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Ranking of Adaptive Reuse Strategies for Abandoned Industrial Heritage in Vulnerable Contexts: A Multiple Criteria Decision Aiding Approach

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Abstract: In recent years adaptive reuse has proven to be a promising strategy for preserving cultural heritage. When the adaptive reuse approach is used for cultural heritage, the expected outcome is not only the building protection, but the preservation of its historical and heritage significance, and the trade-off between the retention of symbolic values and the adaptation to new alternative (economically profitable) uses becomes of paramount importance. Decisions on the allocation of resources for cultural heritage preservation or development are based on a set of multiple, often conflicting, criteria, as well on the preferences of various, and not always consensual, stakeholders, who attribute different relative importance to market and non-market effects of adaptive reuse proposals. In this context, multiple criteria approaches provide a proper theoretical and methodological framework to address the complexity which characterizes adaptive reuse strategies of cultural heritage. This paper aims to contribute to this strand of literature by proposing a multicriteria decision aiding approach for ranking adaptive reuse strategies of cultural heritage. In detail, we present a novel application of the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE) to support the design and implementation of adaptive reuse strategies of abandoned industrial heritage in vulnerable contexts, and evaluate relative tangible and intangible effects. Industrial sites are frequently left to deteriorate, as their preservation is not considered as important as other kinds of heritage structures. Nevertheless, they are characterized by special architectural and technical features as well as by huge spaces suitable to be redeveloped for new uses. The paper focuses on the potential reuse of nine different abandoned buildings located in an industrial valley in the North-West of Italy, with a strong presence of wool and silk factories starting from the 18th century.

Keywords: Adaptive reuse; Cultural Heritage; Multicriteria Decision Aid; PROMETHEE; Strategic assessment

1. Introduction

Adaptive reuse seems to be an increasingly promising strategy for preserving cultural heritage. The conceptual concurrence of the circular economy and the adaptive reuse paradigm has uncovered new challenges to preservation from both a theoretical and an operational point of view. The circular economy represents a pathway to reduce negative externalities and produce positive environmental, social, and cultural impacts to benefit the society as a whole [1]. Similarly, the concept of adaptive reuse involves a change of use of existing buildings or structures according to the needs of new or existing owners [2,3], with the aim to achieve improvements in environmental, economic and social dimensions of sustainability, respectively: material and resource efficiency, cost reductions and intrinsic values retention [4]. When the adaptive reuse approach is applied to cultural heritage, the expected outcome is not only the protection of the building, but the preservation of its historical and heritage significance.

When changes affect a building's heritage significance as well as add contemporary layers that provide value for the future [5], according to a conservation strategy intertwined with the design [6], adaptation can be seen as an opportunity for heritage preservation. This perspective is not new. Adaptive reuse of historic monuments was at the center of a theoretical debate during the second half of the 19th century [7]. A deep and still interesting discussion on the role of change of use in favor of preservation was proposed in 1903 by Alois Riegl's essay "The Modern Cult of Monuments: Its Character and Its Origin" [8]. By identifying several types of values attached to both intentional and unintentional monuments, Riegl investigated different attitudes towards conservation. Starting from his taxonomy, many other classifications of values have been proposed, such as complex social value, a special notion of value, focused on monetary and non-monetary values, as well as on tangible and intangible aspects according to a public and multidimensional evaluation perspective [9,10].

There is a wide agreement on the hierarchical framework of total economic value, a concept of economic value which emerged in the first half of the 1980s. It includes new categories of value (intrinsic, economic, and societal value) for environmental and cultural goods and services besides those which derive from direct use [11], as it has been recently recommended by the European Commission's 2014 Communication "Towards an Integrated Approach to Cultural Heritage for Europe" [12].

Choices about what and how to conserve in order to represent us and our past to future generations reveal that there are many different—and sometimes divergent—values (economic, aesthetic, cultural, educational, political) to discuss [13], namely, goal values—that stress the importance of preserving cultural heritage—and instrumental values—meant for its sustenance [14].

Given these premises, pointing out the guiding principles of adaptive reuse is essential, especially for the complex system of values which characterizes cultural heritage. Although different approaches to adaptive reuse (see for example the review by [7]) and different conservation policies exist, some common principles can be identified [15]: adaptation should preserve the intactness of existing buildings, involving minimal changes consistent to new uses' requirements; adaptation should retain the symbolic values of historical buildings; sustainability principles should inform adaptive reuse design; community engagement should be encouraged and, finally, the selection of potential adaptive uses should consider the instance of fuelling larger territorial economic development processes. Furthermore, [16] identified the various factors which address successful adaptive reuse projects and should be taken into consideration in a comprehensive manner: (i) identification of actors and their views about future uses; (ii) analysis of the existing fabric and district's needs; (iii) classification of conservation actions, including emergency measures, full restoration, proposals for new additions and remodeling, as well as a combination of them; (iv) evaluation of adaptive reuse potentials, grouped into nine headings (physical, economic, functional, environmental, political, social and cultural) and, lastly, (v) decisions about functional changes and new use.

