Relevance of Structural Conditions in the Sustainable Management and Reuse of Historical Military Buildings: An Interdisciplinary Approach

Elisa Pilia(✉), Giovanna Concu, Donatella Rita Fiorino, Emanuele Reccia, and Daniel Meloni

University of Cagliari, 09124 Cagliari, Italy
elisa.pilia@unica.it

Abstract. Nowadays, the management of existing historical military buildings has acquired paramount importance since, assessing the complexity and the significance of its inheritance, military strategies and standards have been changed, and structures have to be updated to meet current safety, energy, and functional needs. In Sardinia (Italy), an island characterized by a high number of historical military buildings and highly affected by the negative aspects of insularity, such as high costs for the supply of materials and energy, the development of sustainable strategies for the management of these buildings, not rarely underutilized or even abandoned, can represent an opportunity to meet current military standards and needs containing public expenses and reducing the environmental impact and additional use of land. The paper proposes an interdisciplinary approach specifically designed for the sustainable management and reuse of this historical military heritage. The proposed methodology emphasizes the aspect of structural safety, combining it with aspects related to conservation and restoration. Starting from the study of indirect sources and the acquisition of geometric/material/structural data using direct analysis and surveys, the protocol identifies a set of descriptors that defines the current condition of the building from both safety and conservation views. At the end of the process of knowledge, the index of priority of intervention is defined considering the overall state of conservation, use, and structural efficiency, to highlight the degree of urgency of the conservation or transformation/reuse processes and allow the sustainable planning of interventions on military real estate assets. The application to a case study is presented and discussed. The interdisciplinary approach has been developed within the research project IMASS-CHAIN (Infrastructure Management Support System CHAIN).

Keywords: military heritage · integrated knowledge · sustainable transition

1 Introduction

The Italian Ministry of Defence's built heritage is a complex and diversified inheritance with high levels of specialism, strict safety regulations, distributed and centralised management as well as a considerable historical value. Its management becomes increasingly

© The Author(s), under exclusive license to Springer Nature Switzerland AG 2024
O. Gervasi et al. (Eds.): ICCSA 2024 Workshops, LNCS 14822, pp. 421–434, 2024.
https://doi.org/10.1007/978-3-031-65318-6_28

difficult as its historical and artistic significance increases, if we consider the current requirement to minimise energy use, pollutant emissions, and land usage.

Nowadays, about 70% of Italy's building stock is approaching the end of its lifecycle in terms of age, exposing it to greater risks of vulnerability, decay, and energy inefficiency. At the same time, current European policies are pushing towards the effective zeroing of land consumption and the sustainability of any building and urban transformation affecting the built heritage (National Green Economy Council 2017). In this context, the recovery and reuse of the existing building stock assume a fundamental role and are rightfully among the actions to promote sustainable development, bringing benefits that affect environmental, economic, and socio-cultural aspects. Globally, several number of cases of conversion show the importance and potentialities of restoring historical military buildings, such as the former English Tanglin Barracks in the Dempsey Hill (Singapore), after several military reuses transformed into a dining, wining and green lifestyle enclave, or the Sardinian Arbuticci Fort, placed in La Maddalena, converted into a museum and actually known as the Giuseppe Garibaldi Memorial.

This process of transition is particularly relevant in the case of large state-owned building complexes, which in Italy are largely part of the above-mentioned Ministry of Defence assets (Fiorino 2021). About 65% of Italian military property is located in Sardinia, an island characterized by a high number of historical military buildings and highly affected by the negative aspects of insularity, such as high costs for the supply of materials and energy, which would benefit greatly from effective strategies for the sustainable management of this building heritage.

Dealing with these criticalities, a research project entitled IMASS-CHAIN (Infrastructure Management Support System CHAIN)[1] has been started, to define an effective protocol for the sustainable management of historical military building heritage.

Within the framework of the IMASS-CHAIN project, the present paper presents a research focused on implementing an interdisciplinary approach designed for the sustainable management of this historical military heritage.

Specifically, the proposed methodology aims to identify a set of descriptors that defines the current condition of the building from both safety and conservation points of view. These descriptors derive from a process of knowledge of the asset, conducted through the study of indirect sources and the acquisition of geometric/material/structural data using direct analysis and surveys. The combination of the identified descriptors leads to defining the priority index of intervention to be carried out on the buildings, taking into particular account the aspect of structural safety, which is appropriately combined with the aspects of conservation and restoration. The priority index of intervention is intended as a tool to highlight the urgency of the conservation or transformation/reuse process and allow the sustainable planning of interventions on military real estate assets. The methodology application to a case study is presented and discussed.

