting from the overall dominance measure, “appraisal scores” for each option are calculated: the result is a complete ranking of options, where the optimal option is the one with the highest appraisal score.

In the present study, AHP has been used to assign weights to “criteria” and “sub-criteria” (the building’s systems, classes of need, classes of user requirements, user requirements), and EVAMIX has been used for deducing a ranking between the alternatives, characterised by qualitative and quantitative information.

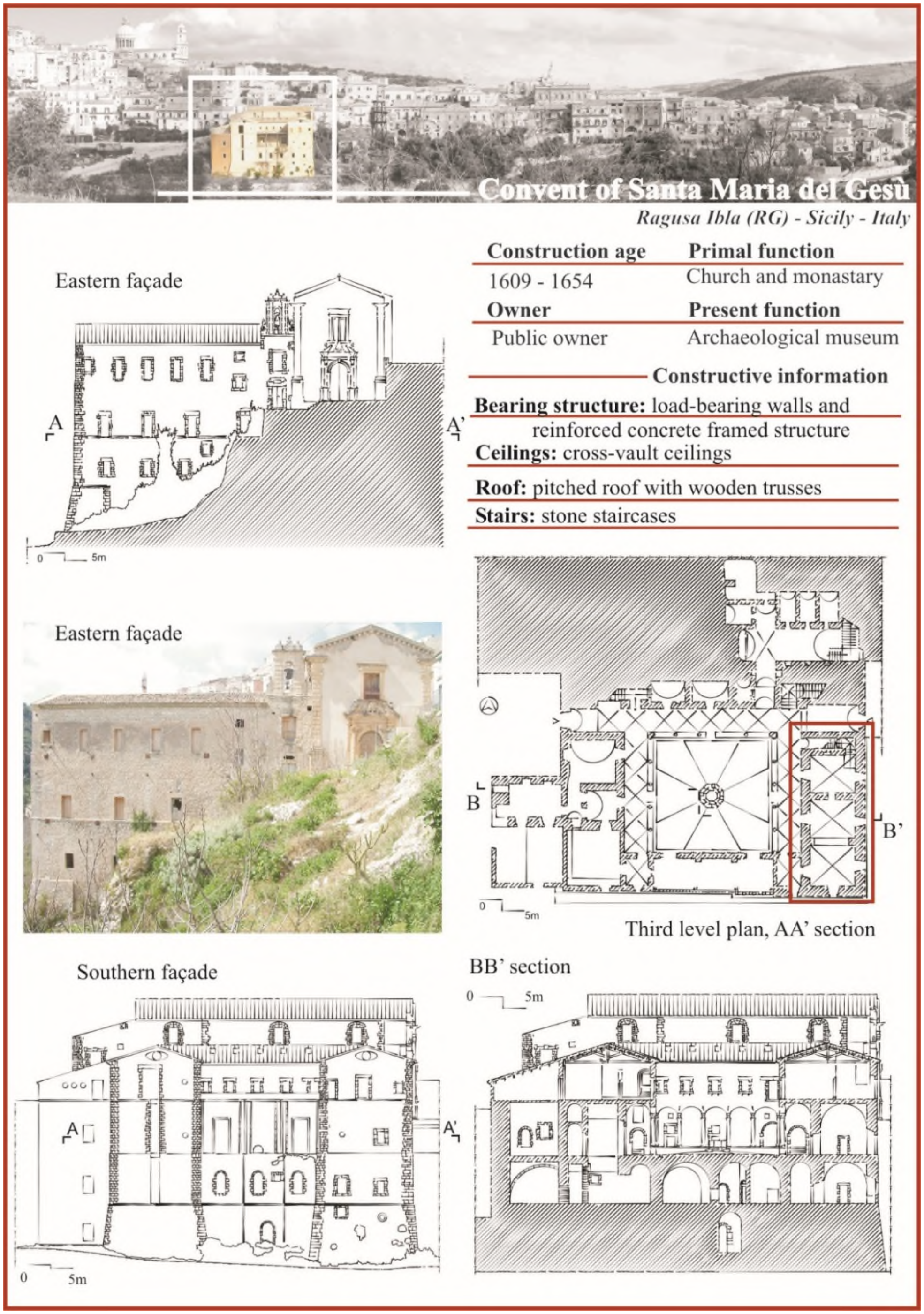
4 Case study and experimental data

The method has been applied to the Convent of Santa Maria del Gesù (Figure 1), an unused building of important cultural value in the historic centre of Ragusa Ibla, in Sicily. The Convent stands on a natural terrace. Its location has influenced the dimensions of the building, which is six floors and approximately 21 m high. Built between 1609 and 1654, the Convent has a central square cloister. The single-nave church lies on the north side of the building, on a higher level than the cloister. The load-bearing walls of the building are made of coursed ashlars. The pitched roof is supported by wooden trusses.

In 1866, the holy orders were abolished and their properties assigned to towns. Consequently, the use of the Convent changed repeatedly; it was used as the city hall, the post office and the primary school. On March 1970, following the collapse of its southern and western façades, the Convent was declared unfit for use. In the early 1980s, the Church was closed to the public. The building subsequently underwent two major restorations, viz., the re-roofing of the Church and Convent (1989) and the reconstruction of the south and west sides of the building using a reinforced concrete framed structure with infill brick facing (2005).

In 2002, the city was included in the UNESCO World Heritage List and the Convent indicated as one of 18 city attractions. The city of Ragusa decided to reuse the building as a museum with the intent of fostering local sustainable development and increasing the supply of public services. In particular, the building is intended to house the Hyblaean Archaeological Museum of Ragusa, currently located in a building that does not allow an adequate exhibition of its collections. Despite the fact that this new destination has been chosen to promote the cultural development of the city and its architectural and archaeological heritage, it is still essential to assess the ability of reuse design to protect the Convent’s cultural identity.

