TEMA
Technologies
Engineering
Materials
Architecture

Journal Director: R. Gulli

e-ISSN 2421-4574
DOI: 10.30682/tema0801

Vol. 8, No. 1 (2022)

Issue edited by Editor in Chief: R. Gulli

Cover illustration: Tokyo International Forum by Rafael Viñoly, interior view.

Editorial Assistants: C. Mazzoli, D. Prati

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e-ISSN 2421-4574
ISBN online 979-12-5477-084-9
DOI: 10.30682/tema0801

Vol. 8, No. 1 (2022)
Year 2022 (Issues per year: 2)

Scientific Society Partner:
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TEMA: Technologies Engineering Materials Architecture
Vol. 8, No. 1 (2022)
e-ISSN 2421-4574

CONSTRUCTION AND BUILDING PERFORMANCE

BUILDING AND DESIGN TECHNOLOGIES

DESIGN STRATEGIES FOR THE RECOVERY AND ENHANCEMENT OF LIGHTHOUSE: SOME CASE STUDIES OF THE LIGURIAN SEA

Giovanni Santi, Serena Braccini

TEMA Technologies Engineering Materials Architecture
e-ISSN 2421-4574
Vol. 8, No. 1 - (2022)

DOI: 10.30682/tema08011

Abstract

This paper presents the first results of ongoing research analysing some coastal lighthouses in the territorial jurisdiction of the Northern Maritime Command of La Spezia, located between the Island of Elba and the Gulf of La Spezia. The research is inspired by the "Valore Paese - Fari" initiative, launched in 2015 by the Agenzia del Demanio, with Difesa Servizi S.p.a, to promote in the real-estate market several currently disused lighthouses by granting them to overcome the management and maintenance problems. Some of the lighthouses on the Italian coasts are now affected by a gradual abandonment caused by the spread of current geo-localisation technologies and remote control and management systems. The research aims to highlight the historical and cultural importance of lighthouses, identifying possible valorisation strategies and development potential in terms of flexibility and ability to adapt to a radical functional transformation. The article firstly outlines a typological atlas of lighthouses and highlights their technical constructional characteristics. Subsequently, the design strategies of the lighthouses under study are defined for their recovery and valorisation in compliance with architectural and economic requirements. Starting from an organic and systematic classification that filled the great lack and fragmentation of available information, a detailed survey was carried out using HBIM throughout the knowledge phase, and the Value Analysis method was used to define design solutions that meet pre-established financial requirements and limits. In summary, the research shows how the lighthouse architectures are linked to the coastal context area, especially to the construction techniques concerning the different local cultures, and can lead to interesting economic and social revitalisation processes of the surrounding areas.

Keywords

Lighthouse architecture, Building rehabilitation, HBIM, Value Analysis, Maritime cultural heritage.

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1. INTRODUCTION

Lighthouses are an iconic symbol linked to extraordinary landscapes and the most important port cities with a waterfront. Their history and technical evolution are closely related to navigation progress, and it is not easy to find a chronological beginning. Parallel to the growth of the great civilisation of the past, and their consequent need for political and commercial control, there was the development of technology and the evo-

lution of light signals to provide aid and security to the fleets [1, 2].

In this context, lighthouses have a significant historical and architectural value firmly rooted in the environmental contexts in which they are located. They are complex structures, the geometry, structure, architecture, and optics of which must be understood to understand their physical nature. This is why, in addition to fulfilling their function of orienting navigation, they are fascinating, and a source of inspiration for poetry, metaphysics, and design experimentation [3, 4], and are also affected by specialised tourism that has been flourishing in several coastal areas and port cities with waterfront capable of providing the ideal setting for escape experiences [5].

Since the end of the last century, the lighthouses have begun a gradual decline due to automation systems that have often made unnecessary the presence of the lighthouse keeper, who left his home inside the lighthouse. The lighthouse keeper's homes are abandoned, slowly falling into a state of disrepair due to the absence of constant maintenance, compromising the intricacy of the entire building complex. The historical and symbolic importance of lighthouses, as evidence of peoples' cultures and icons of territories, has led to the desire for their recovery. In many European and non-European countries, there are numerous interventions of reconversion and reuse of lighthouses in tourist-cultural facilities, information points, and restaurants. This conversion and regeneration have helped activate local economies to the benefit of the community. The Italian situation is characterised by a maritime signalling system that the Navy has always managed, and this is why it is challenging to study this subject, having to deal with a military architecture whose information was secretly kept in the past.

The first complete list of Italian lighthouses dates back to 1876, published by the Central Hydrographic Office of the Royal Navy in Genoa to support technical coordination to regulate issues in the management of lighthouses, as was the case for the French Phares et Balises that were under the control of the French Service of Lighthouses [6]. In 1881 an extraordinary Commission was appointed for the reorganisation of lighthouses and lanterns, which drew up the first organic program of interventions on the coasts of the Kingdom, starting the construction of over 100 signals. The first fundamental law on the subject was promulgated in 1885, giving the management of lighthouses to the Superior Council of Public Works established in that Ministry (Fig. 1).