[1] The project has been developed and co-financed by the Italian Ministry of Defence, with resources from the National Military Research Plan 2020. See the acknowledgements for more info.

The paper is structured as follows: Sect. 2 illustrates the main characteristics of Sardinian military building heritage; Sect. 3 gives an overview of the IMASS-CHAIN research project; Sect. 4 highlights the importance of structural aspects in the process of knowledge of the building and gives an account of the chosen descriptors; Sect. 5 defines the index of priority of intervention; Sect. 6 reports on the application of the methodology to a case study; Sect. 7 summarizes the findings.

2 The Sardinian Historical Military Heritage: Management and Typologies

The Italian built inheritance, even more the Sardinian one, includes a complex and widespread historical military heritage composed of a high number of complexes – each one consisting of a variable number of buildings - heterogeneous in typology, uses and state of conservation. These military compounds distributed both in urban and peripherical contexts according to their function and the Armed Force (A.F.) of provenance, are defined by an extraordinary historical value, and a distributed and centrally organised governing structure.

Due to these considerations, managing these assets is extremely difficult. This is particularly true when they require maintenance and restoration interventions as well as new performance upgrades for responding to new military functions and demands, rationalisation strategies, financial constraints and minimisation of environmental impact. In Sardinia, due to the high number of buildings belonging to military state property, the issue is especially crucial, and it can be seen as a representation of the dynamics and processes occurring not just in the Italian region but also in the larger Mediterranean and European context.

Considering the management of this defence heritage, this is generally controlled by a complex network of institutions, authorities, and departments, both inside and outside the Ministry of Defence. These entities are involved in the infrastructure governance cycle and the legal framework of the main technical-administrative procedures at the various scales of intervention, including monitoring, maintenance, restoration, upgrading, and regeneration. Each of the A.F. has a separate Engineer Corp (*Genio*) specialised in building management, that is hierarchically organised[2] and operates according to precise Directives for infrastructure activities that are regularly updated and typically establish the knowledge, operations, and interactions between various offices. Also, the Engineer Corps register and manage their building stock in an information system platform (Management of the State Property of the Defence Administration) called Ge.Pa.D.D. and entrusted by the AID General Directorate. This platform contains all the information of the complexes designated by a special ID code (Compendium Code) which is organised according to the scale of investigation (building, floor, rooms, and elements) and themes (localisation, history, geometry, structural, technical-performance end hydraulic efficiencies, estimative assessment).

[2] Infrastructure management involves three hierarchical levels, summarised in the directive GEN G-001 as follows: Responsible Apex Commands, Technical bodies of Armed Force, Engineer executive bodies.

Looking at the architectural aspects of this valuable heritage, from the study of the national literature[3], it has been possible to define the historical models developed over time by the Military Engineers (typologies and profiles), with particular attention to the local variants and the diversities between the A.F. Also, the study has considered the uses associated with these typologies (functional taxonomies) and the requirements for today's military logistics. Thus, each functional macro-area has been linked to the type of asset according to the defined taxonomy. This information is fundamental for proceeding with the sustainable planning of interventions on buildings.

In general, complexes are characterised by a variable number of buildings, typologically different and in some cases specifically referred to as the A.F. For instance, the typology of isolated buildings, common in all the A.F., can have two different subtypologies: linear buildings with orthogonal wings or inclined wing, the last ones specifically designed by the Air Force. The Command and the Guard Corps are the uses associated with this building typologies. Other typologies, such as terraced buildings (offset-bodies or comb-shaped), courtyard buildings, and aggregation of volumes with different shapes (U, H, T, L, Z) are instead associated with logistic or residential uses. Moreover, the reuse of former convents is specifically linked to the Nineteenth-century process of reorganisation of the Army inside urban contexts with the installation of multifunctional barracks or hospital structures. Other specific typologies instead relate to A.F. peculiarities such as hangars for the Air Force and lighthouses for the Navy.

3 IMASS-CHAIN: Purposes and Integrated Research Protocol

The IMASS-CHAIN (Infrastructure Management Support System CHAIN)[4] research project aims at implementing an innovative certified and protected protocol for monitoring and intelligent governance of the historical military building heritage, starting from the existing heterogeneous information on the built heritage owned by the Italian Ministry of Defence, and to achieve functional and logistical models of the different infrastructural categories, applicable in a scalar manner from Sardinia throughout the national territory. In pursuing this goal, the project goes beyond the single A.F. (Armed Force) and considers the inter-force Defence infrastructural stock – the Army, the Air Force, the Navy and Carabinieri.