The main problems in adapting the church building to the new function assigned to it depend on the design of exhibition spaces. The shape of the spaces, their system of relationships and their finishing determine their cultural identity and therefore call for careful evaluation of alternative design solutions. The rooms to be used as galleries of archaeological artifacts have cross-vault ceilings, are connected in sequence and have apertures on both sides (facing the courtyard and the east façade). Redesigning them for artifact exhibition requires the installation of interior partitions to serve as “display panels” against which the objects can be viewed from different distances, depending on their size and characteristics.



Construction age	Primal function
1609 - 1654	Church and monastary
Owner	**Present function**
Public owner	Archaeological museum

Constructive information

Bearing structure: load-bearing walls and reinforced concrete framed structure

Ceilings: cross-vault ceilings

Roof: pitched roof with wooden trusses

Stairs: stone staircases

Figure 1 Convent of Santa Maria del Gesù: building survey and technical data

In order to test the assessment method, three alternative display panel designs were proposed. Each panel should allow adequate exhibition of archaeological finds and divide room space so as to outline the visitor route.

The reuse of the rooms on the third floor (Figure 1) - characterised by a rhythmic cadencing of the apertures and cross-vault ceilings – needed to respect perceptual-cultural, morphological-dimensional and material-constructive constraints. Notably, the following constraints to transformation were analysed:

- perceptive-cultural constraints, aimed at preserving testimonies of the previous use of the building and the stylistic and artistic criteria that inspired its construction. To conform to these constraints, transformative action had to adhere to the following criteria: recognisability, compatibility and acceptability of transformations, respect for the collective memory of the community, retaining the building's original appearance, and preserving aesthetic connections with the building's surroundings;
- morphological-dimensional constraints, aimed at preserving the geometric and stereometric configuration of the spaces and their reciprocal relations. In order to respect this category of constraints, the renovation had to adhere to the following criteria: protection of shapes, dimensions and proportions of the building and of its parts;
- material-constructional constraints, aimed at preserving the behaviour of the building materials and techniques. In order to respect these constraints, the renovation should adhere to the following criteria: conservation of the material, respect of the building system (by preserving the function of the buildings original feature and their reciprocal relationships), making sure the pre-existing system remains recognizable, and reversibility and durability of transformations.

The compatibility between the above constraints to transformation of the building's spaces and the three alternative display panels for the exhibition of archaeological finds was assessed. The display panel systems examined were the following:

1. System A (Figure 2), a stackable double-sided display panel with a steel bearing structure and polymethacrylate and medium-density fibreboard (MDF) panels. The structure is connected by slip joints and held together by screws and bolts.

2. System B (Figure 3), a stackable single-sided display panel with a steel bearing structure, aluminium accessories and MDF panels. The structure is connected by slip joints held together by screws and bolts.

3. System C (Figure 4), a display panel held by steel cables hooked to an upper rail fixed to the walls and a lower rail built into the floor. The distance between the upper rail and the floor is 2.50m. The structure is connected by slip joints held together by high-tech polymer clamps. System C can be also used as a screening panel.

To choose the preferable solution among the proposed alternatives, the requirements of the display panels and the magnitudes measuring the satisfaction degree for each requirement (performance markers) were specified.

We tested the degree to which each panel met each user requirement, expressing their performances by quantitative and qualitative values. This assessment was performed to control the quality of use for each display panel, as well as the project's results in terms of building preservation.

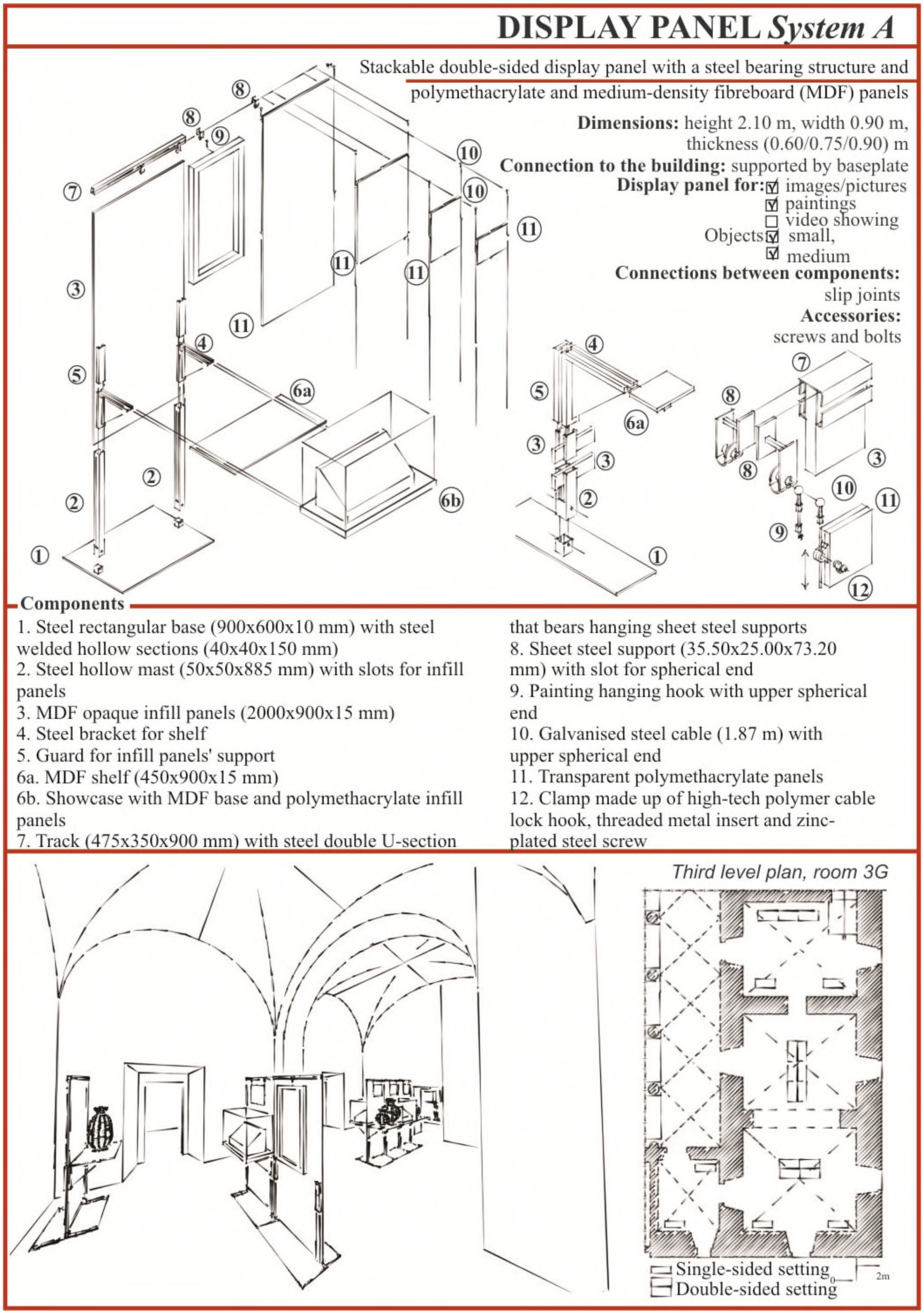
The study referred to the ISO classification of performance standards in buildings (ISO 6241:1984). This classification is based on buildings' user requirements and specifies the requirements of environmental (characteristics of the building's spaces related to their function) and technological systems (characteristics of the building's components related to their function) grouped into seven classes of user needs (UNI/CE 0050). The list of requirements was adapted to include the specific performances required of the display panels and concerns for the preservation of the heritage value of the building.