In 1910 the whole matter passed into the hands of the Royal Navy, which began many works of modernisation until 1915. The service was reorganised by establishing the Inspectorate of Lighthouses to ensure an efficient system of support to navigation: simple entities, autonomous, and with the ability to manage and intervene even in the most isolated points of the coasts. The entire national territory was logistically divided into eight zones, called Lighthouse Zone Commands, which provided the service operation on the stretch of coast under their jurisdiction [7, 8]. After the Second World War, the Navy reorganised the Lighthouse Division, establishing a program of reconstruction, recovery of damaged lighthouses and construction of new ones with the help of the Ministry of Public Works, which continued until 1965. At the end of 1966, the Ispettorato Fari e Segnalmenti Marittimi (Lighthouse and Maritime Signaling Inspectorate) was established under the authority of the Navy Chief of Staff, with the help of a technical office based at the naval arsenal of La Spezia. The network of Italian lighthouses (which today counts about 147 lighthouses and 719 beacons, including maritime beacons and buoys) was divided into six zones of territorial competence: La Spezia for the upper Tyrrhenian Sea, La Maddalena for Sardinia, Naples for the lower Tyrrhenian Sea, Messina for Sicily, Taranto for the Ionian Sea and the lower Adriatic Sea, and Venice for the upper Adriatic Sea [9]. In each of these areas, the Lighthouse Area Command has the task of managing maritime signage and routine maintenance using military and civilian personnel; these Commands depend on the respective peripheral Navy Commands and the Lighthouse Inspectorate. This is why the technical reference on our territory is made up of the bodies of the Navy that deal with the management of the national heritage of lighthouses, which keep the structures and optical devices in good working order and provide for their maintenance and eventual decommissioning, as well as authorising any study and survey activities, and they are: the Lighthouse Logistic Inspectorate in Rome; the Lighthouse Technical Office (MariTecnoFari), based

Fig. 1. *1902 Map of the leading Italian Lighthouses. (Image source: archive Ufficio Genio Marina Militare Livorno).*

in La Spezia, the 6 Area Commands (MariFari). These bodies have the lighthouse maintenance booklets, in which we find all the technical information describing the plant equipment and its condition, information on the main geometric dimensions, location and accessibility through drawings and photographs. However, the data is often incomplete or uneven concerning graphic documentation, creating difficulties in managing this patrimony which, being so particular and complex, would need the contribution of more specialised skills. By integrating traditional instruments with computer tools, it will be possible to achieve a frequent update of the state of health of the various lighthouses and targeted planning of maintenance and restoration interventions.

In Italy, the lighthouse reuse process started in 2015 thanks to the project promoted by Agenzia del Demanio, "Valore Paese - Fari", taking inspiration from foreign national reuse plans [10, 11]. However, only a few lighthouses have been given in concession due to a complex and articulated landscape of buildings located in urbanised and non-urbanised territories, which clashes with numerous regulatory constraints and technical and technological difficulties. In this framework, it is essential to identify theoretical, methodological, and design aspects to transform the existing building related to the concept of resilience, with particular attention to the definition of methods for the knowledge and assessment of critical points and vulnerability of such a sensitive architectur-

al heritage [12]. The paper presents the synthesis of research, started in 2018 and still ongoing, and developed in agreement with the Northern Maritime Command of La Spezia, which aims to investigate and evaluate the recovery methods of some of the lighthouses in the Ligurian Sea located between the Island of Elba and the Gulf of La Spezia. The work is articulated in the first part, in which the scope of the investigation and the methodological approach are outlined; then, the choice of the typological method has facilitated the understanding of the architectural-constructive complexity also in HBIM for this type of highly specialised architecture. Subsequently, the topic of transformability is addressed, satisfying the spatial correspondence – planning and volumetric – for the new uses, and verifying the feasibility of new service volumes. Then, thanks to applying the Value Analysis method, it was possible to identify the various design solutions that, respecting the geometric matrices, the structural grids and the economic resources, have been configured more sustainable in function of the relationship between the building and the place.

2. MATERIALS AND METHODS

The architectural features of a lighthouse can be traced back to those of the military installation of the watchtower. These features change according to the period of construction, construction techniques, the geography of the place and the location in relation to the surrounding buildings. Each lighthouse is unique, with its own identity and character, defining aesthetic and material aspects. This also includes elements such as the overall shape of the structure, its materials, its decorative details, its interior spaces, as well as the different aspects related to its location and natural environment.

The main components of a lighthouse are the lantern and the tower; the first one includes the chamber with the optical and illuminating devices, the second one, located below the lantern, consists of the lantern supporting structure, the stairs and the watch or clock chamber [13–16].

Although a typological classification is difficult because political factors, necessity, location and geography of the place, as well as the technology available at the time of construction, influenced the form and nature of the lighthouse to such an extent that each lighthouse is unique, an initial classification of lighthouses is possible based on their location. A first distinction can be made between isolated lighthouses, lighthouses in ports and lighthouses in the open sea. The former is almost always equipped with a second building, intended for the farmer's house, which is lower than the height of the lantern in order not to limit the angle of illumination. The tower can be integrated into the service building, and it can therefore be placed either along the axis of symmetry, in a corner or on its side, or externally. It varies in geometry externally, while internally, it usually has a circular shape to accommodate helical flights of stairs.

The most common materials used are wood for roofing, stone for masonry, reinforced concrete for newer load-bearing structures such as the tower and staircase, steel for metal latticework, and plaster for cladding. In order to better distribute the weight, stone masonry towers are built with slight tapering as they rise in height to allow the base to support the weight of the tower without becoming unstable.

The various luminaire models include tower, lattice, tower or fortress and block luminaires. The latter are among the most common along the Tyrrhenian and Ligurian Seas, and, being isolated, they are composed of the tower and the service building. Among the analysed lighthouses, the Punta Polveraia one, on Elba Island, is a block lighthouse, characterised by a single-story building with a flat roof, from which there is access to the tower above, located along the axis of symmetry and jutting out from a front. This arrangement creates a very rational floor plan organisation with two living quarters and two offices, typical for this lighthouse.