Within the project, a set of specific objectives have been identified for contributing to the general objective of the research and, although in their individuality, these have been significant for the understanding, interpretation, and management of the military heritage. According to the main project, the study of the buildings has been carried out

[3] The analysis is based on the cases study investigated and from some publications specifically concerning the national Armed Forces (Donesana 1875; Rocchi 1908, Rocchi 2010; Melis 1939; Geniodife 1991; Cassi 1996; FStorelliFTurri2014; Fiorino & Vargiu 2023) and Armed Force directives such as the *Direttiva S.M.E. Ispettorato dell'Arma del Genio, Pub. n. 6252 D.T. n.1 - Direttive per la Progettazione di accasermamenti, Roma, 26.11.1980.*

[4] The project has been developed and co-financed by the Italian Ministry of Defence, with resources from the National Military Research Plan 2020. See the acknowledgements for more info.

through the reconstruction of their historical transformations and the taxonomic classification of military functions and spaces. Then, to understand their state of conservation as well as to be able to make comparisons on the consistency of the heritage and the effectiveness of interventions (maintenance, upgrading, etc.), a series of descriptors and indicators for monitoring, evaluating and comparing the technical, functional and performance characteristics of the properties have been defined and codified. All this information is managed thanks to the implementation of an information management protocol, that transforms the information repository into integrated knowledge. The information collected during the process of knowledge has been dematerialised, and an innovative digital heritage file called DEF (Digital Enhanced Folder) has been implemented. The DEF aims to associate HBIM (Heritage Building Information Modelling), adopted as a knowledge synthesis and project control tool, with the possibilities offered by digital certification processes typical of the blockchain and the potentialities from intelligent predictive models.

The project proposes to identify and develop the management process needed for the adaptation, modernisation, and efficiency improvement of the building stock, taking into consideration the historical and architectural values embodied in the historical buildings, and the sustainability and cost-effectiveness of the interventions. Based on the study of the typological characteristics, uses and facilities required for these buildings, descriptors and indicators are useful for assessing the current state of conservation and, consequently, for monitoring the degree of efficiency and suitability of the constructions after the interventions. In addition, the comparison of these descriptors and indicators with the current regulatory framework can help to assess the nature and intensity of the corrections to be made using appropriate programming, planning and intervention strategies.

Overall, the IMASS-CHAIN project protocol can be structured into three phases (Fig. 1), and has been developed with the interaction and synergic research of five departments of the University of Cagliari (Sardinia-Italy): the Departments of Civil and Environmental Engineering and Architecture (DICAAR); Mathematics and Computer Science (DMI) for the IT aspects; Literature, Languages and Cultural Heritage for the aspects related to archives and history; Chemical and Geological Science (DCGS) for investigations on historical natural and artificial materials; Economics and Business Sciences (DSEA), for economic assessments and financial strategies. Other partners involved are the companies Leonardo S.p.A. and Flosslab S.r.l., important components of the research group to cover the field of data management and blockchain technologies and applications.

A selection of case studies, acknowledged as iconic symbols for each A.F., has been chosen for testing and evaluating the IMASS-Chain protocol[5] (Fig. 2).

[5] Pursuant to art. 333, c. 8 of the Code of Military Order.

