Life-Cycle of Structures and Infrastructure Systems – Biondini & Frangopol (Eds)

Sustainable reuse of public real estate assets meeting structural, conservation and territorial needs

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ABSTRACT: Currently, the recovery of existing buildings assumes a fundamental role, especially the restoration and reuse of the large state-owned properties characterised by significant cultural values, but often underutilised or even abandoned. This wide patrimony can instead represent an opportunity to satisfy the still existing needs of settlements, infrastructures, and services, without further consumption of land. The paper analyses the problem of integrating the conservation-architectural-social criteria for defining new uses of state-owned buildings with the need to meet structural requirements and performance according to current Italian technical standards for construction. A methodological protocol is proposed, based on the definition of sets of indicators, aimed at quantifying the degree of sustainability of new use design hypothesis according to the impact in terms of demand for structural performance upgrading compared with the overall sustainability of the intervention. The methodology application to the case study of a military building is presented and discussed.

1 INTRODUCTION

Approximately 70% of the Italian building heritage, by age, techniques, and construction materials, is approaching the end of its life cycle, and this exposes it to the risks of seismic and hydrogeological vulnerability, to degradation, to energy inefficiency. At the same time, the current European policies of urban regeneration push towards the effective zeroing of land consumption and the sustainability of any building and urban transformation that affects the building heritage (National Council of the Green Economy 2017).

In this context, the recovery of the built heritage assumes a fundamental role and place itself rightfully among the actions promoting sustainable development. In fact, the advantages associated with the reuse of existing buildings involves environmental, economic, and socio-cultural issues. The environmental advantages relate to i) the protection of the built heritage from degradation, ii) the waste reduction, iii) the energy conservation, iv) the reduction of urban decay. The economic advantages relate to i) the reduction of management costs, ii) the boost to the use of local resources, iii) new investment opportunities. The socio-cultural advantages relate to i) the positive impact in terms of job opportunities and income, ii) the promotion and preservation of historical memory, iii) the protection of the historical-cultural identity of places.

In this framework, special relevance assumes the restoration and reuse of large state-owned properties, which in Italy appear to be largely for military use (Fiorino 2021), characterised by cultural values, but often underutilised or even abandoned and which can instead represent an opportunity to satisfy the still existing needs of settlements, infrastructures, and services, without further consumption of land. The issue of the disposal and reuse of historic state-owned assets is very topical and pushes on the one hand to highlight the general institutional stalemate that has led to the abandonment of many assets of great historical value, and on the other to build sustainable reuse scenarios, capable of guaranteeing their conservation and, at the same time, of responding to the pressing needs of containing public spending and identifying new containers of services for the community.

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The choice of the reuse scenario, or adaptive reuse, of the asset is a very delicate issue, which involves both cultural, social, and territorial aspects as well as technical, technological, and economic aspects. Morandotti (2012) effectively focuses on the fact that the sustainable refurbishment of the building heritage should be based on an integrated approach that takes into consideration i) the evaluation of the functional compatibility between the reuse and the building, in terms of both the compatibility between the facilities located in the building and the needs of the current users, and the need for regulatory, operating and system adaptation; ii) the prospect of optimizing the building's performance in relation to its material consistency, residual structural capacity, and state of conservation, but with a view to increasing its energy efficiency; iii) the long-term sustainability of the refurbishment, in the sense of minimizing future interventions, through a monitoring strategy aimed at the planned conservation/maintenance of the building. Besana et al. (2018) highlight the concept of resilience, which in case of the historical built heritage means tolerable transformation that an existing building can undergo without the resulting impacts generating undesirable effects. This means that the building can adapt to accommodate the transformations deriving from reuses maintaining its identity, distinguishability, functionality suitable for new uses and respectful of the historical values of the asset.

Several studies propose methodologies to support the built heritage reuse decision-making, analysing the factors affecting adaptive reuse decision-making and developing general models for adaptive reuse strategies for heritage buildings (Aigiwi et al. 2019, Alhojaly et al. 2022, Bertolin & Loli 2018, Della Spina 2021, Mısırlısoy & Günçe 2016, Ribera et al. 2020, Śladowski et al. 2021). However, to the best of the author's knowledge, the literature is lacking with respect to the specific theme of the influence of the residual structural capacity of the building, and the extent of the structural intervention necessary to meet the reuse needs, on the choice of the reuse scenario.