Lighthouses in ports, which do not need to house the lighthouse keeper for long periods, are distinguished by their height and volume, such as the lighthouse in the port of Livorno. The category of lighthouses in the open sea shows both the need to have space inside for the lighthouse keeper to live, as in the case of the Scoglietto lighthouse on Elba Island in the middle of the sea, and to have imposing heights, either because they are at sea level, or because they are located on fortresses in strategic and visible points, as in the case of the San Venerio lighthouse on the island of Tino in the Gulf of La Spezia (Figs. 2 and 3).

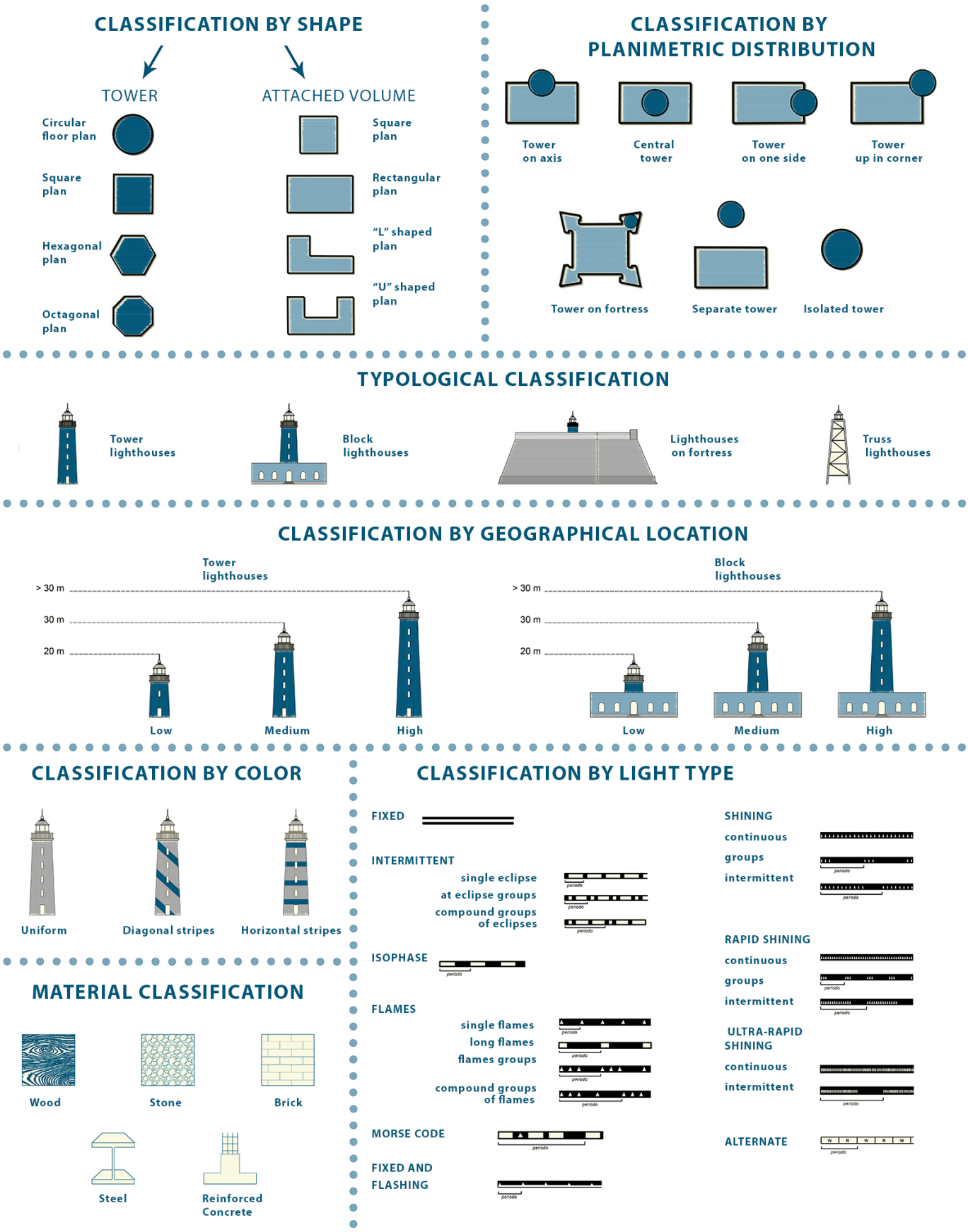

Fig. 2. *Typological classification of lighthouses.*

Fig. 3. *Top: on the left, the block lighthouse at Punta Polveraia on the Elba island; in the center, the isolated tower lighthouse in the port of Livorno; on the right, the Scoglietto lighthouse on the island of Elba in the middle of the sea. Below: on the left, the lighthouse on the San Venerio fortress on the island of Tino in the Gulf of La Spezia; on the right, the Monte Poro lighthouse.*

As well as understanding the architectural and structural features of a lighthouse, the issue of accessibility is crucial for future recovery strategies. Lighthouses, being structures that primarily arise in unspoilt places to be visible mainly from the sea, are often difficult to access. This problem can sometimes be found even in lighthouses located in urban contexts because they are in areas with controlled accessibility; see, for example, the Livorno lighthouse located inside a boatyard. The issue of accessibility, usability and accessibility is therefore of fundamental importance for the life of the lighthouse, and in this context, two main situations stand out, accessibility by land and accessibility by sea.

In the case of urban lighthouses, the structure is sufficiently connected to the territory thanks to the presence of driveways and, in some cases, the public transport network. This may not be the case for isolated lighthouses. In fact, lighthouses are designed to be self-sufficient, so the connections to the service network are often insufficient and, at other times, completely absent. The gradual abandonment of lighthouses has also impacted the quality of land connections. Driveways, mainly footpaths, deprived of constant maintenance, have become unusable and dangerous. The main problems of accessibility by land are related to the overcoming of height differences, the lack of parking areas and the absence of connections to services. The issue of the slope of the communication routes, whether pedestrian or vehicular, is fundamental as it limits access to people with mobility problems, decreasing the usability of the structure. In addition, it is conditioning in choosing the different types of means of transport with which the site can be reached.