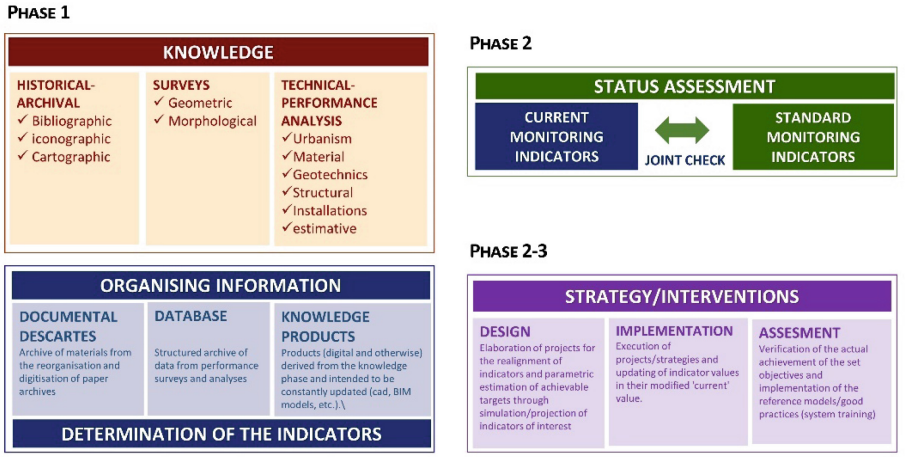


Fig. 1. Methodological scheme of the IMASS-CHAIN project

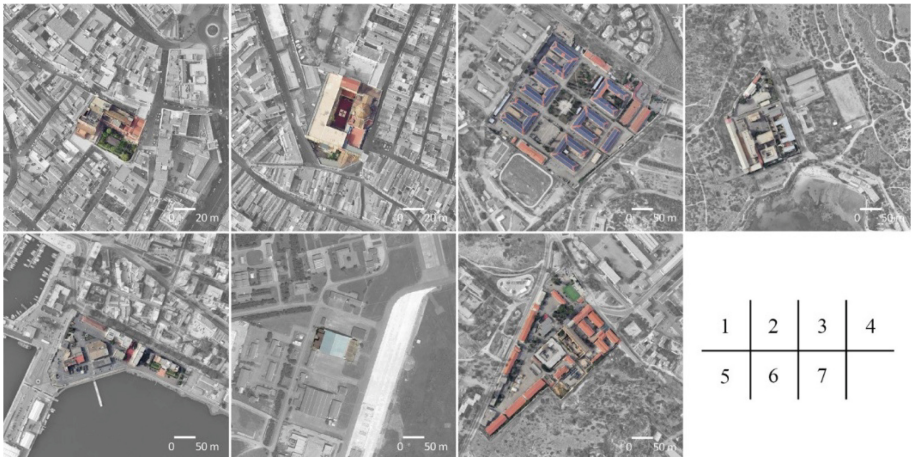


Fig. 2. Identification of the pilot sites: 1) De la Vallée Palace, Sardinia Army Headquarters, Cagliari; 2) De Murtas Barrack, Headquarters of the Military District of Legal Medicine in Cagliari former Military Hospital (typology of former convent, XVII-XX cent.); 3) Riva Villasanta Barracks, Cagliari, 14° Infrastructure Department (typology of functional pavilion barrack, XX Cent.); 4) Carlo Ederle Barracks, Cagliari, Military Documentary Centre (typology of the military complex, XX Cent.); 5) Naval Base, Ex Maricommi, Maritime Military Commissariat Headquarters, Cagliari (typology of naval base, post 1860); 6) Decimomannu Air Base, Hangar PG61 (typology of 555 model, post 1954); 7) Livio Duce Barracks, Headquarters XI Battalion Carabinieri Sardinia, Cagliari (typology of former penal colony, XIX Cent.).

4 The Process of Knowledge Acquisition

In restoration and reuse projects of architectural heritage of historical interest, recognizing the signs of history is equivalent to considering the different levels of protection and transformability of the individual construction elements as well as the relative constraints associated with them which must be recognized by reuse processes compatible with historical memory.

The topic is decidedly relevant if considered in the context of the reuse interventions of historic state-owned structures, mostly characterized by large dimensions, by a high number of construction stratigraphies which are also highly heterogeneous, by different and often contrasting uses during their history, as well as high levels of material compromise, caused by improper use or prolonged periods of abandonment.

A fundamental step for the management of built heritage is the definition of its current condition, in terms of the general state of conservation and detail of its components and all the aspects involved. Therefore, any building management project should start from the process of knowledge of the building itself.

To this end, within the framework of the IMASS-CHAIN project, an interdisciplinary approach has been proposed and implemented, combining the following steps of knowledge.

- Historical-archival analysis, carried out through the materials (historical and contemporary surveys, cadastral cartographies, historical iconographies, inventories, minutes and acts of delivery, technical project documents) conserved in the military archives of the same barracks;
- Chrono-typological and transformation analyses, conducted codifying the information with the *Raumbuch*, a methodology in which every element is uniquely codified and analysed not only under the historical point of view but also in its morphology and state of conservation;
- Morphological and dimensional analysis, also applying geomatics methods and tools such as total station and photogrammetry for the restitution of plans, façades, and sections;
- Analysis and characterisation of building elements (foundations, structures, masonry, facades, floors, vertical connections, roofs, plasters, mortars, decorative elements, fixed industrial apparatus, etc.) and their state of conservation, starting from all the previous analyses and applying proper protocols and tools of diagnostics;
- Structural characterisation of the building and each building element, with reference to the protocol explained in the following Subsect. 4.1;
- Technical performance analyses considering energetic, illumination, comfort, and hydraulics aspects.