The study's evaluation of the adequacy of design solutions related to the environmental system regarded to the following classes of user need: aesthetics, usability and manageability (Table 1).

The "aesthetics" class specifies conditions affecting the perception of the building. The display panels should not diminish the visibility of room spaces (user requirements: transparency, dimensional tolerance of the elements) and should be clearly distinguishable from the pre-existing elements of the building (user requirements: ability to recognise materials and technical structures). In relation to these requirements, the three display panels offer similar performances because of their technical structure and materials, which are different from those of the Convent; but only System C allows for the adjusting of the height and size of the screening panel.

The "usability" class of user needs regards the building's use potential. Design solutions should allow easy moving around and through the rooms as well as granting visibility to the exhibits. The option to change the shape and arrangement of the display panels favours flexibility in room-space design. Regarding usability performance requirements, the display panels offer different performances, reflecting differences in shape, dimensions, connection systems and materials. In addition, while high transparency is a positive feature as far as the aesthetics requirement is concerned, in terms of usability it may reduce the surface available for furniture.

The "manageability" class can be defined as a set of conditions for the operation of the building systems. Features under this heading include reversibility of anchorage of the panels in view of their replacement. Anchorage should require minimum loss of material and/or damage to the original building. Regarding this requirement, while Systems A and B do not require anchorage, the panels of System C need to be anchored to the walls and the floor by means of bolts.



DISPLAY PANEL *System A*

Stackable double-sided display panel with a steel bearing structure and polymethacrylate and medium-density fibreboard (MDF) panels

Dimensions: height 2.10 m, width 0.90 m, thickness (0.60/0.75/0.90) m

Connection to the building: supported by baseplate

Display panel for: ☑ images/pictures
☑ paintings
☐ video showing
Objects ☑ small,
☑ medium

Connections between components: slip joints

Accessories: screws and bolts

Components

1. Steel rectangular base (900x600x10 mm) with steel welded hollow sections (40x40x150 mm)
2. Steel hollow mast (50x50x885 mm) with slots for infill panels
3. MDF opaque infill panels (2000x900x15 mm)
4. Steel bracket for shelf
5. Guard for infill panels' support

6a. MDF shelf (450x900x15 mm)

6b. Showcase with MDF base and polymethacrylate infill panels

7. Track (475x350x900 mm) with steel double U-section that bears hanging sheet steel supports
8. Sheet steel support (35.50x25.00x73.20 mm) with slot for spherical end
9. Painting hanging hook with upper spherical end
10. Galvanised steel cable (1.87 m) with upper spherical end
11. Transparent polymethacrylate panels
12. Clamp made up of high-tech polymer cable lock hook, threaded metal insert and zinc-plated steel screw

Third level plan, room 3G

Figure 2 System A: abacus of technical elements, axonometric projection of the display panel and layout of the room

The overall compatibility of the proposed design solutions with the building's technological system was assessed according to the seven UNI/CE classes of user need (Table 2).

The criteria in the "safety" class assess the ability of the display panels to guarantee users' safety and the protection and prevention of risks due to unplanned events as well as standard behaviour. The display panels offer similar safety performances. The only difference observed was in flexural stiffness out of the plane, which reduces the risk of overturning.

The "comfort" class of need refers to hygrothermic, acoustic and visual behaviours. The degree of thermal transmittance and airborne sound insulation are relevant only in the case of floor-to-ceiling display panels. Therefore, for the analysed design solution, these values have not been considered. On the contrary, the degree of sound absorption and the solar absorption coefficient add to the room's comfort, regardless of the display panel's height.

The "usability" class assesses the degree to which the display panels' can be moved and adjusted according to user requirements. In addition, the possibility of providing the panels with additional components (lighting fixtures, shelves, display cases, etc.) was examined. All three display systems are equipped for the anchorage of additional components, but their different adjustment systems (depending on differences in structure, joins, materials, dimensions, weight, etc.) determine differences in the assessment.