Accessibility by sea is essential in the case of lighthouses located on isolated islets and rocky outcrops, which can only be reached by boat. In this case, careful planning must be carried out, considering the transport of building materials and handling equipment. When choosing the most appropriate use in a redevelopment project, the influence of sea currents and winds that may prevent docking must be considered. For example, the accessibility of the San Venerio lighthouse is conditioned

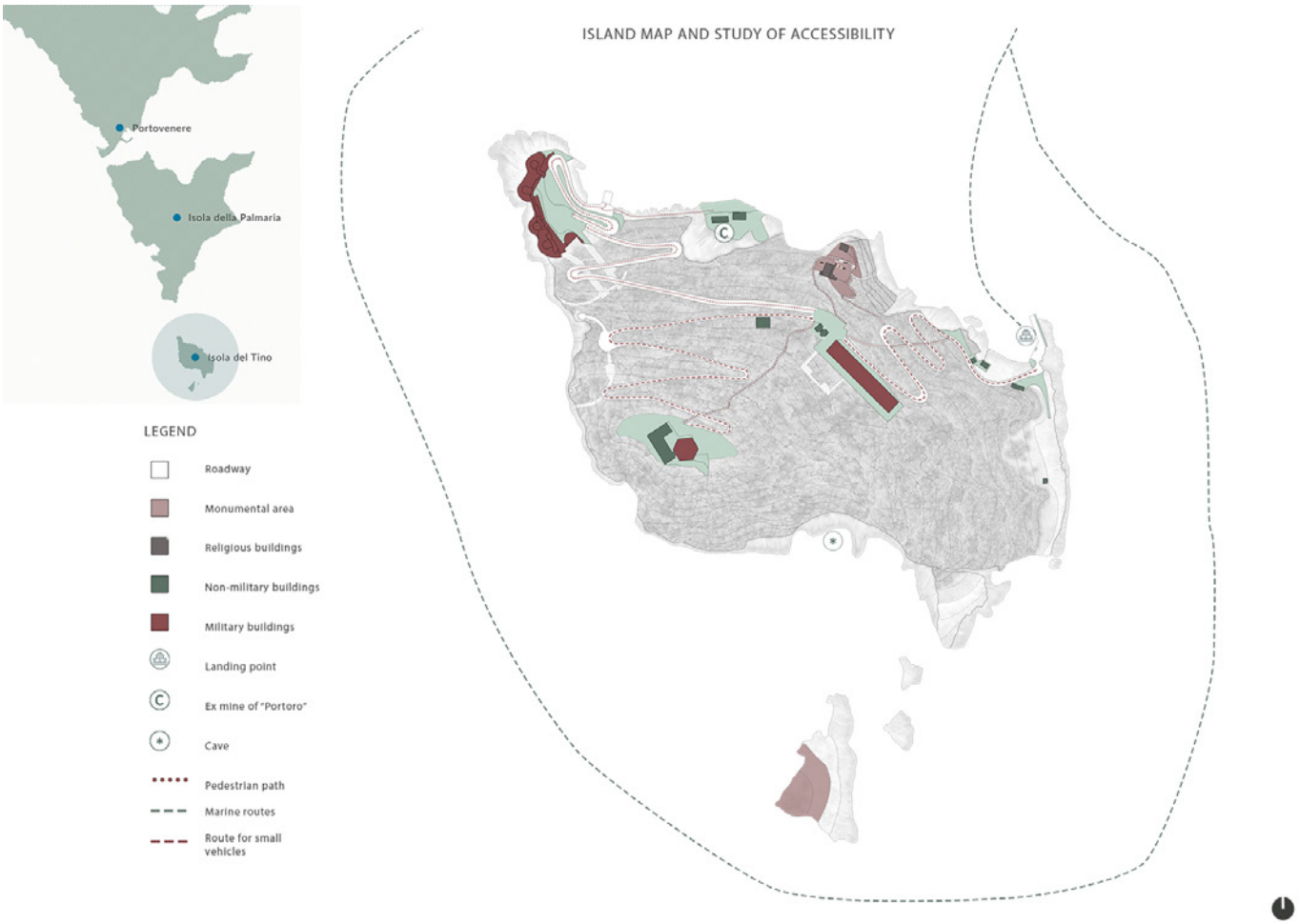

Fig. 4. *Location and current map and study of the accessibility of the island of Tino.*

by sea conditions which, when critical, do not allow docking at the arrival pier (Fig. 4).

The research work began with a reading of the buildings in their historical, relational, technical-constructive and functional aspects through a process that required the preparation of special analytical sheets to codify the artefacts analysed. Specifically, the sheets drawn up and applied for the analysis of the lighthouses contain information regarding the territorial context and relational, typological, technological and material data, plus the current state of deterioration and the usability and accessibility of the lighthouse.

The next phase involved analysis in the field through direct surveys for the graphic restitution of the buildings and analyses of the level and type of deterioration of the structures, as well as the kind of services with which the buildings are equipped, such as electricity, water and sewerage connections. The drawing up of the graphic designs and the analysis of the bibliographic sources made it possible to obtain both an architectural and constructive knowledge of the lighthouses examined in the area of reference. Unfortunately, the existing archival documentation, in many cases, does not include sufficient graphic drawings, which is a limitation for the three-dimensional representation of the buildings. This obstacle has been overcome by using aerial photogrammetry and photogrammetry; considering the difficult geographical location of lighthouses, which prevents optimal positioning of topographical equipment for direct measurement or photographic imaging, it is necessary to find a fast and smart knowledge approach [17, 18].