Under the adaptive reuse perspective, questions about the trade-offs between the retention of symbolic values and the adaptation to new alternative uses often arise. Thus, decisions about the allocation of resources for cultural heritage preservation or development should be based on a wide set of criteria, as well on the preferences of several, not always consensual stakeholders, who attribute different relative importance to market and non-market effects of adaptive reuse proposals. Despite such a level of complexity, there are few studies which provide methodologies for supporting adaptive reuse decisions, mostly focused on environmental, physical, and functional aspects of heritage buildings [16]. Mısırlısoy and Gunçe [16] proposed a qualitative approach for both defining adaptive reuse strategies, according to decision makers' preferences and policy issues, and for evaluating the appropriateness of new uses.

In this respect, to support the choice about the highest and best adaptive reuse of abandoned listed castles in Northern Italy, [17] and [18] defined a multi-methodological approach based on choice experiments and social multicriteria evaluation [19,20]. The proposed evaluation process allows the decision maker (DM) to consider both socio-economic and technical dimensions within the same evaluation framework.

With respect to applications in literature, multicriteria analysis seems to be an adequate theoretical and operational framework for supporting public policies design and implementation in multi-values and complex decision contexts, in which the interests at stake are several and often conflictual. The robustness of muticriteria approaches implementation is mainly due to the following reasons [21,22]: multicriteria tools explicitly take into account several criteria, both quantitative and qualitative; the amount of information about preferences and parameters is relatively small at the early design stage of adaptive reuse strategies; multicriteria analysis is compatible with socio-economic evaluation; multiple actors can be easily involved and the final aggregation of the different positions about the adaptive reuse strategies reflects not only the preferences of the majority, but also that of minority groups.

This paper addresses the issue of adaptive reuse of cultural heritage under a multicriteria decision aiding perspective and contributes to the above strand of literature. In detail, we present a novel application of the Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE). We implement PROMETHEE, an outranking multicriteria decision aiding method based on pairwise comparisons, to rank adaptive reuse strategies of abandoned industrial heritage, and evaluate relative tangible and intangible effects. Industrial heritage sites, especially in vulnerable contexts, are often more at risk than almost any other kind of heritage. Despite the coexistence of many heritage significances (historic, aesthetic, social, and/or technical and both tangible and intangible, mainly related to the work of the past in terms of processes and labor), industrial sites are frequently left to deteriorate, as they are not considered as worthy of preservation as other kinds of heritage structures. Our aim is to provide a decision aiding tool to support the design and implementation of adaptive reuse strategies of abandoned industrial heritage in vulnerable context.

In detail, the paper is organized into five main sections: Section 1 has introduced the issue of values attached to cultural heritage and discussed adaptation as a strategy for preservation; Section 2 provides the theoretical background to the valuation approach here implemented; Section 3 presents the application of PROMETHEE II method to a real-world case study on adaptive reuse strategies of abandoned industrial heritage in Northern Italy; Section 4 discusses the results, whereas Section 5 concludes and proposes future research developments.

2. Methodological Background

The PROMETHEE method is widely implemented in multicriteria decision aiding (MCDA) to cope with real-world decision-making problems [23,24]. The PROMETHEE method aggregates preference information through a valued preference relation and it was first proposed by Brans in the early 1980s [25], and subsequently extended by [26–29]. This method allows the evaluation and ranking of alternatives, identifying the variables that affect such a ranking and analyzing similarities and differences between alternatives.

When multiple criteria are involved in a decision problem, there is not a solution which optimizes all of the criteria simultaneously, and consequently, a multi-criteria problem is usually an ill-posed mathematical problem. In order to efficiently implement PROMETHEE methods, as well as other multicriteria methods, the DM has to provide directly or indirectly some preference information on variables and parameters involved in the modeling, e.g., weights of criteria and shape of preference functions. When the DM provides indirect preference information, e.g., by comparing alternatives according to which preference parameters can be inferred, it requires less cognitive effort than the effort required in the provision of direct preference information, and therefore indirect preference elicitation is broadly adopted in outranking methods [30,31]. PROMETHEE methods are a family of well-known outranking methods (namely PROMETHEE I, PROMETHEE II PROMETHEE III, PROMETHEE IV, PROMETHEE V, PROMETHEE VI, PROMETHEE TRI, and PROMETHEE CLUSTER) that, by partial aggregation and by pairwise comparison of alternative actions, allow the determination of whether, under specific conditions, one action outranks others [32]. PROMETHEE methods are usually grounded in a set of assumptions: (a) the set of criteria is finite; (b) criteria are not hierarchically structured, nor interacting; (c) the parameters of the decision model can be precisely defined. In the PROMETHEE method, actions are first compared pairwise on each criterion according to DM's preferences. Pairwise comparisons provide local scores, which are then aggregated to global scores, obtaining a partial pre-order (PROMETHEE I) or a complete pre-order rank (PROMETHEE II) or an interval pre-order rank (PROMETHEE III).

