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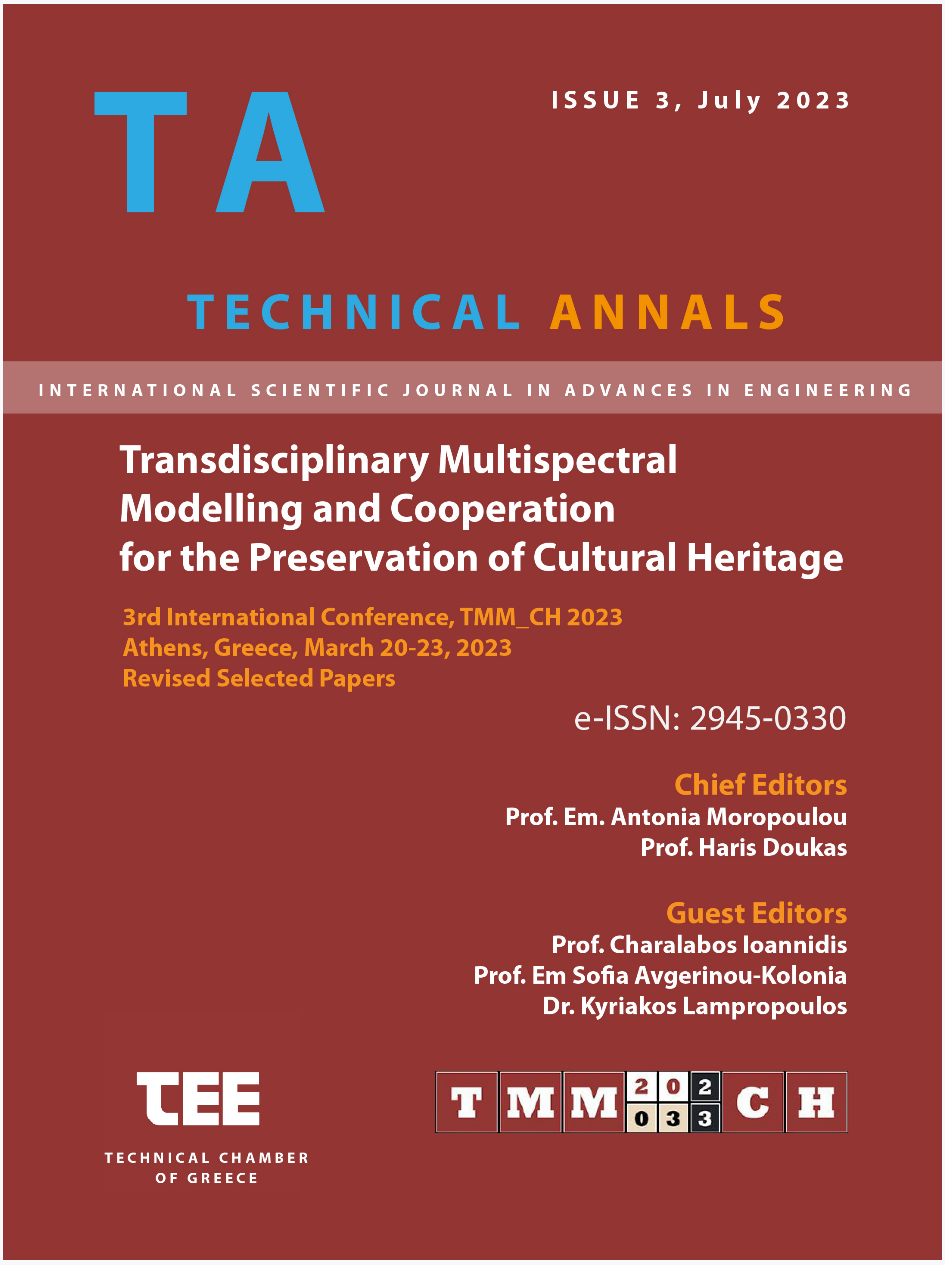

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ISSUE 3, July 2023

TECHNICAL ANNALS

INTERNATIONAL SCIENTIFIC JOURNAL IN ADVANCES IN ENGINEERING

Transdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage

3rd International Conference, TMM_CH 2023
Athens, Greece, March 20-23, 2023
Revised Selected Papers

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Special Issue Editors

Antonia Moropoulou
Haris Doukas
Charalabos Ioannidis
Sofia Avgerinou-Kolonia
Kyriakos Lampropoulos

TECHNICAL CHAMBER OF GREECE

Technical Annals

Journal of the Technical Chamber of Greece

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About

With particular joy, respect and commitment to the history of TEE (TCG), to the future of the scientific role of the Chamber and to the work of Greek Engineers as a whole, the Technical Chamber of Greece is proceeding with the publication of an international scientific journal. After several years without regular scientific publications, due to the special economic situation of the country, but having as a source of our history the TECHNICAL ANNALS, published by the TCG for decades, we undertake this role again to give another scientific podium to the Engineering community.

More specific, the Governing Committee of TCG, in accordance to Decisions No A14/Σ39/2021, A16/Σ7/2022 and A41/Σ16/2022, proceeded to publish of the Scientific Journal entitled «Technical Annals» by the Technical Chamber of Greece (TCG) concerned with Advances in Engineering, in English language. The content of the journal will be available electronically and via Open Access, through the e-Publishing service of the National Documentation Centre (EKT).

The Governing Committee of the TCG assigned the responsibility of the publication to the Editorial Board and the Scientific Board of the Journal.

We inform all Engineers IN Greece and in the World, the Academic and Research Community that we are proceeding with this publication in order to give the floor for communication, publicity and recognition, by the International Community, of the Research and Innovation that Engineers produce in practice, on construction sites,in urban space, in regional areas, in industry, in development, in environment, in energy, in the digital world, in universities, in research centers, in startups, in businesses, etc.

We aspire to attract your interest, find in you critical readers, feed your scientific work and publish the results of your research through the International Scientific Journal of TCG.

Looking forward to an important publication that we'd like to become everyone's business.

Topics

The scope of the journal will include all Fields of Engineering:

1. Civil Engineering
2. Architectural Engineering
3. Mechanical Engineering
4. Electrical & Computer Engineering
5. Rural & Surveying Engineering
6. Chemical Engineering
7. Mining & Metallurgical Engineering
8. Naval Architecture & Marine Engineering
9. Electronic Engineering
10. Engineering of Urban Planning & Regional Development
11. Environmental Engineering
12. Mineral Resources Engineering
13. Production & Management Engineering

Furthermore, it will be concerned with Interdisciplinary Thematic Areas, which are at the cutting edge of Research and Innovation, such as:

Agricultural Engineering and Food Processing, Artificial Intelligence, Aerodynamics, Bioengineering, Circular Economy, Climate Change, Cultural Heritage, Education and Learning Processes, Energy, Environment, Economy, Geoinformatics, Human Modelling, Industrial Symbiosis, Management and Quality Control, Material Science and Engineering, Naval Coastal and Maritime Design Engineering and

Planning, Spatial Planning, Sustainable Development, Systems' and Processes Engineering, Technology, Transportation, Processes, among others, and the thematic areas will be dynamically adjusted and determined taking into account both the progress of Science and Engineering, as well as future trends and the trending concerns and needs of Society.

Information for Volume Editors and Authors

Moreover, conferences, in which TCG is either co-organizing or participating in their Organizing and Scientific Committee, will be able to submit a request to publish their Proceedings (in either Greek or English language) always through the "e-Publishing" mechanism, as long as the request has been submitted to TCG and has the approval of TCG's Governing Bodies, either six months before the conference date *(in cases where the proceedings are to be published prior to the conference initiation)*, or three months before the conference date *(in cases where the proceedings are to be issued after the Conference)*.

The Governing Committee of the TCG assigned the responsibility of the publication to the Editorial Board and the Scientific Board of the Journal; the list of members of each board is herein attached.

Antonia Moropoulou · Haris Doukas · Charalambos Ioannidis ·
SofiaAvgerinou-Kolonia · Kyriakos Lampropoulos

SPECIAL ISSUE

Transdisciplinary Multispectral Modelling and Cooperation for the Preservation of Cultural Heritage

Third International Conference, TMM_CH 2023
Athens, Greece, March 20–23, 2023
Revised Selected Papers

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The Technical Chamber of Greece (TCG) decided to republish in English a Scientific International Open Access e-Journal. The "Technical Annals" - a journal which was counting decades of life following T.C.G. activities – will be edited by the T.C.G. through e-Publishing Platform at the EKT (National Documentation Centre) and will concern all the advancements in Engineering, referring to the disciplines:

- Civil Engineering
- Architect Engineering
- Mechanical Engineering
- Electrical & Computer Engineering
- Rural & Surveying Engineering
- Chemical Engineering
- Mining & Metallurgical Engineering
- Naval Architecture & Marine Engineering
- Electronic Engineering
- Engineering of Urban Planning & Regional Development
- Environmental Engineering
- Mineral Resources Engineering
- Production & Management Engineering

Referring also to interdisciplinary Thematic Areas at the forefront of Research and Innovation such as: Agricultural Engineering and Food Processing, Artificial Intelligence, Aerodynamics, Bioengineering, Circular Economy, Climate Change, Cultural Heritage, Education and Learning Processes, Energy, Environment, Economy, Geoinformatics, Human Modelling, Industrial Symbiosis, Management and Quality Control, Material Science and Engineering, Naval Coastal and Maritime Design Engineering and Planning, Spatial Planning, Sustainable Development, Systems' and Processes Engineering, Technology, Transportation, Processes, et al as dynamically will be defined by the progress of science and engineering, the future trends and the social needs.

Through the e-journal, TCG is aiming to publish at least three volumes per year, to connect Greek Engineers with the International Community of Engineering Science and Innovation, for the benefit of the public interest and the promotion of science through research, innovation, and development, in compliance with its constitutional targets.

Technical Annals is a peer-reviewed journal.

Preface

Innovative scientific methodologies and challenging projects marking future trends in the protection of cultural heritage have initiated through a holistic approach, by merging competence from the scientific fields of architecture, civil engineering, surveying engineering, materials science and engineering, information technology, and archaeology, a universal conversation among scholars, heritage professionals on restoration and conservation, stakeholders, industry representatives, and policy makers. The combined utilization of digital documentation technologies with innovative analytical and non-destructive techniques; numerical, computational; and 3D techniques; and archaeometric and archaeogene methods supports the development of a transdisciplinary multispectral modeling methodology towards the sustainable preservation of cultural heritage. Innovation is enhancing and revealing a critical dimension of the preservation of cultural heritage along with social participation and communication.

The 3rd International Conference on "Transdisciplinary Multispectral Modeling and Cooperation for the Preservation of Cultural Heritage: Recapturing the World in Conflict through Culture promoting mutual understanding and Peace" (TMM_CH 2023), has being held during March 20–23, 2023, at the Eugenides Foundation in Athens, Greece, and discussed modern trends in the original agora of our technological and democratic roots.

The Conference was organized by the National Technical University of Athens (NTUA) in cooperation with the Technical Chamber of Greece, under the patronage of H.E. the President of the Hellenic Republic, Ms Katerina Sakellaropoulou, with benedictions bestowed by His All Holiness, Ecumenical Patriarch, Bartholomew I of Constantinople, His Beatitude Archbishop Hieronymus II of Athens and All Greece and His Beatitude Patriarch Theophilos III of Jerusaleum.

Distinguished scientists and representatives of the National Geographic Society, the Cultural Heritage Finance Alliance, the International Council of Monuments and Sites ICOMOS, the Organization of World Heritage Cities OWHC, the European Society for Engineering Education SEFI, the European Construction Technology Platform ECTP, the International Federation of Surveyors FIG, the International Committee CIPA Heritage Documentation, the World Monuments Fund, AHEPA Hellas and other major International and European Organizations, associations, networks Universities and Research Centers in the field of cultural heritage preservation, participated in the international Steering and Scientific Committees, and addressed the conference at the opening session.

At the 1st and the 2nd TMM_CH Conferences, which were held with great success in October 2018 and December 2021 respectively at the Eugenides Foundation in Athens, with the presence of 350/650 delegates from 22/33 countries from all continents, and over five thousand viewers the emblematic rehabilitation of the Holy Aedicule of the Holy Sepulchre in Jerusalem was presented as an exemplary application, in the field of monuments' protection, of interdisciplinary and multispectral collaboration, as an outcome of innovation, not only on Research, but in the implementation process as well, with emphasis on technological advancements, not only intersecting all the scientific fields of engineers and natural scientists, but also initiating an ongoing dialogue with humanities, such as Archaeology, Theology, Sociology, Diplomacy and Tourism. Innovative knowledge transfer through practice and education is continuing the venture for the rehabilitation projects in the Holy Sepulchre Church, adjoining the National Technical University of Athens and La Sapienza University of Rome with Bezalel Academy of Science and Arts in Jerusalem, in cooperation with Israeli Antiquities Authority, through the Erasmus+ Strategic Alliance EDICULA "Educational Digital Innovative Cultural Heritage related Learning Alliance".

The 3rd TMM_CH conference focused on the latest developments in research and innovation and the identification of novel trends to build an interdisciplinary approach to conservation and holistic digital documentation of cultural heritage. The utilization and reuse of monuments, historic cities, and sites forms the framework for the sustainable preservation of cultural heritage, in accordance with the principles of a circular economy, in terms of the respect and protection of values, materials, structures, architecture, and landscape, with an informed society able to participate effectively in the policies that will design and implement the new strategies required.

Innovative knowledge transfer through practice and education is continuing the venture for the rehabilitation projects in the Church of the Holy Sepulchre, joining the National Technical University of Athens and La Sapienza University of Rome with the Bezalel Academy of Science and Arts in Jerusalem, in cooperation with Israeli Antiquities Authority, the Hellenic Research Institute of Alexandrian Civilization, and Per-petielSI SRL, through the Erasmus+ Strategic Alliance EDICULA "Educational Digital Innovative Cultural Heritage related Learning Alliance".

The issues discussed within the 13 sessions and 13 panel discussions at TMM_CH 2023 were as follows:

1 Historic cities and centers: New Reuse and preservation strategies applying Circular Economy
2 Digital Heritage a holistic approach
3 Machine learning techniques for Cultural Heritage Preservation
4 The Holy Sepulchre rehabilitation project: Transdisciplinarity and innovation in research and education, Emblematic works as source of innovation and transdisciplinarity - Novel educational approach for the preservation of Cultural Heritage
5 Art, Archaeology - Archaeometry – Archaeogene
6 Preserving compatibility, the materiality and integrity of structures and architectural authenticity
7 Earthquake protection and structural rehabilitation
8 Resilience of Cultural Heritage mitigating Climate Change, Natural Hazards and Pandemic Risks and ensuring Biosafety
9 New European Bauhaus initiative for Green Deal addressing energy challenges
10 Green and blue deal for local and regional Sustainable Development
11 Bridging Heritage Stakeholders, Science and Industry, Institutional framework Bridging Heritage Stakeholders, Art, Science, and Industry
12 Advanced Non Destructive and Structural Techniques for Diagnosis, Redesign and Health Monitoring and Quality Assessment of Materials and Preservation Interventions
13 Recapturing the World in Conflict through Culture promoting mutual understanding and Peace

Sharing knowledge, experiences, and recommendations about sustainable cultural heritage approaches and practices, at a moment of great risk and a time of renewed possibilities, has reorientated conversation to explore the current conditions and contours of the world in crisis, recapturing itself through culture and relaunching development.

The TMM_CH 2023 conference was held at the Eugenides Foundation in a hybrid format by both onsite and online attendance for oral presentations. All sessions and panel discussions were accessible for the registered conference participants using the unique link in their personal conference ticket. The opening session and all panel discussions, as addressed to the general public, were livestreamed with free access via the conference's YouTube channel and website.

The 3rd TMM_CH Conference was highly anticipated, attracting researchers from all over the world. It was held with great success, with the physical presence of 550 delegates and online attendance of 150 delegates in real time.

Striving to ensure that the conference presentations and proceedings were of thehighest quality possible, we only accepted papers that presented the results of various studies focused on the extraction of new scientific knowledge in the area of transdisciplinary multispectral modeling and cooperation for the preservation of cultural heritage.

In total, 417 contributions were submitted, and 162 papers were accepted for oral presentation and publication (representing the work of 546 authors from 32 countries) after peer review and consequent revision, with a rate of acceptance equivalent to 39%. A single-blind peer review process was employed with each paper receiving, on average, three reviews. Accepted papers were published in this volume of Technical Annals folloeing the final peer review procedure.

The interdisciplinarity in the preservation of cultural heritage requires holistic documentation with the fusion of the various disciplines' data on 3D models. Computeraided design and advanced computer science methodologies support an interdisciplinary synthesis of the preservation state assessment, i.e. the evaluation of the rehabilitation achieved in respect of the integrity of materials and structures, throughout the design of the restoration of authentic architecture. In parallel, new technologies can be used to enhance research and education and communicate the reuse and exploration of cultural and natural assets, providing, through tourism, external economies to sustain local and regional development in a circular way.

Hence, 23 papers presented at the 3rd TMM_CH conference, integrating all of the above aspects, are published in this volume as a special issue "Transdisciplinary Multispectral Modeling and Cooperation for the Preservation of Cultural Heritage". This is the third volume of the Technical Annals–International Scientific Journal In Advances In Engineering by the Technical Chamber of Greece (T.C.G.). This edition would not have been possible without the commitment of the TMM-CH editors of this volume (Antonia Moropoulou, Haris Doukas, Charalambos Ioannidis, Sofia Avgerinou-Kolonia, Kyriakos Lampropoulos); as well as the valuable assistance of the editing team at Technical Annals managing by Mrs Lilly Athini (Fotini Kyritsi, Eleni Bairaktari, Evridiki Karathanasi, PanagiotisVrelos, Maria Sinigalia, Manolis Erotokritos, Isabella Tsavari, Dimitris Psarris, George Trachanas), to whom we are most grateful

July 2023 Antonia Moropoulou, Technical Annals' Chief Editor

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Digital Heritage - Holistic Approach

Innovative and transdisciplinary educational approach through the EDICULA toolkit

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Abstract. The EDICULA educational toolkit regards an open source educational platform that addresses key issues in the rehabilitation, protection and sustainability of Cultural Heritage (CH) assets, and disseminates valuable know-how and experience both to the wide audience as well as to CH stakeholders, scientists and professionals. The fundamental characteristic of this platform is that it promotes a holistic approach for transdisciplinary documentation, based on the experience and know-how of the EDICULA partners and – in the future – of the users as they will begin to utilize it. Both EDICULA toolkit modules are described after the development of the main thematic areas, the development of the toolkit on a moodle platform, and the preparation and uploading of the educational material. The access to the EDICULA educational platform, the layout of the educational platform, the types of educational material uploaded, the issues related to the toolkit-to-user information presentation approach and educational aspects, the complexities encountered and how they were overcome are being analyzed. The issue of users and degree of commonality between EDICULA-4-all and EDICULA+ educational toolkits is described. Emphasis is given on the way the modules are differentiated from one another. The access level is the main issue, which eventually provides a "smooth" transition between the two modules, ad hoc per user, under the supervision of registered and approved administrators or advanced users with editing privileges.
The joint utilization of both the EDICULA-4-all and EDICULA+ toolkits in the educational, advisory or research processes, is at the core of the EDICULA project's scopes.

Keywords: EDICULA, Toolkit, Modules.

1 Introduction

The EDICULA educational platform provides and supports the education on a holistic approach for transdisciplinary documentation of CH protection and sustainable rehabilitation; a very complex scientific field indeed. This necessitates the introduction of varying levels of complexity – taking into account the education background and needs of the users – with the EDICULA+ toolkit providing the advanced 'complexity" level.

The key issues that this educational toolkit addresses are related to:

- the enhancement of the educational aspects of engineering innovation
- the emergence and establishment of transdisciplinarity as a new trend in the protection of monuments
- the capabilities of multi-modelling methodologies for multi-discipline management and analysis of knowledge
- the capabilities of Augmented Reality (AR) and Virtual Reality (VR) to effectively diffuse information for social responsibility and awareness

Within this framework of key issues, the EDICULA educational toolkit covers the fundamental thematic areas relevant to CH, at an appropriate detail as required and as feasible, through an educational-oriented approach that fuses different information and experience from various use cases into educational material that is effectively organized and disseminated. The educational toolkit focuses on the analysis and dissemination of state-of-the-art scientific transdisciplinary methodologies, and in this matter, to educate users on how to employ them in the field of CH protection, as well as to other relevant fields or use-cases.

This toolkit contains two modules/toolkits, the EDICULA-4-all module, which is addressed to a more general public and the EDICULA+ module, which addresses more specialized users.

The main issues encountered and addressed in the development of EDICULA-4-all module, are to a large degree valid for the EDICULA+ module, since both educational toolkits have a very high commonality. This is expected due to the fact that the field of CH protection covers a wide range of issues, that are of interest to both the general public, as well as to more specialized users. In addition, the methodological approach for the architecture of both toolkits and the development of the thematic nodes, are common to both modules. These have already been described in detail [1]. It should be clarified the thematic subjects are common to both modules, and a common platform (moodle) is used for their development. The differentiation centers on the presentation/accessibility of the uploaded material to the users of each toolkit, based on their educational needs.

There exist other educational platforms, relevant to Cultural Heritage such as those described in [2 – 6]. However, most either exploit existing databases without focused content with emphasis on the prevalent issues of CH protection, or they refer to short educational courses with associated educational material.

1.1 Cooperation framework for the development of the Architecture of the EDICULA Educational Toolkit.

The EDICULA Educational toolkit covers a wide range of thematic areas, relevant to the protection and rehabilitation of CH assets. It is inevitable that not everything can be covered – especially in full detail, however, the close cooperation between the EDICULA partners, with NTUA as the leader organization of Toolkit, manages to provide educational material to those thematic areas where the partners provide valuable expertise.

All partners cooperated in order to provide their own know-how as well as to identify the differences between the two modules. The close cooperation of all EDICULA partners ensured that each partner made contributions across a broader range of thematic areas beyond their individual expertise, essentially enabling them to engage with each thematic area from their unique perspective. This cooperation framework was more effective, providing the opportunity for exchange of ideas and experiences.

In the case of the EDICULA+ module, the special issues involved in these thematic areas, and the creation of necessary educational material, demanded a close cooperation between the EDICULA partners, in order to optimize the specific advanced information to be incorporated as well as to ensure an effective educational attribute, scientific quality and completeness.

2 Overview of the EDICULA Educational Toolkit

During the first stages of the toolkit development, much effort was provided on its architecture, to ensure that the chosen thematic areas are the most suitable and can be accompanied by pertinent educational content upon uploading. [1]

This work describes the following issues:

- Access to the EDICULA educational platform
- Overview of the layout of the educational platform
- Types of educational material
- The toolkit-to-user information presentation approach and educational aspects
- Difficulties encountered and limitations.
- The issue of users and degree of commonality between EDICULA-4-all and EDICULA+ educational toolkits

The educational toolkit addresses three fundamental prerequisites. Firstly, it provides flexibility through its e-learning platform, enabling easy navigation and immediate access to all main categories and activities of the toolkit [7]. Furthermore, no previous knowledge in cultural heritage or its rehabilitation is required to assess EDICULA-4-all. Last, EDICULA+ will provide an easy sequential learning progress, divided into basic and advanced modules, enabling the end-users to experience a learning procedure. The roadmap to the EDICULA Educational Toolkit, as developed, is depicted in the following schematic.

Both EDICULA-4-all and the EDICULA+ educational toolkits are based and developed on the same thematic content – ontologies and utilize the common platform.

However, they adopt a different utilization and adaptation of semantics and narration. Specifically, the EDICULA-4-all educational toolkit focuses on the monument, the values, the aesthetics/architecture and the history. In comparison, the EDICULA+ educational toolkit, focuses on the various disciplines involved in CH protection, the relevant techniques and methodologies.

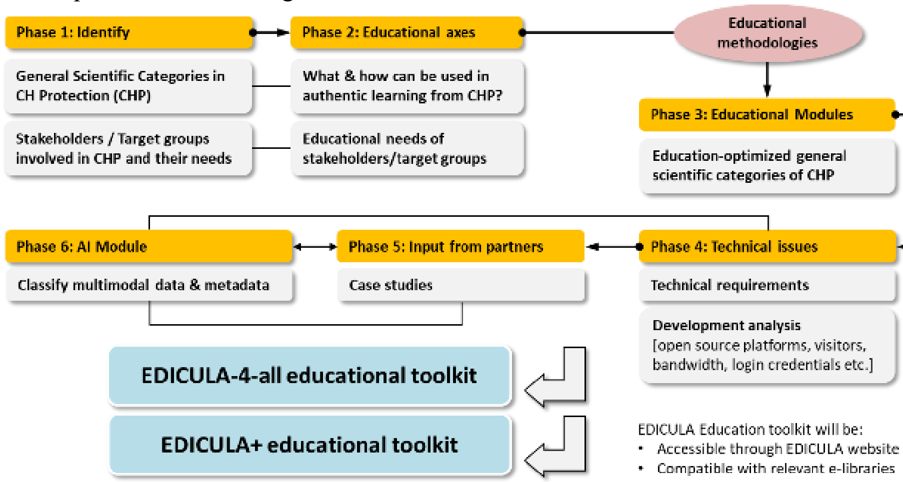

Fig. 1. Roadmap for the EDICULA Educational Toolkit.

The EDICULA educational platform is accessed through the website of the EDICULA project [8], Figure 2.

3 The general layout of the educational platform

The Educational platform is supported by moodle [9], since this is the software platform which also supports the National Technical University of Athens e-learning platform Helios [10], and on which there has been extensive experience throughout the last three academic years after its initiation of use.

The moodle/helios despite its shortcomings regarding the aesthetics and design capacity offers one main advantage, i.e. an organized deposition of data and natural navigation within the uploaded folders. Moreover, the general friendliness of the moodle platform, regarding modifications of the structure (e.g. addition of new folders) is rather straightforward to users with low level of expertise in IT applications. The alternative, i.e. the utilization of specialized software would instead invalidate the whole concept of user interference.

Upon login to the educational platform, the users can see the four main categories of the thematic areas, (Fig. 3) through which they can navigate to study the educational material uploaded to the relevant thematic areas.

The courses are organized within the thematic areas as seen in Fig. 4, with some modifications and additions, as required for the better organization of the educational material and to better serve the educational purposes. [11]

The triangular arrows (Fig. 5) next to the titles indicate categories which can be extended in view (down bold triangle) or contain further subcategories (right bold triangle). Those categories that do not contain any further subcategories are indicated with right empty triangle. The  indicates a course, within which the relevant educational material is documented.

The navigation is straightforward, and the user – depending on his access privileges – can open the respective links (files, website links) as desired. In general, the toolkit provides the impression of an informative website and is treated like that by the user.

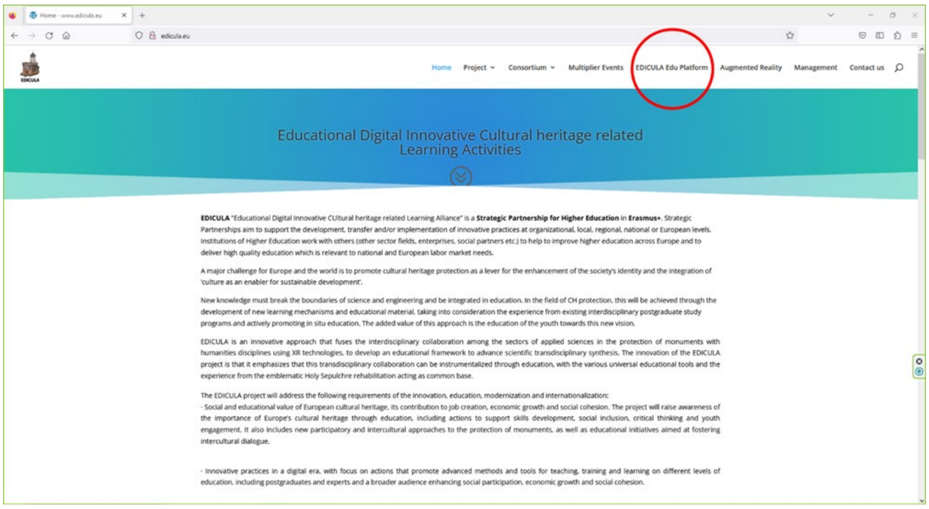

Fig. 2. Access to EDICULA Educational platform through the EDICULA website. [8]

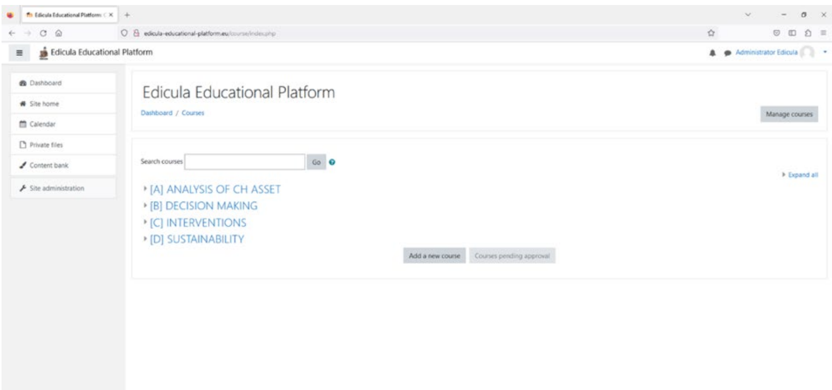

Fig. 3. Introductory page of the EDICULA toolkit with the four main categories.

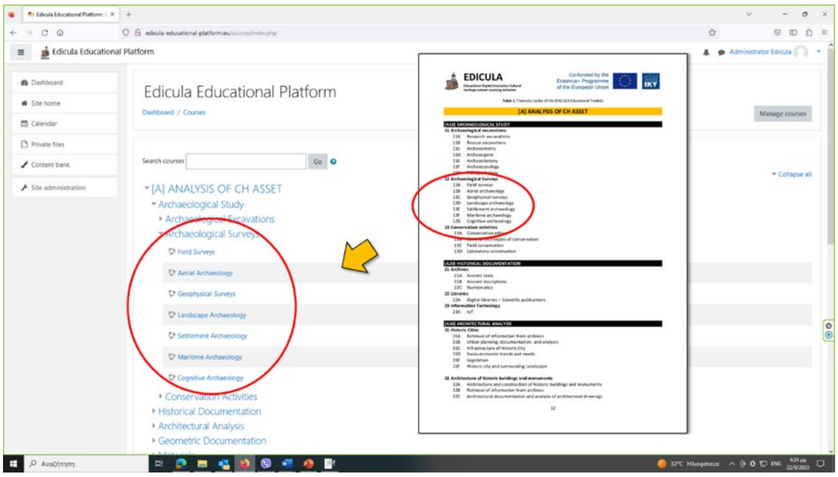

Fig. 4. Organization of categories and courses.

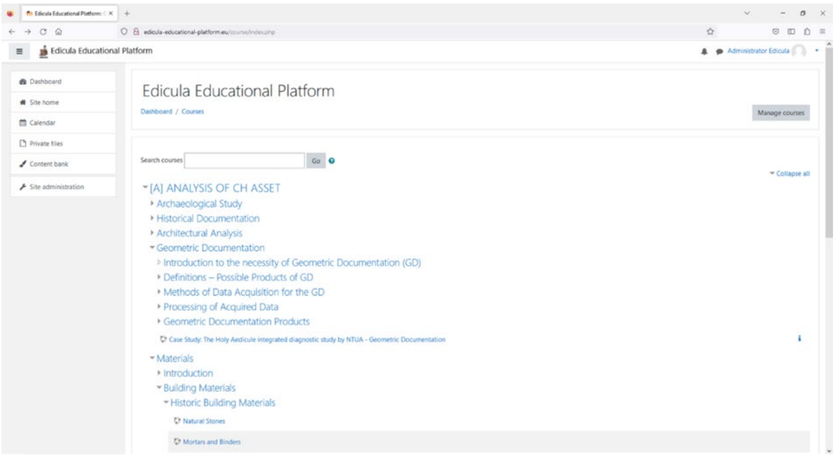

Fig. 5. Example of categories and subcategories page of the EDICULA toolkit.

4 Types of educational material

The EDICULA partners, have coordinated uploaded various types of educational material types, which are available at the EDICULA toolkit. These include the following:

1. Overview presentations–educational lectures [pdf file] (e.g. Figure 6 – see path 🗁 Analysis of CH Asset/Materials/Building Materials/Historic building materials/Natural Stones ➲ Historic building materials-stones)
2. Case studies-projects presentations at conferences / workshops [pdf file] (e.g. Figure 6 – see path 🗁 Analysis …. ➲ Study of the stone rubble masonry of the Holy Aedicule)
3. Links to open access scientific publications (papers) [link] (e.g. Figure 6 – see path 🗁 Analysis …. ➲ Study of the Plaka Bridge historical and restoration stones: link [12])
4. Links to scientific publications (papers) [link], which are not open access, thus, it is not allowed to upload the full scientific paper. It can be downloaded, if the user or their institution has subscription to this specific journal to download the respective pdf file (e.g. Figure 7 – see path 🗁 Analysis of CH Asset/Materials/Building Materials/Historic building materials/Mortars and Binders ➲ Study of historical mortars and design of restoration mortars - General: link [13])
5. Links to websites with relevant information (e.g. Figure 6 – see path 🗁 Analysis of CH Asset/Materials/Building Materials/Historic building materials/Natural Stones ➲ The Jerusalem sheet in 1:50,0000 scale [14]
6. Overview courses within main categories [course with various types of educational material] (e.g. Figure 7 – see path 🗁 Analysis of CH Asset/Materials/ ➲ Case Study: The Holy Aedicule integrated diagnostic study by NTUA - Materials)

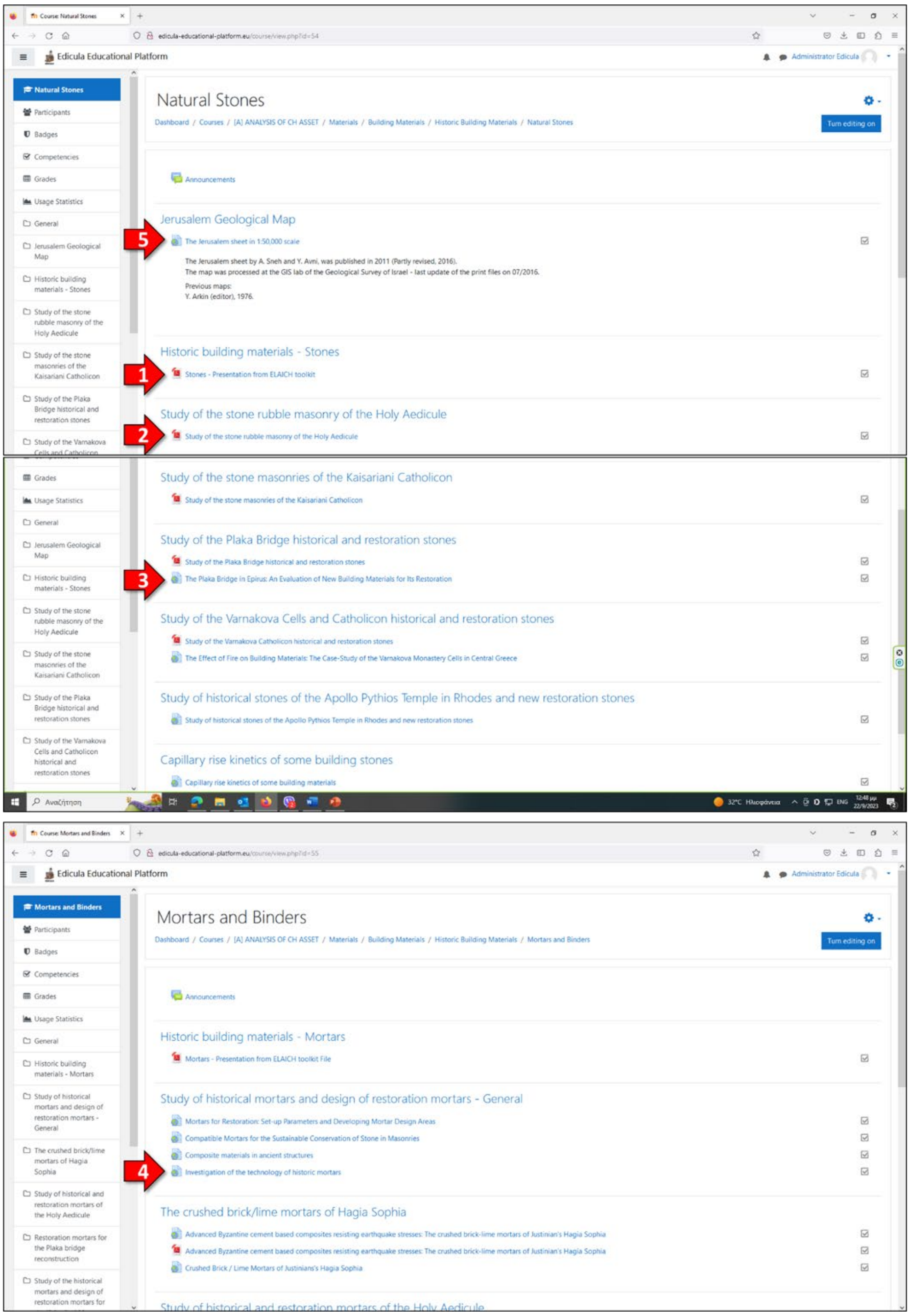

Fig. 6. Examples of types of educational material within the courses of the EDICULA educational platform.