The present paper aims to bring a contribution to this theme by proposing a qualitative methodology to support the decision-making process in which the impact of the structural intervention on the reuse scenario of the asset is made explicit. The methodology, which is divided into a series of steps, is substantially based on the comparative and integrated analysis of i) the structural performance required by the reuse scenario, ii) the residual structural capacity of the asset, iii) the definition of the category of structural intervention necessary to fulfil the reuse scenario demand. The methodology application to the case study of a military building is presented and discussed.

The research illustrated in this paper is part of a larger project, SOSLabs - Research-action laboratories for urban sustainability - funded by the Italian Ministry of Ecological Transition, aimed at supporting the development of the Sardinian SRSvS (National Strategy for Sustainable Development). The research was carried out thanks to a special agreement between the Italian Ministry of Defence and the University of Cagliari.

2 THE METHODOLOGY

The proposed methodology is based on the concept that the choice of possible strategies for the reuse of the asset should necessarily deal with the structural scheme of the building and with the material with which it was built. Therefore, an essential action is the verification of structural compatibility between the current state of the building and the requirements necessary for the reuse scenario, in terms of structural configuration and load conditions. The outline of the methodology is illustrated in Figure 1, which presents a flow chart whose steps are detailed below.

2.1 *Step 1. Identification of reuse scenarios*

The identification of the possible reuse scenarios of the asset derives from the confluence of various factors, among which, i) the possible need to assign to the asset a specific function already identified a priori, ii) needs deriving from the system of relationships that rest on the territory in which the asset is inserted, iii) willingness to satisfy demand of a social nature, iv) previous successful experiences of regeneration of abandoned assets, v) options arising from discussions with stakeholders. This last factor is fundamental to guarantee the correct inclusion of the new function of the asset in the socio-economic-territorial fabric.

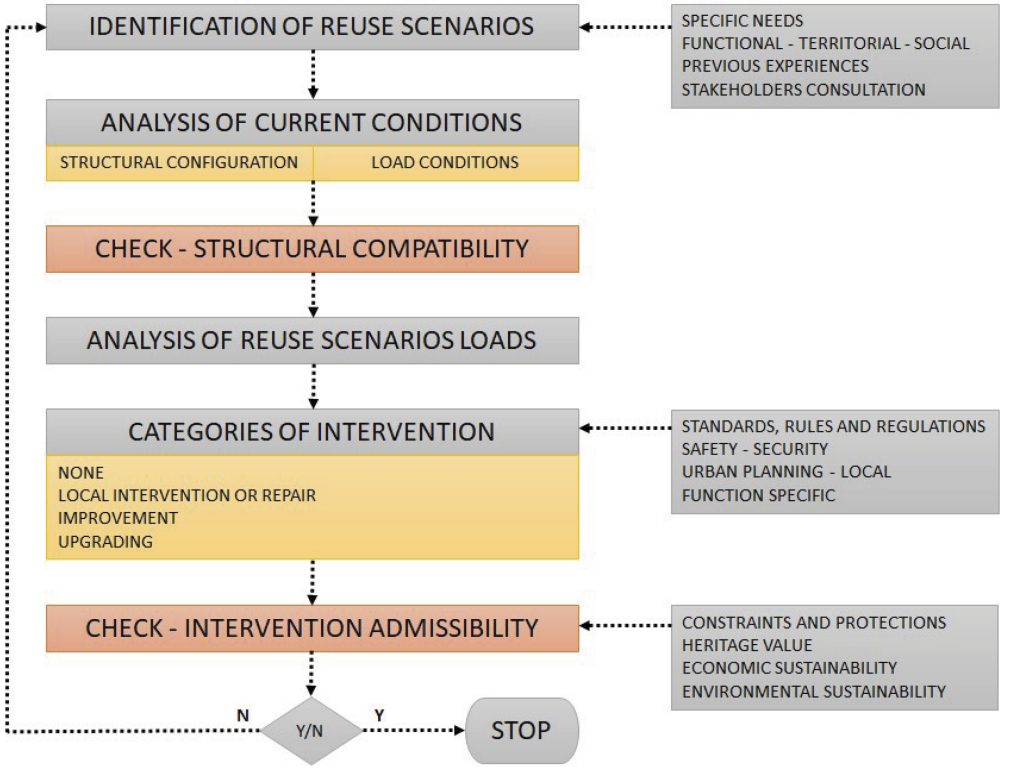

Figure 1. Methodology outline. Step-by-step process.