In detail, the PROMETHEE is generally used to rank a finite set of m alternative actions A={a, b, . . . , m} with respect to a finite set of k criteria G={g_1, g_2, . . . , g_k}, when multiple DMs are involved [33]. It requires additional information to enrich the poorness of the dominance relation on Preference (P) and Indifference (I) and thus the dominance graph [34]. For each criterion j, PROMETHEE methods identify a function P_j that represents the degree of preference of action a over action b with respect to criterion g_j, based on the difference in their evaluation $g_j(a)$–$g_j(b)$, which is a non-decreasing function. The degree of preference (i.e., how much alternative a is preferred to alternative b) is obtained according to the DM's preference function, which transforms the difference in evaluations of the two alternatives into a preference degree, expressed in a numerical scale ranging between 0 and 1, where "1" represents a strong preference of alternative a over b, whereas "0" represents the indifferent preference value between a and b. Six typical preference functions have been proposed in the literature [27,34,35]: Usual criterion, quasi criterion (U-shape), criterion with linear preference (V-shape), level criterion, linear criterion, and Gaussian criterion.

In order to evaluate how much action a is preferred to action b with respect to all of the criteria, an overall preference index Π(a,b) is calculated. Π(a,b) represents the intensity of preference of a over b and it is calculated by a weighted sum of the degrees of preference P_j(a,b) as follows:

$$\Pi(a,b) = \sum_{j=1}^{k} w_j P_j(a,b) \tag{1}$$

where Π(a,b) is the overall preference intensity of a over b with respect to all of the k criteria, w_j is the weight of criterion j and P_j (a,b) is the preference function of a over b w.r.t. criterion j.

It is worth noting that Π(a,b)~0 implies a weak global preference for a over b, whereas Π(a,b)~1 implies a strong global preference for a over b. The weights $w_j > 0$ are scale-independent and represent the importance of the criterion in the decision to be made: the higher the weight, the more important the criterion.

Since each alternative action is compared to the others, a positive outranking flow $\Phi^+(a)$ and a negative outranking flow $\Phi^-(a)$ can be defined:

$$\Phi^+(a) = \frac{1}{n-1}\sum_{b\in A}\Pi(a,b) \tag{2}$$

$$\Phi^-(a) = \frac{1}{n-1}\sum_{b\in A}\Pi(b,a) \tag{3}$$

In detail, $\Phi^+(a)$ represents the global preference for a in comparison to all of the other actions, and thus defines how alternative a outranks the others: the higher $\Phi^+(a)$, the better alternative a is. Whereas $\Phi^-(a)$ represents the global weakness of a in comparison to all of the other actions, and thus it defines how alternative a is outranked by the others: the lower $\Phi^-(a)$, the better alternative a is.

The above two flows can be combined to obtain the net outranking flow Φ(a):

$$\Phi(a) = \Phi^{+}(a) - \Phi^{-}(a) \quad (4)$$

The higher the net flow, the better the alternative.

In this paper, we implement PROMETHEE II, which provides a complete ranking of the alternatives, from the best to the worst, as all the alternatives are comparable on all criteria and no incomparability remains. Comparison of the net outranking flows is used to define the complete ranking of the alternatives. It is worth noting that net flows provide a complete ranking and thus can be compared with a utility function.

Net flows play a fundamental role in the Geometrical Analysis for Interactive Aid (GAIA), a visual tool used with PROMETHEE that provides the visualization and graphical representation of the relative importance of alternatives with respect to the set of different criteria [34] as well as the DM's preferences and their implications. In the GAIA plane, the alternative actions are represented by points, the criteria are represented by axes, whose length indicates their importance in the problem and the information on weights in a vector (the decision stick). According to the visual analysis offered by the GAIA plane, some conclusions can be drawn: the closer the actions, the more similar their performances; whereas, the more distant the actions, the more dissimilar their performances.

The number of PROMETHEE applications to real-world decision problems is significant [36] and this evidence proves that PROMETHEE is a relatively simple ranking method compared with other multi-criteria methods [27]. Despite their implementation being widespread in MCDA, PROMETHEE methods present some drawbacks in their application to real-world decision problems, due to the limitations imposed by their basic assumptions [37]. As a consequence, to overcome these shortcomings, in the last decade many extensions of PROMETHEE methods have been proposed in literature with respect to, among others, weights determination [38], integration with data envelopment analysis [39,40], analytic network process [41] or fuzzy approaches [42,43], recommendations robustness [44], and sorting methods [45].