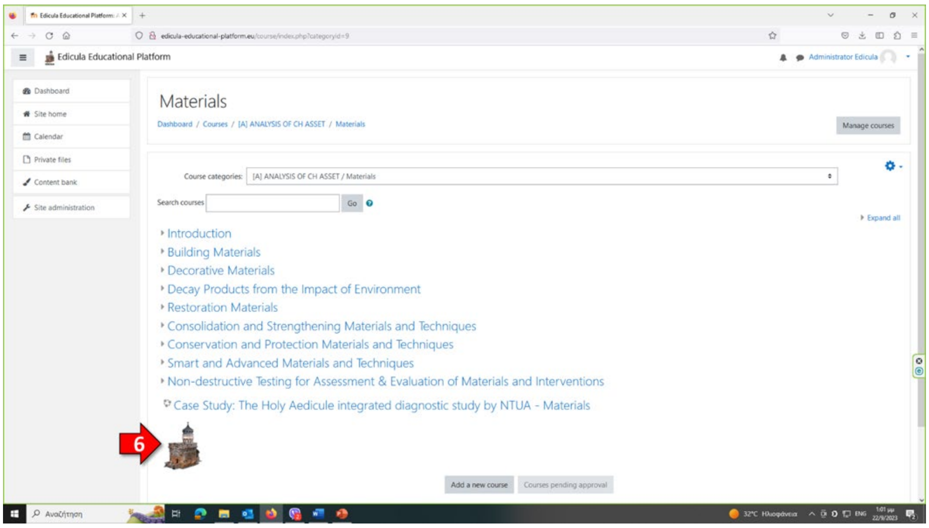

Fig. 7. Examples of types of educational material within the courses of the EDICULA educational platform.

5 The toolkit-to-user information presentation approach and educational aspects

Both toolkits regard a diverse composition of user groups highly dependent on the user's needs and ambitions. These user groups are being described below and have been taken into account to the preparation and type of educational material to satisfy varying levels of needs.

5.1 Access levels to target groups regarding EDICULA-4-all

5.1.1 General public

The general public refers to citizens with a wide variety of social and intellectual skills, but who do not have specialized knowledge in the field of cultural heritage protection, which is the focus of this educational toolkit. Still, this category includes users as diverse as people with basic-level educational backgrounds who are simply interested in the subject of CH protection, people who approach the toolkit from the perspective of economic interest, or people who simply want to obtain some skills and knowledge to better appreciate CH sites during visits. [15]

Since the general public has different expectations and learning capacity compared to more specialized groups of users such as CH students, professionals and experts, they will probably utilize the toolkit through an approach more akin to "surfing the internet". Specifically, the general public with limited knowledge about the various interrelated stages and categories of activities involved in the holistic rehabilitation, protection, revealing and sustainable preservation of cultural heritage, will most probably follow an approach based on “curiosity” (regarding the thematic issues and the terminology), possibly intrigued by the provided emblematic case studies. [15]

In this framework, the inclusion in certain categories of emblematic case studies (Fig. 8), serves to “intrigue” the user (general public) to further investigate the subject, and better understand the terminology employed. For some of them, the inclusion of emblematic case studies (such as the rehabilitation of the Holy Aedicule in Jerusalem) is a “fascinating” subject that will probably generate more questions to them, which the various thematic areas and the uploaded educational material can probably provide them with some answers, or at least help them gain a better understanding of the whole process of CH protection. The gradual inclusion – upon the future utilization of the toolkit by more users and the scientific community – will enrich the variety of case studies within various thematic areas, further intriguing the interest of the general public and acting as the “starting points” of their “journey” in this exciting new (to them) field. An introductory explanatory text is often added to help the user become acquainted with the terminology.

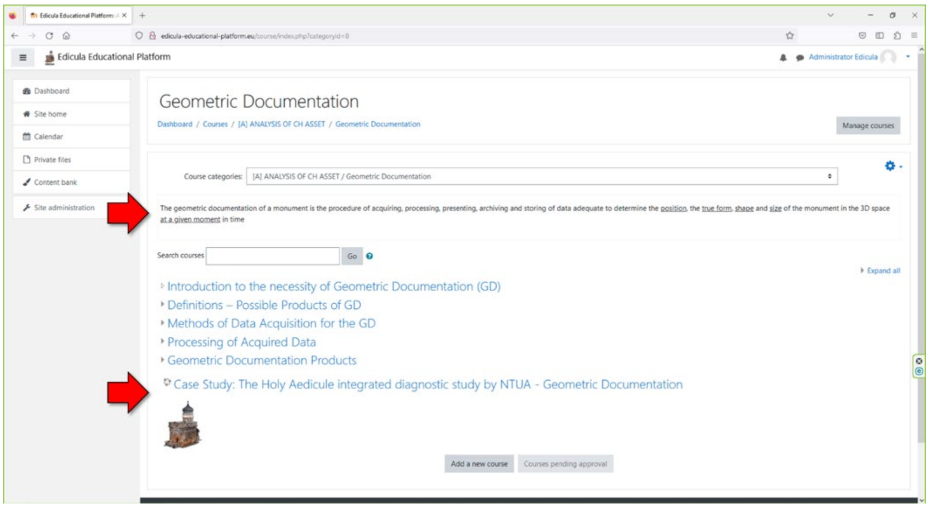

Fig. 8. The inclusion in certain categories of emblematic case studies (lower arrow) with information relevant to the specific category. An introductory explanatory text is often added to help the user become acquainted with the terminology (top arrow).

From an educational point of view, the above approach for the general public aims to ensure that the user is not “bored” through perceived endless provision of specialized subjects, but instead it is the user who selects ad hoc whatever suits their needs and curiosity. The educational material uploaded takes this into account.

The benefits of the toolkit to the general public center around enhancing the awareness of the social and educational value of European CH which can directly and indirectly contribute to job creation, economic growth and social cohesion. Through these types of educational materials, The EDICULA-4-all toolkit will allow the general public to develop new participatory and intercultural approaches to the protection of monuments, as well as educational initiatives aimed at fostering intercultural dialogue.

For the general public the provision of emblematic case-studies, such as the rehabilitation of the Holy Aedicule of the Holy Sepulchre, allows them to relate their own experiences with CH. More than often the “interface” between the general public and CH is tourism and travels. Many people that travel and visit CH assets often develop a need to learn more and better understand the site or monument they visited. Typically, the only resources available on internet are history-oriented websites (e.g. wikipedia), whereas in social media, CH sites are mostly represented by collections of photos. In neither case, however, the public can obtain a satisfactory understanding of the science and engineering behind the restoration, protection, and sustainable preservation of a cultural heritage asset they are interested in. As a result, the public perceives built CH as a “dead” field, which simply relays the story of the past to the present and to the future. As such, the efforts behind ensuring that such a continuity between the past and the future is feasible are totally unknown to them. The EDICULA toolkit addresses the above issues, clearly presenting the science behind the protection of CH.

A specific sub-group of people included within the general description “general public” regards the citizens with economic interest in CH protection. This sub-group includes many professionals not directly related to CH protection, but who would like to benefit from understanding how CH is protected and explore business opportunities. It includes merchants and professionals such as hotel operators, itinerary service providers, travel agents, tourist shops, restaurant / café operators, artists etc. that want to better understand the basic issues in CH protection to improve the services they provide. For example, tourist guides, who are in constant pursue of providing a better and up-to-date description to their clients (tourists), are often eager to add new “specialized” details in their tours or present the whole subject from a new perspective. Others may be interested in renovating properly their own property or business (e.g. a restaurant or a hotel at an old historic building in a historic town), collectively reviving historic neighborhoods (paper architecture). Some professionals such as hotel owners may better explain to their customers about the importance of visit restrictions due to maintenance arrangements, despite the inconvenience it causes to their visit schedule. Additionally, a properly restored monument or historic building in the vicinity of their hotel or business (shop, restaurant or café) enhances the business value of their own property. Some may even want to explore new business opportunities, such as materials or equipment for CH protection.

A special category of the above sub-group regards airlines. All airlines provide inflight magazines and entertainment materials (e.g. videos) which promote travel destinations. The airlines are eager to provide intriguing new information about the cities they provide flight to. An example of such a case was Aegean Airlines, which sponsored flight travels between Athens and Jerusalem during the project of the rehabilitation of the Holy Aedicule of the Tomb of Christ. In order to promote their contribution and enhance the attractiveness of their Athens-Jerusalem connection, they published two articles in their inflight magazine “Blue” [16, 17]. Most airlines promote the history and the preservation of the cultural heritage of their destinations, and thus, are interested in presenting activities that ensure the preservation of CH in their destinations. Such type of information is included in the EDICULA toolkits.

It should be realized that Tourism is a strong driving force for the general public either from the traveling perspective or from the perspective of economic development. In either perspectives, the demand for improved knowledge and the business diversity and business expansion opportunities are interrelated driving forces that often play a similar role.

Furthermore, the general public can indirectly (or directly in some cases) be involved in decision making processes, relevant to the protection of CH. For example, in a historic city, as citizens and professionals are getting more involved socially for the protection of their own city, either from the perspective of active citizens or due to economic interests, local and regional authorities must start taking into account their needs and requests. Therefore, although not directly involved in the actual decision-making processes themselves, or categorized as "stakeholders", the fact that these citizens and professionals start "asking" the right questions and press the relevant authorities for appropriate actions, it is a beneficial outcome and educational need that the EDICULA-4-all toolkit can be a valuable source of information for the general public. The toolkit-to-user information presentation approach for this group is, thus, focusing on case studies, which are presented and organized such that they provide concise and quick knowledge to the users, while acting as a starting point for further elaboration depending on the interests of the users and their level of engulfing the provided – more specialized – knowledge.

5.1.2 Students

The second group of users which the toolkit is addressed to, is the group "students". This term refers, obviously, to a wide-ranging group of users with challenging educational needs and ranges from elementary school students up to post-graduate students. For this group the toolkit-to-user information presentation approach does not only aim to enrich their knowledge in the field of cultural heritage preservation and protection. For users from this group, it is more important to disseminate to them the process of problem solving and the available methodologies and technologies to achieve this. [18]

The EDICULA toolkit is useful for the students since it offers them opportunities to improve their relevant skills in problem solving. For example, the inclusion of presentations focusing on specific subjects and their organization into a methodical set of information, helps them "sharpen" their investigation skills, and how to search for and analyze information. Although the scientific and technical communities are more acquainted with the links to scientific publications (e.g. journal articles), even at the level of students it is useful for them to realize that knowledge has varying degrees of complexity and availability that can only be gradually absorbed. Depending on the accessibility privileges, it would not be controversial to allow students to read a scientific article.

The other main respect of the EDICULA educational toolkit is the active advancement of Interdisciplinarity. In fact, Interdisciplinarity is also an important attribute that students should develop in order to ensure a common language of communication for their future professional skills. In the EDICULA toolkit, throughout the majority of the educational material provided, the interdisciplinary character of all methodologies and technologies employed and more importantly the analysis of their results is systematically highlighted. The emblematic case studies underline the importance of interdisciplinarity to solve complex problems.

The toolkit-to-user information presentation approach, as developed, fully supports the educational needs of this user category.

5.1.3 Experts and professionals in CH-related stakeholders

Another group of users, for which the toolkit-to-user information presentation approach has been appropriately adapted, regards the group termed "stakeholders". The protection of CH and the values it carries is the responsibility of the central government and/or local and regional authorities, which collectively manage a wide range of CH assets. Often, a significant overlap of responsibilities is observed, between the central authorities and local stakeholders (prefectures, municipalities, private interests), most typically having to deal with who is responsible for the management and who is responsible for the maintenance and restoration of a CH asset. As a result, a complex bureaucratic environment is unavoidably unfolded, often with contradicting and unproductive interweaving boundaries of responsibilities. Adding to this rather complex and ineffective situation is the fact that many of these stakeholders are staffed by personnel not fully trained on the holistic character of CH protection, but instead rather apply their respective field of expertise in ad-hoc or discipline-bounded approaches. The situation becomes more complicated when private owners and institutions are involved, which not only perplex the level of ownerships and responsibilities, but most importantly, due to their limited specialized human resources may not be able to identify the real issues involved and how to address them. In either case, i.e., complex environment of ownership/responsibilities or reduced know-how/expertise, the decisions required from stakeholders for effective, compatible and sustainable interventions at CH assets, may not be the optimal ones.

The EDICULA toolkit addresses this important issue for stakeholders. First, it provides various case studies and educational material where the challenges of coordination between stakeholder and the scientific community are successfully addressed. Furthermore, the toolkit provides a systematic organization of the various processes, procedures and technologies involved in the field of CH protection and highlights the importance of scientific support to decision making instead of empiricism. Finally, it delivers case studies where interested stakeholders can study in comparison to the CH assets they are involved into.

In addition, the stakeholders' personnel can review the educational material, and in particular the material describing the use of various innovative methodologies, techniques and technologies, and acquire valuable knowledge of the capabilities of modern scientific tools for the comprehensive analysis of a CH asset. They can develop more overall knowledge, critical thinking and synthesis of all issues. As such, they can better prepare their reports or specifications for technical works, describing in more detail and with appropriate terminology the measures required to protect the CH asset which they are involved into. This is important both for legal purposes (to protect the interests of the stakeholder) as well as for the effectiveness of the interventions required.

Through the interaction with the EDICULA toolkit and its educational material, the personnel from stakeholder organizations can also deal with the requests from the general public or the scientific community for interventions in the CH assets they are involved in their management. The general architecture and organization of the educational content of the EDICULA toolkit, serves exactly this purpose, where it can help stakeholders to select –based on scientific findings – the most effective, compatible and sustainable remedying measures required [1]. Thus, the toolkit is organized such that it supports their decision-making processes, highlighting all the necessary parameters and scientific fields and thematic issues involved, for a holistic and effective determination of the appropriate interventions.

5.1.4 Academic personnel and teachers

This category of users is divided into two large subgroups, based on the level of education. The first subgroup regards the teachers (elementary and secondary education) which utilize the EDICULA toolkit educational to prepare projects or lectures. This can be achieved through the preparation of educational material for students that presents in a concise and appropriately detailed manner (depending on the level of the students) all processes and technologies involved in CH protection, with the aim to educate students of the synthetic process of problem solving in a subject that is familiar to them. Also, the assigning of homework or project work to students, who can use the EDICULA toolkit to solve provided exercises or assignments can contribute. Additionally, teachers can provide additional information for specific monuments (case studies) as part of the learning activities in educational visits to archaeological sites, monuments or historical sites. [18]

The large number of thematic areas and educational material organized in the EDICULA toolkit provide a wealth of information that can satisfy a wide array of educational needs, ranging from non-STEM to STEM to largely engineering thematic subjects. The provision of specific educational material that is more pictorial and simplified mainly addresses the needs of elementary school teachers (note: it certainly does not imply a lower level of comprehension), since it is easier and more effective to transfer this type of information to their students rather than presenting complex information that may otherwise confuse the students or divert their interest.

The second subgroup of this category regards academic level tutors that utilize the toolkit to provide more specialized knowledge on their respective fields. This subgroup achieves this through slightly different approaches like preparing educational material with more specialized terminology and higher level of analysis and educational outcomes. Tutors are able to assign term projects to university level students, either focusing on in-depth analysis of the EDICULA provided case studies or focusing on analyzing in a similar process of analogous case studies or problems. They can also teach university students on how to search for, assess and evaluate scientific literature.

For this subgroup, the citation of specific published work provides a starting point for their students to search the specific subject. It does not, however, act as the sole knowledge provider or claim to be a fully inclusive depository of knowledge and information. As such, just like the students, the academic professors are encouraged via the toolkit-to-user information presentation approach, to search deeper in the thematic field of interest, where the EDICULA toolkit acts as the framework for systematic organization of searching the required information.

For the academic personnel teaching scientific fields relevant to the protection of CH, the whole EDICULA toolkit thematic architecture can facilitate the development of relevant curricula. This is feasible, since the EDICULA toolkit covers all thematic areas required for a holistic approach to CH protection and rehabilitation. Thus, a university educator, in this field, can utilize much of the provided material for the preparation of their lectures. For educators in fields not directly relevant to CH, it is mainly the synthetic nature of the organization of information and the modular type of educational material provided that is useful for them in the preparation of their lectures and notes. The architecture of the toolkits primarily triggers them to approach their course curricula in an interdisciplinary or transdisciplinary approach, where one of the main educational outcomes regards the systematic and science-based process of developing solutions to complex multi-parametric problems. This was similarly addressed in the EDICULA Teachers Course.

5.1.5 Researchers

The user group “researchers” refers to all those affiliated to academic or research institutions, or employed in CH-related organizations, but are not directly involved in decision-making processes for CH assets. For them, the main drive is the production of Innovation and Research, at theoretical or experimental/applied levels. Within this framework, the toolkit-to-user information presentation approach of the EDICULA-4-all toolkit functions as an initial repository source of scientific information. It is important to underline that such a repository can only function at the initial stages of a comprehensive research in the thematic issues addressed, not only because it is not feasible to contain all the scientific knowledge available, but also because – most importantly – the EDICULA toolkits are mainly educational tools and not pure repositories of data, in a sense of data platforms.

The EDICULA+ toolkit, is mainly the one relevant to Researchers, but even at the EDICULA-4-all module is useful for scientists too, especially those who do not have extensive knowledge and experience in the field of CH protection, but are called upon study relevant material for the applications they are interested in.

5.2 Access levels to target groups of the EDICULA+ educational toolkit

In terms of access level to target groups the EDICULA-4-all educational toolkit, is more “narrative” in nature and is addressed to the wide audience (with open access), including basic level of information. Therefore, it regards a set of educational material of non-specialized level of information that can be readily transferred in life-long learning and school education, demonstrating the effectiveness of transdisciplinarity in fusing science into general knowledge. On the other side, EDICULA+ educational toolkit, is the advanced module (with registered access), more “scientific” in nature, addressed to scientists and experts in the field of CH protection with an adequate scientific background or experience. It provides knowledge with more scientific details and encompasses advanced information, relevant studies, scientific papers, data and metadata of the knowledge gained by the consortium in the emblematic use cases such as the restoration of the Holy Sepulchre. It can be transferred to professional and university courses addressed to architects, archaeologists, conservators, students in arts and other relevant engineering disciplines, demonstrating the need for a new teaching framework that promotes cooperation and utilizes complementarity between diverse disciplines. [19]

Within the above general framework, it should be clarified that the user groups do not necessarily indicate the access level to a specific educational toolkit or content therein.

The access level (i.e. what files become accessible and how much they can modify the existing courses) is granted by the administrators of the toolkit upon verification and evaluation. The access level is not analogous to the scientific background or level of expertise but is personalized on a case-by-case.

Although this may sound cumbersome and tedious, it is however more efficient, to avoid users who are self-described as researchers, thus, granted advanced access to the toolkits. This in turn necessitates the provision of one or more administrators, during the future use of the toolkits, to support these features. The EDICULA partners, and NTUA in particular, are committed to support the module for the foreseeable future.

There are four basic levels of user privileges:

1. Administrator
2. Advanced User with restricted editing privileges
3. Advanced User
4. Basic User

5.2.1 Administrator

The administrator has full-access privileges within the toolkit and moodle platform and can edit, add, reorganize or remove thematic areas, courses and educational materials. Currently, the EDICULA participants have each an administrator account, to allow full access to the toolkit. Obviously, upon evaluation from the EDICULA Steering Committee, other users can request and may be approved as administrator. For a non-EDICULA partner to be granted administrator privileges, they need to submit a formal report to the EDICULA Steering Committee describing their expertise, scope and educational rationale and roadmap for development of educational material. The Steering Committee will oversee the progress of the administrator's contribution in the toolkit and may propose modifications of privileges. [20]

The EDICULA Steering Committee is the scientific responsible for the EDICULA toolkits. Therefore, it ensures that any additional approved administrators conform to the strict criteria of scientific excellence, quality of educational materials and ethics that govern the EDICULA project and the EDICULA toolkits.

Potential additional administrators could, for example, originate from prominent academic institutions or CH stakeholders (e.g. Ministry), who in cooperation with the EDICULA Steering Committee could aid in the optimization and further enrichment of the EDICULA toolkits.

The approval procedure mainly aims to ensure that any approved administrator does not modify the toolkit without consultation with the EDICULA Steering Committee and other administrators, in order to avoid deletion of existing educational material or addition of files that are not directly relevant to the scope, quality and ethics of the toolkits.

5.2.2 Advanced User with restricted editing privileges

A user of this category is similar to the one described below but has restricted editing privileges. One of the main benefits of developing the toolkits based on moodle environment is that it consists of discrete "courses". This allows the administrator to provide various degrees of privileges within specific courses to advanced users. For example, a user of this category may be able to only see (and download) the available material in one thematic area (i.e. course) without being able to add or edit anything, while in another thematic area, in which they are experts, they may be approved to add, modify, or reorganize educational materials within that course. In effect, based on the experience of the Helios learning platform at NTUA, advanced users "register" for specific courses within a specific "curriculum". However, unlike the user level described below, they can participate actively in editing its content.

It should be noted that, as in the case of the additional approved administrators, an advanced user with restricted editing privileges also needs to submit a report about their planned activities for final approval by the Steering Committee. The Steering Committee will oversee the progress of the user's contribution in the toolkit and may propose modifications of his/her privileges.

Again, this approval procedure aims to ensure that the user does not modify the toolkit without consultation with the EDICULA Steering Committee and other administrators, to avoid deletion of existing educational material or addition of files that are not directly relevant to the scope, quality and ethics of the thematic areas approved or the toolkits in general.

5.2.3 Advanced User

The advanced user regards a person (typically a CH expert, undergraduate/graduate student, teacher, faculty, stakeholder, or researcher) that requires full availability of the toolkit content for the preparation of their own educational material (teachers and faculty), for informative purposes or for support of relevant reports (CH expert, stakeholders) or as part of their research (researchers). The advanced user, a term which mainly refers to their level of expertise, as compared to the more basic level of the general public or students, will have access (study and download privileges) to most of the material uploaded to the toolkit, albeit, without the ability to modify the content and organization of the toolkits. The administrator, as in the case of the user category described above, may opt to "register" the advanced users to certain thematic areas (courses) or parts thereof.

As noted above, administrator privileges are not limited only to EDICULA partners, but as the Toolkit is gradually being utilized by other institutions, universities and stakeholder organizations, more administrators can be added – upon approval by the EDICULA Steering Committee - that will manage their respective staff, employees and students. It is, thus, up to their evaluation to decide on the extent to which a user will have access to the courses of interest.

5.2.4 Basic User

The basic user regards a person (typically general public, stakeholder, CH expert or secondary education student) who aims to use the EDICULA toolkit either for informative purposes or as part of a course project (especially the students). Again, the term basic user is not representative of their educational level or professional / scientific background but rather to their needs and expectations from the toolkit. Obviously, a basic user is expected to have access to a more limited number of courses and educational material, and no editing privileges. [21]

For secondary education students, it is expected that their teacher will be registered as an advanced user with restricted editing privileges in order to manage the access limitations of the students. Alternatively, this will be done by a full administrator from a governmental body such as Regional School Administration, who in turn will register schoolteachers as advanced users only (i.e. without administrator privileges to avoid unwanted or accidental editing errors) and will overview the whole process of the EDICULA toolkit adoption in school curricula.

6 Complexities encountered

Much effort was made to design an architecture of the toolkit such that not only covers the wealth of thematic areas relevant to the protection of CH, but also is not difficult to use and apprehend the information included in it. However, several complexities were encountered and dealt with appropriately.

6.1 Extent of information uploaded to the toolkit

The main issue often encountered by the EDICULA partners who developed and uploaded educational material to the EDICULA toolkit was the desired and/or feasible extent of information provided in their educational material.

The first issue was if it was necessary to upload educational material to all the thematic areas included in the Toolkit at once. Regarding this, it was clarified during the transnational project meetings that it is not feasible to have available or develop educational material for all thematic areas included in the toolkit, nor the range of expertise of the EDICULA partners can achieve such an enormous challenge. However, the relevant thematic areas have been decided, included in the toolkit architecture and created in the moodle platform, for other users to upload relevant material. Again, it should be underlined that the EDICULA toolkit has not been designed to function as an information repository, but rather than as an advanced educational tool to aid various categories of users to better understand the issues involved in CH protection. As such, it is and will be reliant on the active participation of registered users that can and have the knowledge and expertise to prepare educational material to enrich those currently uploaded to the toolkit. It should be clarified, though, that such additions need to be made by established experts in the field, to ensure that the information provided is scientifically sound. In effect, the registered-users approach aims to ensure that the platform is not transformed into something like the Wikipedia site, where often the information provided is of doubtful validity or misleading.

The second issue was if it is desirable to include presentations/lectures that were extensive in size (i.e. many pages). The size of the educational material provided was purposedly kept to "reasonable" size. The rationale for this was two-fold. First, an extensive educational material (e.g. presentation) would discourage those users not familiar with the terminology involved, potentially diverging their interest to issues other than those discussed therein. Second, as the extent of educational material increases, there is observed a corresponding increase of overlapping with other thematic issues, potentially causing confusion to the users. It was not a trivial process, but with these two guidelines in mind, all EDICULA partners prepared, developed and uploaded the educational materials.

Regarding the third matter the issue was how much simplified or vice versa how much complicated should the educational material be. The "dilemma" of simplification was very important and often difficult to address. Considering that the educational material uploaded would be studied by a wide range of users, it was not straightforward how much simplification could be introduced – to attend the requirements of the general public – without discouraging the more "advanced" users. In most cases an intermediate approach was adopted. The intermediate approach is still appropriate for both extreme levels of users. For the more basic level users, the inclusion of adequate details and understandable terminology aids them to realize – to some degree – the complexity of the issues discussed and intrigue their interest to search the subject further. For the more advanced users, the educational material serves as the initial point of research and as a concise and brief overview of the issues involved. It provides them with broad guidelines as to where to search for additional more specialized information if so desired.

The last issue was the one of providing a comprehensive list of references to scientific publications and if it is desirable to include many (if not all) the scientific references (known to the EDICULA team) for the subject discussed. Similarly with the above, the issue is bounded by two limitations. First, it is scientifically rather difficult to include all references available for any subject discussed. Second, even if such a comprehensive list could be prepared, it would become outdated, unless regularly updated. Instead, the provision of some important and/or representative references to scientific publications, serves (as discussed above) as a starting point for any thorough research on the subject is the most effective approach.

6.2 Overlapping of issues discussed in educational material

As mentioned above, there was a significant concern about overlapping of issues discussed in the educational material in some thematic areas, with educational material uploaded to other thematic areas within the toolkit. This was more common in the emblematic use cases provided in some educational material. To some degree, this could cause confusion to certain users, especially if they have studied educational material from the other thematic areas and could perceive some repetition. However, this overlapping should be instead assessed as desirable. The vast array of issues involved in the protection of CH cannot be approached unequivocally per discipline, nor do not have an impact on other aspects of this field. The overlapping of challenges, requirements, restrictions and cooperation are normal practice for those involved in the field of CH protection and should be presented as such. As long as the educators who utilize the toolkit realize this, they can more effectively address complex educational needs and develop comprehensive educational material for their students. Similarly, the students, through the use of the toolkit, will recognize that certain "problems" have complex and intertwining "answers" and should be approached accordingly.

6.3 The moodle environment

As mentioned above, based on the recent experience of the NTUA with moodle software for the University's e-learning platform Helios, it was selected to support the Educational Toolkit. Although, initially, the EDICULA consortium was oriented to adopt a free, open-source software learning management system such as the combination of WordPress/LearnPress/LearnDash learning environments, it was discussed in the transnational project meetings that a more widespread platform should be selected, on which the participating academic institutions have significant experience. The selection of moodle had the additional advantage that in the future it could be easily integrated to academic institutions already using moodle to support their learning platforms.

For administrator users not acquainted with such a software environment, this was initially difficult to manage and upload the educational material developed. The NTUA IT team helped all EDICULA members through on-line training courses and communication (emails, phone calls, etc.), and as a result, all members got used to the process rather quickly. Another issue regards the focusing of moodle in a course-oriented approach for organization of materials. This is understandable since moodle is a world-class online learning platform. For people acquainted with data repositories this could be problematic since they tend to organize files in categories rather than in courses/topics. However, users that have uploading privileges got used to it quickly. It still creates an increased workload, since descriptive titles need to be added for all files uploaded. An issue encountered by the administrator users was the need, sometimes, to add categories or correct errors during the uploading of the thematic areas on the moodle platform. The most common error regarded the hierarchy of the courses created (thematic nodes), which sometimes proved difficult to correct in the moodle environment. It should be noted that despite these setbacks, the management and organization of the educational material was generally straightforward, although often time-consuming due to the large number of files to be uploaded, the description of each file and the appropriate organization.

An alternative specialized software platform could be developed, probably with a better platform-user interface. However, it would not have the advantages of full and future support that the moodle environment offers. Neither could be utilized by teachers for their tutoring needs, who are mainly acquainted with moodle already.

6.4 Transition from EDICULA-4-all module to EDICULA+ module

From the above analysis, depending on the extent of courses available to the users, they may be regarded to use EDICULA+ as compared to the EDICULA-4-all module. Effectively, the more courses and content the administrator provides access to the user, the more they are shifted from an EDICULA-4-all content to an EDICULA+ content. This access granting process, in effect, defines a "smooth" transition between the two toolkit modules, without universal clear boundaries of their content. It can be vaguely described as a "twin" definition. Both modules are distinct, but no clear boundaries actually exist. From an engineering perspective, one can realize it as a gradual "diffusion" interface between the two modules. The important outcome of such an access setting process, is that there are exist no unique differentiations between the two modules, rather than boundaries per user as defined by the appropriate supervising administrator. This transition affects the analysis of the clusters and the interlinking matrix of the educational content, both of which are governed by the accessibility environment granted to each user.

6.5 Duration of support of the EDICULA toolkit

The EDICULA partners are committed to support the EDICULA toolkit for at least three (3) years after the completion of the EDICULA program. Moreover, the toolkit will continue to be updated with more educational material, through a dynamic participation of the EDICULA partners. Specifically, as the EDICULA partners complete analysis of data from their past and ongoing projects, relevant to EDICULA, they will develop new educational material which will enrich the toolkit thematic areas. Through this dynamic process, the toolkit will be continually updated and enriched which will encourage participation from the scientific community and other users.

7 Conclusions

Already the toolkit is filled with papers, presentations and various project's material in most of its courses. This shows that the toolkit can be a worldwide educational platform that is able to provide all kind of material relevant to its scope. The differentiation between the two modules is confusing but it achieves not to separate them from one another. Thus, the user is able to switch from one module to the other without the need of going to another site. Also, they (the users) are classified according to their rank and their needs from the toolkit, without realizing it. As a result, the two modules are united in some areas and separated in others in order for the toolkit to work better and provide the best experience for the user.

Also, the ability to offer different privileges to users is creating an environment of better interaction. For example, teachers are able to give to their students the appropriate educational material, as mentioned. In general, the toolkit gives the opportunity to every user to share their project or use the content already uploaded for scientific or educational purpose.

In conclusion, the EDICULA educational toolkit in both its modules, is set to become a valuable tool for the public, for students, teachers and educators, stakeholders and researchers, addressing a wide range of challenging needs for knowledge. It is set to serve as the starting point for all these user categories.

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Virtual Reconstruction of Lost Cultural Heritage – The Case of the Historical Church of Pammegist Taxiarch Archangel Michael in Medieval City of Corfu. A holistic Interdisciplinary approach, in Challenging Times enhancing Sustainable Urban Development

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Abstract. The present work is about the application of digital record of Lost Cultural Heritage monument in Corfu island - the case of the Church of 'Pammegistos Taxiarch Archangel Michael situated in the heart of the oldest medieval district of '*Campiello'* in the Old Town of Corfu, built the 14th century. Today, the building has been demolished and a homonymous square has been created in its place. The "*Taxiarch square*" is a free space formed randomly, violently and remnant of the bombings of the 2nd World War. Considering an essential step in understanding and conserving as accurate as the values of the memory of the glorious past, creating a as close as possible digital record of the most important monument in the area for the future, providing a means to communicating the knowledge and value of the tangible monument to the society. Our effort to provide the locals with the necessary information and knowledge of the past architectural and monumental structure of the city in order to ensure a sustaina-ble and conservative development of these areas for the purpose of upgrading the living standard). In our Challenging Times, the data acquired from in-situ research, archives, bibliography and areal photography applied to 3D modeling of important monuments of Corfu Old Town - a UNESCO World Heritage Site in Greece results into tangible reconstructions of the archae-ological, architectural and artistical structure of monuments that may evoke the involvement of the citizens of Corfu in their maintenance and conservation. Our approach consists of using in the contest of the combined methods and data, planning through field and desk. We can affirm that we designed and developed, for the first time, a 3D Modelling of the Taxiarch' church and its bell-tower situated in 'Campiello' district in the Old Town of Corfu. Having used ancient maps, the Land Registry of 1947, the Cadastre map of 1954, for georeferencing purposes it was necessary to select peculiar points with known coordinates, recognizable on the ancient map and still existing on current representations. Applying the comparative method, the analyses were concentrated to the basic characters of the selected points themselves (e.g., planimetric precision, graphic representation on the ancient maps, etc.). These points were considered landmarks because of their lesser reliability as compared with the usual topographic reference benchmarks. In our case we selected lots of reference points throughout the area, to find out the elevation data of the object. At the same time, we used Drones Tech. We tried to investigate the changes in the urban fabric of the old city of Corfu and in the next stage of work, under a subtractive choice of approach**, a 3D Digital Model of the church has been designed and developed.**

Keywords: Lost Cultural Heritage, documentation, elevation data, Orthodox church, Old-Town, Corfu, Digitization, 3-D Modelling,

1 Introduction

The Church of Pammegistos Taxiarch Archangel Michael situated in the heart of the oldest Corfu district, 'Campiello' [1], not recognizable today, has been narrat-ed as an important religious and social center of the 18th century. 'Campiello' was built on the hill, nearby the sea, to provide basic defense advantages, antedating even its fortifications. The small areas where the street widens discovers some old gothic arches incorporated into house walls, relief heads (so called '*mori*'), dating back to the Venetian rule. The narrow uphill streets, surrounded by large buildings consisting of five or six floors, attest to the use of building construction methods opposed to those that are specific to the climate of Corfu.

Fig. 1. Campiello, Distinct urban units, Old Town of Corfu, source: "Multicultural Tourism Pilot Project, Municipality of Corfu Development Enterprise (ANEDK), European Comission DG XVI, 'Culture' ERDF, Article 10, pp.8.

Fig. 2. 1836, MCNIVEN, Maj. Thomas William Ogilvy. Robert Havell. Panoramic View of Corfu, detail: bell-tower of Taxiarch' church. Source: https://www.splrarebooks.com/collection/view/panoramic-view-of-corfu.

Fig. 3. Dodwell Edward, CORFU, panorama (1801). Source: www.360cities.net/image/dodwell-s-corfu-panorama-1801.

Fig. 4 Yiallinas, Angelos, watecolour, Bell-tower of Pammegistos Taxiarch, begin. of 20th C., Courtesy of Mr.Pieris, Y. the use of the photo, Passage through time, Reading Society of Corfu, Yiallinas Foundation, 2019.

At first glance these buildings recall the architectural rhythm of the coastal houses of Northern Italy, ascertaining the "*naval affinity*" of Liguria (north-western Italy), with Venice, which consist of tall buildings surrounding the narrow "*carruggi*" and in a picturesque way, extends towards the sea. The Venetian architecture with the narrow streets that ends up in real "*campiella*"[1], transformed into small squares often adorned with the green of trees and with the presence of no pointed bell tower [fig.2,3,4], also of Venetian style. The '*campielli'* with the churches were the centers of parishes, meeting-places for the aristocracy, to exhibit wealth and piety and a means to express individuality. Literally, during the Venetian domination the hill of Campiello [fig.1,5] was densely built and framed up with many Orthodox churches, such as the Holy Virgin **Our Lady of Antivouniotissa**, 'Pammegistos Taxiarch Archangel Michael', the 'Christ Pantokrator -Transfiguration of the Savior', 'Holy Virgin of Kremasti' with its small square and a cistern, that is reminiscent a small *"Campo Veneziano"* [2], Saint Nicolas 'dei Vecchi', and Saint Helena (today does not exist). What seems lacking in "elegant disposition" in the districts of the old town extending to the sea, responds, on the contrary, precisely to the altitude requirements of the area.

Fig. 5. Views from the narrow streets of 'Campiello' district. Photo: E. Polymeri

Today's Taxiarch' square" is a free space formed randomly, violently and remnant of the bombings of the Second World War [fig.6,7,8,9]. After having sustained big structural damages, during the WW2 Italian bombings of the island, the local authorities demolished entirely the Church of Taxiarch' as well as other considered "dangerous" buildings in the attempt to modernize by opening up free spaces and by maximizing the fluidity and accessibility of the area.