Photogrammetric surveying was necessary to determine objects' spatial position and characteristics (shape, size, etc.) from images. Compared to other 3D scanning methods, the work of taking and processing photos is relatively simple; advantages include the speed of ob-

taining the necessary information, the reliability and objectivity of the data, cost-effectiveness, and a high level of automation.

The acquired images were imported into the Metashape software to create a cloud of points to be exported in .e57 format to be imported into the BIM model by editing a mesh and a model from which it was possible to save orthophotos in .jpeg format; the latter is realistic and in scale representations of parts of the structure, with high definition and containing a high degree of detail of the elements.

The purpose of the orthophoto is to generate realistic reconstructions of the external surface, which, when imported into the modelling software, enrich the amount of information in the model. In the "Element Attributes" section, new surfaces were created, containing photos of the current state as textures; the definition of the latter made it possible to apply these surfaces, for example, to the "Wall" element, obtaining a realistic visualisation of the state of the environment. This step is vital to determine the elements of surface degradation present by modelling them in three dimensions, thus configuring them as objects to which it is possible to add all the information necessary for their description.

Within each "Shape" object, the characteristics of the type of degradation already represented graphically have been inserted, and a new classification called "Analysis of degradation" has been added to which the properties "Description" and "Recovery actions" have been incorporated. In this way, an external operator can identify the element from a descriptive and operational point of view through the object's properties.

In order to make the reading of the degradation elements clearer, an abacus was created, within which a graphic visualisation of the component, the identification ID, the area expressed in m^2, the description of the element and the recovery interventions were inserted. However, some criticalities emerged at this stage, linked to how the different interfaces of the modelling software used (ArchiCAD) were displayed. In fact, the inclusion of realistic surfaces within the model made it possible, on the one hand, to analyse the actual state of affairs, enriching the model with illustrated information, but on the other hand, this visualisation is not possible when switching to a 3D view. For example, when exporting sections, elevations or 3D documents, the display of the elements does not read the texture assigned to the surface but only the solid colour assigned to it; therefore, it was necessary to proceed by choosing another procedure, i.e. overlaying the elements with an "Image Screen" containing the realistic photo (Fig. 5).

Almost all the elements and components of the lighthouses studied were modelled based on reflections regarding semantics and geometric constraints consistent with building practice. Because of this, it was necessary to define personal profiles that also allowed the definition of the masonry compartments and decorative devices, such as battlements or corbels, all non-standardised elements that are not present in the libraries. These elements were modelled and informed manually with all the data collected through archival and documentary research and visual analysis [19].

3. DISCUSSIONS

The problems related to the redevelopment of lighthouses are mainly related to their location and accessibility and the size of the interiors. From the point of view of new functions, this factor can be advantageous or disadvantageous according to the type of future users. As previously introduced, the infrastructural network of connections can be an obstacle in the interventions of requalification because, very often, access is guaranteed only through paths that make the usability and the accessibility of the site very complex. In these cases, the hypothesis of creating new roads is sometimes hindered by bureaucracy and constraints in the area, and it is not easy to reconcile these two aspects. The study area has therefore been analysed to verify the accessibility by land and by the sea of the lighthouses, and this has been possible through the identification of the main roads, making a series of environmental topographic sections along the road sections, studying the orography of the territory, highlighting the progressive distances, the types of roads encountered, the slopes, and the possibility of docking from the sea for boats. Once the different types of transport to be used were identified, a new network of connections to the lighthouses was identified,