2.2 *Step 2. Analysis of current conditions*

The analysis of the actual conservation condition of the asset should lead to recognising and evaluating the residual capacity of the building in terms of quality of materials, static scheme, loads and load-bearing capacity, and global behaviour, for better orientating the strategies of any interventions. This also to comply with the needs of restoration and conservation, i.e., to preserve the existing historical materials, stratigraphies, structures (foundations, load-bearing walls, arches and vaults, horizontal elements, chains), minimising the interventions to replace the historical constructive elements and materials with new ones.

2.3 *Step 3. Check of structural compatibility*

The check of structural compatibility between the current conditions of the asset and the performance request linked to the reuse scenario has the purpose of avoiding important alterations of the overall structural behaviour of the building, which could affect the original distribution of loads requiring significant structural interventions. Making the most of the static characteristics of the existing structural system allows minimizing the invasiveness of the intervention, and consequently the impact on the identity of the asset itself and, last but not least, the maintenance costs over time.

The decisive aspect in the check of structural compatibility is linked to the entity of the overloads, or imposed loads, which include the loads linked to buildings intended use, and the seismic action, with respect to which the existing buildings, especially the historic ones, can be lacking. Technical regulations, such as the Italian NTC (Technical Standards for Constructions 2018), provide indications for the assessment of the loads, and therefore of the actions, acting on buildings according to their type and intended use.

2.4 *Step 4. Categories of intervention*

Depending on the outcome of the structural compatibility check, the type of structural intervention to be carried out on the asset is by and large defined to satisfy the performance requirement linked to the reuse scenario.

It should be noted that the type of intervention may also be influenced by other factors linked to other standards, rules, and regulations, such as urban planning and local ones, those relating to safety requirements (fire prevention), those specific to the new function of the property (space, systems, facilities), etc.

According to Italian NTC, the following three categories of intervention are identified.

- Local interventions or repair. Interventions involving individual structural elements and which, in any case, do not reduce the pre-existing safety conditions.
- Improvement interventions. Interventions aimed at increasing the pre-existing structural safety, without necessarily reaching the safety levels established for new buildings.
- Upgrading interventions. Interventions aimed at increasing the pre-existing structural safety, achieving the safety levels set for new buildings.

In the case of assets of cultural interest, upgrading interventions are to be considered, in general, not compatible with conservation needs, since to achieve upgrading it is almost always necessary alter the material and significantly modify the structural behaviour of the building. Therefore, improvements interventions and local interventions or repair are considered acceptable for these assets. Some factors useful for discriminating the improvement intervention from the upgrading one are the following:

- increase in foundation loads less than 10% compared to the original loads,
- modification of the position of the stiffness barycentre, for each floor, by an amount less than 10% of the dimension of the building measured perpendicular to the direction of application of the seismic action,
- modification of the position of the mass barycentre, for each floor, by an amount less than 5% of the dimension of the building measured perpendicular to the direction of application of the seismic action.

2.5 *Step 5. Check of intervention admissibility/sustainability*

The last step of the methodology involves checking the eligibility of the intervention (upgrading, improvement, repair) to be carried out on the asset. The extent and outcomes of the intervention should in fact be assessed in terms of i) compatibility with the heritage value of the asset, and therefore with any constraints and protections that concern it, ii) economic sustainability, iii) environmental sustainability. The positive outcome of this check implies the admissibility of the intervention, while the negative outcome requires rethinking the specific reuse scenario.

As stated in GBC (GBC Historic Building® HandBook 2017), the need to recover and improve assets of cultural significance focuses on safeguarding the structural behaviour and historical material. Regardless of the assets in which strategic or relevant functions are performed, it can be accepted that the intended use of a building, in general, can be chosen based on the response of the consolidated and restored structures to the overload. In this way, forced upgrading that distort the behaviour of historical structures could be avoided.

3 CASE STUDY. THE CARLO EDERLE BARRACKS

The proposed methodology was tested on the case study of the Carlo Ederle Barracks.

The Carlo Ederle Barracks is a military complex, located in Cagliari (Italy) in the so-called S. Elia promontory, named after the Major of artillery, Gold Medal for Military Valour, Carlo Ederle, who fell heroically on the Piave in 1917. The area, owned by the State Property Administration since 1860, moved from civil to military state property in 1925. It is a complex of buildings built on the initiative of the Ministry of the Interior and to be used as a correctional home for minors, then completed and partly adapted as a military district headquarters. Historically, the first Department encamped in the Barracks was the 13th Engineering Battalion of the Savoy Division, which was followed over time by further and various departments, up to hosting, starting from 1993, the Military District of Cagliari.