1.1 Historical and architectural evidences

Case study: The church of Pammegistos Taxiarch Archangel Michael in the *exopolis/suburbium* (out of the Old Fortress - Byzantine city of Corfu) on the so called "*Judean Mountain*" [3], dated back to the 14th Cent. [4]. Having been a small construction, but a very important church, later, on 1489 there were placed the Sacred Relic of Saint Spyridon, the Patron of Corfu, probably remaining there until 1528/31, when the Saint's church was constructed [5]. In 1729 it was again renovated from the ground up [6]. On March of 1725 the Sacred Relic of Hagia Theodora, the Empress, remained until 1841, then, on 1842, moved to the current Metropolitan Church of the Most Holy Theotokos Spilaiotissis (Grotta) - Hágios Blásios and Hágia Theodora Augusta (Empress, 842-855) [7]. Having had the ownership status *'Jus Comunitaris Publicus'* [8] the Pammegistos Taxiarch church served from 1712 to 1799 as the first Cathedral of the Orthodox Church and the seat of the Great Protopapas. After the *reinstatement* of the episcopal throne of Corfu until 1842 it served as the Metropolitan Orthodox Church [9]. The building was bombed in November 1940 by the Italians and suffered extensive, but not irreversible damage [10]. Having decided to "raze" the Taxiarch church and reconstruct only the 'Christ Pantocrator' church, we have the information that probably, under the protection of the Bishop Methodios Kondostanos the extant parts of the temple, the icons, the sculptures, banners and torches were removed and placed in '*Rolina*' basement - the building along Garitsa seaside [11], and some of them were 'lost' forever. Nevertheless, what remained was demolished. Having received an irreversible decision, the local authorities destroyed the remains of the church and its beautiful, surviving bell-tower [fig.4,8,9] "*Abyssus abyssum invocat*", (*'One misstep leads to another')*.

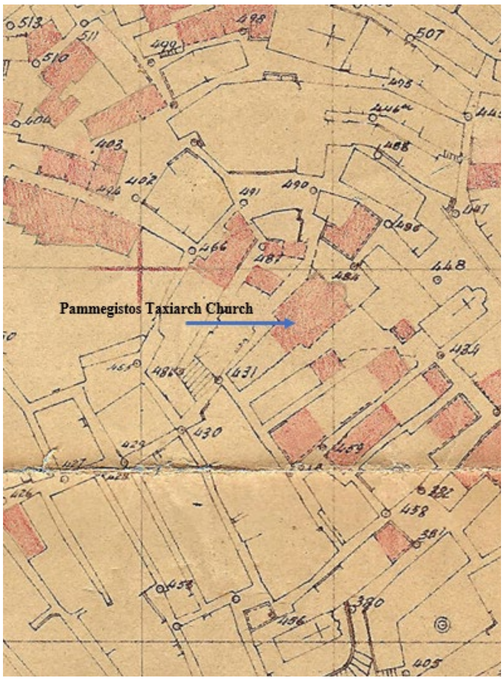

Fig. 6. 22.8.1948, Corfu, Old Town. Demolished buildings register (red) after WW II. Courtesy of Mr. Kollas Leonidas.

Fig. 7. The church after the Italian bombings WW B', newspaper: 'Kathimerini' (Η Καθημερινή), 31 December 1940.

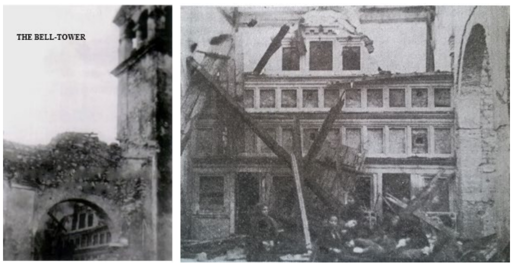

Fig. 8. (α, β), Pieris, I., *Thomas Flanginis and Corfu*, Bulletin of the Society of Corfiot Studies, Corfu, 1993.

Fig. 9. Ventouras, N., Taxiarch church after the WW B' bombing, vignette, Corfu 22.12.1940

Initially, before 1386, probably, the church was a single-aisle temple dedicated to Archangel Michael in honor of the byzantine ruler, Michael II Komninos Doukas (called Michael Angelos in chronicle sources), ruler of Epirus and Thessaly (from ca. 1230) [12]. Later, was widened in the type of a three-aisled basilica. In the 16th and 18th cent., because of the Ottoman incursions the construction was seriously damaged.

The architectural type of the church of Pammegistos Taxiarch Michael is a three-aisled, timber-roofed basilica [fig.10,11], according to the Ionian Islands style, shaped under the influence of the Western church. Having acquired, later, elements of baroque style, the Taxiarch church, we must admit that a small number of dated buildings correspond to the "baroque" and "rococo" in Corfu town. The monument is poorly documented. The three-aisled basilica rarely occur as an exception, whether in the Old Town of Corfu, there are the churches of Virgin Mary of the Foreigners and the Most Holy Theotokos Spilaiotissis (originally built as a single-aisle chapel and later expanded to a greater three-aisled church), while the number is greater in the region. The orientation of the Ionian Islands' temples was not fixed but it was influenced by factors directly related to the topography of the area, meaning the main street or the square, the shape of the plot etc. Especially in the large temples of the city, the religious imperatives were often reconciled with the data of the space, with the consequence that the sanctuary often showed a deviation from the East.

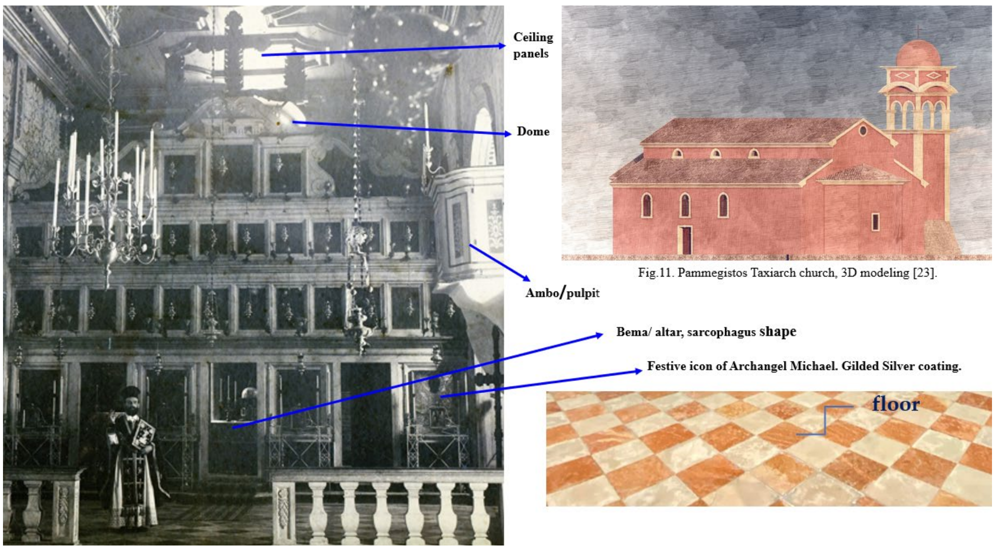

Fig. 10. Interior of the church, early19th Cent., photo, courtesy of Mr. Thymis Constantine.

Fig. 11. 3D modeling [22].

Fig. 12.The floor at the most churches in Old Town of Corfu, were built of stone in square slabs, off-white and pink colour, diagonally placed in a chequerboard ornament arrangement.

Fig. 13. Taxiarch' church, 3-D Modelling designed and developed by Monastiriotis Charilaos - Civil Eng., Foteinos Christos - Structural Eng., Michalas Demetrios - Civil Eng

The three-sided apse of Taxiarch' temple was situated on North-East. The main entrance was placed respectively on the long sides on South and North of the temple, - a peculiarity of the Orthodox churches in the Ionian Islands, mostly due to orientation. In that case the main entrance and the main facade 'create' a second transept-axis of the temple, perpendicular to the strong longitudinal axis, resulting in the creation of a center inside the building, geometric and symbolic. This difference in access reflects issues concerning the positioning of men and women in the temple. Essentially, by asking for the distinguished access of women, a different functional type is created, according to which the western entrance is addressed exclusively to women, especially young and unmarried ones, and leads to the gallery. So, the entrance and the façade are considered secondary.

In Pammegistos Taxiarch Archangel Michael's church the gallery occupied the western part of the temple [fig.15], constituting architectural element, part of the general composition of the interior decoration. Studying the project-study provided by Mrs. Karydi, Alex., Architect NTUA, Urban and Regional Planning MSc., the researcher responsible of the project in 1997- 8 [11], who I heartfully thank for the precious information, we come to the conclusion that there was a covered gallery on the West of the building - the so called '*Volto of San Michele'* (named by the church) connecting the temple with the adjacent building and a *porticus* to communicate [fig.14].

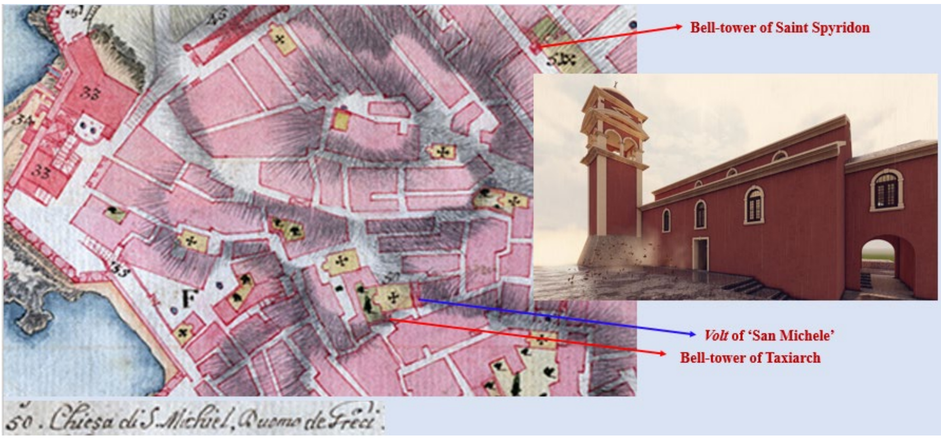

Fig. 14. α). Ganassa Map (detail), Corfu Town, 2nd half – XVIIIth Cent. ('Map, Pianta della Città e Fortezza di Corfù e / suoi sotterranei Corfu "Perla del Levante". Documenti. Mappe e disegni del Museo Correr. Regione del Veneto. Biblion Edizioni, 2010. Caption no.50 refers 'the Church of S. Michiel', Cathedral of the Greeks'. β). 3D Modeling of church complex [22]

The gallery or '*gynaikonitis'* occupied the western part of the temple, constituting architectural element, part of the general composition of the interior decoration. The entrance in West was situated in a lower level, under the volt, having two-sided stone stairs and a metallic fence, probably. The overall length of the construction is approximately 26,40 m., the overall width is 13,95 m. and its total height calculated, might had been approximately 11,7 m. [fig.21].

Fig. 15. Pammegistos Taxiarch church, 3D modeling [22].

According to the archaeological findings, there were unearthed partly, two phases of the building and we assume that were a third one which correspond the earliest phase of the temple [11]. We assume that the 1st phase corresponds in the period of the Despotate of Epirus (13th-14th cent.), then the Byzantine influence was much stronger in the entire city of Corfu and the temple was a small, one-isled church [fig.21] with a semicircular apse and probably named by the Despote Michael II Komnenos Doukas (ca.1230-1266/8), often called Michael Angelos [12].

Fig. 16. 1947. Land Registry, detail.

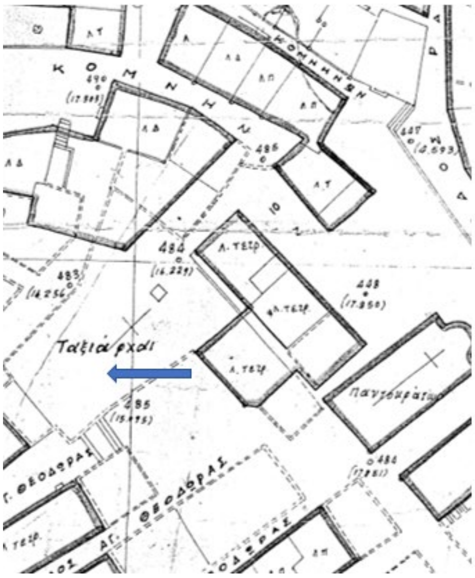

Fig. 17. 1956, Cadaster's Map, detail.

Our approach consists of using in the contest of the combined methods and data, planning through field and desk. We may argue now that we designed and developed, for the first time, a 3D digital Modelling of the Taxiarch' church and its bell-tower situated in 'Campiello' district in the Old Town of Corfu. Having used ancient maps, the Land Registry of 1947 [fig.16], the Cadastre map of 1954 [fig.17], for georeferencing purposes it was necessary to select peculiar points with known coordinates, recognizable on the ancient map and still existing on current representations. Applying the comparative method, the analyses were concentrated to the basic characters of the selected points themselves (e.g., planimetric precision, graphic representation on the ancient maps, etc.). These points were considered landmarks because of their lesser reliability as compared with the usual topographic reference benchmarks. In our case we selected lots of reference points throughout the area, to find out the elevation data of the object. At the same time, we used Drones Tech. We tried to investigate the changes in the urban fabric of the old city of Corfu and in the next stage of work, under a subtractive choice of approach**,** a 3D Digital Model of the church has been designed and developed [fig.11, 13, 15, 24,29].

Inside the church there was a 'typical Corfiot' stone iconostasis [13], framed by icons of Cretan and Ionian Islands painting techniques worked by well-known hagiographers and mural paintings [14].


a.


b.

Fig. 18/a). The two-sided icon of *Virgin Hodegetria* '*Demosiana*', Palladio of Corfu. **18/b)**. Back-side, Saint Arsenios, Archbishop of Corfu (IXth Cent.). Probably work of Ioannina Hagiographers. Date: last quarter of 14th Cent. (Photo: "Byzantine and post-Byzantine Art in Corfu", Sacred Metropolis of Corfu, Paxoi and Diapontian Islands, Corfu, 1994).

Fig. 19. Michael Damaskinos, '*Great Deesis'*, 16th C. At the Episcopal Residence, came from the demolished Church of Pammegist Taxiarch Archangel Michael, Campiello, Corfu [14]

Fig. 20. Michael Damaskinos, 'Saint John Chrysostom', 16th C. At the Episcopal Residence, came from the demolished Church of Pammegist Taxiarch Archangel Michael,

Church of Pammegistos Taxiarch Michael

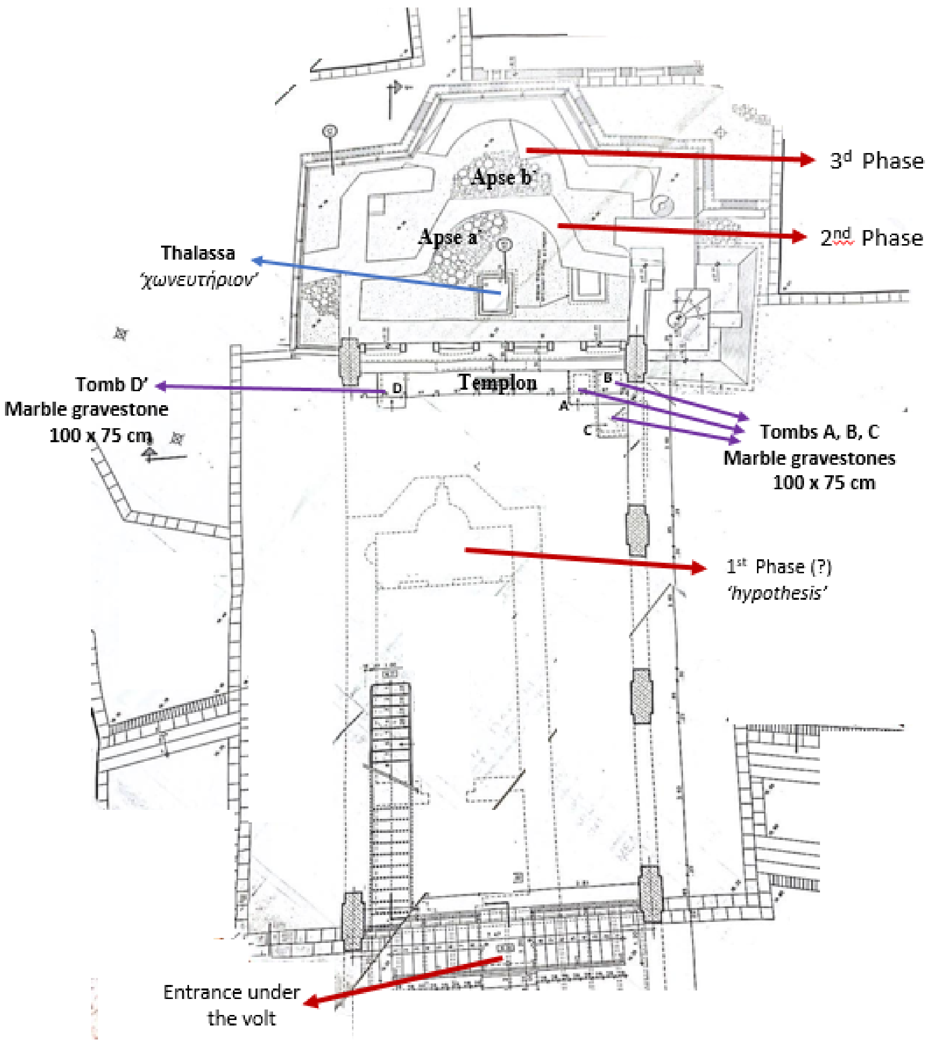

Fig. 21. Plan of the church with its constructive phases [phase (1) is hypothetical], Program Contract of the Old Town of Corfu, Ministry of the Environment, Urban Planning and Public Works of Greece, Ministry of Culture, Public Enterprise for Urban Planning and Housing, Municipality of Corfu, Bureau of the Old Town of Corfu [11], [2].

Fig. 22. a). View of the 'Taxiarch Square' and the 'apse' of the church outlined with low, concrete wall. b). 3D modeling [22].

Fig. 23. Western side of 'Taxiarch Square', Campiello. Photo: E.Polymeri.

Fig. 24. 3D modeling [22].

An important architectural structure part of church's complex was the bell-tower of Taxiarch, a '*baroque style*' construction, situated on the northern part of the building, as drawn by Angelos Yiallinas on 19^{th} cent. [fig.4, ref. 15]. Having survived the bombings of WW B' in a the very good state of conservation, the construction was demolished, immediately after the local authorities' decision. The dimensions of bell-tower's basis calculated, were approximately 3,50 x 3,50 m and its height approx. 17,20 m [16]. During the archaeological excavations that took place on 1997-1999 according to Mrs.Karydi, A. [11] there were found traces of two phases of the apse according respectively in two different historical periods and probably, we support, one in 15^{th} cent., when it was reconstructed and the Sacred Relic of Saint Spyridon was housed in and the second perhaps in the period when Taxiarch' Church became the Seat of the Great Protopapas or when it became Metropolis. During the works in 1997-8, there were unearthed four graves of distinguished officials at least one of the *Great Protopappas*, the head of the Orthodox Church and the *Sacred Congregation/Order* [17]. Having been placed in the area of the *templon*, not usual to burial practices in Byzantine period [18], we assume that they were built earlier, when the church was smaller and were placed in the area out of the church. The graves were built with marble stone of local origin and their dimensions were 100 x 75 cm.[fig.9]. Important is the fact that part of the icons, are saved and exhibited to the metropolitan church of Spileotissa, the Metropolitan Seat and one in private collection [19] the festive gilded icon of Archangel Michael [Fig.23] and some other are now exhibited in the Holy Fathers' church situated in the top of the homonymous hill in the Old Town of Corfu.

Fig. 25. a). Interior, *templon*, early19^{th} cent., photo, courtesy of Mr.Thymis Constantine.
b). The silver gilded festive icon, photo E.Polymeri.

Fig. 26. Festive icon of Archangel Michael from Pammegistos Taxiarch' Church in Campiello, silver-gilded, today at Saint Fathers' Church, Old Town of Corfu (photo Polymeri, E.)

Fig.27. Archangel Michael, 16th cent. (today at the Metropolitan Residence, dim. 97,6x 65cm, (photo: "Byzantine and post-Byzantine Art in Corfu", Sacred Metropolis of Corfu, Paxoi and Diapontian Islands, Corfu, 1994)

Inside, the *templon* was built by stone, was high organized in three levels and an iconographic program was adopted. On the Northern part of the building there was a *prokinitarion* with the festive icon of The Virgin 'Demosiana', one of the oldest in Corfu. According to the 'Baroque style' the *proskinitarion* was shaped like a "*tempietto*" decorated with figures of angels in segmental triangles, on clouds, waving acanthus leaves and a pomegranate hanging in the center [Fig.30]. Through our research we found that the beautiful sculpture fragment, made of marble is placed in wall at the *prothesis*/*presbytery* of Saint Antonio's church in Spilea – Old Town of Corfu. Another, exceptional piece of art is the Archangel Michael [Fig.28, 29] which today decorates the roof of 'Christ Pantocratoras' church and we strongly believe that it was part of the decoration of Archangel Michael Church [11]. The Angel is represented on a circular pedestal and the height is 1.25m. This magnificent piece of art dated back in the 18th C. crafted by a prominent mid-18th-century Italian sculptor Torretto/ Giuseppe

Bernardi (24 March 1694 in Pagnano – 22 February 1773 in Venice). He was also the first teacher, among others, of the famous neoclassicist, Antonio Canova.

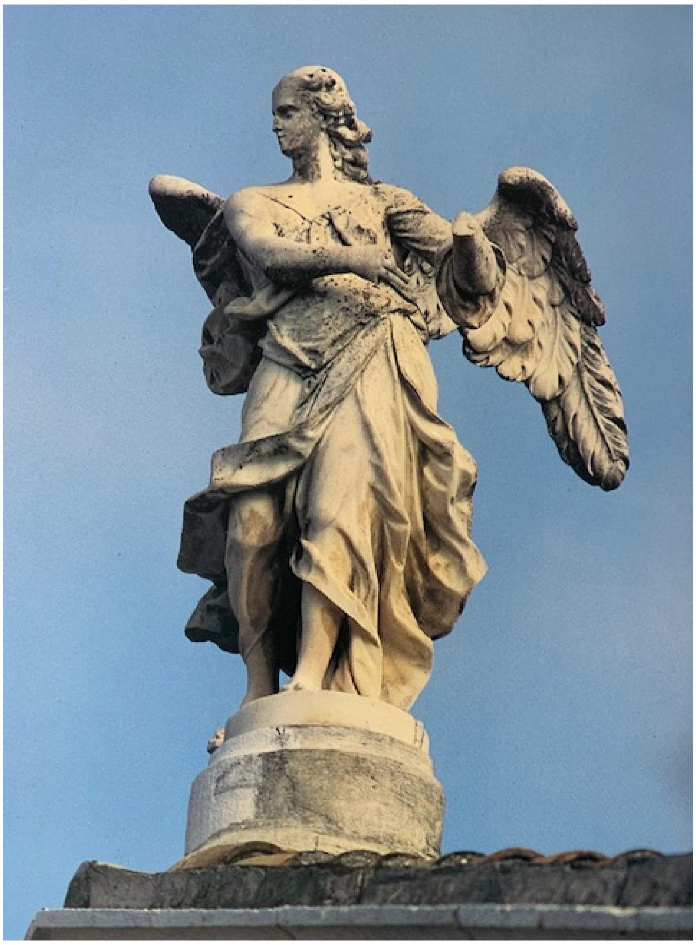

Fig. 28. Torreti, Sculpture of Archangel Michael, marble, source of the photo: "Byzantine and post-Byzantine Art in Corfu", Sacred Metropolis of Corfu, Paxoi and Diapontian Islands, Corfu, 1994.

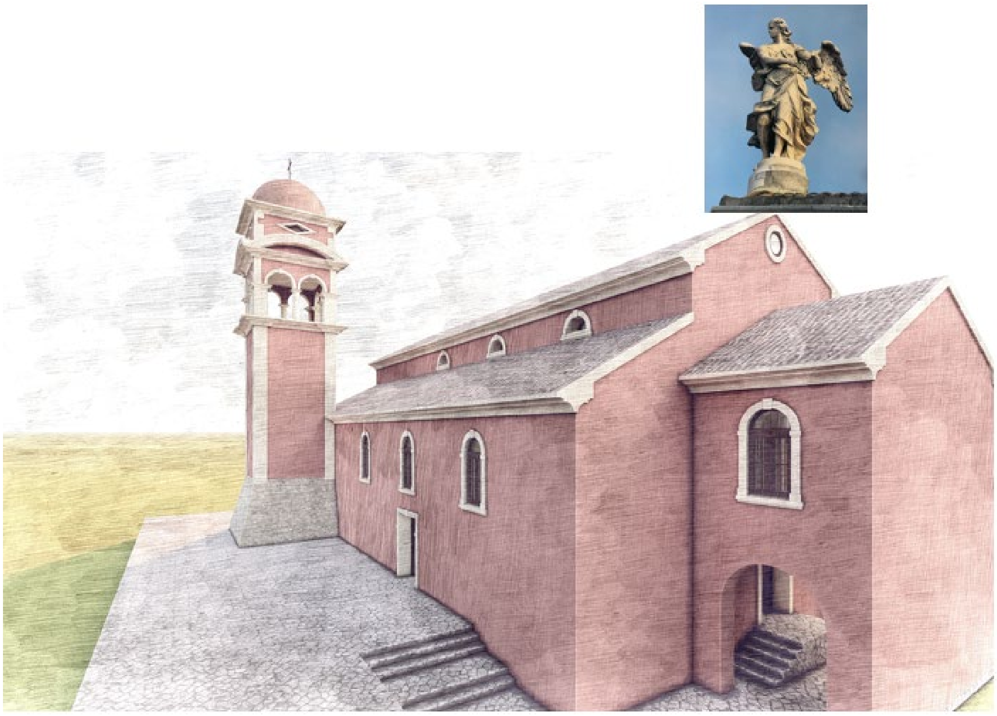

Fig. 29. Pammegistos Taxiarch Archangel Michael church and the Angel of Torreti, 3D modeling [22].

Fig.30. *Proskinitarion* of The Virgin, Northern part of the church. Decoration (yellow arrow), sculpture fragment, marble. Photo. E. Polymeri.

Both churches, 'Pammegistos Taxiarch Archangel Michael' and 'Christ Pantokrator - Transformation of the Savior', on 1922 sheltered temporarily the Armenian refugees coming in Corfu from Asia Minor.

Conclusions

The present work is about the application of digital record of Lost Cultural Heritage (LCH) monument in Corfu – Old Town. The concise presentation of our approach, which propose a framework for the field of the prominence of Cultural Heritage (CH) in historic cities against Climate Change (CC). Given to the fact that the evolution of technology has given an abundance of methods and equipment at the same time, we have the possibility to reach with precision the 3-D Modeling of the lost monument, designed and developed, opening efficiently new orisons to the locals, in upgrading the living standard, while through culture and dialogue we might provide the necessary transformative dimension that ensures the sustainability of development processes.

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20. 3-D Modelling, designed and developed: Monastiriotis Charilaos - Civil Eng., Foteinos Christos - Structural Eng., Michalas Demetrios - Civil Eng.

Digital documentation of three largest subterranean structures of Hagia Sophia: The passage under the eso-narthex, the vaults under the atrium and the hypogeum

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Abstract. The terrestrial scanning project of Hagia Sophia's subterranean structures took place in 2020. This field study enabled the creation of a three-dimensional point cloud model capturing the underground tunnels and structures. Subsequently, in 2022, a more detailed documentation of the older hypogeum within Hagia Sophia was conducted. This study particularly focused on the three largest subterranean structures on the site. The first of these is the passage beneath the eso-narthex, delineating a structural transition between the Theodosian and Justinian periods, spanning from the fifth to the sixth centuries. Notably, the discovery of a previously unnoticed column base on the floor of this structure prompted an update to the plan of the Theodosian atrium. The second focus lies on the vaults beneath Justinian's atrium, requiring an architectural visualization update since Schneider's documentation in 1941. These subterranean structures define the boundaries of the no longer physically existing Justinian atrium, and the debris within them awaits excavation to provide further insights. The last structure examined is the hypogeum dating back to the 4th century. This structure underwent a more detailed redocumentation following a partial clean-up and has been digitally visualized.

Keywords: Hagia Sophia; subterranean; atrium; vault; hypogeum; tunnel

1 Introduction

Once precise metric measurements of a structure are obtained, they become invaluable tools for restoration and maintenance endeavors. Moreover, the process of gathering data enables the utilization of 3D information in various formats, making history and architecture more accessible to a wider audience [1]. Undoubtedly, the subterranean aspects of Hagia Sophia warranted such scrutiny. While the monument's super- structure had been digitally scanned numerous times, the architectural visualization of its subterranean elements had been neglected. The fieldwork for the terrestrial scanning project of the subterranean structures at Hagia Sophia took place between June 29 and July 16, 2020. This groundbreaking project marked the inaugural digital documentation of Hagia Sophia's subterranean realm, which spans a total length of 936 meters.

Consequently, a comprehensive three-dimensional point cloud model of the underground channels and other subterranean structures was acquired and documented [2]. This documentation and visualization initiative raised awareness about the current state of Hagia Sophia's subterranean structures, leading the Istanbul Preservation Board to order their cleaning on October 13, 2021. The cleaning process, which began in the hypogeum on November 15, 2021, was paused on December 14, 2021, due to challenging seasonal conditions and the necessity for a more comprehensive, long-term excavation process. Following the partial clean-up by the end of 2021, an improved environment was established, enabling better visualization of the space. Subsequently, in January 2022, the hypogeum, older than the current Hagia Sophia, underwent a more detailed redocumentation. This study primarily centers on Hagia Sophia's three largest subterranean structures: the passage under the esonarthex, the vaults under the atrium, and the hypogeum. These remarkable spaces interconnect via subterranean tunnels traversing beneath and around the structure, delineated on the plan by their section lines (see Fig. 1).

Fig. 1. The plan of Hagia Sophia's subterranean structures features section lines delineated as 1-1 and 2-2 for the passage under the esonarthex, 3-3 and 4-4 for the vaults under the atrium, and 5-5 and 6-6 for the hypogeum. In this representation, the superstructure scanned by the University of Calabria is depicted in grey, while the subterranean structures scanned via laser technology are highlighted in red. The areas that were measured manually are indicated in yellow

2 Materials and Methods

The scanning process utilized a Faro Focus S 150 Terrestrial Laser Scanner for the passage under the esonarthex and the vaults under the atrium. Equipped with an eight-megapixel HDR camera, this scanner adeptly captured detailed imagery, providing natural color overlays to the scan data, even in low-light underground conditions. Optimal parameters were applied for scanning, including a resolution of 1/8, Quality set at 3×, a scan duration of 03:27 minutes, and a scan size of 5120 × 2133 points. Data processing was performed using Faro Scene software, generating orthographic photographs of the scanned areas.

For the hypogeum, a Leica BLK360 Camera Laser Scanner was preferred regarding its small size and easy use with the properties of 6 mm accuracy in 10 meters, com-pact size (165 mm tall × 100 mm diameter), weighing just 1 kg. This scanner, capable of capturing 360,000 points per second within a 60 m radius, was advantageous for maneuverability in low and narrow spaces, including other underground tunnels.

However, the initial digital documentation of the hypogeum using the Leica BLK360 Camera Laser Scanner required an update due to low resolution, unnatural colors, and unclear structural edges (see Figs. 2-3). Furthermore, rainwater accumulation on the floor negatively affected this documentation. Subsequent to a partial cleanup that involved draining rainwater using a water pump, a more conducive working environment was established. This prompted a different approach for redocumentation opting for an image-based modeling technique rather than using the laser scanner. A 24-megapixel NIKON D5200 camera equipped with AF-S DX NIKKOR 18-105mm f/3.5-5.6G ED VR lens was employed to capture 958 internal and 596 external photographs at 300 dpi. Agisoft Metashape Professional program version 1.5.2 facilitated the creation of a three-dimensional imaging space, resulting in a more refined redocumentation of the hypogeum compared to the 2021 documentation. Despite debris obstructing visibility of the actual height and original floor, future visualization steps post-complete hypogeum cleaning will facilitate a comparative analysis of the structure's true height.

These surveys concentrated on assessing the current condition of the chosen subterranean structures. However, they were not georeferenced or coordinated with the existing scattered surveys of Hagia Sophia due to the preliminary nature of the study. The intention is to re-visualize these subterranean structures after cleaning and to georeference them with the ongoing latest digital visualization of Hagia Sophia's superstructure.

Fig. 2. Section 5-5: Southeast- northwest cross-section showing the middle chamber of the hypogeum and the channels running at its southeastern and northwestern ends.

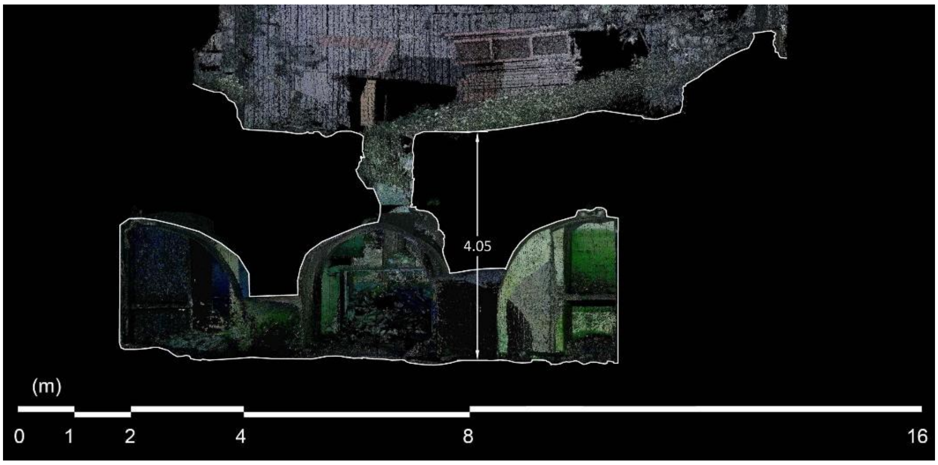

Fig. 3. Section 6-6: Northeast-southwest cross-section of the hypogeum.

3 Results

Given that the initial constructions of the Hagia Sophia complex no longer exist, the study of surrounding and related structures is very important to understand its multi-layered construction history. Therefore, the documentation of the three largest selected subterranean structures holds significant importance in unraveling the intricate layers of Hagia Sophia's history. Each documentation intends to offer insights into the original architectural features of these subterranean spaces and emphasizing the necessity for their thorough cleaning before final documentation.

3.1 The Passage Under the Esonarthex

Accessible through an opening west of the Imperial Gate (see Figs. 1, 4), the passage beneath the esonarthex resides approximately 2 meters below the ground floor. Measuring 4 meters in width and spanning 47.50 meters in length, this space runs along a northeastern-southwestern axis beneath the southeastern half of the esonarthex. Its ceiling consists of cross vaults connected in the middle with the 23 masonry piers aligned in row. Notably, three channels extend from each end of this passage, diverging in various directions. Serving as a central nexus, this passage interconnects with the subterranean tunnels extending both within and outside the Hagia Sophia structure. On the other hand, in comparison to the following two subterranean structures, this passage is in good condition structurally and free of debris.

Fig. 4. Section 1-1:Northeast-southwest cross-section of the passage under the esonarthex.

The floor level of the passage under the esonarthex aligns nearly with the remains of the Theodosian Hagia Sophia's portico (see Figs. 1, 5), suggesting a significant connection. This alignment indicates that when constructing the esonarthex and exonarthex of Justinian's Hagia Sophia, much of the Theodosian Hagia Sophia's atrium was incorporated. This passage serves as a defining space, marking a transitional phase between the two monuments from the fifth to the sixth centuries. Presenting the only visible façade of the foundation of the present structure standing on the previous one, the plastered wall of this subterranean structure also provides knowledge for the foundation substructure.

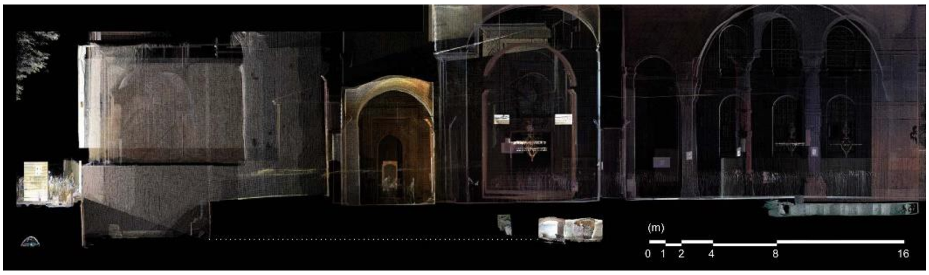

Fig. 5. Section 2-2: Northwest-southeast cross-section extending from the remains of the Theodosian portico to the northern main pier of Hagia Sophia.

The plastered interior surfaces formerly initially suggest that the passage under the esonarthex might have functioned as a cistern [3] (see Fig. 6). However, its connections with channels at lower elevations on the northeastern and southwestern ends refute this function. Instead, this substantial space, believed to be the most voluminous among Hagia Sophia's subterranean structures, appears to have served as an air-ventilation conduit and a transition point to access water lines aligned on its northeast-southwest ends. Notably, there is a column base on the floor of this passage beneath the entry lid, that might have belonged to the Theodosian Hagia Sophia due to its location. While this possibly in situ column base holds promise for shedding light on the reconstruction of the Theodosian Hagia Sophia, no other column bases on the same axis were observed, impeding a definitive assessment. Positioned approximately 1.50 meters from the Imperial Gate, the main axis of the structure, it seems improbable that this base belongs to the interior colonnade of the Theodosian Hagia Sophia's naos (see Fig. 7). Considering a possible column base on the opposite side of the axis, allowing for a total span of only 3 meters, would be insufficient for the beam span of the previous naos. So, this finding suggests that it might have belonged to the arcade of the Theodosian atrium.