The "aesthetics" class assesses the ability of the display panels to maintain their aesthetic characteristics over time. This depends on how easy they are to clean and on regularity of shape. As regards the former, the presence of gaps between the display panels and/or between the panels and the room's surfaces - which might cause dust accumulation – was assessed. As regards the latter, the presence of means to conceal fittings and equipment was assessed. The responses of the three systems to the cleanability requirement, despite differences in shape and anchoring systems, are similar. However, in System C, regularity of shape could be compromised by the lack of means to conceal fittings and equipment.

DISPLAY PANEL *System B*

Stackable single-sided display panel with a steel bearing structure, aluminium accessories and MDF panels

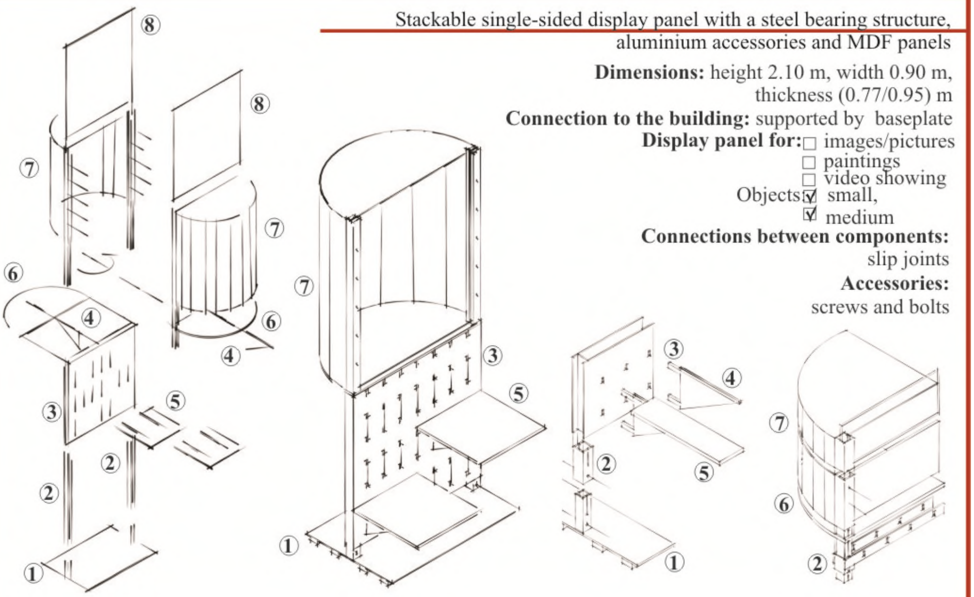
Dimensions: height 2.10 m, width 0.90 m, thickness (0.77/0.95) m

Connection to the building: supported by baseplate

Display panel for: ☐ images/pictures
☐ paintings
☐ video showing
Objects ☑ small,
☑ medium

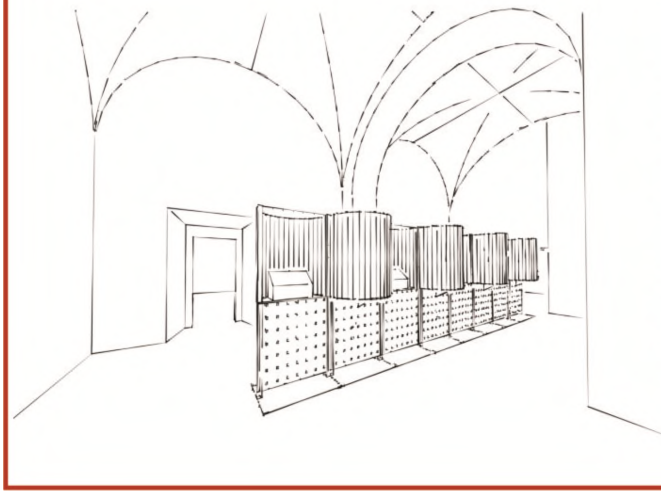
Connections between components: slip joints

Accessories: screws and bolts



Components

1. Steel rectangular base (900x600x10mm) with steel welded hollow sections (40x40x150mm)
2. Steel hollow mast (50x50x885 mm) with slots
3. Opaque infill panel (900x935x60 mm) made up of two perforated sheets steel, plumb welded to two-sheet steel (50x935x5 mm)
4. Aluminium bracket for shelf
5. MDF shelf (450x450x15 mm) for object display
6. MDF half-round shelf (900x45x15 mm) for showcase
7. Showcase made up of steel mast, perforated bent-sheet steel and half-round sheet steel
8. Polymethacrylate infill panel for showcase



Third level plan, room 3G

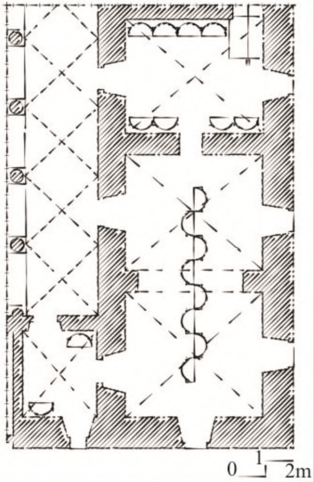


Figure 3 System B: abacus of technical elements, axonometric projection of the display panel and layout of the room

DISPLAY PANEL *System C*

Display panel held by steel cables

Connection to the building:

Upper rail: dry-anchorage by expansion bolts fixed to walls

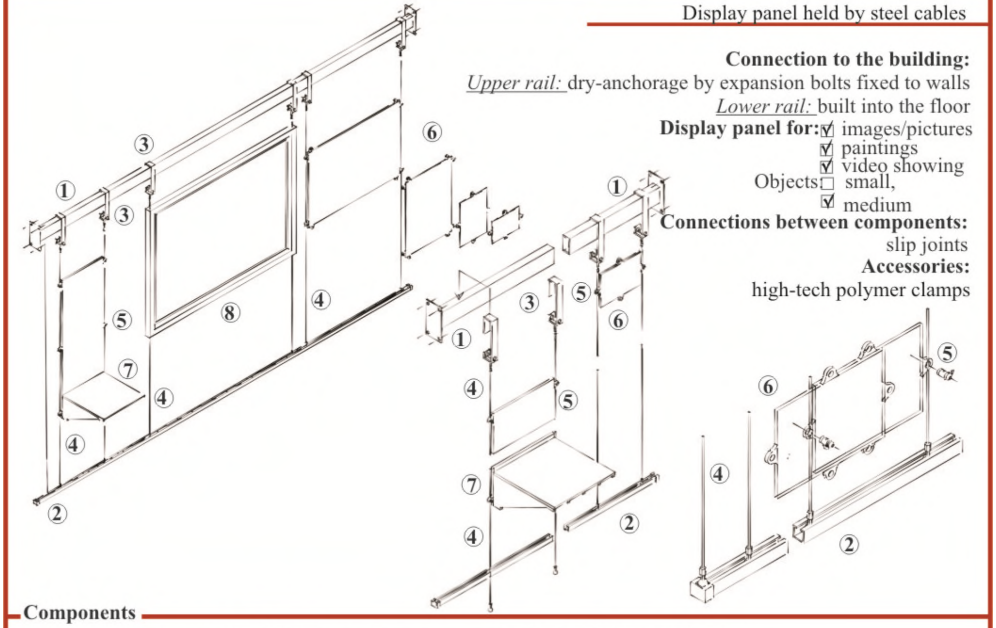
Lower rail: built into the floor

Display panel for: ☑ images/pictures
☑ paintings
☑ video showing

Objects: ☐ small,
☑ medium

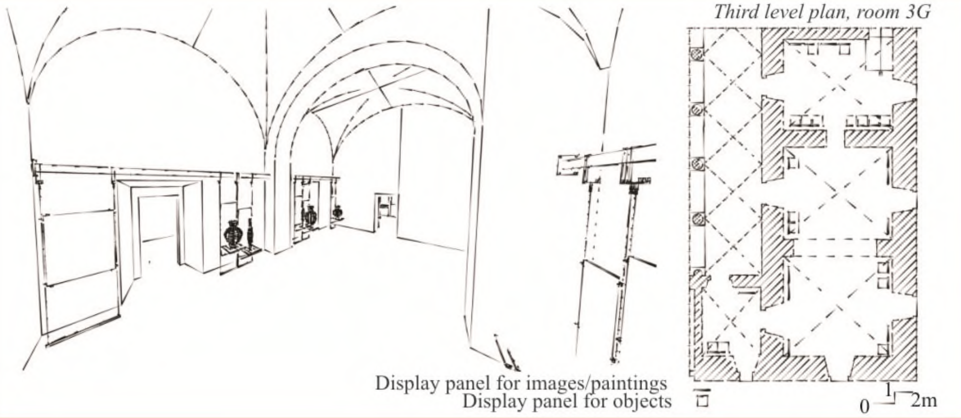
Connections between components:
slip joints

Accessories:
high-tech polymer clamps



Components

1. Upper rail made up of steel hollow sections (100x50x6 mm) welded to sheets steel (220x110x6 mm) to connect the rail to the walls
2. U-cross-section lower rail (31x30x10x4/ 40x30x10x4 mm) built in the floor with housing for the lower spherical ends connected to the steel cables
3. Steel plate U-support (265x62x106x40x6 mm) with a slot for the spherical end of the steel cable
4. Galvanised steel cable (4 mm), with spherical ends and upper nickel-plated metallic stretcher
5. Clamp made up of an element that contains the high-tech polymer cable lock hook, a threaded metal insert and a zinc-plated steel screw
6. Polymethacrylate display frame
7. Polymethacrylate opaque display panel (0.45x1.30x0.015 cm) with shelf
8. White PVC video showing screen (160x120 cm): polycarbonate frame, fixed by two high-tech polymer catches with an internal spring mechanism that makes it easy to adjust the height of the screen. Screen anchored by rubber bands hooked into the frame



Display panel for images/paintings
Display panel for objects

Figure 4. System C: abacus of technical elements, axonometric projection of the display panel and layout of the room

Table 1 Evaluation of the environmental system: the table shows indicators and measures of users requirements for each design solution. The values enclosed in round brackets are weights assigned in the AHP assessment

ENVIRONMENTAL SYSTEM (0.60)								
Classes of Need	**Classes of Users Requirements**	**Users Requirements**	**Indicators**	**Unit of Measure**	**Direction +/–**	**Design solutions**		
						A	**B**	**C**
AESTHETICS (0.225)	Ability to allow the space visibility (0.135)	Transparency (0.068)	Percentage of transparent area	%	+	50	50	69
		Dimensional tolerance (0.068)	Adjustment of the height	cm/m	+	0	0	24,28
	Ability to recognise the element (0.090)	Ability to recognise the materials (0.045)	Use of different technical structures from those of the building	yes-no	yes	yes	yes	yes
		Ability to recognise the technical structures (0.045)	Use of different materials from those of the building	yes-no	yes	yes	yes	yes
USABILITY (0.225)	Flexibility of the element (0.090)	Modularity (0.006)	Use of modular technical devices	yes-no	yes	yes	yes	yes
		Weightlessness (0.012)	Unit weight of the element	Kg/m^2	–	35,00	33,15	5,14
		Easiness to move and manoeuvre (0.019)	Number of anchoring points per unit area	n/m^2	–	0	0	0,8
		Ability to assume different configurations (0.024)	Use of stackable technical devices	yes-no	yes	yes	yes	yes
		Ability to be reallocated (0.015)	Use of anchors and joints that can be reused after disassembly	yes-no	yes	yes	yes	no
		Ability to be recovered (0.014)	Percentage of materials that can be reused without processing	%	+	78,79	14,28	90,62
	Adaptability of the space (0.135)	Ability to be equipped (0.054)	Possibility of double sided arrangement	yes-no	yes	yes	no	yes
		Ability to be furnished (0.081)	Percentage of transparent area	%	–	50	50	69
			Percentage of curved surfaces	%	–	0	44,44	0