4.1 Structural Issues in the Process of Knowledge

The choice of possible intervention strategies for the historic military building must necessarily take into account the structural aspects such as the static scheme, the constituent materials, the residual load-bearing capacity, and the state of conservation. It is, in fact, essential to carry out the compatibility check between the current structural conditions of the building and the performance demand in the possible reuse scenario, in

terms of structural configuration and loading conditions. It is important to avoid relevant alterations in the overall structural behaviour of the building which could affect the original distribution of loads and require significant structural interventions with possible heavy impact on the identity, costs, and on fulfilment of current technical regulations requirements. The most in-depth knowledge possible of the current structural conditions is therefore mandatory.

The process of knowledge acquisition focused on the definition of the relevant structural issues (Fig. 3), as suggested by the Italian regulations NTC (Technical Standards for Construction 2018), consists of the following three main steps:

1. Research, collection and critical review of existing data and information, such as original designs and so on, to reconstruct the building process, the changes the building has undergone over time, and the events that have affected the building over time;
2. Geometric and structural survey, to clearly define the geometry of each element and the overall building, the load-bearing frame, and the type and extent of any damage if present;
3. Determining the properties of materials, such as strength, stiffness, and density.

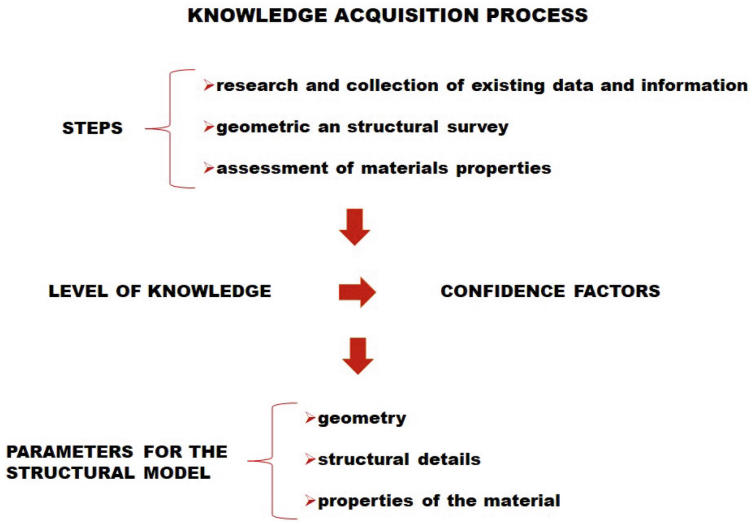


Fig. 3. The knowledge acquisition process

The structural models adopted consider the knowledge, with a level of depth that depends on the available documentation and the quality and extent of the investigations carried out, of the following characteristics of the construction: the geometry and construction details; the mechanical properties of materials and soils; the permanent loads.

Key factors in the structural compatibility check are linked to the maximum extent of overloads, or imposed loads, permitted by current technical standards, such as the Italian NTC (Technical Standards for Construction 2018). These loads include both the specific

loads linked to the intended use of the rooms and buildings and the seismic action, to which existing buildings, especially historic ones, can be vulnerable. The indications for the evaluation of the loads on buildings depending on their type and intended use are provided by the technical standards. A detailed discussion on this topic and the proposal of a 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 can be found in (Concu, Fiorino, Pilia 2023).

Within the IMASS-CHAIN project, the survey, the analysis of the state of structural conservation, the identification of the performance requirement as well as the definition of proper descriptors have been carried out on three levels with an increasing degree of detail: compendium, building and structural element. According to the knowledge acquisition process above described, a set of descriptors of the current structural condition of the building has been identified.

Concerning the choice of building descriptors, the choice fell on descriptors relating to structurally significant documentary information, data necessary for the calculation of the seismic action and descriptors that would give an accurate description of the structural types present on each building. Regarding the identification of structural types, to be able to classify them, reference was made to UNI8290, a classification system that was chosen unanimously with the other groups participating in the project, e.g. plant engineers and architects. For each structural type, the materials, and vertical and horizontal construction types were identified. For the calculation of seismic actions, it is also very important to assess the regularity in plan and height, the distribution of infills and the presence of structural joints. Finally, descriptors were identified for the building to give an idea of the level of knowledge of the building about the percentage of knowledge of its geometric-structural characteristics, material characteristics and construction details. A further set of descriptors has been chosen to identify the type and level of structural damage of the building and each building element.