Fig. 6. The passage under the esonarthex

Fig. 7. The column base on the floor of the passage.

The Theodosian Hagia Sophia and its atrium have been the subject of various reconstruction proposals over the past century. These proposals aim to recon-struct and understand the layout, architecture, and historical significance of this site. In 1909, Antoniadi proposed an atrium with arcades in four directions, despite lacking archaeological evidence [4] (see Fig. 8). Following the museumization of Hagia Sophia, Schneider commenced excavations within the Theodosian atrium. Despite uncover-ing the northeastern half of the portico, Schneider only preferred to illustrate the en-trance façade (see Fig. 11) rather than proposing a comprehensive atrium plan [5].

Subsequently, Kleiss and Mainstone presented two distinct proposals for the Theodosian Hagia Sophia's plan. Kleiss's proposal [6] (see Fig. 9) suggested an atrium with arcades in four directions, resembling Antoniadi's concept. But, this proposal evaluated the Schneider's finding as the southeast wing of the atrium and moved away the atrium in the northwestern direction. So according to this proposal, the position of the mentioned column base would place in the middle of the previous structure's naos, causing a discrepancy. Finally, Mainstone accepted the Schneider's findings as the entrance portico and the northwestern wing side of the atrium and proposed an atrium surrounded with three wings, excluding the southeastern wing [7] (see Fig. 10).

Though this latest proposal appears more plausible than previous ones, the column base in question seems to be located solely in the southeastern wing of the atrium, an aspect overlooked by Mainstone. Therefore, by amalgamating Mainstone's plan proposal with Schneider's façade proposal (see Figs. 10-11), here a new atrium plan layout is proposed. This suggestion integrates elements from both reconstructions, combined with the newly discovered column base mentioned above.

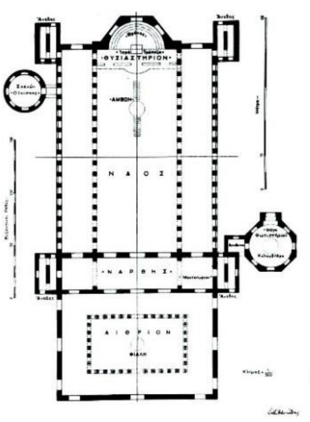

Fig. 8. Antoniadi's plan proposal

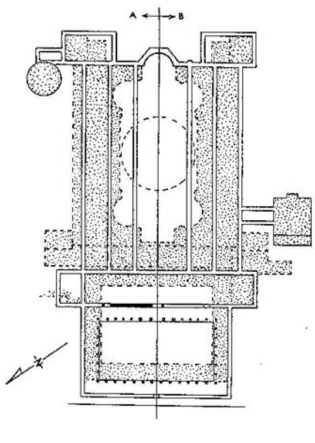

Fig. 9. Kleiss's plan proposal

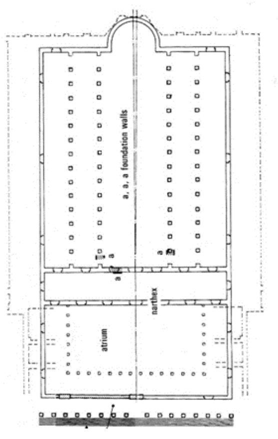

Fig. 10. Maninstone's plan proposal

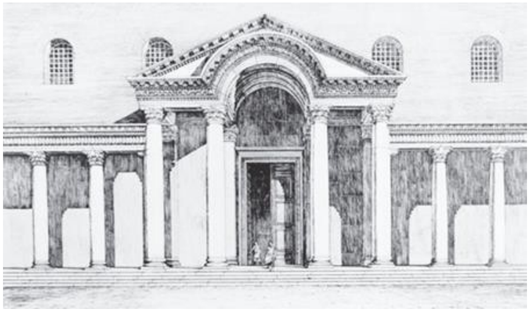

Fig. 11. Schneider's façade entrance reconstruction for the Theodosian atrium

The discovery of the column base within the passage under the esonarthex holds significant implications. This base stands as a pivotal piece of evidence, potentially serving as the sole and conclusive proof of the neglected southeastern wing of the Theodosian atrium, a detail that previously could not be observed by Mainstone. With a diameter of 57 cm compared to the approximately 80 cm diameters of the column bases at the portico, it suggests that the wings of the Theodosian atrium, now absent, were likely narrower than the entrance portico. This unexpected finding has sparked the development of a new proposal for the plan of the Theodosian atrium, possibly indicating the presence of four interior arcades (see Fig. 12). This fresh proposal could potentially enhance new speculative reconstructions of the Theodosian Hagia Sophia (see Fig. 13).

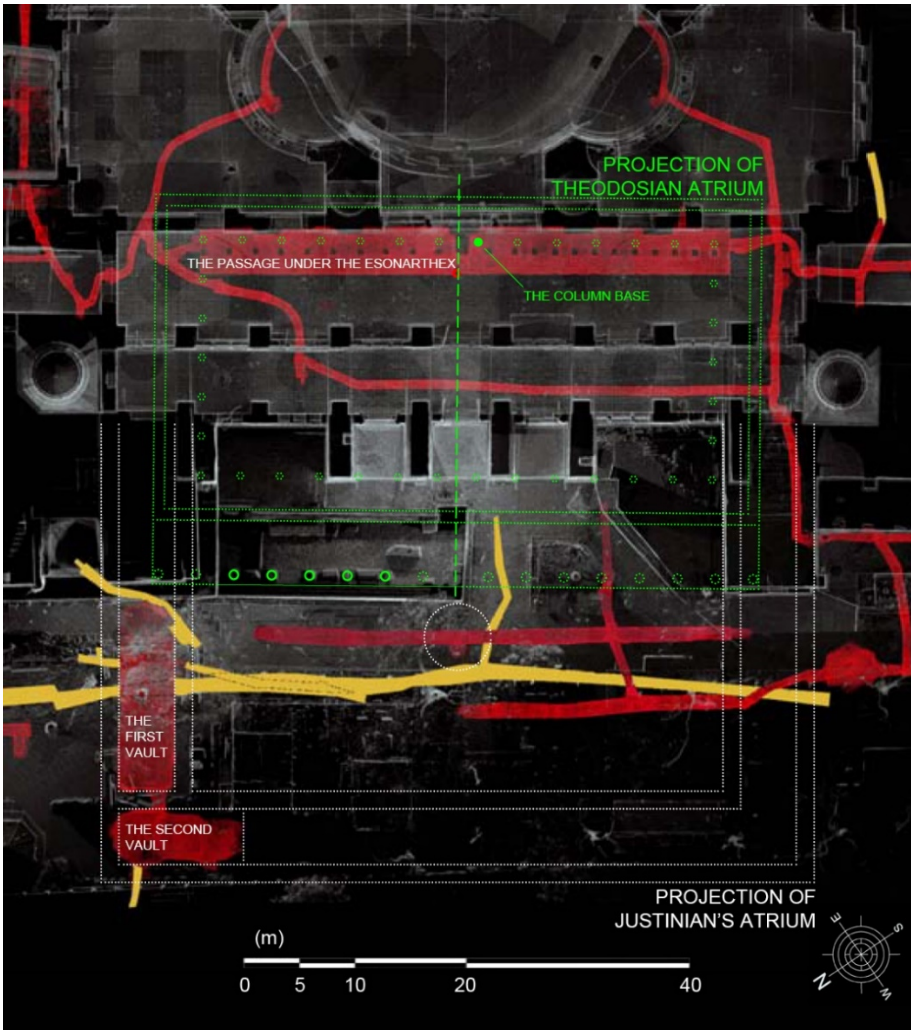

Fig. 12. Reconstruction plan for the Theodosian (in green) and Justinian's (in white) atriums

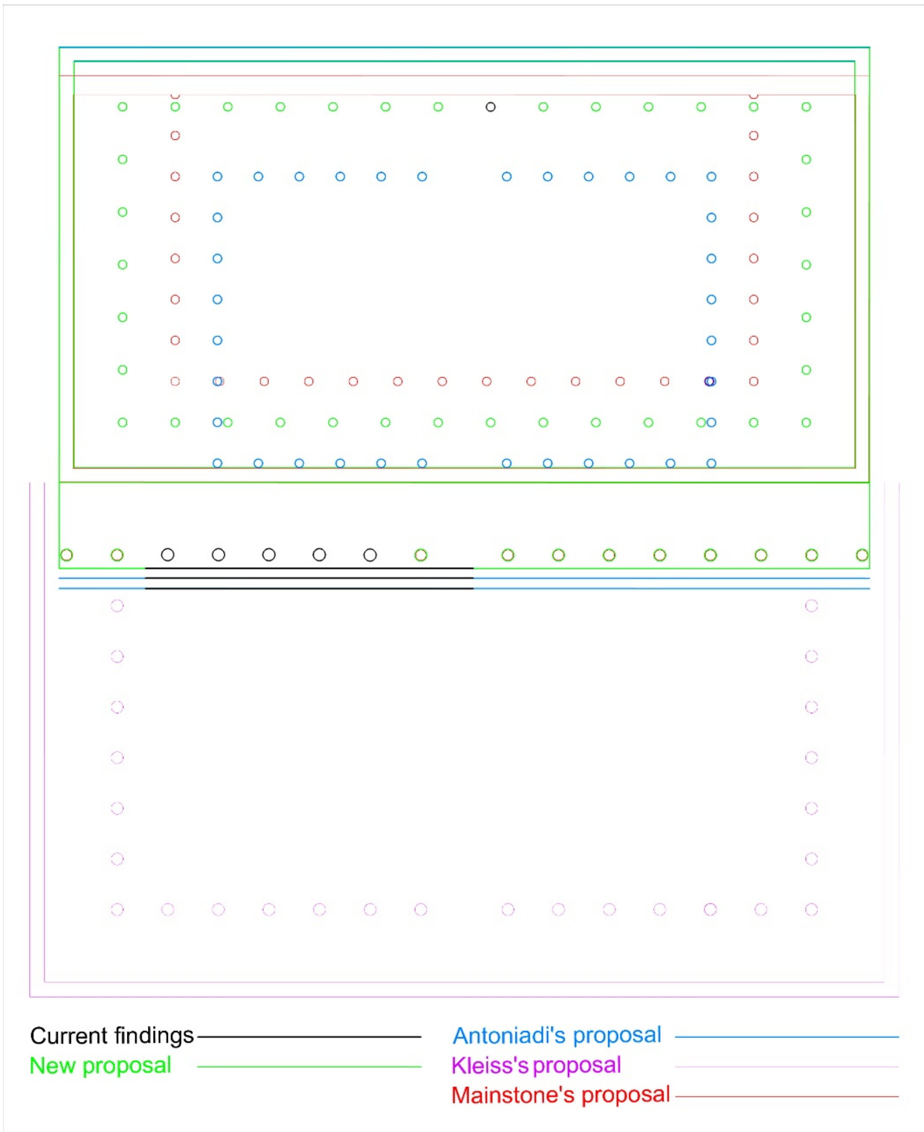

Fig. 13. Scaled comparison of the current proposal for the Theodosian atrium plan with the previous ones

3.2 The vaults under the atrium

To the northwest of Hagia Sophia, stand two impressive subterranean structures that have been digitally documented (see Fig. 1). The first structure, which boasts a rectangular plan and remains unplastered, is accessible from the southeastern edge of its barrel vault. Notably, a chestnut tree has breached its vault, causing structural dam- age over time (see Fig. 14). The second vault also follows a rectangular plan, and these two vaults together form an L-shaped configuration.

Following the conversion of Hagia Sophia into a museum in 1934, Schneider was granted per-mission to excavate the remnants of Theodosian Hagia Sophia [8]. Notably, the marble elements from the Theodosian portico, unearthed during the excavation, dis-played in the garden's northwestern section of Hagia Sophia. One of these stone ele-ments, situated beside the chestnut tree, has compressed and shaped the lower trunk of it as the tree continued to grow. Meanwhile, another chestnut tree, which grew adjacent to the stone element, has also penetrated and damaged the vault of the first subterranean structure which will be defined below. Since Schneider did not document these trees, it can be inferred that they sprouted after his documentation of the subterranean structures within Justinian's atrium [5], essentially after the conver-sion of Hagia Sophia into a museum. Hence, these trees on the site are, at most, 90 years old (see Fig.15).

Fig. 14. View from the first vault under the northeastern wing of the Justinian's atrium.

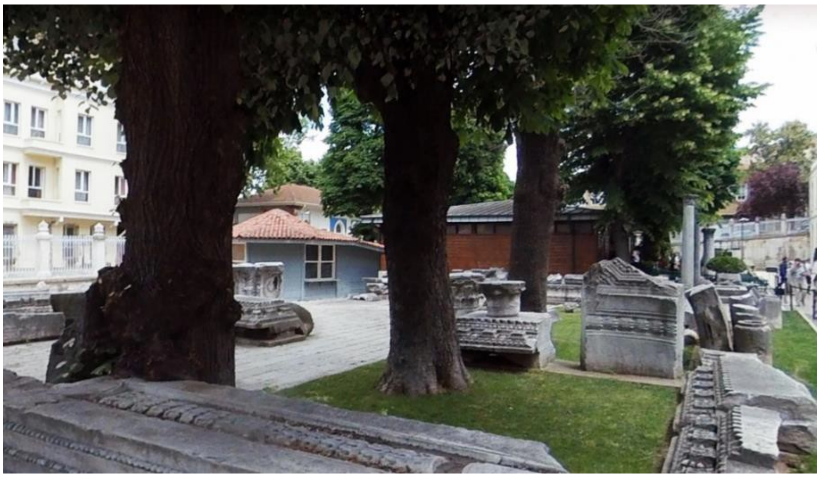

Fig. 15. The tree on the left shaped by the marble element, and the next one penetrating the vault.

The initial vault penetrated by the tree roots measures 5 meters in width and spans a length of 17 meters. But it has gradually filled with debris and soil over time. Consequently, the ground surface and height within the space remain obscured due to this accumula-tion. Within the masonry of the vault, the bricks are corbelled along their longitudinal sides. The unplastered brickwork starts vertically from the northwest side and gradu-ally inclines to-wards the southeast. There are also two waterway tunnels intersecting this structure in the northeast-southwest direction that were later blocked.

This vault is linked to another subterranean structure positioned above, with a chan-nel extending northwestward from its western corner (see Fig. 16). This second vault, could be measured 5 meters in width and 11 meters in length with the debris inside. It is covered by a barrel vault and, akin to its counterpart, is filled with debris and soil that was deposited from the courtyard. However, the brickwork of this vault differs from the previous space and features bricks laid both vertically and horizontally. Partial plas-ters can also be observed on its vault and side walls. Despite Schneider's assumption regarding the continuation of the atrium's substructures beneath the rest wings [5], these presumed spaces were unable to access.

Fig. 16. View from the second vault under the north corner of the Justinian's atrium.

Although Justinian's atrium no longer exists, these two subterranean structures define its northern part beneath the ground. The first vault pertains to the subterranean structure of the northeastern wing, while the second belongs to the subterranean structure of the northwestern wing. The absence of plaster on the surfaces of the first vault suggests that it likely did not serve as a cistern. Instead, it might have functioned as an underground storage cellar, possibly for materials like lamp oil used for the church's chandeliers but not meant to be visible inside.

Conversely, the partially plastered second vault may have served a different cellar function. A comprehensive understanding of the functions of both these vaults awaits further excavation and the removal of accumulated debris. An analysis of materials within the debris and a thorough cleaning of the vaults may offer valuable insights into the functions and specific uses of these subterranean structures within Justinian's atrium (see Fig. 1, 17-18).

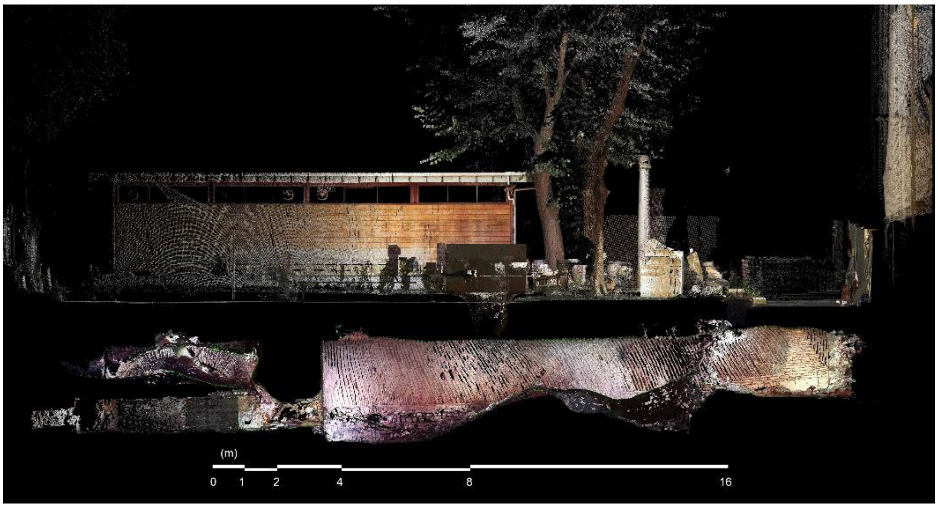

Fig. 17. Section 3-3: Northwest-southeast cross-section depicting the vaults beneath the northeastern wing of the nonexistent atrium. (The first vault is depicted on the right, while the second one above the channel is on the left.)

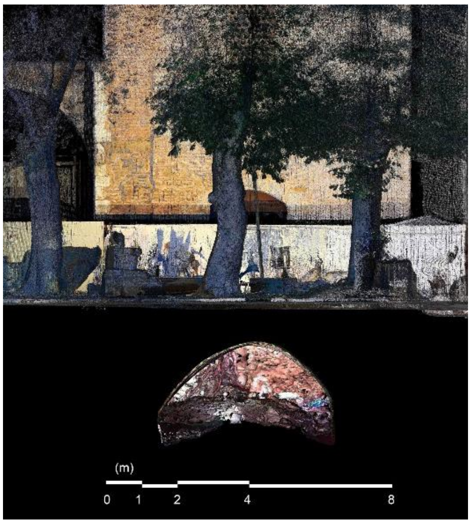

Fig. 18. Section 4-4: Northeast-southwest cross-section of the first vault.

3.3 The hypogeum

The hypogeum is a subterranean Roman tomb situated between Hagia Sophia and the Hagia Sophia Imaret (also known as the "soup kitchen"). Consisting of three chambers interconnected by a passage, this structure is dated back to the 4th century, predating the current Hagia Sophia. Following the conversion of Hagia Sophia into a museum in 1934, this hypogeum was first discovered and documented in 1946 by Muzaffer Ramazanoğlu, the museum director at that time [9]. Ramazanoğlu dated this subterranean complex, noting two distinct layers on the superstructure floor, to the 4th century. Although the hypogeum was republished in 1962 [10], it subsequently faded into obscurity. However, it was rediscovered, along with its pavement floor, during an excavation in 1985 aimed at locating the toilet drain of the guard room attached to the north-eastern wall of Hagia Sophia. The guard room was likely constructed on the hypogeum in the first half of the 20th century. The excavation process then proceed-ed by removing the guard room, which was initially intended for repairs. As the excavation progressed, the original pavement of the hypogeum's superstructure was re-vealed (see Fig. 19). This pavement, composed of white Marmara marbles and Verde Antico marbles even not used together in Hagia Sophia's interior floor, was uncov-ered. Additionally, a smaller white marble surface, along with its marble baseboard from an earlier period, was found approximately 40 cm below the upper level [11,12]. In this context, the white marble pavement within the lower layer, dated to the 4th century along with the hypogeum, suggests it may have been contemporaneous with the initial Hagia Sophia structure. The pavement on the upper layer, positioned at the level of the lower edge of partially surviving buttresses that constructed from brick and stone, is dated to the 6th century together with the attached buttresses [13]. Following the documentation of the hypogeum's superstructure, the marble pavement was once again covered with soil in 1985 for preservation purposes [11,12].

Fig. 19. Marble floor pavement above the hypogeum exposed after the excavation in 1985.

This structure complex spans approximately 60 square meters and lies approximately 4 meters below the current ground level. Comprising three rectangular-planned spaces, each boasting a long side of about 8 meters, this arrangement features various access points. A circular hole, concealed by an iron lid, permits entry to the central space of the hypogeum from the ground level. Additionally, a gradual transition gap allows access to the southeastern end of the space. These three spaces, aligned in a southeast-northwest direction, run parallel to each other and are linked by an arched passage in the middle (see Fig. 20). The chambers situated in the middle and southwest directions lie beneath the Vizier Garden, while the northeastern-oriented chamber is located under the courtyard of the Hagia Sophia Imaret. Notably, the chamber in the middle possesses a distinctive marble door jamb along its southeastern edge. Within the side chambers, niches known as "arcosolia" were traditionally used for housing the remains of the deceased. However, the arcosolia within this hypogeum currently remain vacant.

Fig. 20. View from the hypogeum in 2020 before the cleaning.

The three chambers of the hypogeum were constructed using bricks and are topped with barrel vaults. These original walls and vaults, although plastered, lack any decorative traces, indicating a probable absence of adornment. Around the 6th century, approximately one-third of the two side chambers were filled with cut stone walls, aligning with the upper level of the superstructure floor [13]. These cut stone walls, constructed along the long sides (northeast and southwest) of the side rooms, were elevated to the upper level by cutting through the vaults of these spaces, excluding the arcosolia in the southeast direction. In addition to the added cut stone walls in the side rooms, other stone walls were later constructed on the northwestern sides of the three chambers during a subsequent period. These foundation walls, believed to have been built during the erection of the buttress by Architect Sinan in the latter part of the 16th century to reinforce Hagia Sophia, were crafted from rough stones, differing from the other infrastructure built with cut stone.

Two tunnels are connected to the hypogeum from the southeast and northeast. The southeastern tunnel originates from the rain gutter at ground level between Hagia Sophia and the Skeuophylakion, inclining until it terminates at the upper level of the southeastern edge of the middle chamber. Conversely, the other tunnel begins from the upper level of the northwestern corner of the same middle space and extends northwestward. These tunnels likely coincide in timing with Architect Sinan's buttresses, considering their locations (see Figs. 1-3).

The original ceiling height remains uncertain due to the accumulation of mud and debris on the floor. The buried appearance of the door jamb and the muddy floor surface suggest that the original ground level of the structure lies approximately 1 meter lower than the existing mud surface. At the end of 2021, a partial cleanup in the hypogeum removed 3875 kilograms of mud and debris, leaving the remainder (see Fig. 21). Subsequently, following the temporary removal of rainwater from inside the structure using a motor pump, a more favorable environment was created for documentation. As a result, the hypogeum was re-visualized in higher resolution in January 2022 [14] (see Figs. 22-25).

Fig. 21. View from the debris and mud removed from the hypogeum in 2021.

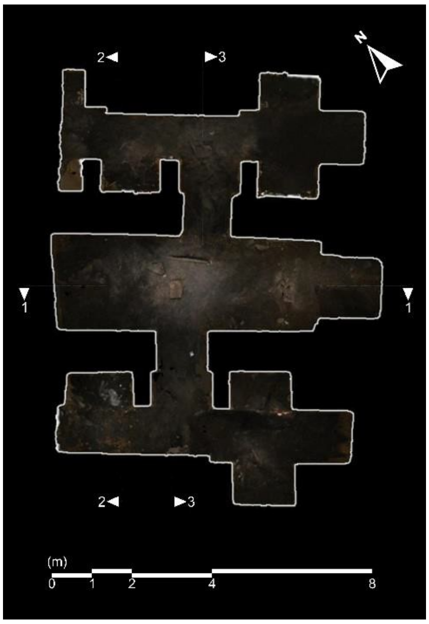

Fig. 22. Plan of the hypogeum

Fig. 23. Section 1-1 of the hypogeum.

Fig. 24. Section 2-2 of the hypogeum

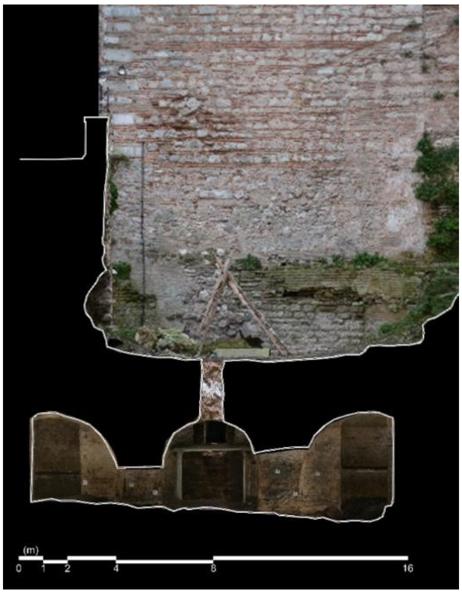

Fig. 25. Section 3-3 of the hypogeum.

4 Discussion

The selection of the three largest subterranean structures within Hagia Sophia for this study was based on their connections to other tunnels and their significant historical importance to the monument. The scan data collected from these structures greatly contributed to understanding their spatial relations with the current superstructure, revealing insights into their original architecture and past functions. However, this documentation also exposed infrastructure issues such as ceiling cracks, humidity problems, and the accumulation of mud and debris within these spaces.

Initiated in 2020, this documentation process highlighted the urgent need for a comprehensive approach to manage Hagia Sophia's subterranean structures. This holistic approach includes general cleaning, maintenance, repairs, documentation, and an archaeological perspective. As a result, the Ministry of Culture and Tourism has placed comprehensive cleaning and preservation efforts for these spaces on its agenda. The visualizations presented in this study advocate for immediate and thorough cleaning, documentation, and preservation. The implementation of archaeological cleaning processes would enhance the accuracy of documenting and dating these structures. Additionally, analyzing cleaned surfaces and archaeological materials found within the debris will significantly enrich the depiction of Hagia Sophia's multi-layered historical features. This study aims to raise awareness of the importance of documenting other historical subterranean structures associated with Istanbul's current aboveground areas.

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The interventions for the main dome of Hagia Sophia throughout its history and a preservation proposal

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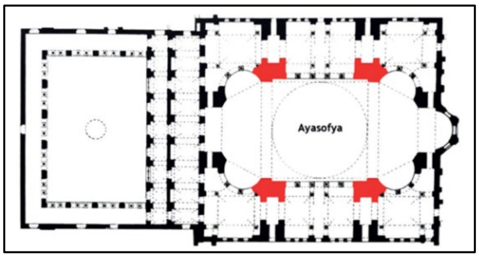
Abstract. Throughout its history, Hagia Sophia has faced seismic risks due to structural issues. The ambitious design led to the complete collapse of the main dome merely 21 years after its construction, and partial collapses occurred in the 10th and 14th centuries. Over time, the structure underwent various repairs and reinforcements. Following the collapse of the southeastern section during the 1346 earthquake, flying buttresses were installed, attaching to the main dome from four directions. However, during the Fossati repairs (1847-1849), these elements were removed and replaced with iron beams, framing the upper perimeter of the pedestal supporting the main dome. The current challenges faced by the main dome are primarily rooted in the design of the piers and arches rather than the dome itself. Since reconstructing these structural elements is impossible, efforts to address the dome's issues have concentrated on retrofitting the supporting system. This study critically assesses the current state of the main dome, examining past interventions. As a solution, it proposes reinforcing the main dome structure by installing a tension ring to enhance stability.

Keywords: Hagia Sophia; dome; arch; retroftting; tension ring; earthquake

1 Introduction

The magnificence of the previous Hagia Sophia structure, razed during the Nika revolt in 532, stood as a pivotal benchmark that Emperor Justinian aspired to surpass in his envisioned new church. So, the new construction would stand as an everlasting response, through its enormous size and uniqueness, to those who had revolted against the emperor. However, its ambitious dome, unparalleled in both preceding and subsequent Byzantine architecture, was also impacted by Hagia Sophia's structural problems from the beginning. These persistent issues were the primary cause behind the dome's collapses and the enduring earthquake risks throughout the structure's history.

Despite the symmetrical placement of the four piers supporting the main dome, their asymmetric edges in multiple directions pose challenges in equitably withstanding horizontal loads. The arrangement makes it challenging to unify them, adversely impacting the structure's earthquake resistance [1]. Another evident static issue, notably observed in the southeast-northwest section, lies in the columns' numerical arrangement between the ground and gallery floors. The ground floor features a 5-arcade arrangement between the main buttresses, whereas the gallery floor exhibits a pattern of 7 arcades. This discrepancy, stemming from the varied column sizes between floors, disrupts the vertical load transfer from the main dome and body walls in an intermittent and discontinuous manner [2] (see Fig. 1-2 [3]).



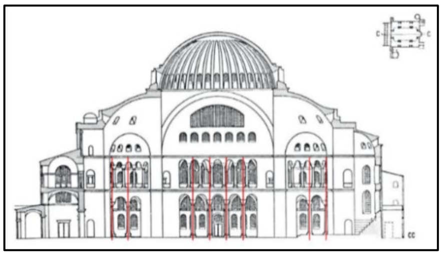


Fig. 1. Main piers in the plan of Hagia Sophia **Fig. 2.** Northwest-southeast cross-section (Impressions in red are made by the authors.)

The vulnerabilities within Hagia Sophia's ambitious load-bearing system led to three collapses: a complete one merely 21 years after the main dome's construction, and partial collapses in the 10th and 14th centuries. Notably, during the last two reconstructions, it's probable that the collapsed and reconstructed main arches gained asymmetrical sections. As a result, the existing issues with the main dome don't solely originate from the initial construction but also from subsequent structural modifications. Continuous repairs and reinforcements have been essential throughout Hagia Sophia's history. However, since reforming the original structural elements like the main piers and arches is impossible, efforts have shifted towards interventions aimed at exterior support for the load-bearing system and the main dome.

2 The dome that was rebuilt three times

Following the earthquakes in August 553 and December 557, both the main dome and the southeastern semi-dome collapsed [4] due to a 6 magnitude earthquake on May 7, 558 [5] around 21 years after the consecration of Hagia Sophia. This destruction was linked to multiple factors, including the inadequate curvature in the initial dome's design, deformation of the main supporting pillars, and distortion of the dome caused by shear forces [6, 7]. Emperor Justinian (r. 527-565), witnessing the dome's collapse during his reign, appointed Isidorus, a young architect and nephew of one of Hagia Sophia's initial architects, for repairs. The prevailing belief regarding the resto-ration activity on December 24, 563, was that it involved altering the dome's shape and increasing its height by 20 Byzantine feet (equivalent to approximately 6.24 meters) [7, 8]. However, recent research indicates that the modified design of the restored dome did not increase its height but maintained the same height while curving the tambour with the dome [6, 9, 10] (see Fig. 3 [9]).

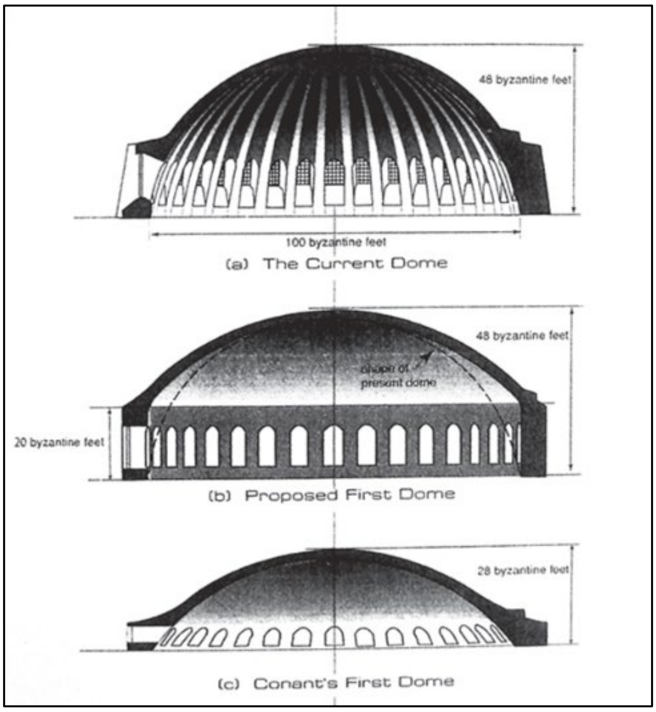


Fig. 3. Sections of (a) the current dome, (b) proposed first dome, (c) pre-proposed first dome

The significant earthquake of 989 directly impacted Hagia Sophia, resulting in the collapse of the northwestern section of its main dome. Armenian architect Trdat, known for his work on the Great Cathedral in Ani, the capital of Armenia, led this repair work. Before commencing the repairs, Trdat presented a model outlining his intended interventions [2, 11]. This restoration involved rebuilding 15 out of the 40 ribs of the main dome and reconstructing the northwestern semi-dome. Additionally, the main northwestern arch, which had undergone repairs in the previous century, was addressed. Hagia Sophia reopened for worship in 994 following these extensive restoration efforts [7].

In the fall of 1343, a series of earthquakes struck the city, followed by another on October 6, 1344, resulting in structural weaknesses within Hagia Sophia. Subsequently, on May 19, 1346, one-third of the main dome collapsed along with the southeastern semi-dome. The restoration efforts were overseen by Stratopedarch Astras and Giovanni Peralta, with completion in 1354 [7]. Notably, within this repair, the main dome was supported by flying buttresses in four directions. These buttresses, displaying Gothic characteristics depicted in Hagia Sophia's descriptions, can be specifically attributed to the repairs in the 14th century (see Fig. 4 [12]). The integration of these flying buttresses with the connections of the remaining 6th-century dome and the reconstructions from the 10th and 14th centuries display the meaningful support they offered to the main dome (see Fig. 5 [2]).

Fig. 4. Detail from Fossati's depiction before restoration

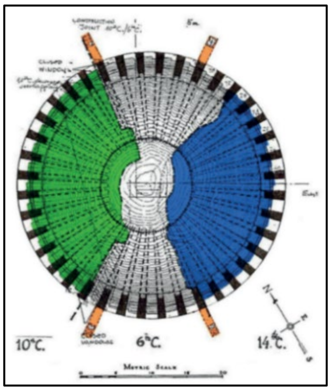


Fig. 5. Flying buttresses colored in orange

Hagia Sophia's main dome has remained intact since 1354, showcasing remarkable stability. Architect Sinan's interventions during the peak of his career in the late 16th century likely played a role in this achievement. Although he didn't intervene the dome, he retrofitted the existing Byzantine buttresses and introduced new ones, potentially reinforcing the structure and aiding in its preservation.

3 Fossati interventions

The most recent structural interventions on the main dome during the Ottoman period occurred between 1847-1849, conducted by Gaspare Fossati and his brother Guiseppe Fossati. Among the significant alterations in this repair was the removal of the flying buttresses that had supported the main dome for the past five centuries, forming a recognizable part of Istanbul's skyline. Instead of these buttresses, an iron frame was installed around the base where the main dome sits, concealed beneath the existing plaster. These elements became visible during the recent plaster rash over the surface (see Fig. 6-7 [13]). However, the structural function of this frame, intended as a substitute for the removed flying buttresses, remains a topic of debate [14, 15]. Its potential positive impact on the dome's structure is considered to be extremely limited due to its location and form.

Fig. 6. Iron frame intervention under the plaster

Fig. 7. Detail from the joint of the iron bracing

In the modeling work conducted in 2010 to investigate the functionality of the flying buttresses removed by the Fossati at Hagia Sophia, both the existing models and the structure itself were tested via static simulations using finite elements in a computer environment. The analysis aimed to examine the structural contribution of the buttresses to the main dome (see Fig. 8 [2]). This limited modeling study demonstrated that the flying buttresses serve an important structural function and contribute to the stability of the main dome [2, 16].

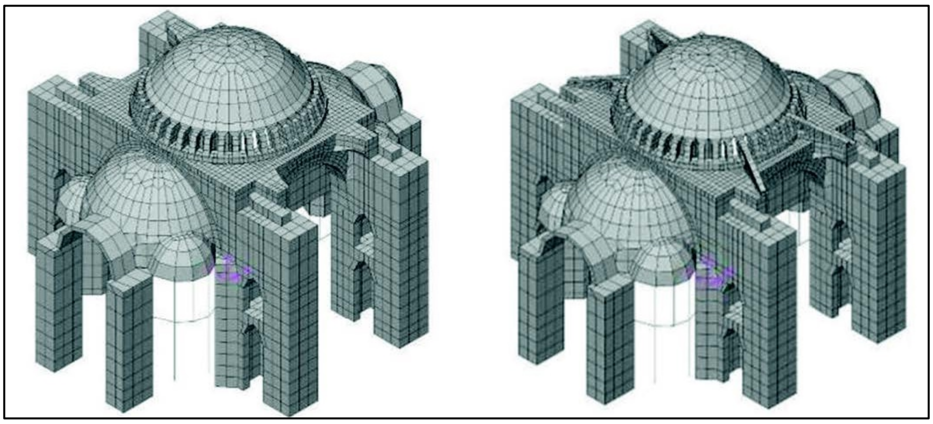


Fig. 8. View of the models of the current state and with the flying buttresses

4 Interventions in the 20th century

The most recent structural alteration to the main dome of Hagia Sophia involves the installation of vaults over the windows. A Japanese team from Tsukuba University identified these vaults as reinforced concrete elements in 1995 [17]. This intervention aligns with early 20th-century building technology. Historical records indicate that in 1909 [18], the windows appeared to be covered only with lead, whereas by 1936 [19], each window was observed to be covered with vaults similar to those seen today [20] (see Fig. 9). While there isn't specific documentation detailing this intervention, visual evidence suggests that the installation of vaults over the windows likely occurred during the early years of the Turkish Republic, established in 1923.