Currently, the Barracks is closed into a trapezoidal perimeter wall long about 633 m that encloses an area of 23380 m^2 and consist of 16 buildings used for different military uses. In particular, the entire area can be divided into two distinct sub-areas, one rectangular and one triangular, separated by the driveway entrance on the north side. The rectangular area, based on the difference in elevation, can be divided into three zones, zone 1 including buildings A, B and C with a difference in height of -3 m compared to zone 2, including buildings E, D, Q which in turn has a difference in height of -3 m compared to zone 3, including buildings G, F, P, H, I, L, M, N, O (Figures 2 and 3).

Figure 2. The Carlo Ederle Barracks. Aerial view.

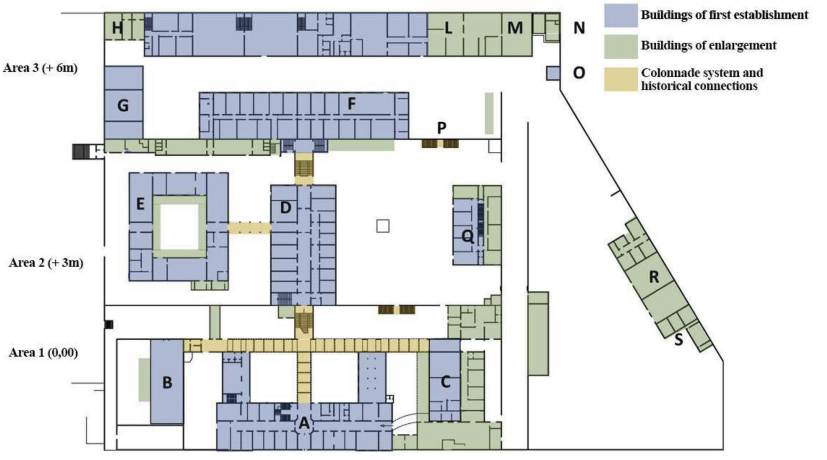

Figure 3. The Carlo Ederle Barracks. Location of buildings and construction evolution.

The Barracks reuse scenarios were defined based on a review of successful regeneration experiences of abandoned buildings and preliminary interviews with stakeholders, as well as on a preliminary recognition of the current state of conservation of the asset. Considering this, the adaptive reuse of the military site considers four possible scenarios: i) hotel complex, ii) residential and social housing, iii) creative hub, and iv) community cooperatives.

Table 1. The Carlo Ederle Barracks. Main information.

Location	S. Elia Promontory - Cagliari
Chronology of the construction	1860|1926|1945
Current use	Barracks
Surface	23317 m^2 (7694 m^2 indoor | 15623m^2 outdoor)
Restriction measures	Military state property | Restriction of cultural interest
Protected areas in which the asset is inserted	S. Elia Promontory – Cagliari | Environmental restriction
Availability/Accessibility	Available and accessible only to employees of the barracks. Extraordinary openings for cultural events. Seasonal public connections only.
Agreements	Protocol agreement between Italian Ministry of Defense and Local Administration for the coordination of military activities in the Region of Sardinia

The state of conservation of the asset was detected through an investigation protocol consisting of indirect and direct analyses. The indirect analyses, aimed at the reconstruction of the historical and architectural evolution of the complex, as well as the identification of its cultural values, were carried out through the critical-interpretative and cross-reference study of the historical documentary and iconographic sources found. This historical-critical analysis was aimed not only at acquiring all the documentation relating to the building history of the asset, but also to that of its past restorations, allowing for a broader understanding of the state of conservation considering previous interventions. The direct analyses consisted of the experimental investigation on the asset through geometric, architectural, and structural surveys, analysis of materials and techniques and state of conservation, aimed at understanding the architectural, material, structural and chronological components of the buildings. All the information were collected within a framework based on the so-called Raumbuch methodology, in which all the constructive elements are represented in details and assessed both in terms of consistency and cultural value.

The overloads relevant to each of the reuse scenarios were extracted from Italian NTC Tab. 3.1.II - Overload values for the different categories of use of buildings.

The comparison between the current structural condition of the Barracks and the structural performance required by the reuse scenarios led to the by and large identification of the type of intervention necessary for each of the buildings making up the complex.