As mentioned, applications of PROMETHEE methods are various and address major issues such as environmental and energy management, water management, business and financial management, logistics, and transportation (see [36] for a literature review); whereas, according to the literature review by [24], PROMETHEE applications in tourism (see e.g., [24,46,47]), social sciences (see e.g., [48–50]), and urban and territorial planning are quite recent (see e.g., [24,51–55]; see [24] for a recent literature review). As far as cultural heritage is concerned, there are some contributions that adopt multicriteria analysis and methods for the evaluation of cultural heritage (e.g., [56–60]), nonetheless to the best of our knowledge there are very few contributions on the application of PROMETHEE methods in the multicriteria evaluation of cultural heritage. In detail, [61] propose an integrated method that combines the Delphi method, fuzzy analytical hierarchy process, and PROMETHEE for the thermal renovation of masonry buildings characterized by a significant heritage value in Algeria; whereas, [62] implement PROMETHEE II to support the design and implementation of reuse strategies for the Ceva-Ormea abandoned railway and evaluate tangible and intangible cultural heritage. The present paper contributes to the above strand of literature, and presents a novel application of PROMETHEE II to the evaluation of adaptive reuse strategies of abandoned industrial heritage in vulnerable contexts, such as the Tanaro Valley in Northern Italy.

3. Application

3.1. Description of the Case Study and Presentation of the Alternatives

The present research is related to the reuse of industrial and cultural heritage located in Northern Italy. In particular, the study concerns the area of the Tanaro Valley in Piedmont Region (Figure 1).

Figure 1. Location of the Tanaro Valley in Northern Italy.

Since the 18th century, the area has been characterized by the presence of important industrial activities in the field of the production of cotton, wool, paper, glass, and other chemical processing. Most of the productive buildings were located along the Tanaro river for the availability of water and other natural resources useful for working activities. Moreover, at the end of the 19th century, the Ceva-Ormea railway was built thus ensuring the strategic connection of the area with the seaports and with the rest of the Piedmont Region [62].

Nowadays, due to the phenomenon of mountain areas abandonment, many productive activities have been relocated and the buildings have been left without any proper function. In order to escape the deep economic depression that has been affecting the valley in recent years, several stakeholders are discussing the possibility of reusing the abandoned industrial buildings for different purposes, such as tourist accommodation, cultural activities, and services for the population. The valorization of cultural heritage could be a driver for territorial enhancement, by attracting new visitors and delivering benefits for the local inhabitants.

Starting from the analysis of the former factories located in the area [63], we identified nine alternative buildings eligible for being reused on the basis of several factors, which can be summarized as follows:

- the buildings still constitute important representative elements for the identity of the local population;
- the historical productive function can be easily recognized in the buildings;
- the buildings are not occupied, thus allowing the introduction of new functions and destinations.

Figure 2 represents the 9 alternatives (i.e., assets) considered in the evaluation process.

Figure 2. Industrial buildings under valuation (source: authors' processing).

3.2. PROMETHEE Method Implementation

In order to evaluate the eligibility to adaptive reuse of the nine selected abandoned industrial buildings, seven scenarios of potential reuse, representing seven different alternative uses (namely, residential building, retirement home, luxury hotel, farmhouse and didactic farm, office building, socio-cultural center, and ecomuseum), were identified with respect to the present one [63]. The main objective is to identify among the nine buildings the best suited to host the seven new functions/uses. In detail, for each decision scenario the nine alternative buildings were ranked from the most to the least eligible to the relative scenario use according to the following 15 criteria:

(a) accessibility by private car (distance in kilometers from the highway "Strada statale 28");
(b) pedestrian accessibility or accessibility by public transport (walking distance in minutes from Ceva railway station);
(c) availability of the whole building space (dummy 1–0, "yes" or "no" respectively);
(d) available area of the property (gross floor area in square meters);
(e) flexibility of interior spaces layout (potential to host alternative uses expressed on a qualitative measurement scale from 1 to 5, where 5 denotes maximum flexibility and 1 denotes minimum or null flexibility);
(f) architectural quality and merit (building artistic and historic value, expressed on a qualitative measurement scale from 1 to 5, where 5 denotes maximum merit and value whereas 1 denotes minimum or null merit and value);
(g) state of maintenance (maintenance conditions expressed according to a qualitative measurement scale from 1 to 5, where 5 denotes optimum conditions and 1 denotes severe abandonment and/or collapse of structural elements);

(h) property value (assumed to be equal to the property cadastral value in Euros);
(i) appurtenance area of the property (empty portion in square meters of land behind and adjoining house);
(j) quality of landscape and natural and built environment features (pristine condition of landscape and the environment expressed on a qualitative measurement scale from 1 to 5, where 5 denotes excellent conditions and 1 denotes very poor conditions);
(k) presence of nearby places of (historical, artistic, architectural, touristic) interest (number of places of interests within 1 kilometer);
(l) acoustic quality in property surrounding environment (distance in meters by noise sources);
(m) presence of nearby commercial activities (number of shops, stores, markets, supermarkets, etc., within 500 meters or walking distance) and sports facilities (number of facilities within 500 meters or walking distance);
(n) presence of nearby public community services and/or municipal services (number of banks, medical clinics, post offices; within 500 meters or walking distance);
(o) presence of nearby lodging and hospitality services (number of bars, restaurants, hotels, etc. within 500 meters or walking distance).