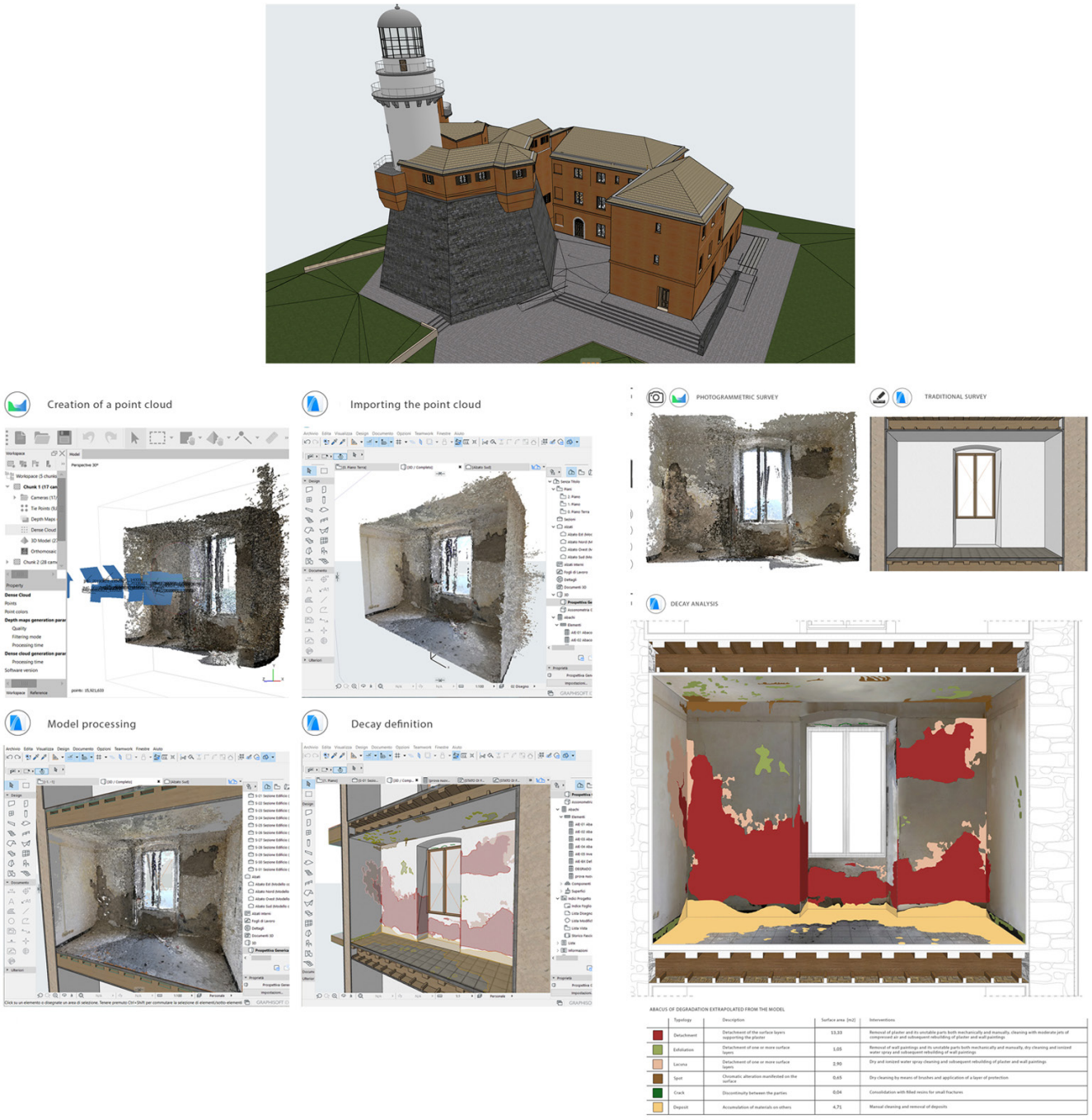

Fig. 5. *Workflow performed from data acquisition to data processing – from 3d model to the decay analysis –. The 3d model of the Lighthouse of San Venerio on the Island of Tino. Study of one of the interiors.*

focused on slow mobility, connected to the main settlements of the island and the scenic coastal areas (Fig. 6).

In the case of lighthouses, we are often confronted with limited volumes in which it is difficult to create additional functional spaces for new uses. This factor greatly influences the design choices, and, as demonstrated by the interventions carried out to date, the simplest option is the one that comes closest to the previous function of the service building, the lighthouse keeper's house, that is, the conversion into accommodation.

In this context, the enhancement of lighthouses should not be seen only as an economic return for the individual manager but as an economic resource for the whole territory. Therefore, making a functional mix coexist inside these buildings, with public-social and private for-profit activities, making the spaces as flexible