MANAGEABILITY (0.150)	Reversibility of the element (0.150)	Reversibility of the anchorage (0.150)	Incidence of the surface of the anchor points that cause loss of material and/or damage to the building	cm^2/m^2	–	0	0	144

Table 2 Evaluation of the technological system: the table shows indicators and measures of users requirements for each design solution. The values enclosed in round brackets are weights assigned in the AHP assessment

TECHNOLOGICAL SYSTEM (0.40)								
Classes of Need	**Classes of Users Requirements**	**Users Requirements**	**Indicators**	**Unit of Measure**	**Direction +/–**	**Design solutions**		
						A	**B**	**C**
SAFETY (0,115)	Stability (0.038)	Behaviour in response to steady and dynamic forces (0.038)	Flexural stiffness out of the plane	f/L	-	0,00217	0,00228	0,03818
	Fire safety (0,038)	Absence of noxious emissions (0,025)	Amount of noxious gases emitted per unit of time	m^3/s	-	0	0	0
		Fire resistance (0.013)	Class of fire resistance	minutes	+	90	90	90
	Safety of users (0.038)	Roughness (0.013)	Presence of roughness in surface finish	yes-no	no	no	no	no
		Ease of use and manoeuvre (0.025)	Presence of elements that can cause injury in use or installation/ dismantling	yes-no	no	no	no	no
COMFORT (0,019)	Thermal and hygrothermal behaviour (0.003)	Thermal insulation (0.001)	Thermal transmittance (*U*-value)	W/m^2K	-	0	0	0
		Ventilation (0.002)	Percentage of the surface that allows ventilation (grids, gaps, etc.)	%	+	0	0,52	79,90
	Acoustic behaviour (0.006)	Acoustic insulation (0.002)	Airborne sound insulation R_w	db	+	0	0	0
		Acoustic absorption (0.004)	Sound absorption	$[m^2]$	-	0,11	0,32	0,56
	Visual behaviour (0.010)	Light absorption (0.003)	Solar absorption coefficient α_s	$0<\alpha_s<1$	-	0,59	0,41	0
		Lighting control (0.007)	Presence of devices for the control of the luminous flux	yes-no	yes	no	no	yes

USABILITY (0,076)	Adaptability of the element (0,025)	Easiness to equip (0,025)	Predispositions for additional components	yes-no	yes	yes	yes	yes
	Adaptability of surface finishing and mechanical devices (0.051)	Easiness to move and manoeuvre (0.020)	Presence of devices for the handling of the element	yes-no	yes	no	no	no
			Element weight per unit area	Kg/m^2	–	35,00	33,15	5,14
		Crush proofing (0.011)	Degree of thermal deformation	h/m/l	l	l	l	h
		Ability to be adjusted (0.020)	Possibility of adjusting the height of the devices for the display of the objects	yes-no	yes	no	yes	yes

The “adaptability” class assesses the capability of the building’s elements to be functionally connected (UNI 8289:1981). The evaluation of the display panels assessed ability to incorporate appliances, dimensional compatibility with the standards of appliance components and dimensional compatibility with technical devices. None of the three systems of display panels, although they are provided with slots for plants, are designed for compatibility with standard appliance components or are adjustable to make room for appliances. Solution B provides the longest cable ducts and the highest number of slots for appliances per square meter.

The “manageability” class assesses maintainability and technical operation. In System C, the difficulty in finding replacements on the market and the complexity of joins and connections with the building’s elements reduce the ability to replace or remove damaged or deteriorated parts of a panel. The ease of assembly of, and availability of replacement for, panel B facilitate repairs, but the shape and the presence of discontinuities in the surfaces might cause dust accumulation and make cleaning more difficult. In this design solution, the curved shape also limits the range of types of usable display equipment (cabinets, shelves, supports for paintings, etc.).

The “environment protection” class assesses environmental impact. The display panels under examination are made of materials that do not cause emissions of pollutants. Therefore, the only environmental impact-related parameter that was evaluated was recyclability, calculated as the percentage of recyclable materials in the panels.

5 Discussion of results

The evaluation process was performed by developing a suitable hierarchy consisting of five levels:

1. The first level is the “goal”, which consists of choosing the design solution that best meets the reuse goals arising from the need for preservation, on the one hand, and adaptation, on the other;

2. The second level is divided into “environmental system” and “technological system”;

3. The third level consists of the “classes of need”;

4. The fourth level includes “classes of user requirements”;

5. “User requirements” were placed at the fifth level.

Once the problem was structured as a hierarchy, it was necessary to assign weights to the elements of the second level (criteria) compared to the goal and then to the elements of the lower levels (sub-criteria) compared to the corresponding higher level. For this purpose, we used the AHP method, carrying out pairwise comparisons between the elements of one hierarchical level and those of the next higher level; the result is the weights shown in Table 1.

In order to rank the alternatives, we first built an “evaluation matrix” (Table 2) and then used the EVAMIX method taking into account the weights previously attributed by the AHP approach.

The results of the evaluation show the following order among the design alternatives for the layout of the spaces of the Convent of Santa Maria del Gesù in view of its use as an exhibition hall:

A = + 0.25

C = - 0.12

B = - 0.14

This result is influenced by the greater weight attributed to the environmental system (Figure 5), intended as the safeguarding of the pre-existent spatial configuration of the rooms, their perceptual-cultural characteristics, and the reused materials and technical systems of the building.