However, it's worth noting a decree dated August 1, 1926, which may offer insight into the timeline. This decree mentions damage of lead coverings and the need for repair, including some plaster windows, to be overseen by the Foundations Scientific Committee [2, 21]. Another decree, dated September 25, 1927, details payments to members of the Scientific Committee, including architect Kemaleddin and along with engineers Mr. Mehmed Fikri, Bahaaddin, Ziya, and Zühdü, involved in these repairs [2, 22]. Press coverage of this restoration revealed the use of 138 tons of lead [23]. Considering the architects involved in the repair, it's likely that an initiative such as covering the windows with reinforced concrete vaults would have been undertaken at that time.

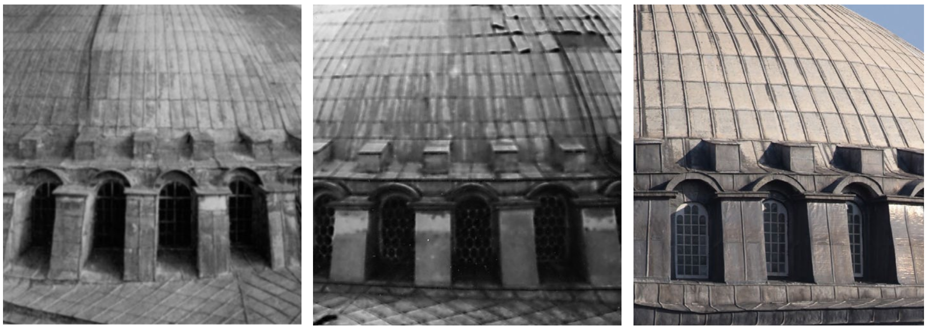


Fig. 9. Detail views from the dome windows in row from 1909, 1936 and 2010.

In a study conducted in 1993, it was observed that wooden construction was built on lower level to reduce the flatness of dome, which occured due to the fact that the 10th century segment in the western part of the main dome was higher than the 6th century segment in the southern part of the dome about 10-12 cm (see Fig. 10 [17]). The effect of this intervention, which is understood to have been made to show the main dome of Hagia Sophia symmetrically, which is actually asymmetrical due to its repairs, in city silhoutte, should be questioned in Hagia Sophia modelings.

Fig. 10. Views from the partial wooden sub construction under the lead cover

The last retrofitting project for the Hagia Sophia dome structure during the Republic period was proposed by Prof. Dr. Mustafa Erdik and Ülker Engineering and Consultancy in 1993 [14]. The proposal aimed to enable the semi-domes and main arches to work in unison during potential earthquakes by establishing a robust connection between them. The recommended method suggested for reinforcing the bond between the southeast and northwest main arches, upon which the semi-domes rely, was the use of anchors (see Fig. 11-12). The project proposed embedding the bodies of the anchors entirely into the semi-domes, with the heads designed to conceal the image without disrupting the facades of the southeast and northwest main arches. Modeling revealed that the planned anchoring bars would provide the required safety for the main dome. Despite this, the project was not accepted due to concerns about the radical structural interventions it would necessitate.

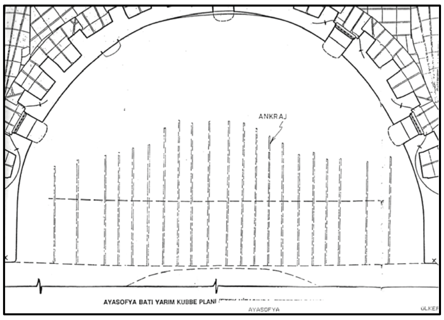


Fig. 11. Depiction of the anchors in plan

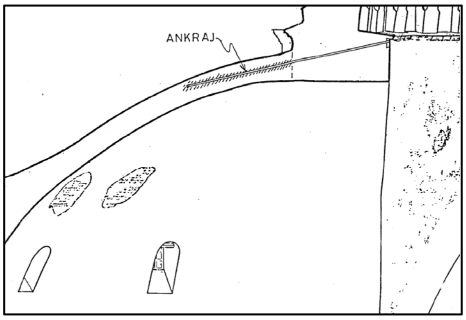


Fig. 12. Depiction of the anchors in cross-section

5 Current Situation

In the most recent measurements, the main dome's diameter in the northwest-southeast direction, supported by semi-domes, was 31.19 m, while in the northeast-southwest direction, it measured 32.55 m [24]. This elliptical plan can be related with the unsupporting of the main dome with the semi-domes in the northeast-southwest direction. And this asymmetry is evident not only in the dome's plan but also in the sections of the main arches on which the main dome rests. Our research involved measuring the cross-sectional areas of the main arches based on recent surveys of Hagia Sophia's dome. The northeast arch exhibits a gross cross-sectional area of 22.9 m², whereas the southwest arch measures 22.4 m² gross. Although the cross-sectional areas of these two opposing arches are similar, the same cannot be said for the other arches connected to the semi-domes. Specifically, the gross cross-sectional area of the northwest arch is 7.2 m², while the southeast arch, notably the weakest, measures 6.1 m². These values include allowances for plaster, hence why they are stated as gross areas. Considering the comparable shares of plaster in the sections, the net areas would show similar ratios to the gross areas.

The significant disparity in cross-sectional areas—where the northwest arch measures less than 1/3 of the northeast and southwest arches, and the southeast arch constitutes almost ¼ of their areas—highlights the structural issues within the main dome. Contrary to expectations, the cross-sectional areas of the northeastern and southwestern arches are not double that of the others. The notably thin sections of the northwest and especially southeast arches define the dome's asymmetrical structure, a result of its destruction and varied reconstruction over time. This structurally irreparable situation may be attributed to the reconstructions during the 10th and 14th centuries (see Fig. 13).

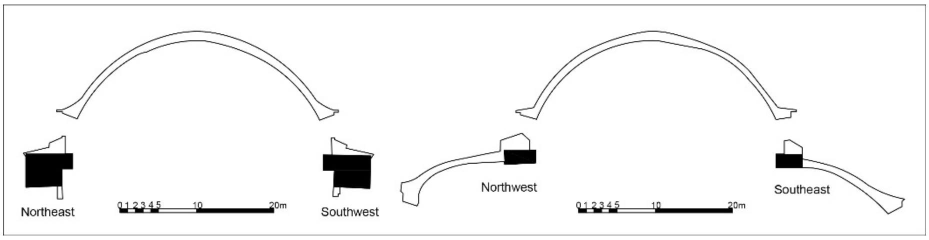


Fig. 13. The occupations of the main arches through the northeast-southwest and northwest-southeast cross-sections of the main dome

6 Conclusion and a preservation proposal

Thanks to the binding mortar's low density and high tensile strength [9], coupled with ongoing reparations spanning centuries, Hagia Sophia has maintained remarkable structural stability. Recent research notes the absence of collapse in the main dome since the 14th century, suggesting that immediate major interventions might not be necessary given consistent maintenance practices [25]. One recent study even suggests the structure is more resilient than its coverings [26]. However, there's a call for cautious reinforcement measures [25]. Rectifying the horizontal and vertical asymmetry in the supporting system is considered impractical, given the structural and decorative challenges it poses. Additionally, any structural interventions that could disturb the current disintegrated load balance that the structure coexists with for centuries, might pose unpredictable risks to Hagia Sophia.

The application of ring beams is a fundamental strategy in the retrofitting of historical masonry structures [27]. In the context of Hagia Sophia, it is identified that the primary collapse mechanism involves the main arches and semi-domes. Results indicate that due to the thrust of the dome the thick arches on the northeastern and the southwestern sides deflect outward while on the southeastern and the northwestern sides, the upper parts of the semi-domes deflect inward. The thrust of the dome arises because of the hoop stresses (peripheral thrust) developed in the lower portion of the dome. To resist lateral thrust, the options include using exceptionally thick walls or, more commonly, employing diagonal support or tension rings at the base. Normally the tension-resisting ring is provided in tension zone to carry the horizontal thrust resulting from the hoop tension. The tension rings prevent the dome walls from thrusting outward (see Fig.14). To minimize the cross-sectional sizes of reinforcing materials, composite materials based on high-strength fibers, mainly carbon, are used. An important advantage of using this sort of composite materials is their effortless adaptation to curved and rough/uneven surfaces.

The vulnerability arises during potential major earthquakes, where the main dome and semi-domes oscillate, posing a risk of hammering over the northwest and southeast arches, known to be the most delicate. This hammering effect could lead to the collapse of arches and semi-domes, with potential partial damage to the main dome [27] (see Fig.15). The proposed use of a tension ring introduces a preventive measure to limit the oscillation of the main dome, resulting in a more controlled and one-sided hammering. This approach aims to minimize damage to the semi-domes and slender main arches, crucial elements supporting the main dome. Positioned as an optimum solution, it seeks to protect Hagia Sophia's main dome without necessitating radical structural interventions.

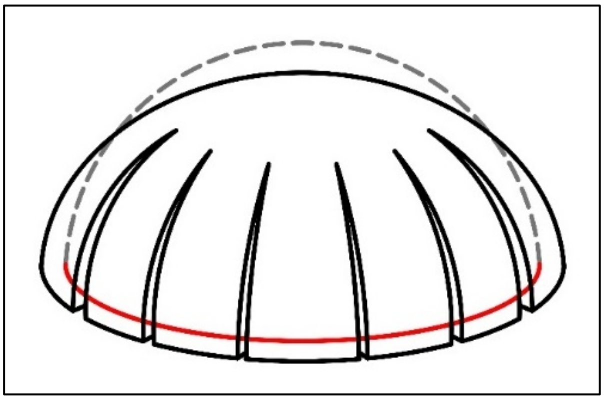


Fig. 14. Deformation of a dome: Tension ring preventing outward thrust

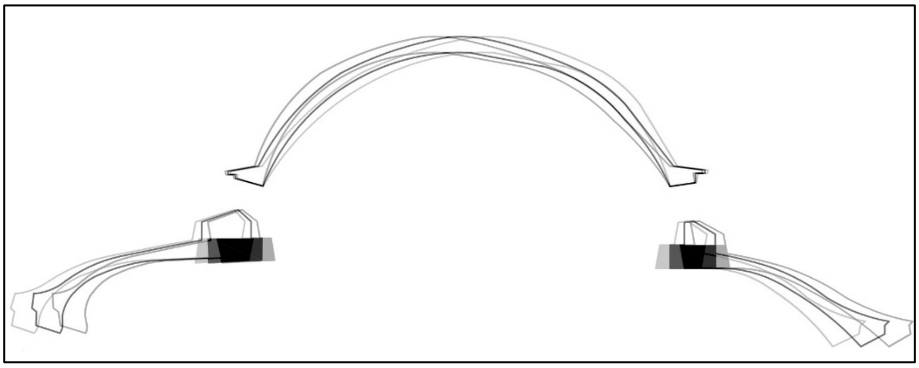


Fig. 15. Representation of the hammering effect on the main dome of Hagia Sophia

The use of CFRP (Carbon Fiber Reinforced Polymer) as a tension ring may be the most suitable material for the dome due to its superficial features that won't alter its silhouette. This choice also allows CFRP to be concealed beneath the lead covering easily. Similar interventions were made for the domes of the Outer Treasury in the

Topkapı Palace in 2009. The Outer Treasury that is a rectangular, one-story structure was built in the 16th century and covered with eight domes arranged in two rows. During the restoration process, the recent 20th-century concrete plasters inside the structure were completely removed, exposing the domes and walls along with traces of cracks. Over the centuries, ground movements might have exerted stress on the structure, potentially causing cracks above and below the domes. After extensive discussions, it was decided to reinforce each dome of the structure by applying carbon fiber tapes above the surface [28]. That intervention was one of the first CFRP uses for a cultural heritage in Istanbul after the earthquake in 1999 (see Fig.16).

Fig. 16. View from the crack under the dome and CFRP intervention above the dome.

Therefore, a comprehensive modeling study will prove the effect of using CFRP for the proposed tension ring, aiming to minimize interference with the visual integrity of Hagia Sophia. This proposal aims to deliver effective earthquake protection for the main dome of Hagia Sophia while preserving its appearance through the intervention of a ring of CFRP beneath the lead coverings. The preservation of Hagia Sophia's three-part structure, reflecting different historical periods, is crucial for its integrity (see Fig. 5). Hence, preservation efforts must align with its existing form, emphasizing retrofitting methods that uphold the dome's structural integrity and visual appeal. The study proposes a theoretical preservation method - tension ring encircling the main dome from the exterior (see Fig. 17). This proposed approach aims to provide supplementary support to the existing structure without altering its historical integrity, offering a potential solution to maintain its stability and safeguard its architectural significance.

Fig. 17. Representation of the tension ring around the main dome of Hagia Sophia

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Murat Reis complex: Survey, Documentation and Restoration of the Mosque

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Abstract. At the northern end of the new city of Rhodes, just outside the medieval city an 8-acre "dead zone" includes the cemetery and the "Murat Reis" complex. Murat Reis the Elder, after whom the complex takes its name, was one of the important corsairs that served the Ottoman Navy during the Suleiman reign. Shortly after the death of Murat Reis in 1609, a complex of important monuments was created around his tomb, which includes the mosque, the purification fountain and the tekke accommodation buildings. The subject of this work was the historical and architectural documentation, the constructional analysis, the recording of the pathology and the elaboration of a proposal for the restoration of the mosque. Compared to the other mosques of the city, the Murat Reis is a special example with characteristics of the Ottoman Baroque era with the introduction of neoclassical elements. In addition, the mosque stands out for the morphology of its minaret, which is not found in any of the other mosques of Rhodes. In this study, the main findings of a detailed research are first presented, regarding the historical development of the city and the zoning rearrangements that took place during the Ottoman period in Rhodes. In the next stage, the historical, architectural and structural documentation of the mosque is carried out, as well as the understanding of the pathology and the qualitative diagnosis of the main causes of damage. On this basis, an intervention proposal was drawn up, aiming at the architectural and structural restoration of the mosque, as well as the highlight of the history, function and value of the Murat Reis complex as a single entity.

Keywords: Rhodes city, Ottoman period, Mosque, Cemetery Complex, Restoration

1 Introduction

At the northern end of the new city of Rhodes, just outside the medieval city, today an 8-acre "dead zone" includes the cemetery and the "Murat Reis" complex. (Fig. 1).

This paper attempts to highlight the methods and procedure of documentation, analysis, diagnosis, assessment and restoration of this important monument, as part of a wider area that should be preserved and promoted. It is based on a relevant thesis [1] realized in the framework of the interdepartmental postgraduate program "Protection of Monuments", of N.T.U.A.

The first stage of the project comprises archive research regarding literature on the historical development of the city and the zoning rearrangements that took place during the Ottoman period on the island. Having collected the above data, the research focused on the evolution of the area where the Murat Reis complex is located, as well as on the recording and evaluation of its current architectural and structural characteristics.

The second stage includes the recording process, and systematic surveys, accompanied by the photographic documentation of the mosque. To this end, multiple visits to the monument were necessary, in order to further examine and verify various hypothesis that arose during the study. At the same time, the research also focused on other mosques of Rhodes in order to find information, concerning the historical construction techniques that could have been applied, as well as the methodological approaches that were applied in the following years in their research, documentation and restoration. [2,3,4]

The final stage was the investigation of the architectural construction phases of the building and the formulation of a restoration proposal, including the general principles adopted and the objectives of the intervention and a detailed description of the required works.

Fig. 1. Aerial photography of Murat Reis complex and cemetery (Google EarthPro)

2 Historical context

In 1522 AD the Ottomans occupied the city of Rhodes, bringing serious rearrangements to the island. Many existing buildings were adapted to the needs of the oriental way of life, and churches were converted into mosques, while at the same time, 7 new mosques were built. The fortified slope surrounding the walls of the medieval city, turned into an extensive Muslim cemetery (Fig. 2) The area was constantly expanding since the Islamic tradition forbids the exhumation of the dead [5].

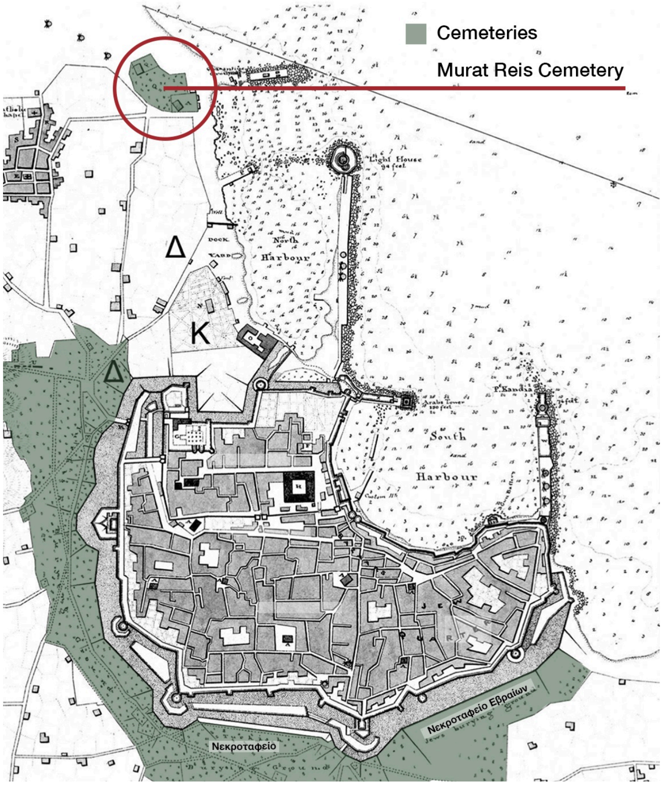


Fig. 2. Urban planning of the city during the Ottoman rule. Cemeteries are marked with green color. Murat Reis Cemetery is marked with red circle.

Ottoman rule, came to an end with the arrival of the Italian army in 1912. The Italian authorities began to carry out projects that decisively shaped the urban planning of Rhodes. As for the medieval city, the aim was to isolate it with a ring road system, and to turn the cemeteries around the walls into green spaces, which were designated as a "monumental zone" [6].

Of the vast area occupied by the cemeteries, only Murat Reis was preserved, due to the fact that important personalities of the Ottoman period were buried there. [5]

2.1 The Murat Reis complex

It is located on the North East end of the Rhodes City, close to the administrative center, which includes important public buildings such as the courthouse, the town hall, etc. Murat Reis, today perceived as a cemetery, is actually a "külliye", i.e., a complex of buildings with various functions centered around an institution.

Murat Reis the Elder, after whom the complex takes its name, was one of the important corsairs that served the Ottoman Navy during the Suleiman reign. Having taken part in numerous campaigns during his life, he died in 1609 during the siege of Avlona in Albania and his body was buried in Rhodes [7]. Shortly after his death, it was believed that his tomb had the ability to answer prayers, and thus Murat Reis was canonized. In the following years, his tomb became an object of worship for the Muslims of Rhodes and the opposite coast of Anatolia, who visit it till this day, leaving some tribute (usually clothing) [8].

During the Ottoman rule, certain orders began to operate on the island, such as the Mevlevian dervishes and the Nakşibendi. The Ottomans, following the model of the big cities of the Ottoman empire, wanted to attach their tombs to charitable and religious facilities, in the form of a complex. Thus, shortly after the death of Murat Reis, came the establishment of the mosque and the purification fountain, while a Sheik was assigned to live in a space within the cemetery and thus the tekke was established [9].

The complex, today, consists of an important monumental ensemble (Fig. 2), that extends around the mausoleum of Murat Reis and includes:

- The mosque, which was originally built in 1636 by Ebu Bekr Pasha, but over time was destroyed and rebuilt in 1797 by Murabid Hasan Bey in the form we know it today [8].
- The purification fountain, which was built by Mabeyinci Hamdi Bey in 1845-46 AD. with the donation of Sultan Abdülmecid [9].
- The tekke accommodation buildings, in which eight different historical phases have been recorded, from approximately 1700 to 1925 AD. In 2009, the buildings were restored and today they house the Municipal Conservatory of the city of Rhodes [10].
- The Guardian's Residence
- The mausoleums (türbe)

The cemetery area contains today a small portion of preserved tombstones, about 237, that reveal that Murat Reis complex was a burial place for Ottoman officials and Khans of Crimea, as well as their families [11, 12]. As part of the general conversion of Muslim cemeteries into green spaces during the Italian occupation, the tombstones were moved and placed in closely spaced rows behind the tomb of Murat Reis [9].

Fig. 3. General plan of the Murat Reis complex

3 Survey and documentation of the mosque

3.1 Architectural analysis

The mosque was built to serve a small community of dervishes, as well as worshipers visiting the tomb of Murat Reis. Following the typology of the Bursa's mosques in its simple form, it consists of a prayer hall with a square floor plan (Fig. 4) with internal dimensions of 7.80 x 7.80m and a height of 9.00m. The hall is covered with a hemispherical dome supported by arches, squinches and pendentives, forming an octagon.

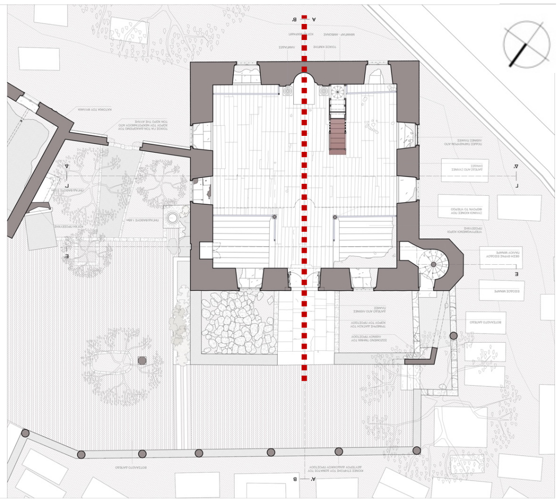


Fig. 4. Plan of the Mosque. The mihrab is located directly opposite the entrance door following the symmetry axes of the square floor plan.

The southeast wall of the hall is called "kibble" and symbolizes the direction to Mecca. In its center is the mihrab, that is, the prayer niche towards which the faithful must face when they pray. The mihrab of the Murat Reis Mosque, is entirely painted over, while the fact that verses from the Koran are absent is surprising.

To the right of the prayer niche is placed the "minber", the pulpit where the imam ascends for the preach. It is a wooden structure with steps leading to the seat, which is covered with a polygonal canopy. It is one of the larger pulpits found in the mosques of Rhodes. Its length is 3.00 m and its height reaches 5.00 m. The entrance is formed by two wooden columns carrying a painted panel, and it does not have shutters to close it, like that in the wooden minbers in the Turkish mosques.

The length of the north-west wall of the hall is occupied by the mezzanine, (Fig. 5) which is accessed through the inner stairs of the minaret. It is characterized by privacy, as the screen of crossed wooden plates is so high that it prevents anyone from seeing the worshipers praying. Usually, the mezzanines are reserved for praying women, however there is no official document confirming that this mezzanine was a place of prayer for women.

a)  b) 

Fig. 5. (a) Section of the Mosque looking to the NW, where the mezzanine is also shown**,** (b) View of the mezzanine from the SE (March 2022)

The painted decoration (Fig. 6) of the mosque, is a typical example of the trend that appeared in the 18th century in Ottoman buildings, known as Turkish baroque. The influence of Western architectural forms, led to the replacement of traditional Arabic or Persian themes with decorative reliefs and Western motifs. All these decorations were executed with watercolors on top of the first coat of plaster.

a)  b) 

Fig. 6. a) General view of the painted decoration with floral motifs between the arches. b) Detail of floral motifs

Before the entrance of the mosque, there was a stone arched porch, the "revak", which is considered as the outer extension of the prayer hall. From the part that is preserved in the western area of the temple, as well as from the springer of the arch in the east, it seems that the façade of the porch was constructed with three consecutive arches. (Fig. 7a). This assumption is also confirmed by the photographic archives (Fig. 7b). The porch was covered with a flat roof, which is confirmed by the beam sockets on the northwest wall of the mosque and by the preserved section of the porch.

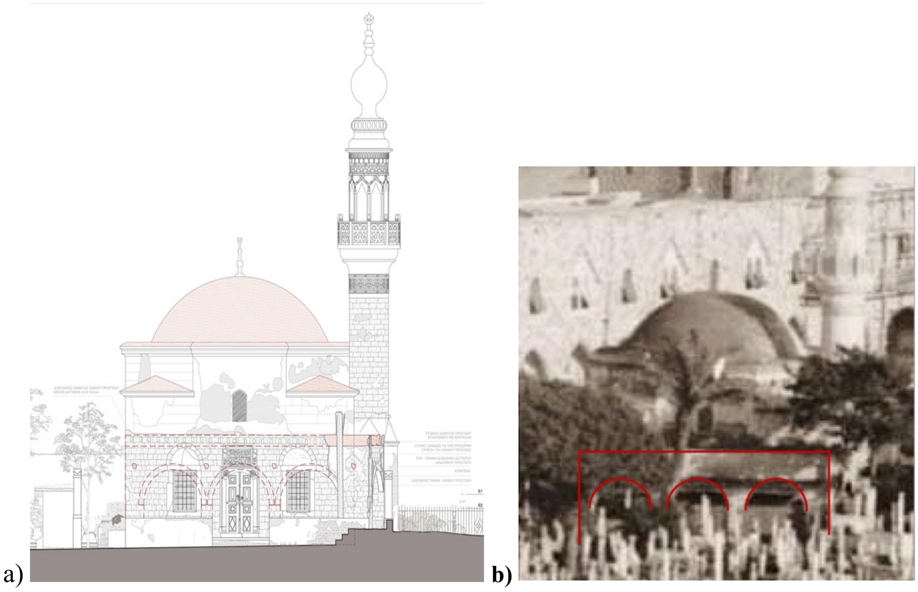


Fig. 7. (a) Representation of the porch's façade. **(b)** Photo of the Mosque in 1927, on which the porch is shown with red lines. [Reproduced from the archive of Stavros Georgallidis]

A drawing by Balducci (1931) (Fig. 8a), shows a second porch - probably wooden, which was attached to the colonnade of the courtyard, in front from the aforementioned stone porch [13]. Its existence is also confirmed by photos from the Italian archive (Fig. 8b).

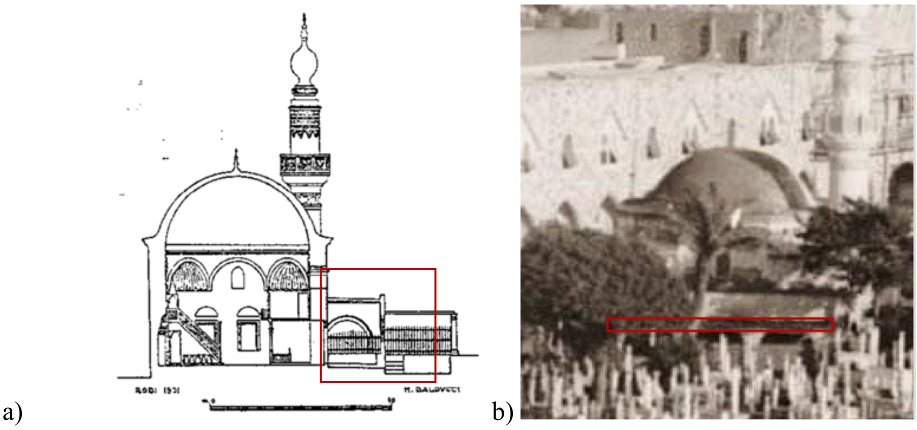
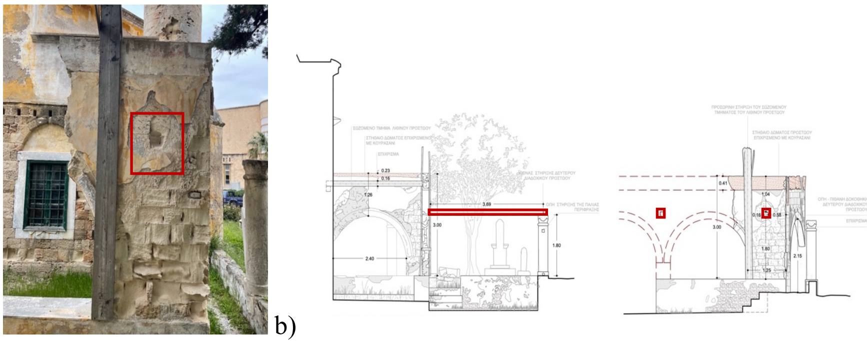


Fig. 8. (a) Drawing by Balducci (1931) showing the second porch [10]. **(b)** Photo from the Italian archive

In addition, a hole measuring 15 x 17 cm that can be seen in the surviving part of the stone pediment, directly opposite the corner column of the courtyard, reveals that there were probably joists in which the beams of the wooden porch were placed transversely. The surviving hole (Fig. 9a) seems to be an opening, which confirms the scenario that the wooden porch was built later to meet the prayer needs of the believers. Based on the position of the columns of the yard and the existing hole, it seems that there were 4 beams that were based on the columns and in the beam-holes between the arches (Fig. 9b). It is possible that there were also secondary beams that were placed perpendicular to the main ones in order to support the flat covering of the wooden porch.



a) b)

Fig. 9. (a) Photo of the existing part of the porch showing the hole (march 2022). **(b)** Representation of the second wooden porch.

Externally, the monument reveals its strict internal structure. The central rectangular space rises to the level where eight arches forming an octagon permit the transition to the dome's hemispherical shape.

On the northwest façade, where the plasters and renders are missing, we can distinguish the marble window frames and the arched lintels, which on the other sides have been covered with render and plaster. Thus, the façades of the mosque were originally designed and built with ashlar masonry without any renders and plaster, which were added later, probably in the 19th century.

On the southwest side is located the 19 m high minaret. The original minaret, which had a conical top, as was customary in the Muslim mosques of Rhodes, suffered severe damage from bombings and/or earthquakes and was rebuilt during the Italian occupation in the form we know it today. At that time, elements of orientalism were used abundantly, due to Italian interest for the Middle East and Africa. The access to the original minaret was through the mosque, from an internal arched opening, which was later closed and the access moved outside. The upper part of the minaret, which includes the balcony, has plaster decorations with geometric and floral motifs.

3.2 Description of the structural system

The Murat Reis Mosque seems to be constructed with three-leaf stone masonry[1], having a width of 0.95m. As can be seen from the areas where the plasters are missing the stonework, is composed on its outer face of ashlar masonry. Internally, from the partial detachments of plaster, it appears that ashlar stones were used to shape only the corners and the frames of the openings, while the rest of the walls were built with rubble masonry. According to documentation deriving from similar Mosques in Rhodes [2,3,4], the inner infill of the stone masonry is probably filled with relatively good quality of infill material, consisting of big pieces of rubble stones and mortar without many voids.

The masonry seems to be reinforced with a horizontal timber system (xylodesia). Specifically, underneath the load bearing elements of the mezzanine (i.e., as bedding for its timber beams) and above the openings (level of lintels), 3 timber wooden laces of 11x9 cm were found. The position of these laces suggests that they are part of a wooden horizontal framing system for the tying and confinement of the building. Due to the plasters, it was not possible to document their existence at other levels. As documented from other similar structures, the possible positions of wooden frameworks are above the openings, at the base of the masonry, at the level of springing of the arches and at the base and the top of the tympanon of the hemispherical dome. A better presentation of their possible position in the structure of Murat Reis Mosque is given in the drawing of Fig. 10.

Fig. 10. The possible position of the horizontal timber laces system (xylodesies)

The hemispherical dome rests on arches, squinches and pendentives, through which the loads are transferred to the perimeter walls. They are made of carved sandstone and the final finishing of their edges is done by plastering. The dome is also made of local sandstone and is plastered with kourasani (hydraulic mortar consisting of lime, pozzolan and crushed bricks).

[1] This was not possible to be documented in situ, but is it presumed due to the thickness of the wall and the available information regarding similar Mosques in Rhodes, as for example the Recep Passa Mosque [11].

The floor of the mosque is wooden, without regularity in the placement of the boards, which differ from each other in size. The wooden planks are nailed onto joists with a section of about 9x9 cm and the space between them is filled with pebbles and mud.

The load-bearing structure of the mezzanine (Fig. 11), consists of wooden beams with an average cross-section of 8 x 10 cm, which rest on one end on the external NW masonry and on the other end on a large beam of dimensions 18 x 23 cm, which rests on the masonry of NE and SW walls. The large beam is supported by two wooden columns on either side of the central entrance area and two corbels in contact with the walls.

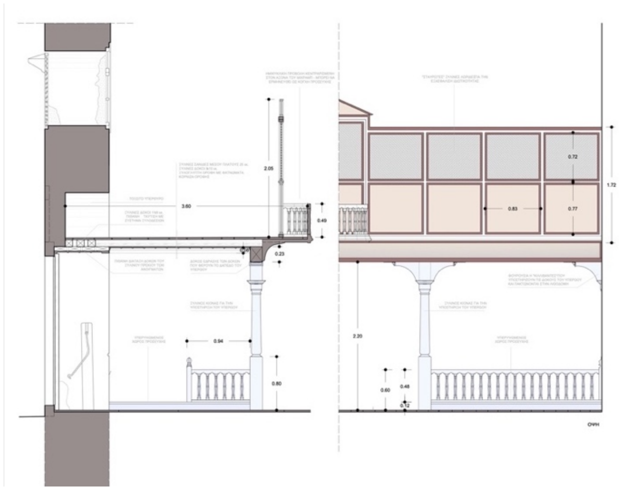


Fig. 11. Constructional details of the mezzanine

From the in situ existing part of the stone-arched porch, it appears that it was made of a single row of sandstones. The arches were connected on the NE side to the load-bearing wall of the mosque and on the SW side to the base of the minaret. Its flat roof was made of 29 wooden beams of medium dimensions 8x16 cm. which were based on the beams of the NW side of the mosque and the beams of the porch. To protect from the inflow of water, a final coating with a highly cohesive material, called "patelia" in the local dialect, was used over timber planks. It is a clayey soil, usually mixed with algae or oleanders, which provides waterproofing for a certain period of time [6].

The minaret has a hexagonal base which touches the SW face of the mosque without being connected to it. Its body consists of 21 concentric rows of stones, 19-20 cm high. The cohesion of the construction is enhanced by the use of mortar between the joints of the stones, (Fig. 12)

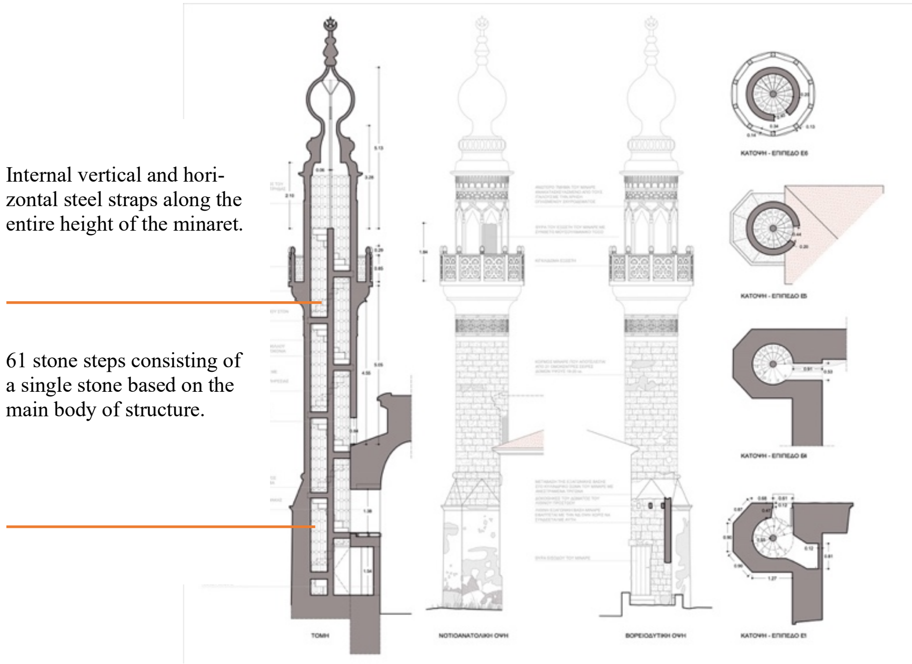


Fig. 12. Constructional details of the minaret.

The staircase of the minaret is formed by 61 stone steps. Each step consists of a single stone, which is shaped like a 'trapezium'. This 'trapezium' moves circularly by one position per level. The way the steps in the minaret were put together, could not be precisely determined, however, the most common way is for the step to be based on the main body of structure or even to be a part of the body. The staircase is a very important structural element for the stability of the minaret, due to the significant weight that adds to the center of gravity of the structure, as well as due to the continuous connection of the cylindrical external masonry to the core of the minaret, along its height (Fig. 13).

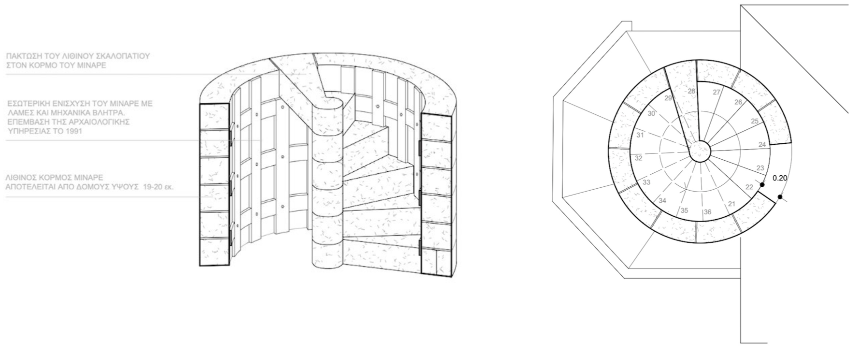


Fig. 13. Construction detail of the staircase of the minaret. The internal intervention with metallic vertical and horizontal steel straps is also shown.