Subsequently, based on the analysis and systematisation of the data, the factors (descriptors) capable of representing, punctually and effectively, the state of the art of the building and its variation consequent to the realisation of interventions (maintenance, corrective, upgrading, etc.) were identified.

The objective was to systematise all the descriptors and to select from among them, those particularly useful for monitoring the transformations over time and, consequently, first to represent and then to simulate the impact on the building heritage of the interventions, both in terms of technical and performance effectiveness and cost.

5 Index of Priority of Intervention

According to the specific objectives of the IMASS-CHAIN project and the descriptors defined for the structural aspects, it has been possible to define an important indicator to support the decision-making choices concerning the military built heritage: the index of priority of intervention, which can be related to both the building and the individual element. In fact, following the results of the study of the regulatory framework and analysis conducted on the buildings, it is possible to express the degree of urgency for the activation of the transformation process.

This index of priority is defined by assigning a scale of numeric values of two descriptors: the damage index, strictly linked to structural aspects, and the degree of transformability, linked to conservation/restoration aspects.

The damage index is defined globally and locally. The global damage index expresses an indication of the level of damage/vulnerability at the level of the building depending on the severity of the damage.

In the presence of structural damage, rather than non-structural damage or external hazards which occur rarely, there will be higher levels of the damage index. Structural damage is generally more critical to resolve than non-structural damage. The global damage index is defined as follows:

- Index 1 | low damage index. There is no significant damage to the structural and non-structural elements, nor specific external hazards;
- Index 2 | medium-low damage index. There is no significant damage to the structural and non-structural elements, nor specific external hazards. The possible presence of other minor risk factors is considered;
- Index 3 | medium-high damage index. There is damage in non-structural elements, or specific external hazards and minor risk factors;
- Index 4 | high damage index. There is significant damage in the structural elements or the non-structural elements in association with external hazards and minor risk factors.

The local damage index indicates the percentage of damage spreading at the level of the structural element and the relative severity. The greater the extent of the damage, the higher the damage index will be, i.e. more interventions will be necessary to resolve it.

The local damage index is defined as follows:

- Index 1 | low damage index. The damage affects less than 10% of the element;
- Index 2 | medium-low damage index. The damage affects between 10% and 30% of the element;
- Index 3 | medium-high damage index. The damage affects between 30% and 50% of the element;
- Index 4 | high damage index. The damage affects more than 50% of the element.

The degree of transformability is associated with the historical interest of the building, strictly related to the cultural value of its constructive elements: historic-artistic interest, historic-constructive interest, historical-textual interest, historical-textual-functional, or to the non-value, typological-material incongruence, or inadequacy to standards.

These degrees of transformability can be summarised in:

- Grade 0 | Not transformable, historic, and artistic interest. All the buildings marked with an interest cannot be altered and/or removed in any way. The only allowed intervention is conservation and maintenance;
- Grade 1 | Building with a compromised historic-artistic interest. This happens when the elements of this building are consistent with the artefact but no longer efficient in terms of technical performance. In this case, a moderate improvement intervention is permitted.

– Grade 2 | Not listed building but compatible within the complex. This grade is associated with buildings highly characterised by elements without a specific historical and artistic interest, but which are nevertheless compatible with the historical context in terms of both material and performance. In this case, an extraordinary maintenance is allowed.
– Grade 3 | Not listed building incompatible within the complex. The building is incongruous from the material, functional and performance points of view, as it is a modern/contemporary addition. It can constitute an anthropic degradation and for this reason, can be removed or replaced.

The damage index and the degree of transformability are then combined through a matrix that provides the priority index of the intervention (Fig. 4).

Damage index / *Degree of transformability*	*Grade 0* | **Not transformable building, historic and artistic interest** > conservation (4)	*Grade 1* | **Building of compromised historical and artistic interest** > conservation and partial reintegration (6)	*Grade 2* | **Uninteresting but compatible building** > extraordinary maintenance (8)	*Grade 3* | **Building to be removed** > new integration (10)
Index 1 > global | low demage > local | less than 10% (0)	4	6	8	10
Index 2 > global | medium-low damage > local |between 10% and 30% (4)	8	10	12	14
Index 3 > global | medium-high damage > local |between 30% and 50% (8)	12	14	16	18
Index 4 > global | high damage > local |more than 50% (10)	14	16	18	20

Index of priority*
High priority: 20-14 | Medium priority: 12-10 | Low priority: 8-4

Fig. 4. Matrix of the index of priorities of intervention

According to the matrix, the index of priority of intervention defines three levels of priorities: high priority for buildings with a score between 20–14; medium priority for scores between 12–10; low priority for scores between 8–4. The index of priority can be an effective tool for understanding and assessing the real urgencies and priorities of intervention within the wide historical military-built heritage, and for supporting a more coherent and strategic programme of interventions that should be evaluated and confirmed after an economic assessment of costs.

