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Original article

Reusing grain silos from the 1930s in Italy. A multi-criteria decision analysis for the case of Arezzo

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ABSTRACT

Italian grain silos from the 1930s are emblematic buildings of an historical period characterized by technological progress and particular economic and political conditions. Due to their unfavourable morphology related to the specific agro-industrial purpose, their conservation and adaptive reuse constitute a major challenge, even if supported by their historical, technological and, sometimes, even artistic values. For this reason, most of these buildings remained abandoned for a long time and are now affected by a serious material degradation. This study attempts to overcome the difficulties in selecting the best reuse proposal through a multi-criteria decision-making method. This approach makes it possible to effectively compare different scenarios and identify the most satisfactory use for the silos. The multi-attribute decision analysis applied to the case of the silo of Arezzo demonstrates its effectiveness and potential in the context of historic buildings.

1. Research aims

This study addresses the adaptive reuse of Italian grain silos built during the 1930s, a significant architectural heritage today largely unused. The selection of the most suitable use is a complex decision problem because of the coexistence of different objectives and several constraints, such as the preservation of the values of the silos, the interest of private investors and the needs of the community. The aim of this work is to identify a methodology to find the best adaptive reuse for grain silos by means of multi-criteria decision-making (MCDM) approach. A significant step is the identification of a robust set of attributes, which are tailored to a case study in Italy. Seven design proposals are evaluated by four decision makers and compared on the basis of 57 attributes, which are suitably defined in this work. In this way, it is possible to assess the effectiveness of MCDM for this particular typology of industrial architectural heritage.

2. Introduction

The high dynamism of our time and the rapid changes of our society, combined with a weak legal protection of more recent architecture, have been seriously threatening important elements from the heritage of the 20th century [1]. In particular, this regards industrial buildings, whose appearance is considerably far from the well-known appreciated typologies of the older heritage.

In Italy, the reference law for the protection of cultural heritage (i.e., the Code for the Cultural Heritage and the Landscape [2]) does not define specific conservation requirements for different heritage typologies, nor in relation to a specific era, it solely requires the buildings to be aged at least 50 years. A more detailed classification of eligible properties for preservation is provided by the Central Institute for Cataloguing and Documentation (within the Ministry of Cultural Heritage), which considers industrial architecture together with fortified and religious buildings, residences, rural buildings, infrastructure, and so on.

Since the late 1980s, many initiatives and international organizations such as DOCOMOMO International[1] stressed the aesthetic, technical and social values of modern heritage, thereby encouraging international debate about its preservation. They also highlighted the need for common methodologies and criteria to assess the significance of modern heritage and to identify values and intervention priorities, proposing shared approaches to conservation and reuse [3,4].

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[1] DOCOMOMO: Documentation and conservation of buildings of the modern movement.

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Italian grain silos of the early 20th century represent a problematic typology of architectural heritage: highly *function-specific* industrial buildings mostly made up of reinforced concrete. They are worthy of preservation since they witness a particular period of the economic, rural and political history of Italy, and possess technological and, sometimes, aesthetic values. Nowadays, most of them are abandoned and are hardly adaptive to other uses due to their particular structural configuration, the material deterioration and because their location is often within marginal urban and social contexts. Besides, reuse is penalized by the negative attitude toward the memory of the Fascist regime and by the construction material itself (i.e., reinforced concrete) that exhibits an unfavourable aged aspect (as opposed to, for example, stone or brick masonry). Its repair typically requires innovative technologies and also high costs.

The research of a new use for these buildings can be eased and optimized through a multi-criteria decision-making (MCDM) method, whose application allows evaluating preservation aspects together with the compensative socio-economic advantages.

The first part of the paper introduces grain silos and the current challenges in their reuse, with particular attention to those of the 1930s. Then, a methodology for the selection of the best reuse proposal is developed, focusing on the MCDM analysis. The application to the case of Arezzo reveals the difficulties in approaching the adaptive reuse of these function-specific industrial buildings and highlights the potential of decision-support procedures for the grain silos typology.

3. Multi-criteria decision-making analysis

A formal methodology to deal with complex decision problems is provided by multi-criteria decision-making (MCDM) analysis, consisting of a set of techniques that aims to comparatively assess alternative projects or heterogeneous measures.