In the following years, important repair and strengthening structural interventions were carried out in the minaret. Internal vertical and horizontal steel straps were placed, using bolts and special cement mortar. Repairs and repositioning of the collapsed upper part were made too and a stainless-steel metal tube was installed to the last step of the ladder, in order to strengthen the stability of the upper part. More information about the date and type of the applied interventions will emerge after further investigation.

3.3 Architectural-construction phases and historical pathology reconstructions and alterations

According to the historical, architectural and constructional analysis, an attempt is made to clarify the architectural and constructional phases of the mosque accordingly, as well as the major interventions and modifications due to its historical pathology.

Two main phases of construction can be distinguished

- 1st phase 1636 AD: Construction of the original mosque by Ebu Bekr Pasha.
- 2nd phase 1797-1798 AD: Reconstruction of the mosque by Murabid Hasan Bey in the form we know it today.
- 3rd phase (probably during the 19th century): The facades of the mosque were plastered.

Additionally, the following important collapses, reconstructions and modifications should be mentioned:

- 1912 AD: Collapse of the upper part of the minaret by the bombardment of the Italian troops.
- 1912-1920 AD: Reconstruction of the upper part of the minaret by the Italians in its current form. It is possible that along with the reconstruction of the minaret, the second porch was added.
- 1943-1957 AD: Collapse of the porch possibly due to the bombings or the 1957 earthquake.

3.4 Pathology and qualitative evaluation of the main causes of damage

The unsafe condition of the mosque forced its closure since 2000, thus increasing the damage due to the lack of use and maintenance. The prayer hall does not face serious structural problems. In particular, vertical cracks of small width are observed at the key area of the arches of the squinches. These cracks are connected to the structural behavior of the hemispherical dome, which transfers horizontal thrusts on its base. Thus, the eight arches of the octagon formed underneath the circular base of the dome transfer this thrust to the rectangular perimeter walls. As expected, cracks appear also at a lower level, between the base of the arches of the octagon and the key areas of the arched window lintels.

Apart from the above pathology, it has to be mentioned that, the main problems faced by the prayer hall, are related to the aging of the materials due to the lack of maintenance, rising moisture from the ground to the masonry, but also descending from the dome, resulting in partial collapses of plastering and the painted decoration of the dome.

In addition, the accumulation of moisture in the walls resulted in the rotting of the timber horizontal reinforcements, compromising their utility.

The most important structural problems faced by the mosque are found in the area of the porch, which has collapsed and has been temporarily propped up with wooden elements. By its nature the porch is a vulnerable structure seismically compared to the mosque and is exposed to the environmental conditions at a faster rate. The stones of the porch, due to the loss of the renders and plasters, are exposed to descending moisture, direct effect of rain and soluble salts transported from the sea. Thus, they suffer surface erosion in the form of sanding, which progresses from the outer surface to the inner, reaching a great depth. As a result, in addition to the weakening of the mechanical strength of the stones, wear develops unevenly between adjacent stones.

The minaret, due to its height and slender proportions, is also one very vulnerable part of the mosque. In the cylindrical body of the minaret, the stones have crumbled and in some places the building mortar has deteriorated. At the same time, vertical cracks are observed, some of which have been roughly cemented. In addition, the entry of rainwater into the interior, led to oxidation and decay of the internally added steel splint (vertical and horizontal straps connected to the masonry).

4 Presentation of the mosque restoration proposal

The main proposals for the morphological restoration of the mosque are the following:

- The preservation of the phase that the mosque was plastered and the revealing of the morphological elements of the openings that have been covered with the plaster. (Fig.14)
- The opening of the inner access of the original minaret to the southwest wall of the hall and the addition of a rigid metallic frame with glass in the arched opening.
- The reconstruction of the stone porch according to its original form, as documented in this work.
- The reconstruction of the wooden successive porch in the form of a pergola, as its original form could not be fully documented.

Fig. 14. Restoration proposal of the NE façade following the existing phase of the plastering with the horizontal zones in ceramic and ocher colors.

As far as the structural restoration interventions are concerned, further survey and documentation of various elements that are not yet fully documented and need in situ investigation and research is considered to be a priority. On the basis of the investigation results a detailed and thorough structural analysis should follow in order to reach a solid diagnosis of the causes of damage an assessment of the load bearing capacity of the building in its current state and a documented proposal for the structural interventions to be adopted. In what follows some first ideas and proposals are given based on the qualitative evaluation carried out in the framework of the present investigation.

Regarding the foundations, from the geometry and pathology surveys, there is not any indication for the need of extensive strengthening interventions. It is more likely that it will need to be locally repaired by applying deep repointing and grouting to fill possible void space due to timber elements degradation as well as interventions to possibly existing timber elements. To deal with the rising humidity on the perimeter walls, the construction of a drainage ditch is recommended. In all cases in situ inspection and investigations are recommended, in order to determine the necessary intervention scheme.

In all masonry perimeter walls, is proposed to initially remove the deteriorated plasters of the façades in order to reveal the stone masonry and the window stone frames. Subsequently, it is necessary to examine the quality of the jointing mortar, remove any cement mortar and apply re-pointing using a lime-pozzolan composition to be determined on the basis of analysis of the characteristics of existing stones and mortars. Stones that show a lot of wear will be replaced with new ones with the same physico-chemical, mechanical, color and texture characteristics. Based on the data we have so far, it seems that there is no need to strengthen the entire masonry with systematic grouting, which may be necessary for the repair of the cracks in selected areas. However, before the restoration works, in situ investigations should be carried out to better document the building materials and the type of construction of masonry in its face and in its width (one leaf, three-leaf, quality of infill material, percentage of voids, etc.) On the basis of such an investigation and the results of the structural analysis to be realized for the entire monument, the decision of applying systematic grouting will be taken.

In case of decayed timber reinforcements embedded in masonry, it is recommended - where possible - to re-install wooden beams, which will be connected to each other with bolts and stainless-steel plates. The new beams will be re-positioned from the corners of the walls of the mosque, after the sporadic removal of the ashlars and the cleaning of the voids left by the timbers, in order to facilitate their insertion into the holes.

If timber reinforcements are not found at the upper levels, or if the aforementioned solution is not technically feasible, an external confinement of the masonry, using adequate stainless-steel elements will be applied, based to the results of the structural analysis, that has to be performed.

The most important operation is the reconstruction of the porch. Due to the high percentage of worn stones and loss of material, the surviving section will be removed and reconstructed from new carved sandstone. The new wooden beams of the flat roof will be reinstalled in the existing nests of the NW face. On top of the beams the wooden sheathing will be nailed consisting of timber planks (ceiling) and a layer of marine plywood plates over them, in order to improve the diaphragmatic behavior of the roof. To connect the diaphragm to the NW wall of the mosque, a stainless-steel L type beam is placed above the wooden beams around the perimeter and in contact with the masonry, which is connected to it through rods that are anchored to its inner side. The L type stainless steel element is screwed on all the timber beams completing the connection of the diaphragm with the NW wall of the mosque. The roof's small inclinations are formed with wooden elements of varying height on which a second layer of marine plywood plates is nailed. The surface is smeared with bituminous emulsion and the final coating is done with a waterproofing membrane with fine aggregates. At the end, a mortar finishing of kourasani is applied (Fig. 15).

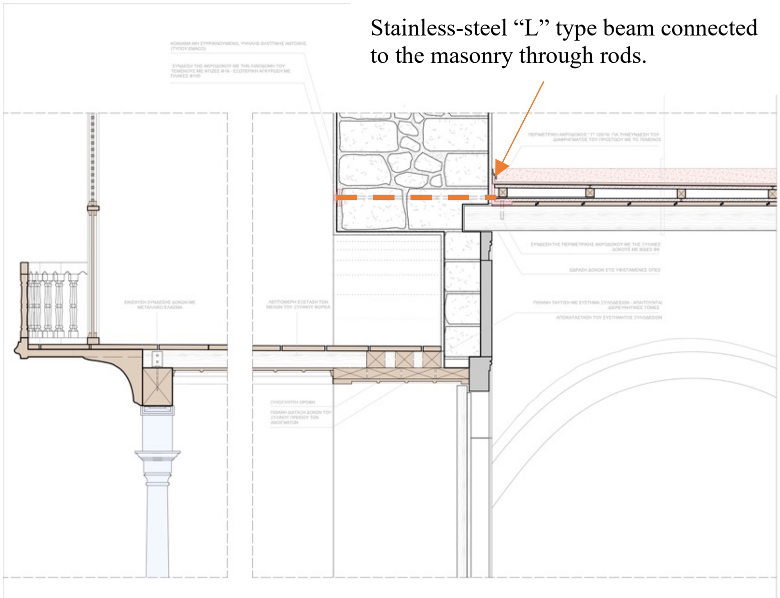


Fig. 15. Construction detail of the restoration proposal of the porch.

The wooden 2nd porch, since there is no sufficient documentation of its original form and structure, is proposed to be constructed in the form of a pergola (Fig. 16). For its construction, 4 wooden beams of 15x17 cm will be used, which will be based on a timber main beam over the colonnade of the courtyard. The connection with the timber main beam and the columns will be reinforced with L-shaped metal elements. In the other direction, the beams are placed in the beam holders of the porch. Across the main beams every 30 cm secondary wooden beams of 9x8 cm are nailed. The shading of the pergola will be completed with arbors.

Fig. 16. Representation of the restoration proposal of the porches

For the minaret, the in-situ documentation of the geometry and the quality of the historic construction (stones, mortars, possible internal metallic connecting elements, etc.) and the interventions should be first carried out, including the connections of the reconstructed upper part with the underlying masonry and of the internal metal construction with the perimetric masonry. The static and dynamic behavior before and after the 20th c. interventions should then be analyzed, in order to identify the main causes of past damage and collapses, assess the behavior of the minaret in its current situation (with the reconstructed upper part and the internal metallic straps) and verify its bearing capacity under vertical and horizontal actions. On the basis of such a study, the decision will be taken for retaining the past interventions or for their removal and replacement with new interventions to be indicated by the aforementioned study. In this framework, alternative solutions should also be examined, to improve the current situation, as in some cases the demolition and reconstruction may be questionable and quite harmful for the adjacent parts of the historic structure. In case the internal steel straps intervention would be proved efficient, by the structural study, the sanitization of the metal elements is recommended by thoroughly cleaning and then coating them with anti-rust and anti-corrosion materials. Then it will be primed and repainted.

Regarding the masonry of the minaret, systematic repointing and grouting may be necessary after cleaning the loose mortars with a specially shaped blade, but this is also to be decided on the basis of the in-situ investigations findings.

Finally, in order to deal with the rainwater inside the minaret, it is proposed to install glass shutters with a metal frame in all openings.

5 Conclusions

The Ottoman architecture that developed in the city of Rhodes applied forms according to the rules of the capital of the Ottoman Empire. The mosques of Rhodes mostly followed the Bursa typology adapted to the traditional techniques, tool equipment, available materials and climatic conditions of the island. Their morphological variations are related to the architectural trends of the time each mosque was built, or to the reconstructions of the minarets from time to time, both in the Ottoman and Italian periods.

The monument under consideration belongs to the square hall type with a dome without openings. Compared to the other mosques of the city, the Murat Reis is a special example with characteristics of the Ottoman Baroque era with the introduction of neoclassical elements. In addition, the mosque stands out for the morphology of its minaret, which is not found in any of the other mosques of Rhodes. Its restoration is considered imperative, as it is one of the few cases of mosques that still exist outside the medieval city limits.

Since the mosque is only a part of an important historical complex and a landmark, the overall protection and promotion of the ensemble are critical and important. Taking into account its special character and the need for integration into the contemporary life of the city, the accessibility to all social groups must be ensured. In this direction, the research aims to contribute as a starting point, to the protection and promotion of an important monument of Rhodes, the Murat Reis complex.

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Uni and interdisciplinary approach for the sustainable preservation of Cultural Heritage

Public Procurement & Mediation to Facilitate Procedures for the Preservation of World's Cultural Heritage

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Abstract: All levels of legislation from national rules to international Treaties include provisions for heritage procurement and alternative dispute resolution. Each law has got its own scope and field of application: some of those are obligatory, with direct effect and supreme. Practitioners thus need to apply the right texts for the conclusion of public contracts and for the resolution of their disputes. Mediation is being proposed as a very modern and flexible tool for disputes' settlements arising in a contest. Some examples of successful public procurement may be found here and a superficial approach to the Hagias-Sofia project.

Keywords: public procurement, mediation, world's ancient and religious heritage monuments

1 Introduction

Ancient monuments and other buildings of cultural heritage belong to the State, where they are located. National authorities have got the obligation to save their treasures, along with the power to exploit them. Some monuments in remote locations are bonded to eras of wealth and to immortal heroes [1]. In fact, some of those have got such a large significance to mankind that also lie under the surveillance of UNESCO and are protected from international Treaties [2].

We are arguing herein that public procurement and mediation methods may assist the initiative of the most interested parties, who want to be involved in cases of restoration and reuse of cultural heritage monuments. This is an article following my attendance of the 'International Conferences on transdisciplinary, multispectral modelling and cooperation for the preservation of cultural heritage' *(Athens, 2018-2023)* *.

2 Selecting Suitable Procurement Procedures

Public procurement regulation globally is nowadays aiming at markets' opening, at enhancing development worldwide, allowing growth in decentralized regions via public calls for offers of goods, supplies, services and works. At the same time regulation of procurement allows the combat of bureaucracy and corruption in the public sector. When the Authorities need to purchase, they must follow transparent procedures on a non-discriminatory basis. It is vital that the contract notices drawn-up by the Authorities are advertised efficiently. We are referring to commercial contracts for pecuniary interest [3].

Provisions for public contracting may be found in all levels of legislation: national laws, the European Directives, the Government Procurement Agreement of the WTO, as well as the Uncitral Model Law of the United Nations [4]. Each type of legislation has got its own scope and field of application. To choose the most suitable framework corresponding to their needs, practitioners must first comply with obligatory rules of supremacy and direct effect.

2.1 Dealing with Procuring Authorities

It may be a Municipality, a Ministry, or other bodies governed by public laws **[5].** We are referring to Authorities serving the general interest, being financially dependent from the State and strictly supervised by it. In other words, every State demands order and direction, free exercise of its *ius imperium* all in all **[5].** This principle is important to all Entities, who are interested in going into business in a foreign country. It is a rather exceptional case but: appreciation, affiliation, autonomy and recognition of status is, what a religious Authority will expect, when established in a foreign country [6].

National Churches may act as procuring Authorities, while Churches abroad may only act as private entities: for example, in 2010 the ECHR declared the Orphanage of Pringkipos island as property of the Patriarchate of Constantinople. It follows that the Patriarchate is free to act privately for the restoration and reuse of that notable, wooden building of the 19th century [7]. Another kind of analysis would be required though, to explain property rights of religious movable and immovable monuments.

The exceptional tangible and intangible value of a monument may indicate the need for recourse to different types of procedures. For example, the holy Temple of Hagias-Sophia in Istanbul: it is cradle of a great, living religion – heritage of the mankind, an architectural authenticity at risk, it may thus require special procedures.

Additional close surveillance from the competent international organizations may be required in the case of restoration of most prestigious monuments (e.g. UNESCO committees, Churches' internation Council).

Ideally, cooperating Authorities may agree on some common policy objectives, which may be included in a public contract as secondary policies [8]: e.g. a clause to fight unemployment during the execution period of the contract, or a common target for environmental protection and the case of pandemics.

2.2 Identifying the Economic Operators

The term includes suppliers, service providers and work contractors**.** Selection depends on qualitative criteria and on an equal-treatment basis. This means that the procuring authority will require high standards for the financial and technical capacity of the bidders: particular bidders involved in criminal practices, should be excluded and eliminated. Offerors may be groups of companies of various forms *(perhaps any institution to the extent it can justify commercial activity)*, even natural persons etc.

Restoration of some monuments may allow offerors to participate in open contests. For example, for the preservation of the ancient theatre in the city-center of Larissa, an international competition was held from the local Authorities. In such cases the contracting entity will collect as many applications as possible; it will assess the offers and will be lead to an impartial decision. There may be numerous opportunities for bidders, where public markets, can be opened-up to competition.

2.3 Institutional Funding

Public procurement should be open to institutional funding and procedures should be reviewed by the competent Courts, tribunals etc. There should be transparency at all stages along with equal treatment of the bidders**.**

Public funding *stricto sensu* had been initially introduced to correspond to the needs of entities, entrusted with a public service *(schools, hospitals and other services of general economic interest).* In Europe the preservation and reuse of monuments has been so important, that it includes 107 art. TFEU. Competent Authorities may receive direct state-aids for the protection of significant cultural heritage *(e.g. the EC state-aid to the Cyprus Cultural Centre)* [9].

Furthermore, there are other specialize dinstitutions and international organization shaving as their scope cultural development. They may offer funds and may allow maintenance and operation of areas of cultural significance [10].

It would need further scrutiny, to understand, that the restoration, maintenance and operation of an emblematic Holy Temple should justify special treatment from the State, such as taxes' exclusion and other financial advantages [11]. One may speak about the exceptional social and spiritual activities of non-economic nature, namely offering pilgrimage and mass services corresponding to the needs and the history of many nations. Speaking in European terminology, a so-called block-exemption should be necessary for the ecclesiastical monuments of the Orthodox Patriarchate, that lie around the cradle-temple of Christianity in Istanbul.

However, the commercial reuse of the surrounding area, may distort competition in the local market and it should thus not be favouritised with advantages.

2.4 Relevant Types of Contracts

Design Contests: are used when the contracting authority needs a plan, especially in the fields of town-planning and civil engineering. They are mostly used in the case of prestigious buildings, also for the design of IT infrastructure projects. The publication of a 'Notice' for a negotiated or a restricted procedure, is necessary and then a Jury representing the procuring Entity, will assess the offers/proposed projects and will reach a decision. Design contests may be held independently from the rest of the work [12]. The design will be usually followed by either the execution of a public work, or the service of an IT project.

The complexity of each project, will indicate the need for recourse to a so-called ***'framework agreement'*** [13] for the parties to be able to identify all the contracts involved. These definitions are important, as they set the threshold values, consequently affected by the field of application of legislation. They may furthermore be helpful, to create an eligible way in the multiple, administrative permissions and negotiations required, securing at the same time legal certainty**.**

Public Private Partnerships – PPPs: we are referring to multi-complex financial and legal agreements, which may cover all stages of a public contract and allow economic operators to enter in a competitive dialogue with the public sector [14]. PPPs nowadays fall within the scope of all legislations. They may be mostly suitable for the renovation and reuse of an ancient area and have proved to be very useful in practice.

Public Concession: is a special type of a PPP, where the works or services and supplies to be carried-out, would consist either in the right to exploit the work, or in this right together with payment. A concessionaire often accepts the works and then the operational and financial risk of providing a rather public service, in the broader sense, in return for the chance of making a profit through the exploitation of the service. A concession would be most suitable to combine private practice along with serving the public interest. In our thoughts a concession will be necessary for the reuse of a holy temple, as a museum open to tourists with special and exclusive rights granted.

P.F.I. – a Private Finance investment: we are arguing here that holy cultural heritage monuments, strongly bonded to the history of a great, living religion *(the Justinianian-Byzantine temple of Hagia-Sofia)*, should be entrusted to the experts of that nation [15]. We are talking about the cradle of Orthodox Christianity around the world, an architectural authenticity: that ethical criterion alone, should lead to the conclusion of a concession agreement via P.F.I., from entities representing the Patriarchate of Constantinople and for the nations whose memories are closely attached to it. That decision from the Turkish part, could be justified even on the basis of philanthropy.

Supplies and services contracts: supplies involve the purchase or rental of goods/subjects of commercial transaction e.g. the leasing of cranes. Services in an even broader category, which covers all public contracts for pecuniary interest, which do not fall within the field of application of works or supplies' contracts. These may include immersive reality tools in the case of virtual reconstruction of monuments, reconstruction and visualization of heritage artworks, other 3D modeling's, novel techniques and digital modelling.

- Repair services: *e.g. frescoes retouching*
- Research & development services [16]
- Technical consulting services: *e.g. eco-smart strategies*
- Architectural services [17]
- Computer supplies and services: IT software, *e.g. www.acropolisvirtualtour.gr*

At this point we should note that European, international and national laws set specific standards e.g. the European technical approval, so-called "EC". This means that the characteristics described in an offer/documentation, should meet certain criteria of methods, quality and functions [18]. However, technical requirements/norms should be setting minimum standards and by all means these should not have such a character, that will undermine free participation in a contest**.** The most important minimum standards should be requirements for security: public health and safety. It follows, that in contracts referring to the restoration of a place of significant cultural heritage, the required standards will be very high, even if the procedure will not be open to competition. So, how will the parties involved, commit to the highest values and bring the best results?

3 Mediation & Dialogue's Facilitation

Mediation has been rapidly developing as an international language for dispute resolution. Although it began as a means to settle cases in the private sector only, its scope and field of application progressively proves to be efficient in all types of disputes [19].The parties involved may deliberately choose mediation procedures rather than recourse to Court, which might end up to be exhausting: very expensive and time consuming**.** As a means to first serve the private sector, mediation may be useful in cases related to the trading of collectables. Furthermore, it can be very useful for the loan and exchange of movable monuments between museums.

Most importantly mediation will allow the parties to freely express their feelings for actions of the past. This is why we are arguing, that tracing mutually beneficial interests, is the most preferable way to bring closer people for centuries in conflict.

Relevant laws may be found at all levels of legislation: national laws, in the European directives, the Uncitral Model law and the globally known Panels for Disputes' Settlements of the WTO [20].

Court procedures are necessary, as Judges have got the power to impartially impose sanctions, to judge on criminal matters, to implement compensations, to re-assess relationships between private persons and the State. Access to the judicial system should not be undermined and no one should escape with impunity. The heads of the European Commission for citizens' rights argue that: 'better results will be reached by achieving a balanced relationship between mediation and judicial proceedings'[21].

3.1 Mediation in Public Contracts

Mediation should be part of the free access to review procedures at all stages of public procurement: from the first Notice to the execution of the contract. A***'mediation Clause'*** should be included to all contracts for the parties to have equal access to justice and alternative dispute resolution. Such a clause is mandatory in European public contracts [22]. From another point of view, the Greek law of public procurement n. 4413/2016 has numerous provisions, giving to bidders the opportunity for recourse, arbitration, conciliations and other alternative dispute resolution means, issuance of non-binding Opinions, at the same time with a right for Court reviews *(from interim measures, to the highest levels of jurisdiction).*

Furthermore, before the conclusion of a contract, during the so-called ***'technical dialogues'***, the procuring Authority would require access to all kinds of information e.g.

on new technologies, in this frame it will be the bidder's duty to present all the necessary know-how at a preparatory stage. These dialogues are almost vital, in contracts where confidentiality and security reasons prevail. However, such dialogues may not be used, during the award procedures as a means to distort competition. When there is a necessity to share exclusive information, when the parties need to tackle some technical issues and requirements, then dialogues are mostly indicated [23].

Mediation methods will also be useful during the ***'competitive dialogues'*** before the conclusion of a public-private partnership e.g. the exemplary PPP of the medieval city of Rhodes, as has been presented elsewhere. Dialogues among persons with mediation skills, will allow negotiations in confidentiality and impartiality, which are vital for a monument of world's cultural heritage**,** as it has been noted by S. Panagopoulos in [14].

3.2 Cross-Border Cultural Mediation

***'Communities are the first Heritage Protectors*'** said Professor V. Michel of the Poitiers-HerMA Uni., on behalf of UNESCO in 2018 [24].

Further to legality, the author has taken into account this phrase: -who can best preserve a Holy Temple in a remote location, how can we be friendly to the local organizations and the civil servants? A bit of cross-border cultural mediation will be helpful, when the circumstances do not allow immediate understanding**.** For example, encouraging public dialogues between the inhabitants and the Orthodox Patriarchate in Istanbul, may be efficient, because these two Authorities are obliged to live together and share a small part of the city of Istanbul.

In the past Conferences the ideas of creating circular economies, as well as developing pilgrimage tourism have been presented [25]. These goals may not seem too far-fetched, if the Authorities and the most affiliated parties engage from the beginning to creative dialogues using mediation principles and skills. It will be necessary for locals to discuss in honesty and forgiveness, so as to be pro-active against violent reactions. The values of alternative dispute resolution may help to avoid blaming and bullying amongst inhabitants [26]. Mediation methods will allow approaches closer to human rights. For example, an invitation for cooperation between professional archaeologists, can be a further fine initiative.

Even in cases where recourse to Courts has been inevitable due to severe criminal acts of the past *(e.g. the case of Cyprus, where international Court judgements bind the parties)*, mediation may provide a solution towards the future [27].

The Euro-Tunnel has been a European work followed by quite a fascinating legend: for centuries the French and the English had been suffering from dreadful sea-battles, which were taking place in the Manche Channel. One would just need to step on shipwrecks and cadavers to cross that Sea. But a bit after the end of the 2nd world war, those two countries realized their common interests: the French started digging from their part of the coast and the English started digging from their side, until they actually met underwater, where they shaked hands, giving a promise for world peace. Since 1998 the Euro-Tunnel has been one of the busiest places in Europe transferring everyday people and goods.

4 Conclusion

The restoration of buildings of cultural heritage is included in all types of procurement, offerors should compete and such initiatives should be open to institutional funding and review procedures. PPPs may prove to be an ideal solution for emblematic monuments. A holy temple though, heritage to mankind, should be protected by a concession contract and its restoration should be entrusted to the most affiliated party via a P.F.I.

Ideally, restoration and reuse procedures begin with a design contest. The parties should engage in creative, technical dialogues using mediation principles, so as to achieve the best results. Economic operators from their part will need to prove excellency in financial and technical qualifications along with competency. Dialogues and mediation will assist at every stage.

We have tried to tackle legal issues on initiatives that have been lasting for decades, accompanied by demanding administrative permits, international surveillance, tough negotiations and Court rulings. That effort should be easier in a framework of goodwill and legal certainty.

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Highlighting of the Interwar identity of the Fokionos Negri street-linear park; The iconic Lanaras apartment building

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Abstract. The Greek legal framework for the protection of the architectural heritage of the center of Athens promotes, for historical-political reasons, its archaeological wealth and neoclassical interpretation, neglecting the protection and promotion of important buildings and open spaces of the 20th century. These are modern monuments that complete the city's image and identity, interpreting its evolution mechanisms and the way that people appropriate it in the everyday life. The research project aims to study the historic urban landscape of the Fokionos Negri street- linear park that has been formed during the first half of the 20th century and hosts many buildings characteristic of "Athenian modernism". It is an area of significant importance for the functional and social evolution of the wider center of Athens. The research goals have a triple approach, architecture, landscape and social. One of the main goals is the presentation and analysis of the notable morphological and typological features of the interwar apartment buildings on the street, but also of the history of their people. Through maps, archival research, personal observations, interviews with the linear park owners and patrons, film and photographs, we focus on interwar apartment buildings along the street, when the park was the leisure center of Athens. This approach is presented in the issue we created for one of the Interwar apartment buildings and landmark of the area, the Lanaras family's apartment building. The methodological choice appears to provide information of deep empirical and interpretive value which contribute to the understanding and appreciation of the historical urban landscape in Greece.

Keywords: Historic Urban Landscape, Interwar Urban Heritage, Fokionos Negri Street, Athenian Modernism, Kypseli.

1 Introduction

The Urban Landscape indicates the lifestyle of the inhabitants, their activities and their interactions, the beliefs and values of the residents, the affiliations of the city to the geographical location, time, climate, economy, society and politics [1]. The Landscape is the first manifestation of historical, socio-cultural, economic and natural elements of the city, a complicated cell which is a result of the action and reaction between human and environment [2]. In this interaction three parameters are influenced: society, culture and economy [3].

By examining the history of urban change and studying the different perspectives of urban studies and related theorists of architecture and urban planning, four main approaches to the Urban Landscape can be proposed:"*artistic approach, functional approach, perceptual/ situational approach and sustainable approach*" [4]. The geographic, anthropological, cultural and sociological-economical parameters of the landscape point to the need for a multidisciplinary approach to its conception, while the ways in which it affects imaginary and collective behavior point to the need for sensitive management policies. This means establishing a reliable method of Urban Landscape assessment that takes into account people's shared values and wishes [5]. In this frame, the research project[1] aims to contribute both to the documentation of the interwar architectural heritage of Athens and to the production of a broad framework of knowledge that may be the basis for how to understand and appreciate the historic urban landscape in Greece, in order to elaborate the criteria of its protection and prudent management.

2 Highlighting of the Interwar identity of the Fokionos Negri Street-Linear Park

Understanding and valuing Historic Urban Landscapes (H.U.L.) [6] [7] is an area currently being studied worldwide. The approach of UNESCO to managing H.U.L.is holistic, integrating the goals of urban heritage conservation and social and economic development [5]. The research project aims to study the H.U.L. of an area of Athens (the Fokionos Negri linear open space) that has been formed during the first half of the 20th century and hosts many buildings characteristic of "Athenian modernism". It is an area of significant importance for the functional and social evolution of its surrounding (Kypseli) and the wider center of Athens. The study area's structure derives from the location of the upper and middle class around the historic center of the Greek capital from the end of 19th century to the '60's and '70's, when it represented a specific way of life and recreation. Around '90's the area received the negative impact of suburbanization and, today, has developed a multi-cultural character. One of the objectives of the research is to identify and study the buildings of special architectural / historical / cultural value, which contribute in a special way to the construction of the urban landscape [8]. They bear witness to the overlapping layers of the city's history, the mechanisms of spatial production which operated in each era and they indicate the way of life, the values and the social context of the time. Such buildings are the residential buildings of the interwar period.

It is obvious that the rescued buildings from the cities' past show, among others, the selective way in which the administration evaluates and manages the collective

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[1]The PhD research in progress titled "Diachronic interpretations of interwar urban landscapes. The "modern" apartment buildings of Fokionos Negri".

memory. The Greek legal framework for the protection of the architectural heritage of the center of Athens promotes, for historical-political reasons, its archaeological wealth and neoclassical interpretation, neglecting the protection and promotion of important buildings and open spaces of the 20th century. These are modern monuments which complete the city's image and identity, interpreting its evolution mechanisms and the way that people appropriate it in the everyday life [5]. The PhD research will insist on the interwar buildings, as it is an insufficiently studied and anyway not protected part of our architectural heritage (threatened by modern building activity). The interwar apartment buildings are also a characteristic part of the residential stock of the study area, which is also connected to the time when the wider area was composed and the linear park was formed.

The interwar residential buildings in the area need to be studied because:

- They bear witness to the introduction of the vocabulary and compositional principles of the modern movement in Athens (and the major cities of Greece) in a critical historical period. A period in which occurs the collapse of the "Great Idea", the consolidation of national borders and the attempt to reconstruct of the economy and the institutions of the Greek state. This era sees the fixation on archeology recede in favor of the trends of modernization (if not Europeanization) manifested in all fields of social life while, at the same time, the debate develops around the characteristics that constitute the peculiarity of modern Greece.
- They bear witness to the production mechanisms of the space in that time (the forms of ownership, the construction methods, the institutional framework of urban planning, the housing standards, the relationship between public / private space, etc.)
- They retain important architectural qualities (in their form, function and placement in space) as projects by well-known architects and residences of many of the influential personalities of that period.
- They capture elements of the way of life, morals, consumer and aesthetic preferences (taste) of the upper classes of the time. In this way, they refer to the form of the society and the relations that governed it at that time (class structure, dominance relations, symbolic order) [9].
- In their comparison with the most modern buildings, they narrate the changes that have occurred since then in the production of the housing stock in Athens. Through this comparison, we can distinguish changes in the aesthetic standards, principles, relationships and ethos of social coexistence, ways and rhythms of life and in the priorities of urban and architectural planning.

3 The Issue of the Lanaras Family's Apartment Building

The research goals of the study of Historic Urban Landscape (H.U.L.) in the case of the Fokionos Negri linear open space have a triple approach, architecture, landscape and social [10]. One of the main goals, as mentioned, is the presentation and analysis of the notable morphological and typological features of the interwar apartment buildings on the street, but also of the history of their people. This approach is presented in the issue created for one of the interwar apartment buildings and landmark of the area, the Lanaras family's apartment building.

The Lanaras apartment building is an emblematic building of this category which has a high architectural value and aesthetics, it is the project of a well-known architect of that time, it was the property and residence of a family that marked the industrial history of the country, it occupies a distinguished position in terms of linear park of Fokionos Negri and has a strong imprint on the collective memory as it is located close to historical haunts of the area and we can see it in various films and photo reports from the time when the linear park represented a recreation pole in the center of Athens with a very special physiognomy and radiation.

In preparation for my research, I have already studied the Lanaras apartment building [11] through archival research, personal observation, interviewing one of the original owners who still lives in the building, as well as patrons of the park- a methodology that I shall follow for the evaluation of the others "modern" apartment buildings surrounding the linear park.

3.1 The Property Address/Date of Erection

Lanaras Family's Apartment Building. Address: 23, Fokionos Negri Street & 46, Eptanisou Street, Kypseli, Athens.Date of Erection: 1937-1938



Fig. 1. (Left)[12], **Fig. 2.** (In the middle)[13]&
Fig. 3. (Right) [14] Aspects of the Lanaras Family's Apartment Building

3.2 The Owners

The apartment building had, when it was built, the character of a large family one. The original owners were the brothers Konstantinos, Thomas, Stavros and Theodoros Lanaras. The Lanaras family, a well-known family of industrialists originally from Naoussa, a city in Northern Greece, traditionally associated with weaving, due to its waterfalls, has associated its name with the beginnings of the Greek textile industry. The family business starts operating in 1909 and reaches its peak in the interwar period, playing a leading role in the textile industry – one of the most powerful sectors of the Greek economy at that time. From 1932, the "Lanarades" expanded their business activities in Athens, establishing new factories, which were also staffed with workers from Naoussa.

As Mrs. Poly Lanara describes in personal communication (2018), Konstantinos and Olga Lanara, nee Angelos Angelakis, were the owners of the first floor of the apartment building, while Olga's parents (A. Angelakis family) owned the ground floor apartment. Thomas and Aphrodite Lanara were owners of the 2nd floor, Stavros and Maria Lanara of the 3rd floor and Theodoros Lanaras and Olga Lanara-Angelaki of the 4th floor. Periklis Lanaras, son of Konstantinos and Olga, and his wife Polyxeni (Poly), after their marriage in 1953, lived on the first floor, while since 1982; Poly Lanara lives in the ground floor apartment. Along the way, the descendants of the original owners transferred the apartments to different owners. For a while, the owner of the 2nd floor apartment was the Benaki Museum. Their second cousins, Giorgos and Alexandros Lanaras, are the owners of the well-known Lanaras house in Anavyssos, by the architect Nikos Valsamakis.

3.3 The Architect Engineer- Civil Engineer

As Mrs. Polly Lanara said in her interview to *Flâneur* magazine (2015), "*my house was built by a famous architect (Ioannis Zolotas) in 1937. My father-in-law ordered it*." It is a fact that the highly aesthetic apartment buildings of the interwar period were designed by important architects at the behest of wealthy landlords and echo the class stratification of urban formations. Although Mrs. P. Lanara adds that it was the first apartment building to be built in Fokionos Negri Street, our research has shown that there are some apartment buildings which were built in the early to mid1930s that still exist today[15].

Ioannis G. Zolotas studied civil engineering at the National Technical University of Athens, where he graduated in 1914, subsequently acquiring the specialty of architect. His seat was in Athens, on Syngrou Avenue no 2 upper floors [16]. During the period 1914-1915 he worked as an engineer of the Directorate of Railways of the Ministry of Transport, while from 1915 to 1921 he was a reserve military engineer. His projects, during this period, are the study and execution of the barracks of Drama and Kavala (two cities in Northern Greece, with an important tobacco industry at the time, which joined the borders of the country after the Balkan wars of 1912-1913), the military hospital of Drama and the study of the construction of the extreme supply of Drama. From 1921 he worked as a freelancer, preparing architectural studies and erecting buildings. Some of his projects are the Piraeus Association Building, for the study of which he was awarded, and the Post Office Building in Athens [17].

3.4 The Lanaras Apartment Building and the modern architecture

In the interwar period, Greek architects had become familiar with the vocabulary and construction logic of the modern movement, and high-rise residential buildings with a reinforced concrete structure and particularly comfortable apartments proliferated in the big cities and especially in Athens. Emmanuel V. Marmaras (1985) uses the term "Urban Polykatoikia" ("Urban Apartment Building") for this kind of buildings [18]. He wanted to give "*emphasis on its urban component to significantly cover the two main implementing factors, namely the production process developed in Athens at the time and the social content it acquired*" [5]. The Lanaras apartment building is a typical example of the interwar modern architecture, bears the aesthetic characteristics launched by the Bauhaus School, and at the same time has a special personality and excellent construction quality.