The graphs (Figures 6-7) show that when the environmental and technological systems are given equal weight, solution A is the best result. In particular, through a “sensitivity analysis” we can increase the weight of the environmental system; in this case, solution A responds with a higher score, while the scores of solutions B and C decrease. For the technological system, the graph is exactly reversed.

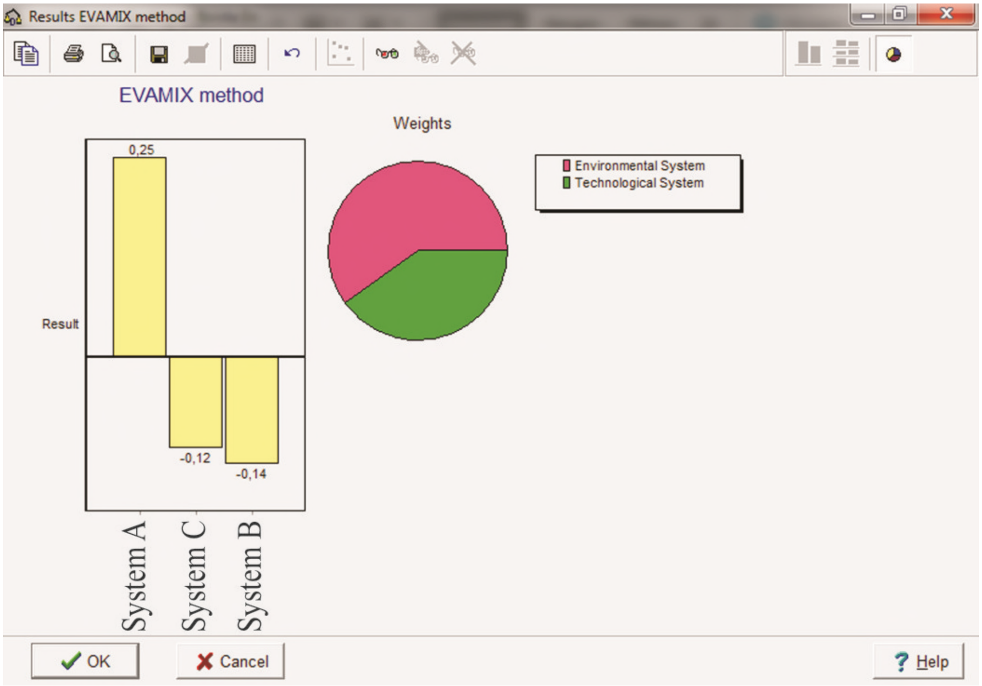


Figure 5 Evamix method: bar diagram of the results and pie chart of the environmental and technological system's weights

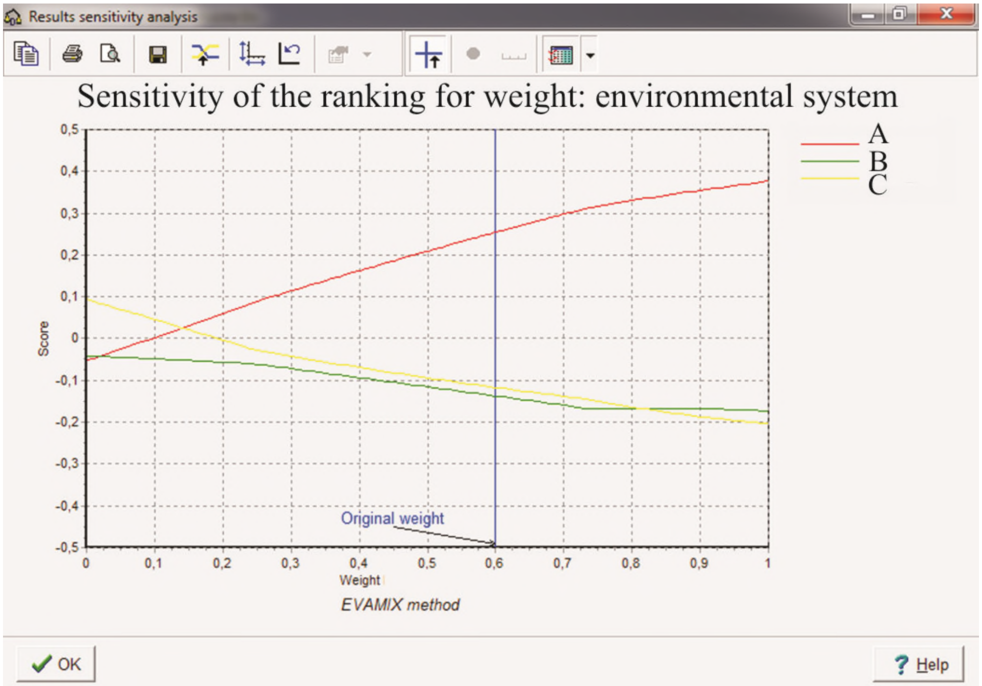


Figure 6 Evamix method: results of the sensitivity analysis of the environmental system