It is worth noting that the criteria were chosen on the basis of the characteristics of the alternatives to be evaluated. Indeed, the criteria consider all the relevant aspects of the decision problem under examination, including environmental quality, economic aspects, infrastructural elements, and architectural features. Most of the criteria were inspired by the literature on real estate economics (e.g., property value, state of maintenance), sustainable urban development (e.g., quality of landscape and natural and built environment) and reuse of abandoned real estate assets (e.g., presence of nearby places of interest).

To structure and solve the decision we proceeded according to the following steps:

Step 1. Construction of the evaluation matrix. A double entry 9 × 15 table for the selected alternatives and criteria was compiled by using cardinal (quantitative) and ordinal (qualitative) data. This matrix accounts for deviations of evaluations on pairwise comparisons of two alternatives, e.g., a and b, on each criterion. The complete evaluation matrix (Table A1) is reported in Appendix A.

Step 2. Identification of the preference function $P_j(a,b)$ for each criterion j. For each criterion, a preference function has been identified, as well as an indifference (q) and preference (p) threshold respectively. Linear preference functions were identified for criteria (a), (b), (d), (h), (i), (m), (n), (o), (p), and (q), respectively. A usual preference function was identified for criterion (c); whereas U-shape preference functions were identified for the remaining criteria (e), (f), (g), and (l).

Step 3. Identification of valuation scenarios. Seven scenarios representing potential changes in present use were identified. These scenarios are meant to cover potential uses that in a real-world situation may be successfully hosted in abandoned industrial buildings. The scenarios are the following: (i) residential building; (ii) retirement home; (iii) luxury hotel; (iv) farmhouse and didactic farm; (v) office building; (vi) socio-cultural center; vii) ecomuseum.

In order to rank the alternatives with respect to each scenario, we simulated the investment decision of a potential entrepreneur who has to identify which action, among the nine alternative actions (i.e., buildings), can better perform in the scenario under investigation. Following a reference-based ranking approach, inspired by the seminal work in [64], alternatives were evaluated on a qualitative basis, that built on expert judgments provided by different groups of stakeholders [65,66]. For this purpose, we identified a panel of seven experts including entrepreneurs, investors, and practitioners in the field of real estate, tourism, and cultural heritage. Due to their relevant experience and strong interest in the field of industrial building reuse, they acted as DMs.

Step 4. Criteria weighting. To assess the criteria importance we implemented the method of cards proposed by Simos [67,68] and revised by [69]. According to the Simos method, the DM is given a set of cards with a criterion name on each and then he/she is asked to rank the cards/criteria in ascending order and introduce white cards if he/she deems the difference between criteria is larger, i.e., the larger the difference, the greater the number of white cards [70]. We then asked the DM to state the ratio z, that represents how many times the last criterion is more important than the first [69], which defines a fixed interval between the criteria weights. The weights were determined by implementing the SFR software [69] and by interviewing the panel of seven experts, i.e., one for each scenario. Each expert played the role of a DM who has to identify the most eligible building for being transformed according to the specific scenario. Table 1 displays the weights generated by SFR software, whereas Figure 3 provides a graphic representation of the 15 criteria and relative weights. As shown in Figure 3, it emerged that experts agree on assigning a higher weight (relative importance) to building typology and architectural features, and specifically available ground area and flexibility of interior spaces layout assume great importance due to their potential in adaptive reusability [71–73]. Accessibility plays a major role for the luxury hotel scenario and the farmhouse and didactic farm scenario; whereas the presence of nearby commercial activities and public community services does not play a major role in the transformation process. In addition, it is worth observing that the property value and the state of maintenance of the building are of minor relative importance in the retirement home and the eco-museum scenarios compared to the others. This is due to the fact the experts involved considered different criteria more relevant for the project feasibility, such as the appurtenance area in the retirement home scenario, and the quality of landscape in the eco-museum scenario. In addition, the panel of experts attributed greater (relative) importance (i.e., a higher weight) to the building state of maintenance when real estate assets are transformed into office buildings rather than in residential buildings. This is contingent on the specificity of the real estate market in the area under investigation, where retail and office buildings generate higher returns on investments than residential buildings, and to retrofit costs, which increase for office buildings, because of a niche demand for high quality improvements. This in turn reflects greater opportunities to arrange public–private partnerships, attract private sponsorships, and provide financial resources required to undertake investments [74].