The Facades are configured with straight balconies 1.20 m wide with curved outer walls at the corners in connection with bay windows (*erker*), but also with corner ones (Fig.1, 2&3). The balustrade is linear, metal, with art deco elements above a built parapet (Fig.2&3). The bay windows (*erker)*, rectangular in shape with a width of 1.20 m, are arranged symmetrically in the building, on the A', B' and C' floors, have openings around the perimeter and are continuous at their outer corners (Fig.1&3). They are not independent architectural protrusions on the facade of the apartment building, but are kept at the same vertical level (face) as the parapet of the balconies. A single mesh of elements is thus created, which is located in a projection with respect to the basic vertical plane of the facade.

The front view on the 4th floor (penthouse) and on the Roof is formed by a continuous balcony with the same linear, metal railing. The existence of the balcony at the level of the 4th floor creates a cornice, which gives the feeling of crowning the building. On the eastern front view towards the uncovered area, there is a covered terrace (semi-outdoor area) with the same linear metal railing. The openings are individual, wooden opening with roller shutters, while in the curved part of the A', B' and C' floors they are continuous. The collaboration of bay windows, balconies and openings create an interesting geometric relationship.

The central exterior door is placed in the curved part of the building, in a recess with three steps and is metal with glass (Fig. 4). It is sheltered from a cantilever. There are also two secondary, asymmetrically placed, exterior glass and metal doors as well (Fig. 2 &3), which form the independent entrances to the raised ground floor apartment.

Construction / Facilities / Materials. The load-bearing structure of the apartment building is made of reinforced concrete and a proof of its construction quality is that during the major earthquakes (1981 & 1999) in Athens, according to Mrs. P. Lanara (2018), it did not show any damage, as was also established by the levels of engineers, who conducted the corresponding post-earthquake controls. The apartment building has a shelter, as, according to the extensive program of Civil Protection from the regime of I. Metaxas (1936-1940), the construction of an underground anti-aircraft shelter was mandatory in every newly erected building of three floors or more (including the ground floor)[19]. During the German occupation, the apartment building was requisitioned and turned into a hospital, according to Mrs. P. Lanara.

According to the principles of the modern movement, the apartment building had amenities, such as central heating (currently has natural gas heating), lift (central and auxiliary), as well as telephone and electrical wiring and fully equipped kitchens. It is impressive that a closed car parking area with an entrance from Eptanisou Street, which belonged, according to Mrs. Poly Lanara's description, to the apartment on the 1st floor, was provided for during the construction of the apartment building. While the second floor apartment includes the two warehouses with a vestibule, located on the mezzanine above the garage on Eptanisou Street, as described in the corresponding sales contract. Also, the courtyard on Fokionos Negri Street has been converted into an outdoor car parking area, as evidenced by the existence of a garage door.

The luxury in the interior construction of the space (Fig.11,12,13&14) is displayed with wooden floors with the decoration of meanders and other geometric designs in the reception areas, wooden paneling on the walls, heavy wooden interior doors, elaborate plaster ceilings and stained glass windows in the openings of the lounge. The bedrooms also have wooden floors, while the auxiliary spaces (kitchen, bathroom) have flooring with a mosaic with large marble pieces.

The Main Entrance. The entrance consists of three functional units, characteristic feature of the interwar apartment buildings: the external entrance area, the vestibule and the stairwell area (Fig.4&5), thus offering the visitor the feeling of a smooth transition from the external public environment to the interior private space.

The front door recedes (Fig.4), leaving an open space in front of it, which opens outwards with pleated walls. This space is essentially the extension of the public space to the private space and stimulates the way of transition from the outside to the inside. The vestibule (Fig.5) is separated from the stairwell space by a double-leaf wooden door with glass, axially placed, thus creating a second internal entrance and has a staircase to the level of the central circular hall, which has great height.

The Main Stairwell. In this space is also the concierge in an independent closed space, but with a large opening, so that there is the possibility of checking those entering the apartment building. The stairwell area and the elevator are on an elevated level by four steps (Fig.5), in relation to the central hall. As a peculiarity, the placement of the central entrance of the apartment building on the curved corner (Fig.4) is noted, which is a rather rare choice, as is the circular shape of the central hall (Fig.5).

The vestibule and the main hall are decorated with white, gray and black marble, with elaborate floor and wall design (Fig.5). The staircase (Fig.6) is impressive, also decorated with the same types of marble and has bronze sconces and apartment bells decorated with animal designs (Fig.7), cast iron balustrade with wooden handrail (Fig.9) and stained glass in the openings (Fig.10). The entrance doors of the apartments are solid dark wood with glass opening. The elevator doors are also wooden (Fig.8).



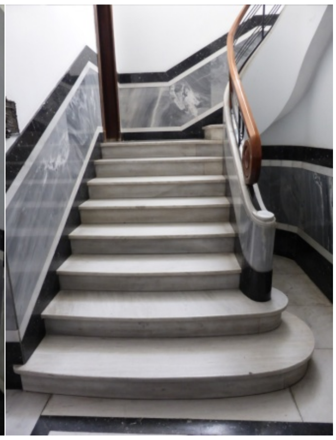
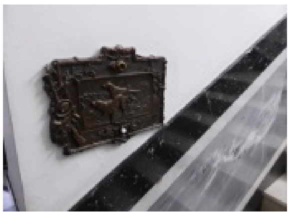


Fig. 4. (Left)The main entrance**, Fig. 5.** (In the middle) The vestibule and the central hall**&**
Fig. 6. (Right)The main staircase (Archive of G. Eleftheraki)



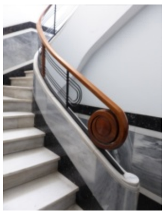
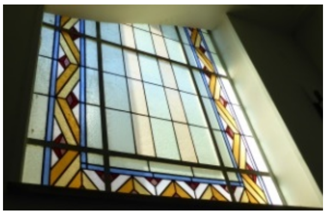
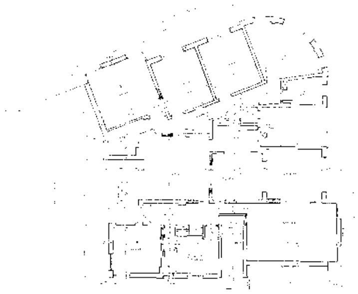
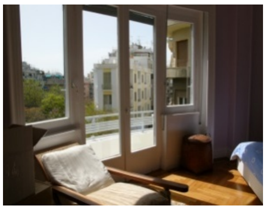



Fig. 7. (Left) Bronze apartment bells, **Fig. 8.** (In the middle-left) Wooden elevator doors, **Fig. 9.** (In the middle-right) Cast iron balustrade with wooden handrail &**Fig. 10.** (Right) Stained glass (Archive of G. Eleftheraki)

The 1st, 2nd & 3rd Floor Apartment. The apartment building consists of four floors, 1st, 2nd, 3rd and 4th (penthouse apartment), an elevated ground floor and a semi-basement. Each floor is a separate large apartment (five apartments in total), while the ground floor apartment has independent entrances, not through the main entrance of the building. According to the apartment building internal regulation, the apartments can only be used as residences. The building has been erected on a plot of land, with an area of 662.87m2, and is adjacent to the street line, while it is located at a distance from the lateral boundaries, leaving uncovered space in the eastern part of the plot.

The floor plan (Fig.11) of the 1st, 2nd & 3rd floors is similarly configured as a typical floor, with a total area of 365.35 m2, according to the imprint floor plan (1998) of the architect engineer D. Dais. It consists of an apartment with an area of 320.91m2 and two common areas (staircases and elevators). The common area K.X.1 (21.98 m2) is the central stairwell and the main elevator of the apartment building, while the common area K.X.2 (12.46 m2) is the service stairwell with the auxiliary elevator, located in contact with the service room and in the same functional space as the kitchen. The social separation is evident in the floor plan, as there is a social organization of the spaces (for the tenants of the apartment and for the service, which a residence of this size needs).

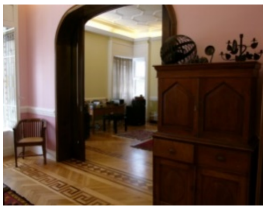



Fig. 11. (Left) Floor plan of **t**he 1st, 2nd & 3rd floor apartment (Archive of G. Eleftheraki), **Fig. 12. & 13.** (In the middle up & down) Interior views of the 2nd floor apartment (Archive of G. Eleftheraki, ©P. Tranidou), **Fig. 14. & 15.** (Right up & down) Interior views of the ground floor apartment (Archive of G. Eleftheraki)

The "Public" Space of the Apartment. The entrance – hall introduces the visitor to the apartment and the reception areas, the main living room, the separate living room (with the stained glass) and the dining room they dive access to each other, that is, they are rooms-passages of primary use, where movement and function are correlated (Fig.13). Their proximity to the entrance and their placement facing Eptanisou Street, so that they have access to natural lighting and ventilation, are the translation of their "public" position in the floor plan of the apartment.

The stained glass room and the dining room have a west orientation, while the living room is located on the eastern side and has access to a covered terrace of approximately16 m^2 and 2.90m wide, which can be used most of the year, as a "natural extension" of the living room. This roofed veranda "looks" towards the lateral uncovered area of the plot, in a sense a courtyard, with an eastern orientation and at the same time, it has a side view towards Fokionos Negri, thus acquiring a unique character. It is protected enough from prying eyes to maintain its privacy, but at the same time, it is not cut off from the outside environment.

The "Private" Space of the Apartment. Inthatzone of the residence belong the three comfortable bedrooms, which are located on the view on Fokionos Negri (Fig.11& 12), with a southern orientation and communicate with each other through a third space-corridor. The corridor, like the hall and the entrance, are transitional spaces that articulate the parts of the residence with each other and, at the same time, act as a filter between the "private" and "public" space. The two bathrooms, which serve the residents of the apartment, are located diametrically opposite the access corridor to the bedrooms and have natural lighting and ventilation, and big bathtubs and wash basins.

The Kitchen & Service Area of the Apartment. The comfortable kitchen with large marble sink, solid wood cabinets and lots of storage, together with the adjacent service area (service room and w. c.) is located towards the eastern and northern uncovered area of the plot and in proximity to the auxiliary staircase and elevator. These two spaces form a hybrid subset of the apartment, which maintains a dual character. It has the privacy of bedrooms, as a non-clean space, which should not be projected, but at the same time, it also has the need to be immediately adjacent to the dining area, so that meals can be transported and served with speed and ease. It is characteristic that between the dining room and the kitchen there is a corridor, a transitional space which serves, on the one hand, to isolate the smells of the kitchen from the rest of the house and, on the other hand, functions as a storage area for tools and electrical appliances, such as the washing machine. This transitional space also leads to the roofed terrace in front of the sitting room, providing immediate service during the summer months, when it is mainly used.

The Ground Floor Apartment. The apartment on the raised ground floor is designed in a similar way to the apartments on the 1st, 2nd and 3rd floors. Its area is smaller than these floors, due to the reduction from the central entrance area of the apartment building, but it remains a very large apartment. The arrangement and structure of the "public" and "private" space, the kitchen and the service room remain in the same logic, as described above, as well as the luxury of its interior. It has sitting rooms, as well as large and comfortable reception areas, with walls covered with tapestries, Saridis furniture and expensive decorative objects (Fig. 15). The two bedrooms, which have the same orientation as the other floors towards Fokionos Negri, include a lounge and large wardrobes-furniture (Fig.14).

Mrs Polly Lanara. The owner of the ground floor apartment has lived in the apartment building since 1953, after her marriage to the scion of the well-known family of industrialists, Periklis Lanaras, while she has lived in this apartment since 1982. She had studied classical music and wanted to become a soprano, but **"***chose her husband than opera***"**. She has lived a rich life and has traveled almost all over the world. After the collapse of the family industry, she uses her apartment for TV and film shoots (personal communication, 2018).

3.5 The Lanaras Apartment Building in Greek Cinema

In the stills from the film *"Neither cat. Nor damage"* (*"No harm. No foul"*)(1955) we see the wealthy protagonist (actor Lambros Konstandaras) sitting and waiting for the beautiful protagonist (actress Ilia Livykou), in the famous pastry shop of the era *Select* (Fig.16), which started operating during the second half of the 1940s on the corner of Eptanisou and Thiras Street, opposite the Lanaras apartment building, where its entrance can be seen. Then, in November 1959, the "*new Parisian*" Select was opened, in the place of the *Media Luz* cinema on 26 Fokionos Negri Street and Eptanisou Street, where it is still today. We can distinguish the Lanaras apartment building on the left of the Fig.17.

Fig. 16. (Left) Stills from the film *"Neither cat. Nor damage"* (*"No harm. No foul"*) (1955) [20]**, Fig. 17.** (Right) Panoramic view of Fokionos Negri from the height of Eptanisou Street in front of *Select* (1964) [21]

3.6 Opinions for the Lanaras Apartment Building and the Fokionos Negri linear park

Architects. The Lanaras apartment building with the purist and rationalist directions in its design, "*it impresses even today, with the quality of its construction, its curved forms and the robust appearance of its volume, as it projects dynamically in a diagonal direction towards the axis of Fokionos Negri*", M. Biris, professor N.T.U.A., observes in his article "A living urban architecture" in the tribute "Kypseli. The urban yesterday, the colorful today", published on February 23, 2003 in the insert "Seven days" of the newspaper *Kathimerini* [22]. In the same dedication and in her article entitled "The Genealogy of Kypseli", the architect Maria Vaschenhoven writes that the Lanaras apartment building "*with its solid volume, the rough proportions and curved forms of its elements, the diagonal arrangement ofits marble-clad entrance is imposed as an element of urban reference in the area*"[23].

Habitants. "*My house is across the street from Select so I go there for coffee. I've been living here since 1953. On the site of the Max Perry* (opposite today's Select) *was a famous tavern. Every night when the theaters closed, all the famous actors came to eat there. They chatted and joked until six or seven in the morning.* […] *The road used to be* (until the mid-1930s) *a river and that's why we have so many trees. Here was a pond; we had water every day* […]. *Fokionos Negri Street was called Via Veneto. But now it changed, everyone moved to the suburbs, except for those who died. I was twenty years old when I came here* […]". P. Lanara, interview to *Flâneur* magazine (2015)."*The functionality of the Lanaras apartment building is noteworthy*" P. Tranidou - resident of the apartment building, personal communication (2018).

4 Epilogue

In conclusion: a) The methodological choice to connect the study of the buildings on the one hand with the stories of their inhabitants and on the other with the narratives of the current residents of the area seems to yield information with experiential depth and interpretive value. b) The Lanaras apartment building has architectural qualities (functional and aesthetic elements) that are characteristic of the Athenian modernism of the interwar period, but even today are required in the study of high-end residential buildings (a finding that advocates the need of the characterization and protection of such buildings). c) Through the study of the interwar buildings we come into contact with the economic-social processes and the persons who influenced the development of the area we are interested in, if not the history of the country itself. This allows us to formulate questions about how the current residents, workers and patrons of the area experience and evaluate the changes that have taken place in the urban landscape, how they perceive its production processes, the persons and social relations that signify it.

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Restoration and highlight of Agioi Theodoroi church in Nafplio with the use of CAD technologies

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Abstract. The church of Agioi Theodoroi is located north of the new city of Nafplion in Greece. It is not proclaimed monument, but it constitutes important historical evidence of recent history of the city and of Greece in general, given that it is documented to be associated with one of the protagonists of the Revolution of 1821 Theodoros Kolokotronis and therefore it is inextricably linked to the collective historical memory.

This paper has a twofold objective. On the one hand, it describes the work of restoration and highlight of the church of Agioi Theodoroi, on the other hand, it presents the first results from the processing of the architectural, geometric, and historical data related to the building. The data resulted from both systematic interdisciplinary documentation and local community contribution, following an open invitation for relevant evidence. At the same time, the paper attempts to contribute to broader research related to the development of integrated data management methodologies at the scale of historic buildings and ensembles, in a single digital environment based on CAD technologies. Furthermore, this approach as well as the thematic maps developed, can facilitate, as a first and crucial step, the design and implementation of compatible conservation and enhancement interventions.

Since the beginning of building constructions to date, and the parallel systematic recording using CAD technologies, important data have emerged regarding the different construction phases of the monument. The results of the above allow the systematization and control of the ongoing restoration works. Finally, it is noted that this is the recording of a design documentation process that is implemented in parallel with the implementation of the project, a fact that will allow, within the completion of the project, to draw useful conclusions for the management of similar projects and for the contribution of digital technologies to the construction process.

Keywords: Cultural Heritage, CAD, Thematic maps, local communities, multidisciplinary approach.

1 General project details

1.1 Introduction

As mentioned, the church of Agioi Theodoroi is located north of the new city of Nafplion, in the “Neo Byzantio” or “Kültepe” area, near the main road connecting Naflion to Argos, on Kalamata Street. It is a small, simple construction, single aisled church with pitched tiled roof and a semi-circular sanctuary arch. The church is not proclaimed monument, but it constitutes important historical evidence of recent history of the city and of Greece in general, given that it is documented to be associated with one of the protagonists of the Revolution of 1821 Theodoros Kolokotronis and therefore it is inextricably linked to the collective historical memory. Today the church belongs to “Holy Church of Saint Constantine and Helen” in Naflion. Due to celebrations for the 200 years anniversary of the Greek revolution, the committee “Greece 2021” has approved the financing of its restoration.

In recent years, scientific interest, and research towards the systematization of the scientific field of Architectural heritage and digital technologies has been increasing [1, 2]. In particular, research concerning religious monuments and churches appear and focus on issues such as the development of appropriate methodologies, protocols and guides for 3D digitization [3, 4, 5, 6], comparison of technologies and tools of digitization [8,9], development of integrated digital data recording and management solutions [10, 11], interconnection of geometric, architectural and historical data of the monuments with the aim of a holistic approach to the documentation and understanding of the monuments [12, 13, 14, 15, 16], development of accessible applications to end users with the aim of raising awareness of architectural heritage issues [17, 18, 19, 20]. Furthermore, of special interest for this presentation are research projects that focus on capturing, documenting, and highlighting small-scale historical temples with the use of digital technologies. We find research projects with emphasis on recording methodologies [21, 22, 23], database design and development [14], comparison of different technologies [24] and non-expert access to collected data [25].

This paper presents the initial diagnostic procedures as well as the first results from the plaster removals and the test sections in the construction field. The diagnostic procedures include the creation of multidisciplinary thematic maps in Computer Aided Design (CAD) environment, which incorporate: (a) data of historical and architectural documentation and (b) data of geometric documentation. It is about a work in progress and is proceeding with multidisciplinary collaboration between historians, architects, archeologists, material science engineers. Of particular interest is the involvement of the local community in support of the project and in archival/bibliographic research. Finally, the completion of the project will bring changes to the map of the city’s points of historical interest since it is located outside the historic city center. This event should have as its goal both the sustainable protection of the monument as well as the sustainable development of the wider area.

1.2 Description of the current condition of the building

For this building there are no older studies, nor is it mentioned in the literature. The works on the restoration and enhancement of the church began in September 2022. An autopsy was carried out during which the following was established: Externally the temple was presented as a simple and unstructured building, with a prismatic volume and low proportions. The external surfaces of the walls were plastered with cement mortars. A semi-open space with a single-pitched tiled roof precedes the entrance to the church, and a newer metal door with glazing on the west façade leads inside. Internally, it is a single aisled, covered with a wooden roof carrier of newer construction, but originally it probably had a dome supported on the sufficiently thick masonry. A modern wooden iconostasis (templon) isolated the Sanctuary from the main temple. Regarding the form of the foundation of the monument, it was unknown and was not possible to be evaluated with certainty. The roof is formed on a wooden support of a newer construction, which is covered with a wooden layer (slim wooden boards). The trusses are placed at distances of about 90 cm and are located on the side walls of the temple. The covering is with Byzantine-style tiles with mortar. The roof of the niche of the sanctuary is covered with the same type of tiles. On the perimeter of the roof, a cornice is formed on the outside, which protrudes about 40 cm. All the exterior walls had been plastered (probably also grouted) with thrown cement mortar. All the exterior walls were additionally painted. The door of the church is newer, metal, single leaf, glazed and about 1m wide. Internally, the iconostasis was simple and isolated the sanctuary from the main temple. It extended across the entire width of the temple and had two doors, one of the Beautiful Gate and one to the north, which corresponded to the area of the Prothesis. It was found to consist of two sections, the lower section was a newer wooden structure while the higher section was an undated earlier wooden structure. The floor finish was ceramic tiles, and its layering was unknown. The inner surfaces of the walls were entirely covered in lime plaster. In the church there was an elementary electrical installation to cover lighting needs.

The surrounding area of the church was arranged in two levels, on the level of the west side where the entrance is and on the level of the north side of the temple. On the west side of the church, there was a platform with a floor of ceramic tiles. The roofed semi-open area/space on the west side is bound by two supporting walls. On these walls, along their entire length, were built later, linear benches. Moving further north, two large stair landings were formed, ending at the final level, 35 cm high from the western entrance. On the north side of the church, on its body, a linear bench, made of cement-bricks, had been built along its entire length, interrupted only by the north-ern opening of the church. The northern side of the surrounding area is bordered by a road, Kalamata Street. The whole surrounding area was paved with ceramic tiles. After visual inspection, no significant structural problems were found, and the building problems were limited. There was limited damage to the walls that was related to the descending and rising humidity and was manifested by spots mainly in the lower zone of the eastern wall and specifically in the niche of the sanctuary and in the nearby places. The church was facing several aesthetic problems, partly due to modern interventions. Initially, a small, crumbling warehouse built on the body of the church, at its northeast end, was

identified as a problem. Also, the newer coatings had altered the image of the monument and its historical and artistic value was not highlighted. Finally, it was found that there was a lack of design in the surrounding area and no information signs that would allow the visitor to understand the historical value of the church (see Fig.1).
Summarizing, four main objectives were set:

- Dealing with building and structural problems to eliminate the risks posed by their presence and to prevent further damage.
- The aesthetic upgrade of the church and its immediate surroundings.
- The highlighting of its degraded historical value.
- The use of the restored monument by the local community.

Fig. 1. North–West view of the church before the building works. (7/9/2021)

1.3 Building and structural works

The following were defined as the basic principles of intervention: The preservation of the authenticity of the monument through the conservation, restoration and maintenance of the elements that have remained unchanged. The highlighting of those elements that have been damaged, but their restoration is possible. The use of traditional materials and building methods, with the commitment that, where these seem insufficient, the parallel use of modern methods and materials that have been tested in other similar interventions will be made. The distinct differentiation of the new materials from the original parts of the monument. The reversibility of interventions as far as possible. The clear morphological and construction separation of the new constructions that will be implemented.

Based on the above, the following works have been launched: Removal of newer surface coatings and mortars from the external faces. Grouting with compatible materials, local grouts in cracked areas if required. Disclosure of foundation and its possible reinforcement. Construction of a drainage ditch around the perimeter of the church. Test sections of internal coatings where necessary. Floor removal/ dismantling and reconstruction with compatible materials. Remodeling of facades and construction of a belfry (bell tower). Configuration of the surrounding area, with care for access for the disabled, configuration of a parking area and placement of an information sign and supervisory material.

To date, the removal of plaster on the exterior masonry, the test cuts on the interior masonry, the excavation of the northern part of the surrounding area, the removal of interior floors and the detachment of the newest part of the iconostasis have been carried out (see Fig.2, Fig.3, Fig.4, Fig.5)

Fig. 2. North–West view of the church. Removal of plaster on the exterior masonry. Excavation of the northern part of the surrounding area. (24/9/2022)

Fig. 3. South–East view of the church. Removal of plaster on the exterior masonry. (24/9/2022)

Fig. 4. Interior of the church. Test cuts on the interior masonry. Removal of interior floors Detachment of the newest part of the iconostasis.

Fig. 5. Interion. Removal of plaster on the interior masonry. (23/6/2023)

1.4 Scientific conference and invitation to the local community to participate.

In parallel with the above, the Department of Architecture, University of Thessaly, in collaboration with the Municipality of Nafplio and the Holy Church of Agioi Konstantinos & Eleni in Nafplio, organized a scientific conference entitled "Restoration and Promotion of the Church of Agioi Theodoroi of Nafplio - Interdisciplinary Approaches" [26]. The purpose of the conference was to inform, exchange documented opinions and interact between different specialties of scientists and the local community on topical issues of restoration and promotion focusing on the specific project. At the same time, a student workshop was held at the construction site of Agioi The-odori (see Fig.6). The topics were related to:

- the post-Byzantine churches of Argolis and other regions of Greece.
- The Architecture, of the city of Nafplio in the Ottoman and Post-Revolutionary period.
- Theodoros Kolokotronis and his story.
- The history of the ownership status of the temple.
- The role of the church as a historical and religious place.

Also, historical evidence (photographs, contracts, documents, plans, etc.) of the temple that were granted to the research team by citizens was presented. Finally, the discussion included topics such as the role of cultural heritage monuments in urban development and the prospects that can be created for the city of Nafplio with the completion of the specific project.

Fig. 6. Student workshop on site (19/11/2022)

2 Project Methodology

2.1 Process

In order to make use of all the data and information obtained from the above actions, the methodology shown in the following diagram was followed (see Fig.7). This includes Geometric, Architectural and Historical Documentation. To date, the first three steps have been largely completed.

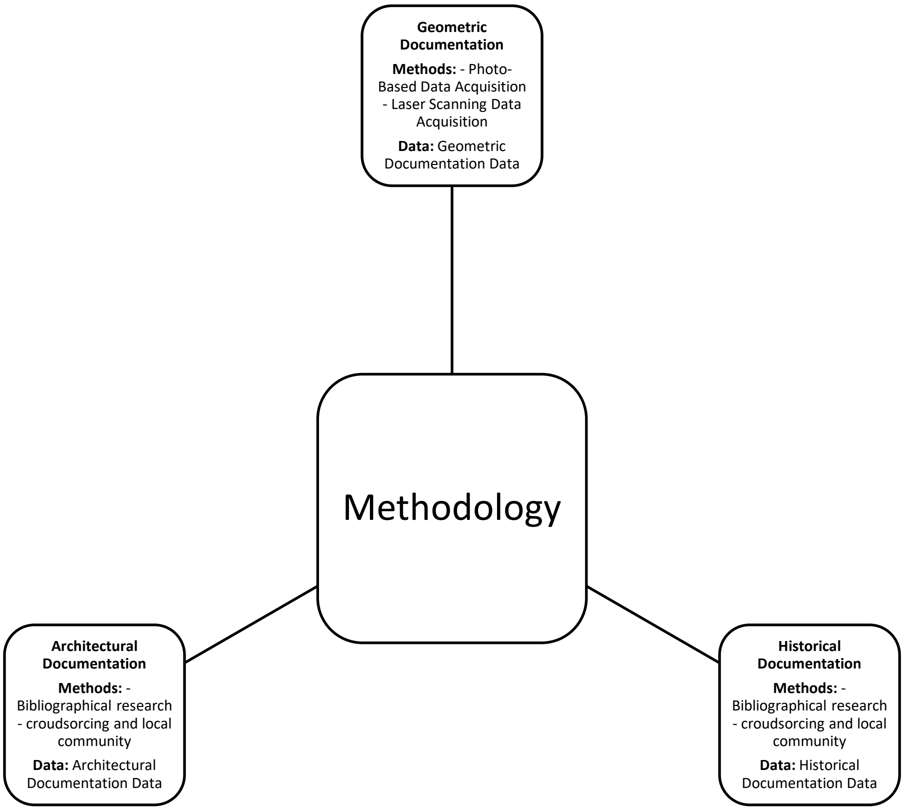

Fig. 7. Diagram of the process

2.2 Geometric Documentation

Technological developments in the field of geometric documentation offer many different combinations for the geometric documentation of monuments, depending on their size, the level of complexity, the desired and required accuracy of the developed outputs and equipment. In this paper, a combination of different methods was the ideal solution for geometric and architectural documentation to achieve the desired results.

Geometric surveying in tape and laser. Six hand-drawn sketches were made in which the detailed dimensions of the temple were marked. The sketches show the horizontal section (floor plan) at a height of 1m, the four elevations and the north-south axis section. Measurements were taken with a tape measure and verified with a Bosch PLR 40 C laser accelerometer, provided by the research unit "Architectural Design, Digital Construction and Building Technology" of the Department of Architecture, University of Thessaly, with an average spatial resolution of ±5-6 mm. The accuracy of the measurements with the tape measure was two decimal places and with the laser to three decimal places, information that was not considered worthwhile and was ignored. The external contour of the building was confirmed by a Trimble 5800 GPS topographic device which gives a deviation of 0.25m. The design material produced facilitated further processing of the architectural documentation of the church and allowed the design team to empirically observe and understand the details and particular parts of the structure on site.

Photo-Based Data Acquisition. A database of photographs was created which provided the necessary information of the facades and surface details of the structure as well as the necessary information for the development of the building material maps. A Canon PowerShot SX50 HS digital camera with a 12.1 Megapixel sensor (1/2.3" CMOS) with a 24 - 1200 mm (50X) lens was used for the acquisition of data based on photographs. A Parrot Anafi unmanned aerial vehicle (UAV) with an HDR: 4K 30fps camera provided by the research unit "Architectural Design, Digital Construction and Building Technology" of the Department of Architecture of the University of Thessaly was also used. These cameras were used for photorealistic texture mapping and for the quality of the im-ages produced. A specific number of digital images were taken depending on the difficulties encountered in each case. In addition, the tree trunks, almost in contact with the south façade, added difficulties to the data collection process. Therefore, images were taken at close range (in many cases, less than 1.5 m). Digital images were taken from different angles and distances. In the case of the western façade, documentation was very difficult in the highest part due to the proximity to the semi-conservatory. In total, about 20 images were taken for each façade from different distances and multiple angles, covering the exterior facades of the church. In addition, all exterior walls incorporating texture, surface variation, material variation and alterations were obtained in the developed model of the church. two levels of headings should be numbered.

2.3 Architectural and Historical Documentation

As mentioned above, a preliminary survey was carried out to collect all available information on the architectural analysis of the monument since there was no previous documentation for this particular building. Also, a scientific conference [26] was organized with invited speakers from different scientific fields (history, archaeology, architecture, law) directly or indirectly related to the temple. In addition, in the context of the conference, an open invitation was made to institutions and citizens of the local community to contribute evidence related to the temple. Finally, a survey was carried out on previous interventions in the temple. All interrelated information regarding the documentation and investigation of the current state of preservation of the temple consists of various elements. Beginning with the historical documentation, a complete and in-depth understanding of the structure and history was achieved through a thorough literature search, including past photographs, drawings and plans of the historical documentation (see Fig.8, Fig.9, Fig.10).

At this point it should be noted that it is important to complement the project with the on-site application of the non-destructive techniques of digital microscopy, infrared thermography, and ground penetrating radar to generate data for material characterization and deterioration diagnosis of building materials.

Fig. 8. Photographic documentation of the west façade (adopted from [14]).

Fig. 9. Photographic documentation of south-west view (Adopted from [14]).

Fig. 10. Photographic documentation of north facade (Adopted from [14]).

3 Results

3.1 Geometric Documentation Data

The next step was to process the sketches and photographs of each facade and convert them into drawings using CAD technologies. Initially, each façade was worked out as a different project using masks of edited images. After processing the data for all facades, a 3D model of the Catholic Church was constructed. Selected images were used to process the orthoimages of each facade to ensure quality texture. To advance the interdisciplinary process, four orthoimages were created, one for each facade of the church. These orthoimages served as blueprints for further processing of thematic maps incorporating not only qualitative information but also quantitative data. (See Fig.11, Fig.12)

Various methods were used to develop two-dimensional drawings (plans and sections). The required resolution was ±1.5 cm. In addition to the architectural documentation of the structure, the survey aimed to identify various deformations and alterations compared to the original condition of the structure. First, the planes of the sections were determined in two sections that constitute the main axes of symmetry of the monument. In addition, a horizontal section at +2.10 m elevation was defined to cross most of the temple openings.

Fig. 11. Orthoimage of the north façade.

Fig. 12. Orthoimage of the south façade.

3.2 Historical Documentation Data

The reason for the in-depth historical research, financing and implementation of the project was the change in its ownership status. The building was donated in 2015 by the Retalis family to the legal entity of the Holy Church of Saints Constantine and Helen. In order to proceed with the transfer process, an inspection of the ownership documents was carried out, which revealed the systematic and documented link between the building and Theodoros Kolokotronis.

According to data provided by the Retalis family and based on the research of the notary Nikolaos Tobras [27-30], the documents concerning of the ownership of the wider area, in which the church is located, are as follows:

- Law 10/23-05-1839 entry 18th, Theodoros Kolokotronis, Land and place Nafplion" (see Fig. 13).
- The will of Theodoros Kolokotronis of 3 May 1841, where he invites Charalambos Papadopoulos Mnemonas - Notary Public of Nafplio to his estate near "Kioulutepe" on the outskirts of Nafplio, to prepare and write it.
- The publication by the Athens District Court of 25 May 1868 of the secret will of Lieutenant General Ioannis Gennaios Th. Kolokotronis, which had been submitted to the notary of Athens St. Tavanakis. In this document, the land in Nafplio, as in other places, is not mentioned in detail, but is left to his heirs as common. (See Fig. 14)
- The contract number 15.987/02-08-1871 of the notary of Athens Vasileios Lambrolis where it is mentioned that in September 1869 a distribution report had been issued by the Magistrate of Nafplio.7 In this contract it is mentioned that relevant

drawings depicting the fields were attached to the relevant report. Also, that the land that had passed to the grandfather of the parties to the contract, General Theodoros Kolokotronis, constituted National Lands.

- In 1898 Angeliki, widow of Theodoros Ioann. Kolokotronis (or Falez) declares that under the 14.529/1890 contract of the notary Tasos N. Economou and in conjunction with the secret will of Ioannis Gennaios Th. Kolokotronis, i.e., her father-in-law, which had been filed with the notary of Athens St. Tavana, who had been a trustee of the estate, occupied a land in the location "Kioulu Tepe" of Nafplio of about forty-five acres. It also contains a church honored in the name of Agioi Theodoroi and is bordered on the east by the old Argos Street, on the north by the fields of the heirs of Constantine Th. Kolokotronis formerly and already owned by K. Retalis, west with the new Argos Street, south with river and the fields of P. M. Iatrou and Michael Damoulou. He sells the above land to the brothers Konstantinos D. Retalis, Gregorios D. Retalis, farmers, residents of Aria, Nafplion and Georgios D. Retalis, wine seller, resident of Nafplion by shares. It excludes from the above land the holy church of Agioi Theodoroi, which he retains, and which will pass to the buyers after its death, but from now on it appoints them as managers and responsible for the maintenance of the church.
- In 1900, on the 29.184 contract of the notary Tasos N. Economou, some of the heirs of Ioannis Kolokotronis promise and undertake the obligation towards the Retalis brothers that if the heirs of Panagiotakis Th. Kolokotronis, with whom, as mentioned above, they were in conflict, ask for a percentage of the above major land, they will assume this financial obligation and the Retalis brothers will not be liable.
- Subsequently, in the course of time, the Retalis brothers divided the central undivided land among themselves and George D. Retalis received the part that included the holy church of Agioi Theodoroi, of fifteen acres. His children inherited it when he passed and they in turn distributed his property by a relevant contract of 1932 of the notary of Nafplion, Panagiotis An. Perrakis.
- The new land that was created and which included the church, was given to Michael Georg Retalis. His heirs Penelope Arvanitis née Retalis, Niki Chiotakakakou née Retalis and George M. Retalis, in 2015 donated the Holy Church of Agioi Theodoroi to the Holy Church of St. Constantine and Helen of Nafplio.

Moreover, G. Chorras [28], refers to the property of Theodoros Kolokotronis in Nafplio and gives another dimension to the issue. He wrote that “the victors, worn out by the struggles, looked to Nafplio, in Kolokotronis’ words, ‘as the anchor of Greece”. In addition to Theodoros Kolokotronis, G Chora mentions the property of Bouboulina in Agia Moni, Miaoulis at the Prophet Elias and Manto Mavrogenous next to Agios Spyridon and essentially claims that Nafplio was an attractive destination for important personalities of the revolution.

The church of Agioi Theodoroi is neither mentioned nor analyzed by researchers of Byzantine architecture, besides, it is not a listed monument until today. In its present form, it is a small, mono-spatial, runic church with a gable roof and semicircular sanctuary arch. Ioannis D. Varalis, Associate Professor of Byzantine Archaeology at the

University of Thessaly, Department of History, Archaeology and Social Anthropology, in his presentation [26], attempting to link the temple with similar cases, mentions the following characteristic buildings of post-Byzantine temple architecture in Argolida.