6 Case Study

The interdisciplinary protocol leading to the definition of the index of priority of intervention has been applied on one of the pilot sites described in Fig. 2: the Riva Villasanta Barracks, headquarters of the 14° Infrastructure Department, placed in Cagliari, in the area between the San Bartolomeo hill and the Poetto Avenue, typologically composed by six functional pavilions (1-3D and 1-3S), and two other blocks, the Command (C) and the dining (B) buildings (Fig. 5).

Each structure of this complex, built in the XX century and independent as functions, has been analysed and studied through the interdisciplinary approach described in Sect. 4.

In particular, after its in-depth investigation and the definition of the set of descriptors, the functional barrack 3S has been used for testing the index of priority of intervention, according to the damage index and the grade of transformability.

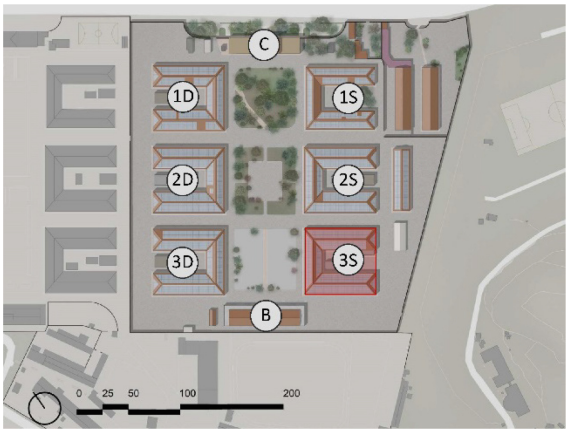


Fig. 5. Riva Villasanta Barracks, headquarters of the14° Infrastructure Department. Localisation of the functional pavillon 3S

The building is one of the six U-shaped modular bodies that are part of the complex and is intended for office and service use. The building develops on a partially mezzanine level above ground, planimetrically inscribed in a rectangle of approximate dimensions 64.00 × 58.00 m, with blocks approximately 14.00 m wide. The internal courtyard houses a technical compartment for technical systems. The building is therefore characterized by regularity in height, with regular openings and very dense windows. From a planimetric point of view, the plan is not compact and has a recess which makes the system irregular under the NTC2018. The internal distribution of the rooms is made up of quadrangular rooms with an average size of between 5.00 m and 6.00 m on each side. The load-bearing structure is made up of longitudinal walls, both the perimeter and internal partition walls, and the transverse walls that define the quadrangular rooms arranged at regular intervals. The elevation structures are made - as in the other structures of the compendium - from load-bearing partitions in limestone ashlars. Initially, the double-pitched gable roof was created using wooden trusses, but, following an intervention to position photovoltaic

panels on it, it was rebuilt in brick and concrete with a system of reinforced concrete beams. The foundations are direct and continuous, with increased thickness compared to the wall above. The state of conservation of the structure is generally good; no significant manifestations of damage and instability were detected.

On the one hand, considering the damage index, the building has value 1, low damage index, both at global and local levels, since there is no significant damage to the structural and non-structural elements, nor specific external hazards, and the damage affects less than 10% of the element.

Also concerning the degree of transformability the building has value 1, since the building, built around the 1930 and 1940, has a historical interest but it is partially compromised by some constructive elements that are not totally compatible and sustainable from the technical-performance point of view.

The combination of the damage index and the degree of transformability by using the matrix described in Fig. 4 gives an index of priority of intervention of 6, which is a low-priority index.

The application of the procedure and the definition of the index of priority of intervention for all the buildings in the compendium will allow the management and planning of the interventions in terms of urgency and priority.

7 Conclusions

This paper presents an interdisciplinary methodology for the definition of the index of priority of intervention on buildings belonging to military state property.

As part of the broader IMASS-CHAIN research project, aimed at defining an effective protocol for the sustainable management of historical military building heritage, a methodological protocol is proposed here, following the process of knowledge suggested by current legislation, for the determination of the state of conservation of buildings belonging to military state property. This protocol highlights the particular relevance of the aspects linked to the structural performance of the construction.