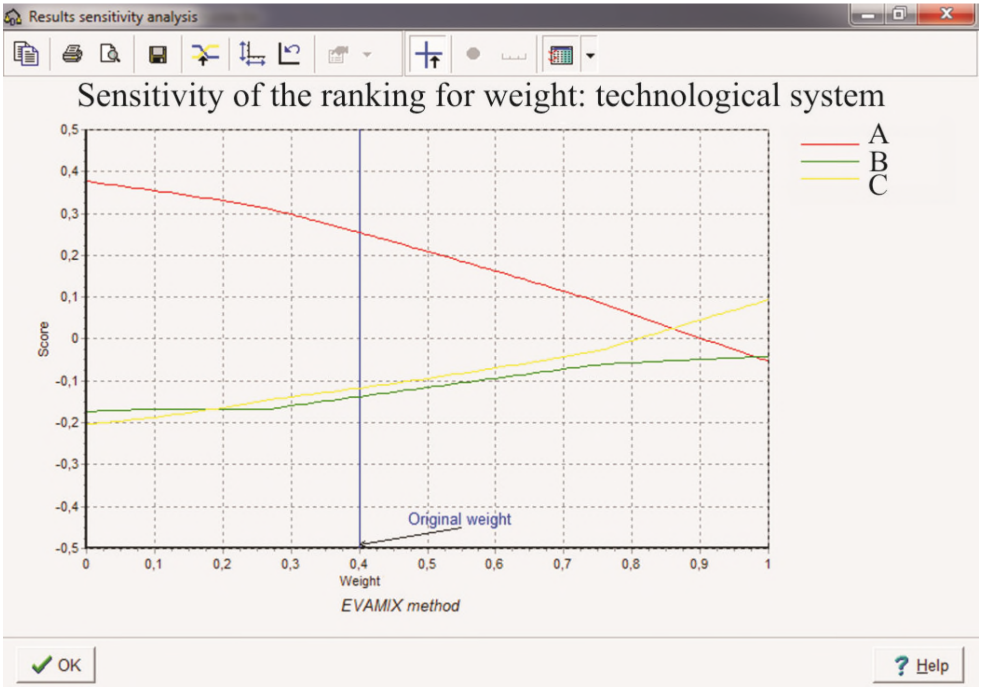


Figure 7. Evamix method: results of the sensitivity analysis of the technological system

6 Conclusions

The method proposed in the present essay evaluates alternative design solutions for the adaptive reuse of heritage buildings. It involves ranking solutions according both to their compatibility with the building and their ability to meet the requirements of the new use. The compatibility of the project transformations is assessed in terms of their ability to safeguard the identity of the building, preserving forms, constructive systems, components, materials and relationships between parts. The requirements are identified through a performance-based analysis of the project's ability to meet the needs of the new users. The evaluation goal consists of choosing the best design solution on the basis of its ability to meet the need of building preservation and the requirements of the new use. The assessment criteria are structured in a hierarchical scale, including the goal (first level), the "environmental system" (characteristics of the building's spaces related to their function) and the "technological system" (characteristics of the building's components related to their function) (second level), the "classes of needs" (third level), the "classes of user requirements" (fourth level) and the "use requirements" (fifth level). The evaluation relies on the combination of two multi-criteria methods: Analytic Hierarchy Process (AHP) and EVAMIX. The AHP method assigns weights to criteria by means of pairwise comparisons. The results obtained are used in the EVAMIX method to process the "evaluation matrix".

The ability to perform evaluations arising from the aims of the project allows adaptive methods to be chosen for the priorities assumed in the recovery design: this adjustment is possible through the variation of the weights assigned to the performance requirements in the pairwise comparisons and through the choice of different evaluation criteria in the comparison of the user requirements and performance requirements of each design solution.

With the changing of the set of user requirements and the evaluation criteria, the assessment method can be used to analyse design solutions for all the technical elements of a building or for a compatibility control of previously completed work on pre-existing buildings.

Consequently, the method developed here is a tool that can be used by several operators to assess adaptive reuse projects:

1) Designers, to whom it provides guidance in decision-making during project development;

2) Public bodies that release permissions for the implementation of adaptive reuse projects, to which it provides a tool to check the compatibility of the building transformations proposed by the designers;

3) Clients that need to evaluate alternative design solutions to be applied on their properties, to whom it provides a decision support tool.

In the designer training field, the application of the above assessment method can show students that an adaptive reuse project is not the result of arbitrary decisions or subjective inclinations of the designer, and highlight the complexity of the decision-making process and the profusion of variables involved in the transformation of heritage buildings.

The above assessment process allows designers to foresee the outcome of transformations, giving them an effective tool in the decision-making process. The assessment process can also be used by clients in choosing design solutions and by public departments in performing control activities (Engineering and Design Department, Department of Cultural Heritage, etc.) in order to verify the impacts of reuse projects.

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Towards a better, stronger and sustainable built environment

Aims and scope

Today's design strongly seeks ways to change itself into a more competitive and innovative discipline taking advantage of the emerging advanced technologies as well as evolution of design research disciplines with their profound effects on emerging design theories, methods and techniques. A number of reform programmes have been initiated by national governments, research institutes, universities and design practices. Although the objectives of different reform programmes show many more differences than commonalities, they all agree that the adoption of advanced information, communication and knowledge technologies is a key enabler for achieving the long-term objectives of these programmes and thus providing the basis for a better, stronger and sustainable future for all design disciplines. The term sustainability - in its environmental usage - refers to the conservation of the natural environment and resources for future generations. The application of sustainability refers to approaches such as Green Design, Sustainable Architecture etc. The concept of sustainability in design has evolved over many years. In the early years, the focus was mainly on how to deal with the issue of increasingly scarce resources and on how to reduce the design impact on the natural environment. It is now recognized that "sustainable" or "green" approaches should take into account the so-called triple bottom line of economic viability, social responsibility and environmental impact. In other words: the sustainable solutions need to be socially equitable, economically viable and environmentally sound.

IJDST promotes the advancement of information and communication technology and effective application of advanced technologies for all design disciplines related to the built environment including but not limited to architecture, building design, civil engineering, urban planning and industrial design. Based on these objectives the journal challenges design researchers and design professionals from all over the world to submit papers on how the application of advanced technologies (theories, methods, experiments and techniques) can address the long-term ambitions of the design disciplines in order to enhance its competitive qualities and to provide solutions for the increasing demand from society for more sustainable design products. In addition, IJDST challenges authors to submit research papers on the subject of green design. In this context "green design" is regarded as the application of sustainability in design by means of the advanced technologies (theories, methods, experiments and techniques), which focuses on the research, education and practice of design which is capable of using resources efficiently and effectively. The main objective of this approach is to develop new products and services for corporations and their clients in order to reduce their energy consumption.

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