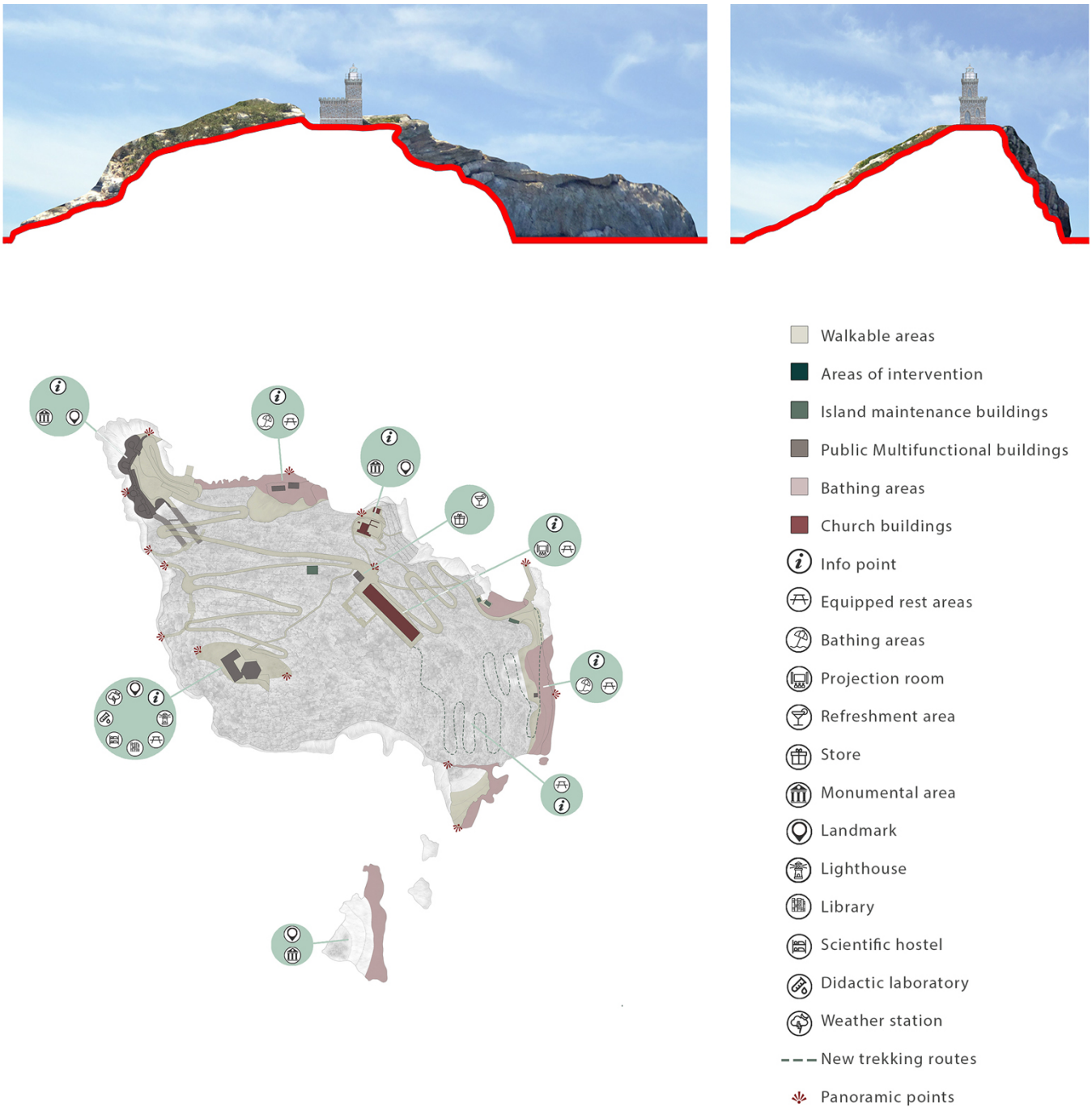

Fig. 6. *Above: altimetric profile of the area surrounding the lighthouse of Scoglietto, Island of Elba. Below: verification of the accessibility of the Island of Tino with the new proposed destinations.*

as possible according to present and future functional needs, can be a winning strategy.

The research during the economic assessment for the recovery and possible disposal of lighthouses has dealt with the analysis of the current offer in the field of lighthouse accommodation, focusing in particular on accommodation facilities included within the lighthouses located along the Mediterranean coast, then extending the analysis to the European and non-European context.

Lighthouses re-functionalized for hotel use are present along all the Mediterranean coasts, especially in Croatia, where a process of valorisation of these buildings for tourism purposes has been undertaken for some time. Similar structures are also present in France, Malta, Greece, Spain, Canada and the United States overseas. The structures an-

alysed were identified by searching booking sites, tourist agency sites and reading online articles, making it possible to file lighthouses based on location and offered services. In addition to their hotel purpose, lighthouses have also been converted into museums, observation points for animal species, and centres for sports practices. One good practice worth noting is the Canadian lighthouse decommissioning program in Quebec, the Route des Phares, which is an example of how lighthouses could be managed without necessarily converting them into luxury hotels while at the same time making cultural, intelligent, niche tourism use of them [20].

The analyses show that hotel structures built in lighthouses abroad have an average cost of overnight stay considerably lower than in the two Italian cases, Capo Spartivento in Sardinia and Capo di Punta Fenaio on the island of Giglio, and this favours a more significant presence on the tourist market.

Obviously, the problem of seasonality is to be considered in the financial budgets, involving, above all, non-hotel structures that close during the whole winter period.

In the development of this phase of work, the feasibility of design hypotheses was therefore verified, which, after a conservative recovery of the structures, have the purpose of making the spaces livable and able to accommodate multiple functions according to the various spatial areas.

The project solutions for the lighthouses of Elba and the one on the island of Tino have been elaborated thanks to a synthesis of the information gathered during the initial phase of the research, which concerned the geographical-administrative location, the urban destination and the level of transformability, the existence of constraints, taking into consideration the period of construction; but, above all, referring to the call "Valore Paese - Fari" which has the objective of a recovery aimed at developing sustainable tourism, linked to the culture of the environment and the sea.

The research, at this stage, applied the Value Analysis Method to estimate the utility of the asset, through the seven classes of requirement [21, 22], verifying whether the artefact was more or less transformable, then the possible functional destination. This was possible by imposing specific objectives on the Value Analysis: to respect the pre-existent historical sites and the environmental context, to enhance a building of historical value, to refrain from major structural changes, to preserve the external appearance, to preserve the function of maritime signalling, to concentrate the new design inside the historic building and in the adjacent areas, to make the site usable by the whole community, to create a tourist and cultural attraction, to realise an original project on the territory, to offer efficient services complementary to the new destination of use, to spread the history of the territorial area of reference, to guarantee complete functional correspondence of the work in the arc of its hypothetical useful life, to guarantee the economic sustainability of the intervention in terms of both realisation and management, to strengthen the accessibility and the usability.

The analytical results have shown that where there is insufficient usable space available to carry out the functions, utility is low enough to advise against the further study of a functional transformation proposal. This is because the utility, in relation to the overall cost invested in refurbishing the asset, would not be worthwhile. In such cases, it is, therefore, advisable to proceed only with the recovery of the lighthouse in order to ensure its original function as a maritime signal.

For the development of the project proposals that envisage the change of use of the transformable lighthouses, the method of the participatory tool was used both with the populations and with the cultural associations of the territories on which the lighthouses insist, see for example, for the San Venerio Lighthouse the Associazione Amici dell'Isola del Tino set up in November 2020 to promote cultural activities in support of the island [23]. This process made it possible to understand how the asset's alienation could be perceived and how the reuse of the lighthouse and its area could be imagined. The results showed a favourable position for the sale of the property for individual enjoyment by hypothetical private buyers, a future functional destination for tourist accommodation activities, and scientific and cultural activities.

In general, the potential of these artefacts is numerous; think of niche tourism or study and research stay for scholars, artists, writers or musicians (Fig. 7).