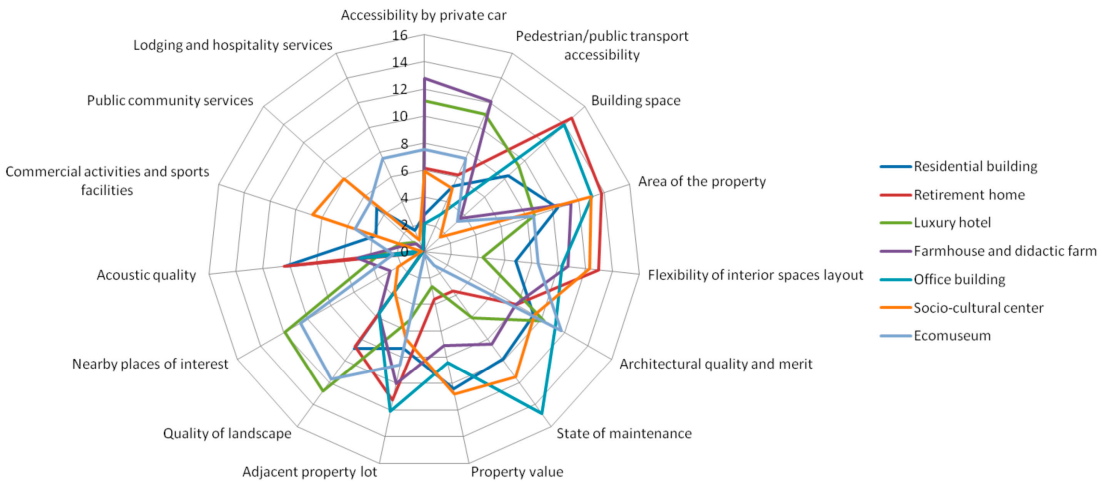

Figure 3. Radar graph representation of criteria and relative weights according to the different decision scenarios.

Step 5. Calculation of the overall preference index Π(a,b) and of the outranking flows, i.e., positive flow $\Phi^{+}(a)$ and negative flow $\Phi^{-}(a)$ and comparison of the outranking flows to define complete ranking of the alternatives. The results in terms of complete ranking of the alternatives are discussed in the following section.

Table 1. Criteria weights according to the different decision scenarios.

Criteria	Decision Scenarios						
	Residential Building	Retirement Home	Luxury Hotel	Farmhouse and Didactic farm	Office Building	Socio-Cultural Center	Ecomuseum
Accessibility by private car	2.71	6.16	11.09	12.8	2.02	5.9	7.5
Pedestrian or public transport accessibility	5.27	6.16	11.09	12.1	2.94	5.1	7.5
Building space	8.34	14.69	9.41	3.6	13.94	1.6	3.3
Area of the property	10.38	13.83	8.58	11.4	13.02	13	8.5
Flexibility of interior spaces layout	6.8	12.98	4.36	10.7	10.27	12.3	8.5
Architectural quality and merit	9.36	7.86	10.26	7.8	11.19	9.4	11.7
State of maintenance	9.87	3.6	6.05	8.5	14.85	11.5	1.3
Property value	10.39	3.6	2.68	7.1	8.44	10.8	0.2
Appurtenance area	7.32	11.27	5.21	10	12.11	6.6	8.6
Quality of landscape	8.85	8.71	12.78	5.7	5.69	3.7	11.7
Nearby places of interest	0.15	0.18	11.93	2.9	0.19	2.3	10.6
Acoustic quality	10.39	10.42	3.53	5	4.77	0.2	2.3
Nearby commercial activities/facilities and sports facilities	3.73	0.18	1.85	1.5	0.19	8.7	5.4
Public community services	4.76	0.18	1.01	0.8	0.19	8	5.4
Lodging and hospitality services	1.68	0.18	0.17	0.1	0.19	0.9	7.5

4. Results and Discussion

By implementing the PROMETHEE II method, a ranking of alternatives has been obtained for each decision scenario. Figure 4 shows the results of the PROMETHEE evaluation for the different intended uses considered in the study. According to the obtained results, alternative 5 (Cotton mill in Ceva) is the most suitable building to be reused for different purposes, including residential building, luxury hotel, farmhouse and didactic farm, socio-cultural center, and ecomuseum. This is due to the fact that the building is in a good state of conservation and it is very flexible to host new and differentiated functions. Alternative 6 (Chemical factory in Scagnello) embodies the best features to be reused as a retirement home or office building due to the possibility of a vast adjacent area that can be used for complementary functions. Conversely, building 7 (Lime kiln in Trappa) is ranked in the last position in all the considered decision scenarios. This is mostly due to the very rigid internal organization which makes the building unsuitable for reuse.