Finally, the compatibility of the interventions with the need to protect the heritage value of the asset was assessed, aiming at quantifying the degree of sustainability of the proposed reuse scenarios. Since now no assessments have been made regarding the environmental and economic sustainability of the interventions.

4 RESULTS

As an example of the analysis process carried out on each building of the military complex, the results relating to the building identified as block 4 (Figure 4) are reported below.

Table 2 shows the overloads associated with possible reuse scenarios and previous use. Table 2 refers to the intended use categories indicated in Italian NTC Tab. 3.1.II - Overload values for the different categories of use of buildings.

The integrated analysis of the performance required by the reuse scenarios, including the fulfilment of standards, rules, and regulations other than NTC as mentioned in 2.4, and the current static conditions of the building led to the by and large identification of the type of intervention to be carried out on the building according to the reuse scenario. The result is shown in Table 3.

The outcome of the integrated analysis shows how the level of intervention is different according to the building reuse scenario. It can be noted that one of the scenarios would require an upgrading intervention, involving substantial changes in the overall structural behaviour of the building.

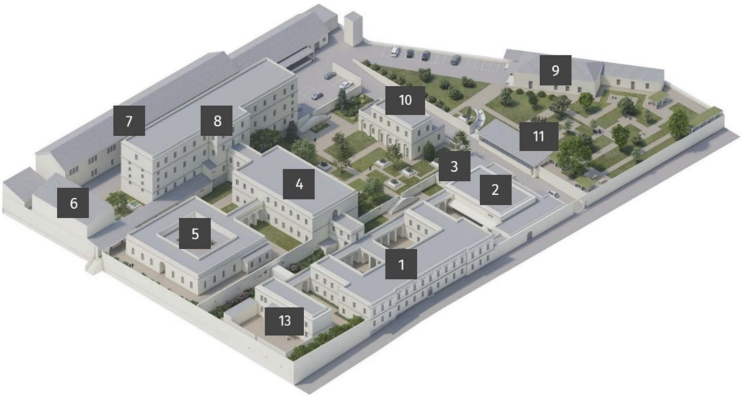

Figure 4. The Carlo Ederle Barracks. Building's labelling.

Table 2. Overloads according to the reuse scenario (Italian NTC Tab. 3.1.II - Overload values for the different categories of use of buildings).

	Use Scenario				
Overload* (KN/m^2)	Previous Offices (B1)**	Scenario 1 Hotel Complex (C2)	Scenario 2 Housing (A)	Scenario 3 Creative Hub (C3)	Scenario 4 Community Coop (D1)
q_k	2	4	2	5	4
Q_k	2	4	2	5	4
H_k	1	2	1	3	2

*q_k = uniformly distributed vertical loads; Q_k = concentrated vertical loads; H_k = linear horizontal loads
**B1 = internal offices; C2 = fixed seating areas; A = residential areas; C3 = Areas susceptible to crowding; D1 = shops.

Table 3. Categories of intervention according to the reuse scenarios (Italian NTC Tab. 3.1.II - Overload values for the different categories of use of buildings).

Intervention	Scenario 1 Hotel Complex	Scenario 2 Housing	Scenario 3 Creative Hub	Scenario 4 Community Coop
Local/Repair		X		
Improvement	X			X
Upgrading			X	

The illustrated procedure was applied to all the buildings of the Barracks, leading to a framework of general interventions which constitutes a fundamental tool for the decision-making process relating to the choice of final reuse scenario.

The framework of the interventions to be carried out on each building should obviously be evaluated as a whole and should be included in the set of useful indicators for evaluating the sustainability of the intervention itself and of the reuse scenarios.

5 CONCLUSIONS

The present paper presents a methodology to support the choice of the reuse scenario of large state-owned assets focused on the impact of the structural intervention that the asset should

undergo to satisfy the demand for structural capacity connected to the reuse scenario. The key element of the methodology is the check of structural compatibility between the current conditions of the asset and the performance demand of the reuse scenario, whose main factor is given by the entity of the overloads, imposed by the specific standards, depending on the intended use. The methodology was applied to the case study of a military complex, the Carlo Ederle Barracks in Cagliari (Italy).

The results support the concept that the structural capacity of the asset should be considered a key indicator for the choice of the reuse scenario. The methodology could become an important tool to support the public administration in the recovery and reuse strategies of state-owned real estate assets.

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