The earliest references relating to MCDM trace back to Benjamin Franklin [5,6] and to the mathematical contributions of Georg Cantor [7] and Pareto [8], who firstly studied the aggregation of conflicting criteria into a single composite index. Since then, thanks to the contributions of Operational Research, multi-criteria analysis was employed in different areas, deriving techniques from other mathematical disciplines, such as mathematical modelling, statistical analysis and mathematical optimization.

MCDM can be classified in two categories — multi-objectives decision analysis (MODA) and multi-attribute decision analysis (MADA) — in relation to the decision context and the complexity of the mathematical model [9–11]. The first type is commonly used to determine the optimal compromise solution with a probabilistic approach, which assumes continuous solution spaces. The second one utilizes a deterministic approach with a finite domain composed by a finite number of alternatives and requires multiple attributes to determine choices. MADA methods do not aim to compute an optimal solution; rather, they aim to determine a rank of decision alternatives that is optimal with respect to several criteria. The main difficulties in the application of MADA are related to the definition of the attributes starting from the construction of a sound knowledge framework.

Recent studies [12] examine scholarly literature pertaining to decision analysis and identify the most common MCDM methods, which are multi-attribute utility theory (MAUT) [13,14], analytic hierarchy process (AHP) [15], fuzzy set theory [16], analytic network process (ANP), case-based reasoning [17], data envelopment analysis [18], simple multi-attribute rating technique [19], goal programming, ELECTRE [20], PROMETHEE [21], weighted-averaged sum (WAS), the technique for order of preference by similarity to ideal solution (TOPSIS), and additive ratio assessment (ARAS).

The widespread diffusion of MCDM in urban planning [22–25] is connected to the need of justifying policy choices and to the possibility of involving the community in the process. By providing quantitative data to solve a planning problem, it is an important communication tool within the decision-making body, the evaluators and the wider community. The method can be set up on a regional scale to locate high-impact constructions [26] or to compare environmental impacts and values [27,28].

Over the last few years, different MCDM have been applied for heritage assessment, but none of them is preferably adopted. A common purpose is to rank alternative scenarios for reuse or enhancement of historical buildings and sites [29–31]. Other valuable applications in the management of cultural heritage allow grading different sites in order to identify investments and conservation priorities [32–35]. Many cases related to the reuse of architectural heritage are studied through MAUT, considering only qualitative attributes [36]. AHP and ARAS methods have been applied to define the priorities for reconstruction and renovation of heritage buildings [37,38], considering the opinions of representative stakeholders of the decision problem. The AHP or TOPSIS grey methods have been applied to rank reuse alternatives for the upgrading of vernacular buildings [39], taking into account multiple quantitative and qualitative criteria and experts' opinions. Advanced studies developed a five-level project selection model based on ANP in order to prioritize a set of construction projects [40] or to evaluate projects through fuzzy theory, thus considering the uncertainty in the assessment [41].

4. The grain silos of the 1930s

For a deep understanding of the values, distinctive features and reuse potentialities of grain silos of the 1930s, it is necessary to outline the origin of the typology and its development over the centuries in Italy and worldwide, moving thereafter to analyse Italian examples and their conservation issues.

4.1. Origins and development of grain silos

Long-term grain storage has been always one of the main actors in political and economic history since man created permanent settlements. In relation to climatic, environmental, economic and social conditions, storage facilities developed in different typologies, from old grain pits to current grain silos. Since the 12th century, specific masonry warehouses, the "Granges", spread throughout Europe thanks to monastic orders (e.g., in France, England, Belgium), showing fortified features in some cases (i.e. Cuna, Spedaletto and Montisi in Tuscany, Italy).

Between the 15th and the 19th centuries, grain reserves were stored in multi-storey masonry buildings, which were sometimes very large (e.g., "Granili" in Naples), while around the mid-19th century, innovative mechanized buildings — the so-called "grain elevators" — appeared in the major American ports to stock and move faster the shipped wares. American grain elevators even fascinated the leading members of the Modern Movement, from Walter Gropius [42] to Le Corbusier [43] and Erich Mendelsohn [44]. In fact, through the purity of their volumes, these buildings were able to express a new monumentality devoid of historical references, and to show the aesthetical and structural potentialities of the new construction technique: the "reinforced concrete" (Fig. 1).

The introduction of machineries, powered first by steam and after by electricity, represented an actual revolution in grain storage buildings, so that mechanized grain elevators started to be built all over the world. Some important examples in Italy dating back to the 1900-1920s are in Genoa, Leghorn, Naples and Civitavecchia (the latter was unfortunately destroyed by bombing during World

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