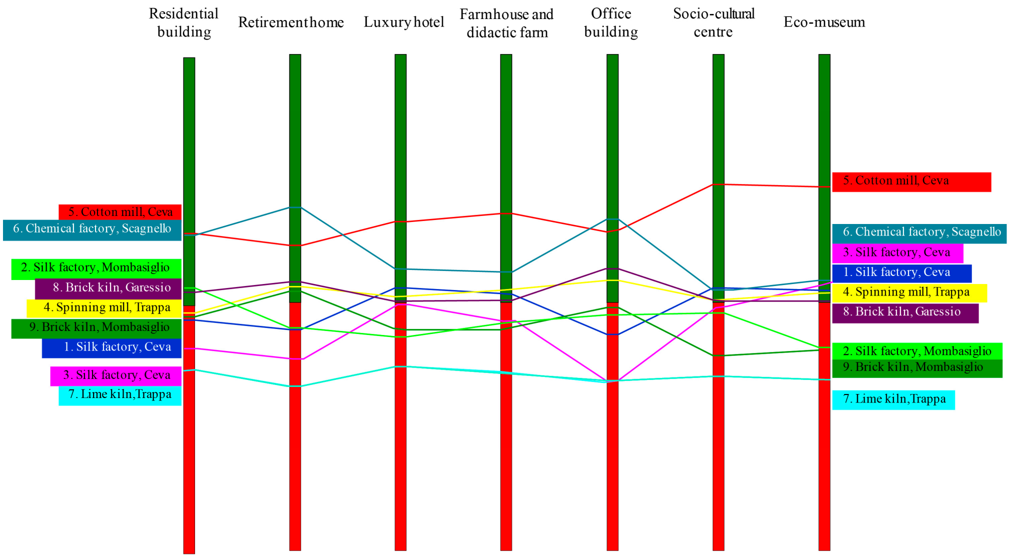

Figure 4. Ranking comparison for the different decision scenarios.

The obtained results can be further investigated using the GAIA (Geometrical Analysis for Interactive Aid) plane that provides valuable information in addition to the PROMETHEE ranking [34]. The GAIA method offers a two-dimensional representation of the multidimensional problem, allowing a deeper understanding of the issues under examination. Among the different visualizations provided by GAIA analysis, of particular importance is the plane where the axis represents the decision scenarios (i.e., the points of view of the different experts), whereas the points represent the alternatives. The red axis is decision one and it represents the aggregation of the alternative performances according to the set of weights of the experts (Figure 5).

As shown in Figure 5, the experts focused their attention on criteria in two different ways. Representatives of the socio-cultural center and eco-museum are very close to each other, as well as the luxury hotel and farmhouse. They defend the same criteria evaluation as the axis are oriented approximately in the same direction and they prefer alternative 5 (Cotton mill in Ceva). On the other hand, the office building and retirement home representatives prefer alternative 6 (Chemical factory in Scagnello). In general, there is not a very strong divergence as all the preference axes are oriented to the right.

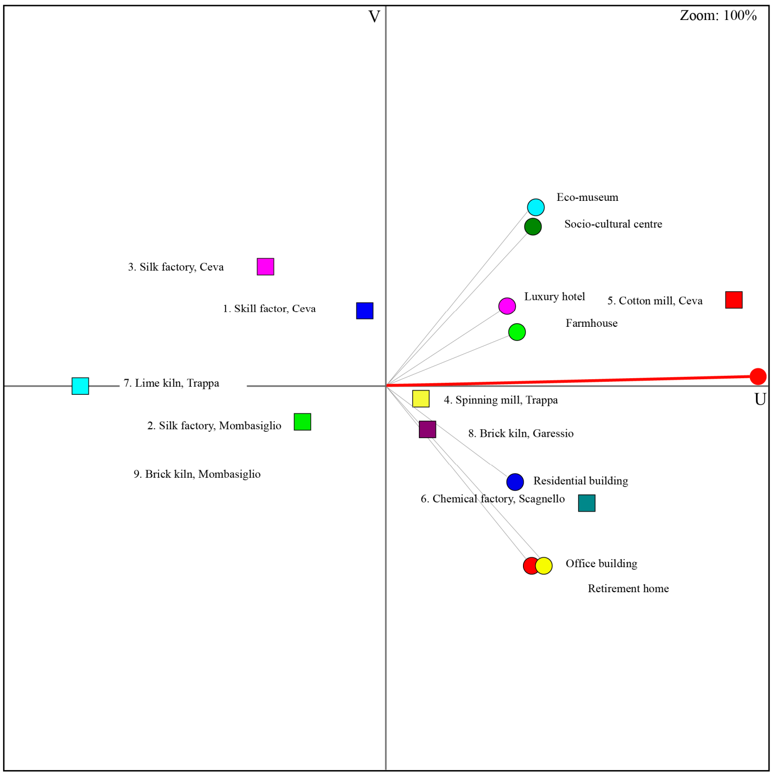

Figure 5. GAIA plane for the decision scenarios under investigation.