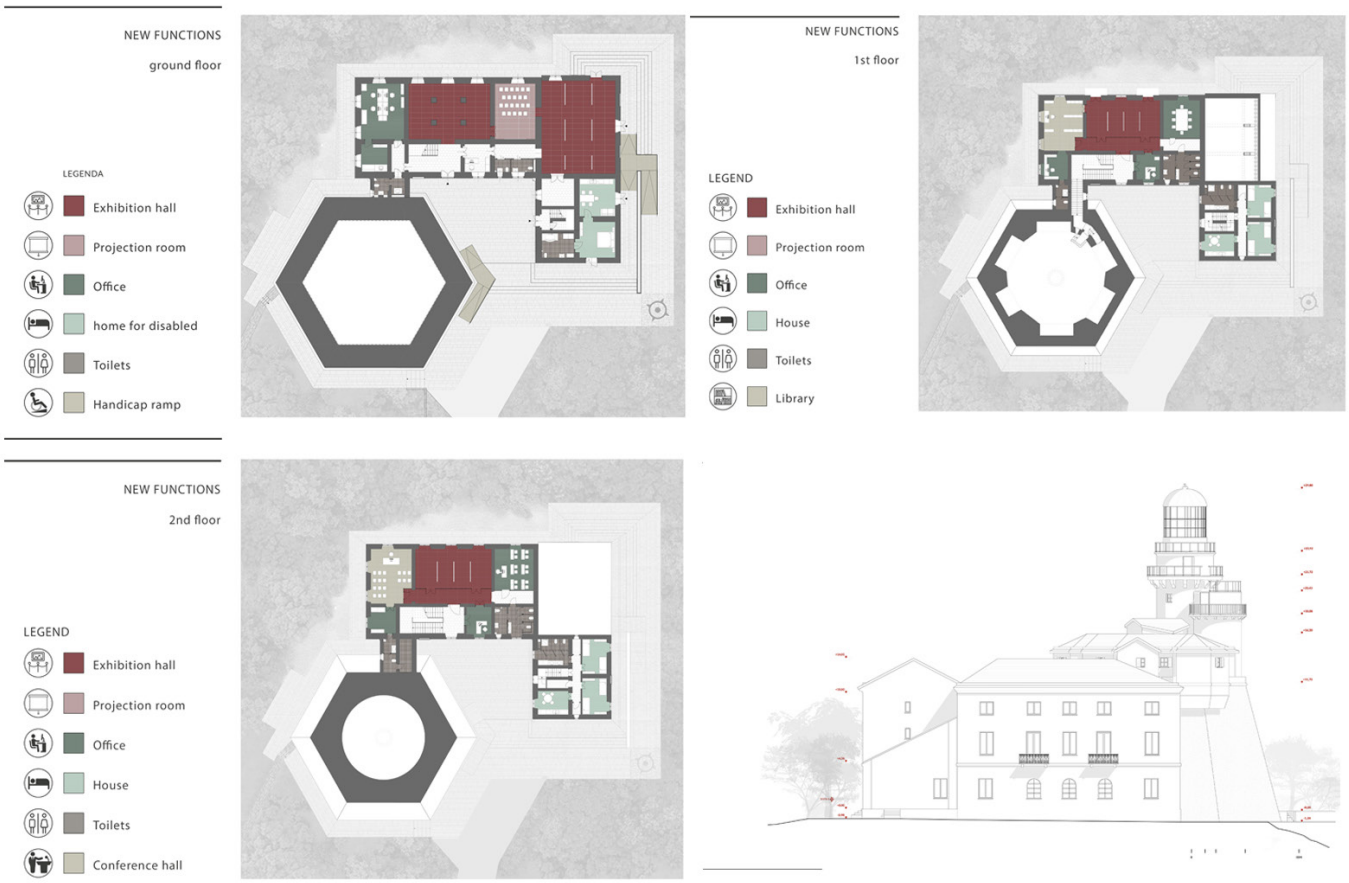

Fig. 7. *The new function for the building complex of the San Venerio Lighthouse on the island of Tino must be confronted with the place; the island is a protected park area and under military protection. The discussion with the cultural associations of the site and the Marina Militare has been proposed, within the main block, a museum to make visitors know the history of the island and its peculiarities. On three levels, through a continuous museum path, there are exhibition halls, conference rooms, library, educational laboratories and research offices, allowing a contemporary use of the various environments without creating interference flows.*

4. CONCLUSION

The study develops the theme of military maritime architecture focusing on the recovery and enhancement of Italian lighthouses. With their solid architectural identity, these buildings are an integral part of the coastal landscape and belong to the architectural heritage of a nation. So far, the work is not simple cataloguing but a valuable resource for preserving and protecting lighthouses. In fact, the goal is to codify a global working method that relates all aspects, from geographical location, geometry, materials, optics and structural components.

For each variable, it is necessary to design a dedicated survey procedure, to test also the effectiveness of a classification system able to provide a guide for the reading and knowledge of these buildings. The first results of the work show that the technological evolution of a lighthouse, leaving aside some fundamental steps in the evolutionary path in the construction techniques and realisation of the towers, mainly concerns the system of illumination of the lantern.

The cognitive and analytical phase is very complex for this type of building; that is why it is necessary to use complex tools for the geometric and volumetric restitution of the building bodies. In fact, as far as the parametric and integrated design is concerned, the research has revealed the difficulty linked above all to the geometric or technological uniqueness of most of the constructive elements of which the lighthouses are composed. From this, it emerges that, by integrating the parametric design and the data collected through surveys, also conducted with innovative methods, HBIM can be a valuable tool in the hands of the Public Administration for the formation of an intelligent catalogue of the historical building heritage, especially in the function of maintenance works.

An essential phase in the study has been the economic evaluation of the possible interventions for the recovery and the potential alienation of the lighthouses. The Value Analysis method has turned out to be helpful for the estimation of the utility related to the available/necessary resources to catch up a satisfactory result, arriving therefore to a first exhaustive cognitive picture of the potentialities of the analysed lighthouses.

The future challenge will be to sensitise the interested parties to start reasoned and articulated recovery and valorisation projects; projects that are sustainable and that make the lighthouses usable to the majority of citizens, finding a balance between the State's need to make money and the need to preserve the history of the lighthouses, transforming them into custodians of the territory and historical, naturalistic and environmental attractions.

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