The index of priority of intervention has been defined by the combination of two factors: the damage index, closely linked to the structural aspects, and the degree of transformability, dependent on the conservation and restoration aspects. This index can be acknowledged as an indicator of the general state of conservation of the building, but above all, it is intended as a useful tool for planning the interventions to be carried out on the large number of properties belonging to the vast military built heritage.

The proposed methodology can easily be extended to other sectors of the Public Administration, that, like the Ministry of Defence, need to make conscious decisions on the efficient use and valorisation of their building stock.

Credits The introduction and conclusion are written by all the authors; par. 2 is edited by E. Pilia, par. 3 is edited by D.R. Fiorino; par. 4 is edited by G. Concu, E. Reccia, and D. Meloni; par. 5 and 6 are edited by G. Concu and E. Pilia.

Acknowledgements. The research is included in the three-year research project entitled IMASS-CHAIN - Infrastructure Management Support System Chain, co-funded at 50% under the National

Military Research Plan 2020 (CIG: 884399685F - CUP: D84H22001380001) by the General Secretariat of the Difesa/DNA and contract execution mandate to the Directorate of Works and State Property (GENIODIFE). The leader partner is the University of Cagliari with coordination of the Department of Civil and Environmental Engineering and Architecture (DICAAR) (PI. Prof. Donatella Rita Fiorino), in collaboration with the Department of Mathematics and Computer Science (DMI). Partner: Fosslab S.r.l./Leonardo S.p.A. Start of the project 01.12.2022. Moreover, the study is included in the framework of the Collaboration Agreement between the University of Cagliari and the Italian Ministry of Defence, specifically dedicated to the cooperation in the field of the redevelopment of military areas, signed on 19.09.2023 and still in force (scientific coordinator Donatella Rita Fiorino for the University of Cagliari and col. Pasqualino Iannotti for the Ministry of Defence - GENIODIFE).

References

1. Cassi Ramelli, A.: Dalle caverne ai rifugi blindati, Istituto Italiano del Castelli, Mario Adda Editore (1996)
2. Concu, G., Fiorino, D.R., Pilia, E.: Sustainable reuse of public real estate assets meeting structural, conservation and territorial needs. In: 8th International Symposium on Life-Cycle Civil Engineering, Milano, Italy, July 02–06, 2023, In: Biondini, F., Frangopol, D.M. (eds.) Life-Cycle of Structures and Infrastructure Systems. CRC Press, Taylor & Francis Group, London, UK (2023)
3. Donesana G.: L'accasermamento delle truppe Considerazioni generali e cenni storico critici sulle caserme d'Italia. In: Rivista Militare Italiana, II, tomo IV, XX (1875)
4. Fiorino, D.R., Vargiu, M.: Tra terra e cielo. Le infrastrutture aeronautiche in Italia, dalle prime esperienze al Secondo Dopoguerra, Difesa Servizi SpA - Edizioni Rivista Aeronautica, Roma (2023)
5. Fiorino D.R.: Military landscapes. a future for military heritage. In: Proceedings of the Internazional Conference, La Maddalena, 21–24 giugno 2017. Skira, Milan (2017)
6. Fiorino, D.R.: Sinergie. Percorsi interistituzionali per la riqualificazione delle aree militari. UNICApress, Cagliari (2021)
7. Geniodife: Edilizia Militare, Dieci anni 1980–1990. In: Edilizia Militare numero speciale (1991)
8. Melis, A.: Caratteri degli edifici Distribuzione, Proporzionamento, Organizzazione degli edifici tipici, Editrice Libraria Italiana, Torino (1939)
9. National Council of the Green Economy (Consiglio Nazionale della Green Economy): Verso l'attuazione del Manifesto della Green Economy per l'architettura e l'urbanistica (2017). https://www.statigenerali.org/wp-content/uploads/2017/11/ssge_2017_documento_gdl_architettura_urbanistica.pdf
10. Rocchi E.: Le fonti storiche dell'architettura militare, Officina Poligrafica editrice, Roma (1908)
11. Rocchi E.: Storia delle fortificazioni e dell'architettura militare, Associazione Italia, Genova (2010)
12. Storelli F., Turri F. (eds.): Le caserme e la città I beni immobili della difesa tra abbandoni dismissioni e riusi, Palombi Editori, Roma (2014)
13. Technical Standards for Constructions (Norme Tecniche per le Costruzioni): D.M. 17.01.2018, Italian Ministry of Infrastructures and Transportation (2018)
14. UNI8290: Building system classification (1987)