5. Conclusions

In this paper, a multiple criteria decision aiding method was applied for supporting a decision-making process in the context of the reuse of industrial cultural assets [75–77]. Using a mix of qualitative and quantitative criteria, seven different reuse scenarios were considered for the redesign of different abandoned industrial buildings in Northern Italy. The different scenarios were drawn by a panel of experts that allowed the assigning of weights to the different criteria involved in the evaluation model.

The case assumes particular importance as the phenomenon of the reuse of abandoned industrial buildings is getting more and more important, especially in Italy. In fact, the social and technological changes that have characterized our recent decades have significantly altered the national productive system and today in Italy there are thousands of industrial assets of architectural quality which constitute a real resource for the territory [62].

The application developed in the present study confirmed the advantages of using the PROMETHEE method for supporting complex decisions, as it enables the comparison of alternative scenarios by taking into account the opinions of the different experts involved in the problem. The multi-experts' analysis turned out to be very useful in clarifying the most appropriate function for the considered buildings according to the typologies of reuse intervention. Moreover, the GAIA visual analysis proved to be effective for the representation of the results of the evaluation process and for the exploration of conflicting criteria and values.

Besides the overall coherence of the results obtained in defining the most eligible building to adaptive reuse with respect to specific uses, the present study might have interesting policy implications. It might represent a useful tool for policymakers in the re-thinking process of the entire industrial district and the conceptualization and design of a more general and multi-purpose master plan, aimed to re-launch and valorize the territory under investigation.

As a future research perspective, it would be of scientific interest to integrate the PROMETHEE evaluation with GIS (Geographic Information Systems); through this combination, it would be possible to provide specific thematic maps to facilitate communication and dissemination of valuation results [78,79]. These further outputs would play a major role in supporting broader stakeholder involvement. The soundness of the results and the ranking obtained by PROMETHEE method implementation is dependent on the panel of experts who played the role of DMs. Nonetheless, their views were useful to restrict the potential adaptive reuse strategies to a set of feasible ones, to be subjected to a larger legitimation process by the prospective involvement of local communities. Further research might be devoted to the development and implementation of sensitivity and robustness analyses that could check the stability of the model outputs, and thus reinforce the robustness of the final results.

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Appendix A

Table A1. Evaluation matrix.

	Criteria														
	Accessibility by Private Car	**Pedestrian Accessibility or Accessibility by Public Transport**	**Building Space**	**Area of the Property**	**Flexibility of Interior Spaces Layout**	**Architectural Quality and Merit**	**State of Maintenance**	**Property Value**	**Appurtenance Area**	**Quality of Landscape**	**Nearby Places of Interest**	**Acoustic Quality**	**Nearby Commercial Activities/ Facilities and Sports Facilities**	**Public Community Services**	**Lodging and Hospitality Services**
Unit	km	minutes	0/1	m^2	1–5	1–5	1–5	€	m^2	1–5	No.	km	No	No	No
Min/Max	min	min	max	max	max	max	max	min	max	max	max	max	max	max	max
Preference function	linear	linear	usual	linear	U-shape	U-shape	U-shape	linear	linear	U-shape	linear	linear	linear	linear	linear
(q)	1	10	-	50	1	1	1	10,000	200	1	2	0.1	1	1	1
(p)	5	5	-	100	-	-	-	50,000	500	-	5	1	5	3	5
1. Silk factory, Ceva	0.50	13	0	565	3	2	3	115,423	1000	3	8	0.26	9	7	3
2. Silk factory, Mombasiglio	6.60	16	0	380	3	2	4	13,421	1000	4	2	4.13	1	6	3
3. Silk factory, Ceva	0.05	3	0	510	2	3	2	199,826	100	2	10	0.02	17	78	11
4. Spinning mill, Trappa	0.00	33	0	5255	3	5	3	645,172	5400	4	0	0.01	0	0	2
5. Cotton mill, Ceva	1.00	11	0	1850	4	4	5	177,655	6300	3	10	0.51	22	21	10
6. Chemical factory, Cagnello	10.70	21	1	1675	4	4	1	52,069	6700	5	3	6.3	0	0	0
7. Lime kiln, Trappa	0.06	38	0	335	1	3	1	20,403	1200	4	0	0.08	0	1	1
8. Brick kiln, Garessio	0.55	36	1	300	2	4	3	128,846	11,700	3	1	0.44	8	3	3
9. Brick kiln, Mombasiglio	5.30	16	1	170	5	2	2	0	1500	4	0	2.93	0	3	0

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