- Ligurio, monastery of Agios Mercurion, late 17th and early 18th century (single-aisle basilica)
- Prosymni, church of St. John, 18th century (?) (Single-aisle Basilica)
- Asini, church of Agios Dimitrios, 18th - 19th century (single-aisled basilica)
- Argos, Agios Charalambos in Trikoupis property, approx. 1830 (Single-aisled basilica)
- Asini, Transfiguration of the Saviour, 14th - 15th century and wall. 1569 by Theodosius Kakavas (single-aisle basilica)
- Epidaurus, monastery of Panagia Polemarcha, 15th and early 18th century (Triclinic Basilica)
- Argos, church of St. John, 1829 (Triclinic Basilica)
- Nafplio, church of St. George, addition of western portico and narthex, 1834 (triple-aisled basilica)
- Ligurio, Assumption of the Virgin Mary, 1701 (Cruciform inscribed)
- Ligorio, Agia Marina, 1713 ("Cruciform inscribed")
- Argos, Agios Vasilios, late 17th century (Cruciform)
- Plataniti, Assumption of the Virgin Mary, late 17th century (Cruciform)
- Argos, Agios Nikolaos, late 15th c. and ca. 1700 (Cruciform)
- Arachneio (Heli), complex of the churches of Agios Nikolaos (Assumption of the Virgin Mary) and Agia Marina, late 15th - early 16th century (Cruciform churches)

Based on the above and on the evidence that has emerged so far from the external plaster removals in the project, the church of Agioi Theodoroi represents a typical example of post-Byzantine church architecture in Argolida, following the type of the single-aisle basilica with a gabled roof with a tiled roof that we find in Lygourio and Asini. The masonry is for the most part with rough or semi-worked stones, bonded with mortar and is differentiated on the eastern side where the niche of the sanctuary is located. The sanctuary consists of a three-sided niche and is one of the places where the masonry layers are built of many large, squared stones, with very small joints and almost no mortar. Most of the interventions are on the west side of the church and around the upper layers of the masonry, which proves the multiple interventions on the roof. Of particular interest is the corner connecting the eastern and western sides of the church. Before the work was started, all the walls were plastered and painted. During the external plaster removal of the walls, different building phases gradually appear. Inside, the temple is single aisled (mono-spatial) and there seems to have been a large arch supporting the roof, starting from the floor, and forming a semicircle. Today there is only part of the arch as shown in the section AA drawing (see Fig. 15).

It should be noted that the only drawing documentation in which the temple building appears are two. The topographical diagram for Nafplio of the French scientific expedition of the Moria (1828-1836) [29] and the attached drawings of the contract number 15.987/02-08-1871 of the notary of Athens Vasileios Lambroulis. In it Theodoros (or Falez) of Konstantinos Kolokotronis and Rallou Karatzas (grandson) sells to his daughter's husband (his son-in-law) various parts of the original inheritance both located in Dalamanara Argolida, and in the location "Kipos Kiouloutepes" which he held ex-dividedly with his sisters from their father (see Fig. 14).

ΕΦΗΜΕΡΙΣ ΤΗΣ ΚΥΒΕΡΝΗΣΕΩΣ

ΤΟΥ ΒΑΣΙΛΕΙΟΥ ΤΗΣ ΕΛΛΑΔΟΣ.

ΑΡΙΘ. 10. 1839 *ΕΝ ΑΘΗΝΑΙΣ*, 23 *Μαΐου.*

ΣΥΝΟΨΙΣ ΤΩΝ ΕΜΠΕΡΙΕΧΟΜΕΝΩΝ.

Διάταγμα Περὶ ἐλαττώσεως τοῦ ναύλου τοῦ Βασ. ἀτμοπλόου «Μαξιμιλιανοῦ». — *Δηλοποιήσεις* — 1) Περὶ ἀνανεωθέντων πωλητηρίων ἐθνικῶν κτημάτων παρὰ τοῦ Ἐλεγκτικοῦ Συνεδρίου. — 2) Περὶ ἀναγνωρίσεως τοῦ Κ. Α. Βερτράνδ ὡς Ὑποπροξένου τῆς Παππικῆς Κυβερνήσεως εἰς Σύρον. — 3) Περὶ ἀναγνωρίσεως τοῦ Ἱππότου Κ. Δαβὶδ Πασιφίκου (David Pacifico) ὡς Προξένου τῆς Α. Μ. τῆς Βασιλίσσης τῆς Πορτογαλλίας, τοῦ δὲ Ἱππότου Κ. Δ. Μορέλλη ὡς Γεν. Προξένου τῆς Α. Μ. τοῦ Βασιλέως τῶν δύο Σικελιῶν εἰς τὴν Ἑλλάδα. — 4) Περὶ διορισμοῦ τοῦ Κ. Laurent Jules Bammucci ὡς Προξένου τῆς Ἑλλάδος εἰς Πάνορμον τῆς Σικελίας. — *Ἀγγελίαι* ἀφορῶσαι τὴν δημόσιον ὑπηρεσίαν.

ΔΙΑΤΑΓΜΑ

Περὶ ἐλαττώσεως τοῦ ναύλου τοῦ Βασ. ἀτμοπλόου «Μαξιμιλιανοῦ».

ΟΘΩΝ

ΕΛΕΩ ΘΕΟΥ

ΒΑΣΙΛΕΥΣ ΤΗΣ ΕΛΛΑΔΟΣ.

Ἐπὶ τῇ ἀπὸ 12 Ἀπριλίου τ. ε. προτάσει τῆς Ἡμετέρας ἐπὶ τῶν Ἐσωτερικῶν Γραμματείας ἀπεφασίσαμεν καὶ διατάττομεν τ' ἀκόλουθα·

1. Ἡ πληρωμὴ τῶν θέσεων διὰ τοὺς μεταξὺ Πειραιῶς καὶ Σύρου μετακομιζομένους διὰ τοῦ ἀτμοταχυπλόου «Μαξιμιλιανοῦ» ἐπιβάτας προσδιορίζεται εἰς Δρ. 8 διὰ τὰς πρώτας θέσεις καὶ εἰς Δρ. 4 διὰ τὰς δευτέρας.

2. Τὰ παιδία μικροτέρας ἡλικίας δέκα ἐτῶν θέλουν πληρώνει τὸ ἥμισυ δικαίωμα τῆς ἄνω τιμῆς, κατὰ τὴν θέσιν τὴν ὁποίαν κατέχουν.

3. Ἡ πληρωμὴ τῶν αὐτῶν θέσεων διὰ τὰ λοιπὰ μέρη, ὅπου διαπλέει τὸ αὐτὸ ἀτμοκίνητον μένει ἡ αὐτή, ἥτις ἐπροσδιωρίσθη εἰς τὸ ἀπὸ 23 Αὐγούστου (4 Σεπτεμβρ.) 1837 Ἡμέτερον Διάταγμα καὶ ὑπάρχουσιν ἐν ἰσχύει ὅσα δὲν ἀντιβαίνουσιν ἐν τῷ παρόντι.

4. Ὁ Ἡμέτερος ἐπὶ τῶν Ἐσωτερικῶν Γραμματεὺς θέλει ἐνεργήσει καὶ δημοσιεύσει ἀναγγέλλων τὸ παρὸν Διάταγμα·

Ἐν Βαρεμπόπη, τὴν 4 (16) Μαΐου 1839.

ΟΘΩΝ.

Ὁ ἐπὶ τῶν Ἐσωτερικῶν Γραμματεὺς τῆς Ἐπικρατείας
Γ. ΓΛΑΡΑΚΗΣ.

Fig. 13. Documentation Law (FEK) 10 / 23-05-1839 (Adopted from [13]).

Η ΔΙΑΘΗΚΗ ΤΟΥ ΣΤΡΑΤΑΡΧΟΥ
ΘΕΟΔΩΡΟΥ ΚΟΛΟΚΟΤΡΩΝΗ

ΣΧΟΛΙΑ & ΚΡΙΣΕΙΣ

ΛΑΪΚΗ ΣΧΟΛΗ

ΠΕΡΙΛΗΨΙΣ

ΘΕΟΔΩΡΟΣ ΚΟΛΟΚΟΤΡΩΝΗΣ

Fig. 14. Documentation publication by the Athens District Court of 25 May 1868 of the secret will of Lieutenant General Ioannis Gennaios Th. Kolokotronis (Adopted from [13]).

Fig. 15. Documentation of the attached drawings of the contract number 15.987 / 02-08-1871 of the notary of Athens Vasileios Lambroulis (Adopted from [14]).

3.3 Architectural Documentation Data

For the needs of the project, floor plan, section and elevation drawings were prepared to date (see Fig. 16, Fig. 17). The architectural documentation drawings (derived from the geometric documentation) provided information on the state of preservation of the structure. The construction phases of the project were observed and validated as well as individual alterations to the surface of the structures. In addition, the developed orthophotos from the geometric documentation process were digitized for each façade, contributing to the interdisciplinary process as presented in this paper. Each element is to be classified in terms of building material, deterioration, architectural and artistic details (see Fig. 18, Fig. 19). During the process of mapping the classified data, several layers of information were created, forming a database.

The external dimensions of the main temple are 5.60 m × 9.90 m, and the dimensions of the basic rectangular plan are 3.90 m × 8.30 m. To the west, the frontage is extended by 3.50 m. The thickness of the wall construction varies due to the semicircular section of the masonry. At the height of the present road the thickness of the north wall is about 83cm, on the south frontage 83, 75 cm, on the east frontage 85, on the sanctuary niche 50cm and on the west 73cm.

From the data of the project so far, two large construction units have been identified, the main single-space temple (Construction Unit A - KEA) and the portico on the west side of the temple (Construction Unit B - KEB). The main temple comprises the following building units:

1. The construction sub-unit 1 (KEA1) includes the pitched roof, consisting of a main truss on which the ridge beam is supported and four smaller trusses with

different slope on which are supported the rafters, the thin wooden layer, and the Byzantine-type tiles.

2. The construction sub-unit (KEA2) includes a small perimeter zone at the top of the masonry. A large section of the western masonry has also been included in this sub-unit. The upper part of the western masonry remains undetermined due to the non-completion of plaster removal works.
3. The construction sub-concept (KEA3) includes most of the masonry of the main temple. It is rough or semi-worked stones (combination of small and large sized stones), bonded with mortar. Large stones are used in the corners and carved material has been used in the opening on the north side.
4. The construction sub-unit (KEA4) appears exclusively in the polygonal niche of the sanctuary (eastern side) and consists of carved stones. Of particular interest is the fact that this type of masonry is found starting about 15-30 cm above the present ground level. Further work will be needed to identify and study the foundations of both the eastern and southern sides.
5. Construction sub-units (KEA5) and (KEA6) are located on the south side in limited locations. In particular, a double section of masonry has been identified in (KEA5) and a construction discontinuity has been identified in (KEA6) above the current opening.
6. The portico on the west side of the temple includes the construction units (KEB1) and (KEB2)
7. The construction sub-unit (KEB1) includes the two rough or semi-worked stone walls of the portico while (KEB2) includes the two piles. From the excavations in the northern part, it has been established that the foundations of the two sub-units are at a higher level. It has also been established, from photographs taken in the 1950s and 1970s, that the portico has undergone various alterations.

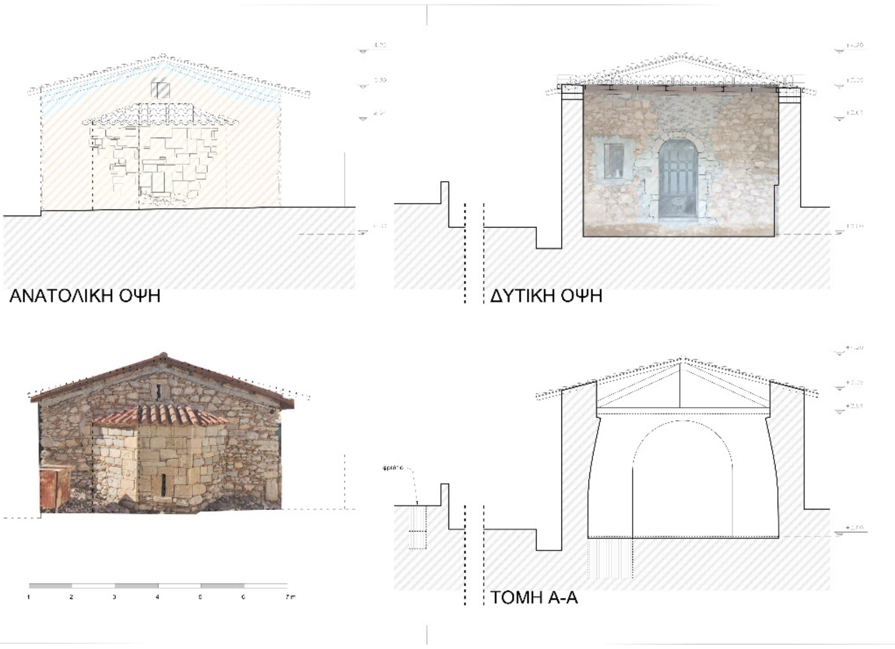

Fig. 16. Clockwise Architectural drawing of the East Façade, Architectural drawing of the West Façade, Cross Section A-A drawing, Orthoimage of the East Facade

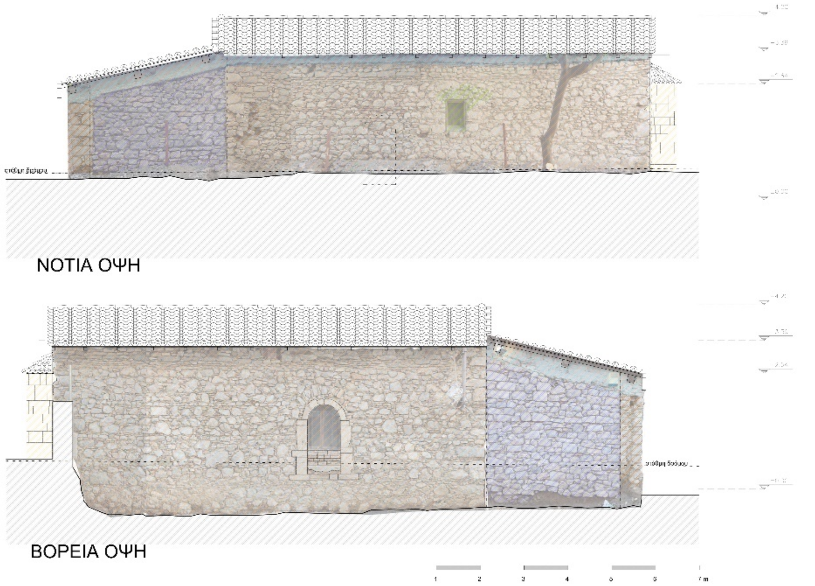

Fig. 17. Up Architectural drawing of the South Façade, Down Architectural drawing of the North Façade.

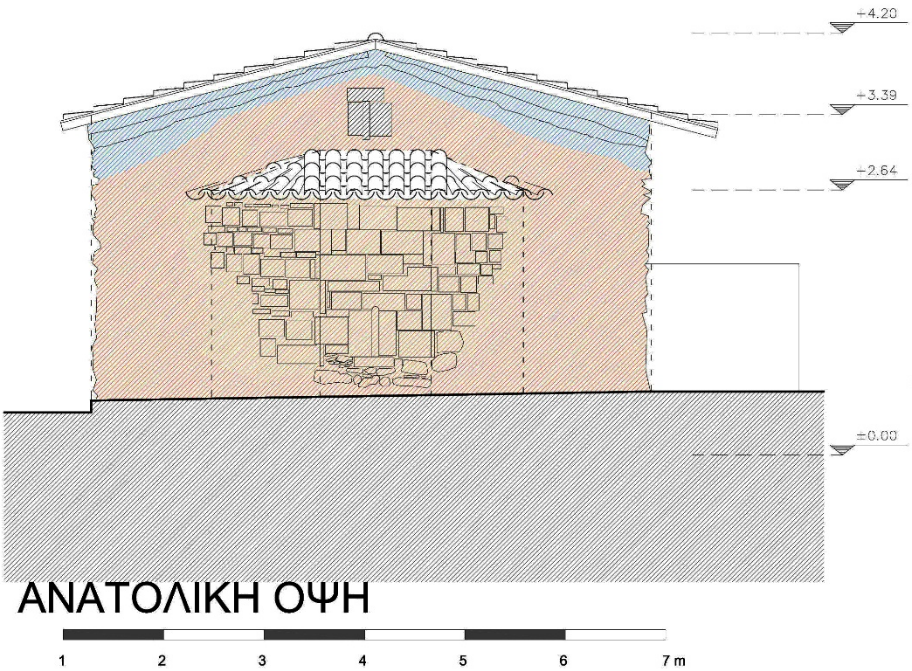

Fig. 18. Construction phases thematic map-east façade.

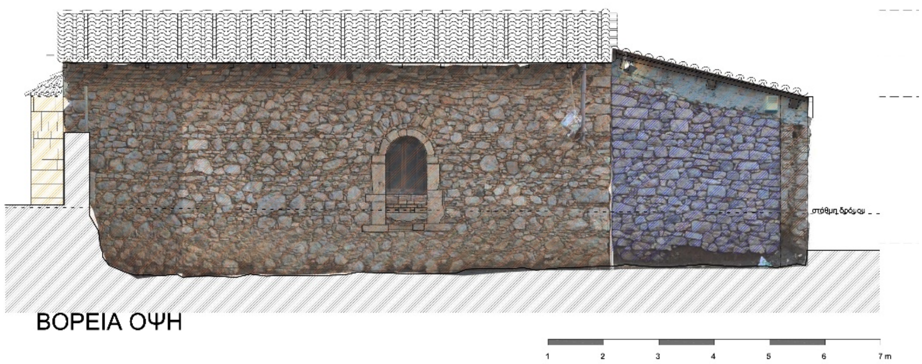

Fig. 19. Construction phases thematic map – north facade

4 Conclusion

As shown in the construction phases of the monument (images), the main church retains the original building materials except for the roof, a large part of the west façade and the window of the south façade, where there is an undocumented restoration that took place in the 1950s. In addition, older and more recent building interventions have taken place on the portico and are probably related to the interventions on the west elevation and the double masonry that appears on the corner of the west and south elevations. The eastern side has suffered the least interventions but the part of the masonry of the polygonal niche of the sanctuary remains unclear.

Besides the thematic maps of building phases, it is important to develop thematic maps of building material and decay in order to be able to perform a combined (historical / architectural / decay of materials) qualitative and quantitative assessment of the state of the monument.

This paper describes the progress of restoration and enhancement of the Church and the first results from the introduction of a specific interdisciplinary data representation methodology using CAD technologies. The data is derived from historical, architectural, geometric, structural and deterioration documentation (Figure 21).

The representations relate to the state of preservation in terms of pathology of building materials in combination with the geometric and architectural documentation data. The construction phases of the monument are also depicted, ensuring sustainability in terms of planning and implementation of conservation and restoration interventions. Each documentation process contributes equally to the illustrated diagram to create the multi-thematic thematic maps.

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Post-earthquake assessment of monumental building in Croatia by 3Muri software

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Abstract. A series of earthquakes in and close to city of Zagreb, Croatia during the 2020 severely damaged the masonry cultural heritage buildings built in the 19th century. The article presents the assessment of post-earthquake design of retrofitting of damaged historic masonry structure of the former synagogue in city of Sisak, Croatia erected in 1890. The former synagogue was severely damaged during the recent earthquake. For the purposes of the post-earthquake retrofitting and strengthening, an analysis of the damaged and retrofitted structure has been carried out to justify the selected retrofitting measures that included a partial reconstruction of heavily damaged structure. The equivalent frame model based on the discretization in terms of piers and spandrels was created (SEM - Structural Elements Model) to obtain the simulation of earthquake response of structure using the 3Muri 13.9 software. In this paper the procedure and results of the analysis of seismic resistance of the strengthened structure is presented because of the successful cooperation of structural engineers, architects and conservators.

Keywords: Earthquake 2020 Croatia, Monumental Building, Retrofitting, Structural Elements Model, Assessment, 3Muri program

1 Introduction

The year of 2020 was the year of serious earthquakes affecting the north-western part of Croatia including capital Zagreb. On 22. March 2020 the M_W 5.4 earthquake with epicenter in the northern suburban scattered populated hilly area of Zagreb was the first in row of earthquakes that culminated with 55 km south-east M_L 6.2 earthquake close to the village of Strašnik in Banovina region of Croatia. According to [1] the accelerograms of Strašnik earthquake has been recorded in 6 seismograph stations located in Zagreb area in average distance of 52,5 km. The highest PGA amplitudes were derived from the records of station named QKAS located in Zagreb area 57.8 km north of epicenter. The value of the horizontal south-north direction PGA (pick ground acceleration) was 0.248g and the value of the vertical PGA was 0.125g. The values of corresponding PGAs obtained from accelerograms recorded in other 5 stations were roughly 50% of the QKAS recorded values. Author [1] explains the reason for differences with the geological characteristics of locations where stations are located. In case of QKAS they may be identified as ground type C according to Eurocode 8, while on other 5 locations the ground properties correspond type A (see Fig.1(a)).

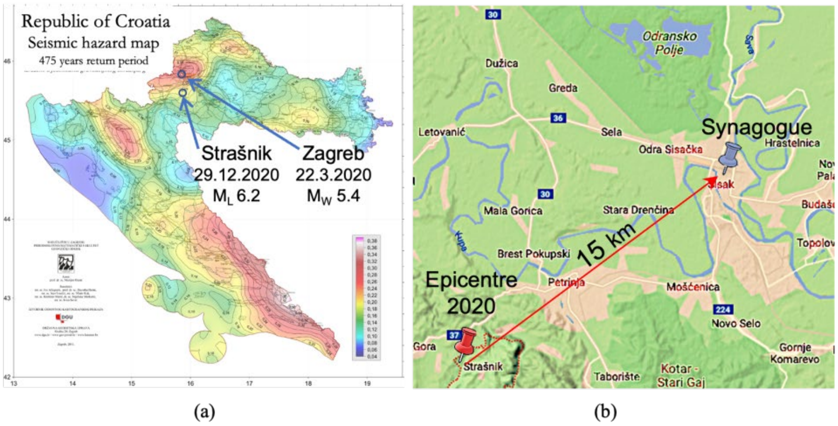


Fig. 1. Location of earthquakes in Croatia in year 2020 (a) and location of building of former Synagogue in Sisak, presented in this article (b)

Article presents and discusses the concept design of retrofitting and partial reconstruction of the monumental historic building affected by the 29. December 2020 earthquake having epicenter 15 km South-West of its location (see Fig.1(b). The concept is the result of teamwork of architects, conservators, and structural engineers (the authors of this article). The efficiency of proposed retrofitting measures has been assessed by program 3Muri which is in wider use for assessment of seismic resilience of masonry structures.

2 Description of building and concept of retrofitting

The building was constructed during the period from 1862 and 1892 in romantic historicism style as a synagogue financed by the local Jewish community of Sisak. During WW2 the building was expropriated and adapted for use by the authorities. From 1967 until 2020 earthquake, it serves as a music school. Due to its historic and architectural values it is registered as a cultural monument.

It is erected at very demanding location because of geological characteristics and archeological remains of Roman town Siscia established in the 1st century B.C. Beneath the building are layers of soft alluvial deposits up to 30m deep, formed by three nearby confluenting rivers: Sava, Kupa, and Odra (see Fig.1(b)). During the December 2020 earthquake was present phenomena of local soil liquefaction in wider area of town Sisak. The builders were aware of geotechnical conditions and thus foundations were constructed of brick masonry in good mortar down to depth of 280 cm.

Layout of building is of orthogonal shape long 20.15m and wide 16.15. The height of the building is 15,5 m. Parts of the building, as originally constructed, are of burned clay solid bricks laid in lime mortar. Brick dimensions are l/d/h=30/15/7.5cm. Their characteristic compression strength is 15 MPa. Lime mortar is of different quality in ground floor and first floor walls. Mortar on the first floor is of very poor quality with an estimated compressive strength of 0,2 MPa while the mortar of ground floor walls has estimated compressive strength of 0,7 MPa.

After expropriation of synagogue during the WW2, the ground floor interior was changed by adding partition walls of different thickness. The central open space was divided in height by massive new floor structures (see Fig.3(a)). Façade windows were partially or entirely closed by masonry infills. The massive masonry arches supporting the timber domes and domes themselves were preserved in the original form while passages between rooms were partially or entirely closed (see Fig.4).

(a) (b)

Fig. 2. Building before (a) and its front façade after (b) the earthquake of December 2020

Earthquake of 29. December 2020 seriously damaged masonry walls. Gamble of western façade collapsed and façade walls severely cracked (Fig.2 (b)). Other façade walls sustained less damages concentrated merely along the contacts of original and infilled parts of walls in the original openings. Similar patterns of damage developed in the first-floor walls (Fig.4 (a)) where masonry arches cracked along their perimeter lines. Lightweight timber dome (Fig.4 (b)) supported by masonry arches remained undamaged. In general, the western massive part of buildings sustained mayor structural damages. Assumably it may be the consequence of tilting of the western part of building due to local ground properties where phenomenon of liquefaction might develop during the earthquake excitation.

Learning from the earthquake response of building the concept of partial reconstruction and retrofitting was developed as joint endeavor of asset owner, architects, conservators, and structural engineers. The main suggestion of structural engineers was to use lightweight materials where possible to reduce future inertial horizontal forces due to earthquake excitation and to reduce vertical loading transferred to problematic ground.

(a) (b)

Fig. 3. Longitudinal (East-West) (a) and lateral (South-North)(b) cross-section of buildingacquired from 3D point cloud model after earthquake of December 2020

(a) (b)

Fig. 4. The first floor (view towards West) damaged by the December 2020 earthquake (a) and attic with upper surface of the main timber dome (view towards West) (b)

3 Concept of partial reconstruction and retrofitting of building

Upon request of owner the layout building interior and shape and dimensions of façade openings should be returned to the original shape of building. It was a challenging task from the perspective of seismic resilience especially because of the conservator's request for preservation of original structural elements anywhere it is possible. However, the general understanding of the need to introduce the structural elements made of wood due to reduction of masses has been achieved. Following the suggestion of team members responsible for structural issues, intervention would encompass following:

- Removal of ground floor inner walls, floor structures above the ground floor and walls of the first floor including masonry arches, timber domes and roof structure.
- Restoring window openings on the ground floor to their original shape adding the r.c. encirclements.

- Repairing of ground floor façade walls by grouting and partial replacing of week mortar and construction of the inner r.c. frames (see Fig.5) and laying of horizontal r.c. tie beams atop the repaired ground floor façade walls.
- Construction of the first-floor inner masonry walls and façade walls extended to roof knee and gable walls with horizontal r.c. tie beams.
- Installation of laminated timber arches and domes on the first floor and CLT floor diaphragms (see Fig.6). Poz.1 and 2 are 15 cm thick CLT panel, Poz. 3 is 18 cm thick CLT panel, Poz. 4, 5 and 6 are timber domes.

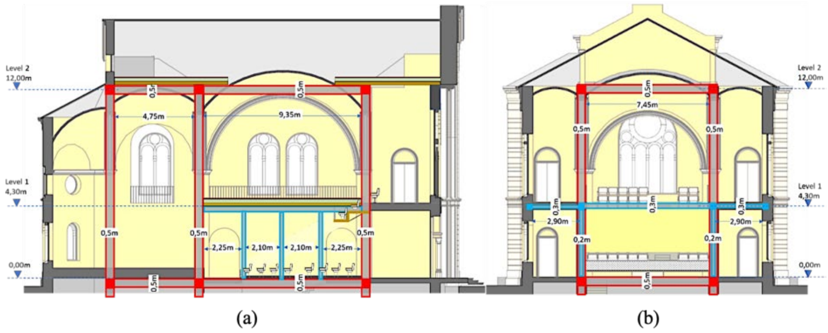


Fig. 5. Concept of retrofitted and added structural elements: longitudinal (East-West) (a) and lateral (South-North)(b) cross-section of building.

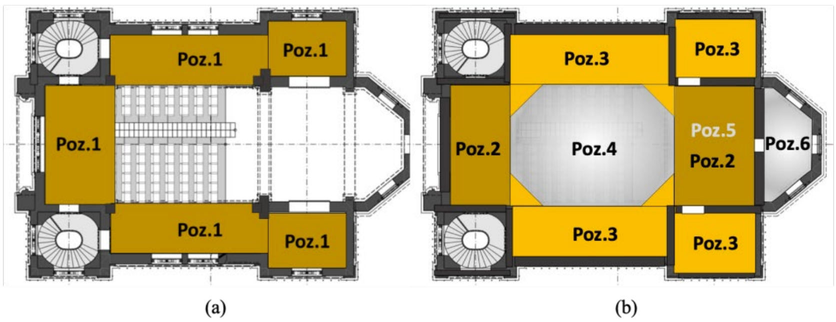
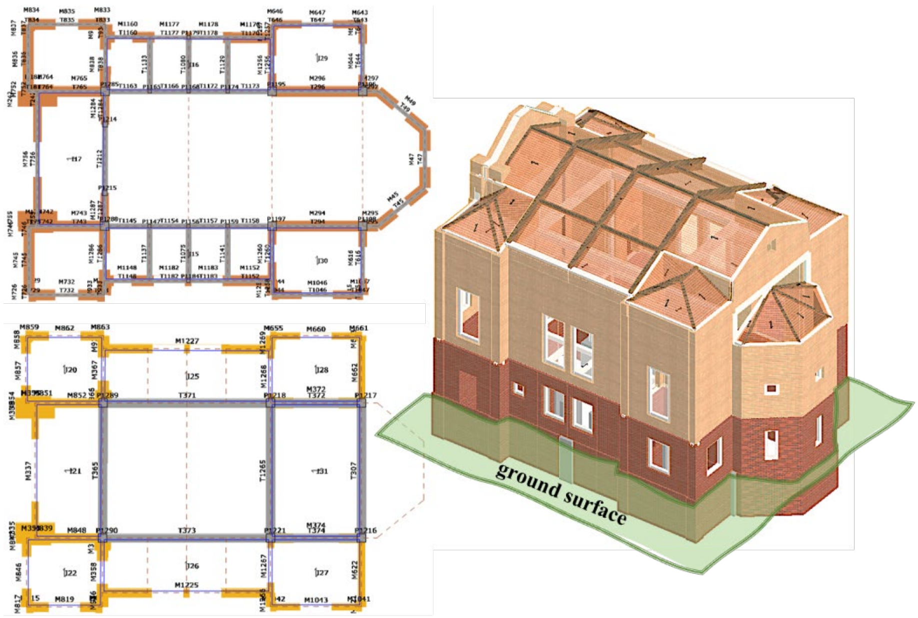


Fig. 6. Added horizontal diaphragms on first floor (a) and attic level (b)and timber domes on the attic level (b).

The thickness of the ground floor masonry walls is 61 and 46 cm, while the first-floor walls will be thick 46 and 30 cm. Use of the bricks of the same type as originally used is requested by conservators. The percentage of reinforcement of main inner frame columns is equal to 3.5% of their cross-section area. The percentage of reinforcement of main inner frame beams is equal to 1.2% of their cross-section area.

4 Seismic resilience assessment of the retrofitted building

The soundness and adequate earthquake resistance of proposed structural concept was verified by seismic analysis of the equivalent frame model based on the discretization in terms of piers and spandrels was created (SEM - Structural Elements Model). The simulation of earthquake response of structure was carried out by the 3Muri, v.13.9 [2] software for the assessment of structures constructed of masonry and mixed materials through a non-linear (pushover) and static analysis. Theoretical background and practical application of software is presented in [3]. 3Muri is also frequently used for assessment of buildings affected by the earthquakes in Croatia in the year 2020 [4] such is the herein presented case.

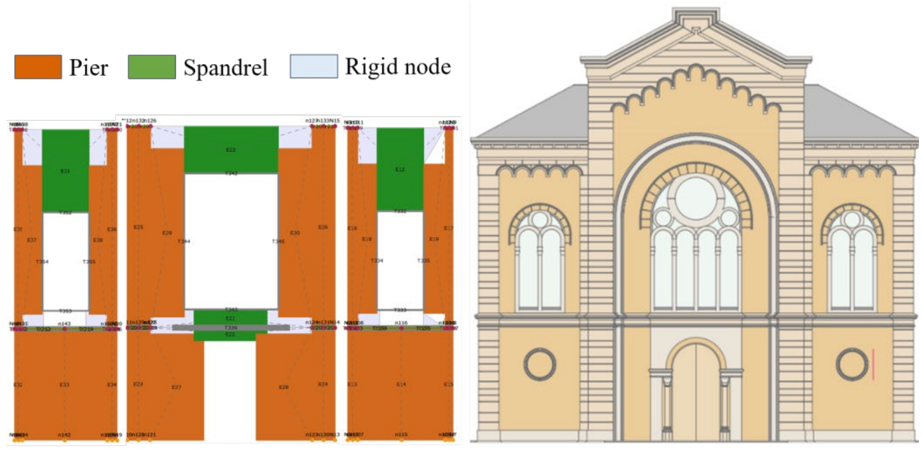


(a) (b)

Fig. 7. Ground floor and the first-floor layout of building model (a) and its 3D model (b)

In the presented layouts of ground and first floor (see Fig.7 (a)) and 3D model of building (see Fig.7 (b)) the position of existing and new structural elements (masonry walls, r.c. frames and timber roof structure). The existing masonry which will be repaired is in darker color while the new one is in lighter color.

In the equivalent frame approach, only the in-plane response of the URM walls is considered, and each wall is discretized by a set of masonry panels (piers and spandrels), where the non-linear response is concentrated, connected by a rigid area (nodes). The wall idealization into an equivalent frame affects both the elastic field, since it alters the actual deformability of the wall due to the simplification of introducing rigid nodes, and the nonlinear phase of the response, since the regions where the cracks and nonlinearity are likely to develop are assumed a priori. Despite these simplifications, this approach is one of the most spread both in engineering practice and at the research level thanks to its computational efficiency in performing nonlinear analyses and its reasonable accuracy, as proven by various numerical simulations in the literature [5]. Fig. 8 illustrates the discretization of the entrance façade walls.



(a) (b)

Fig. 8. Equivalent frame idealization (a) of the entrance façade (b)

In Table 1 are presented mechanical properties of masonry as used in the model of building. The properties of the existing masonry have been derived from the results of standard on-site testing of masonry ("flat jack" compressive test, mortar joint shear test) and laboratory testing of bricks and mortars. The properties of the new masonry were derived from the published sources. The sheer strength of masonry macro-elements was calculated according to Turnšek-Čačovič theory [6].

Table 1. Mechanical parameters assumed in the SEM model.

Solid brick and lime mortar[1]	**E [MPa]**	**G [MPa]**	**w [kN/m3]**	**f_m [N/cm2]**	**τ_0 [N/cm2]**
Existing masonry	1600	250	18	150	5
Newbuilt masonry	2100	350	18	230	7,6

(1) E: modulus of elasticity, G: shear modulus, w: average specific weights, f_m: compressive strength, τ_0: shear strength. The strength values must be divided by the CF, assumed equal to 1.2.

4.1 Results of the modal analysis

The modal analysis was performed to interpret the dynamic response of the whole building in the original and new configuration. The effect of replacing reinforce concrete heavy rigid floors with lightweight cross-laminated wooden floors is in reducing of total mass of building (M_{TOT}) for 9%.

Table 2 shows the main results of the modal analysis of building in the new, retrofitted and partially reconstructed configuration in terms of period (T), frequency (n), and percentage of participation mass (%Mx, %My, and %Mz). The results are illustrated by selecting the first 10 modes; the most significant ones in terms of participation mass are marked in grey.

Table 2. Results of the modal analysis

Lightweight rigid floors (CLT) M_{TOT} = 1.320.430 kg										
Mode	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
T [s]	0,67	0,47	0,45	0,43	0,33	0,25	0,25	0,23	0,22	0,19
n [Hz]	1,45	2,12	2,22	2,31	2,98	3,96	4,11	4,31	4,49	3,35
$\%M_x$	0,00	0,05	0,11	**66,86**	4,71	0,02	0,80	0,90	0,00	1,15
$\%M_y$	**60,88**	5,32	0,02	0,00	0,04	5,22	0,08	0,13	22,38	0,00
$\%M_z$	0,00	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00

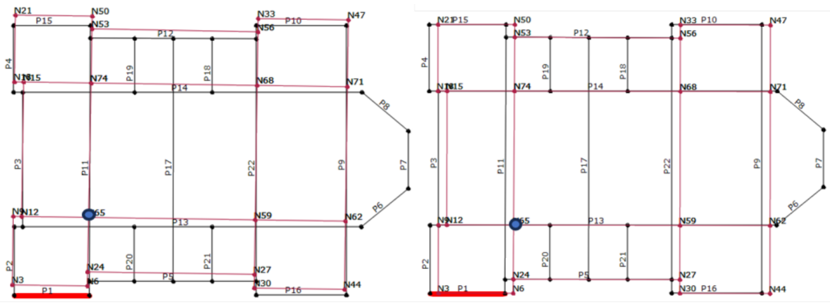


Fig. 9. Comparison of modal shapes for Modes 1 (a) and 4 (b)

4.2 Results of nonlinear static analysis

Nonlinear static analysis was performed on the global equivalent frame model (Fig. 7). Pushover curves were extracted by plotting the shear at the base of building (V) as a function of the mean displacement of the nodes placed at the last floor (d). The control node was defined according to displacements calculated by modal analysis (Fig. 8). The corresponding capacity curves (V* − d*) of the equivalent Single Degree of Freedom (SDOF) system were defined, by following the general principles of [7], based on the evaluation of the participation coefficient Γ and the mass M* of each unit (having extracted from the 3D model the data related to each of them). Thus, each capacity curve was obtained by dividing the displacement d by Γ ($d^* = d/\Gamma$) and the base shear by the product ΓM* ($V^* = V/(\Gamma M^*)$). Finally, for the seismic verification, the capacity curve was compared with the seismic demand. The analyses were performed by adopting, for each examined direction (+X, −X, +Y, and −Y), two different load patterns (LPs): proportional to masses (hereafter referred to as “uniform”) and proportional to the product mass per height (hereafter referred to as “pseudo-triangular”). The results refer to the analysis step corresponding to a 20% decay of the base shear, assumed as representative of the Significant Damage limitstate (SD) and Damage Limitation limit state (DL).

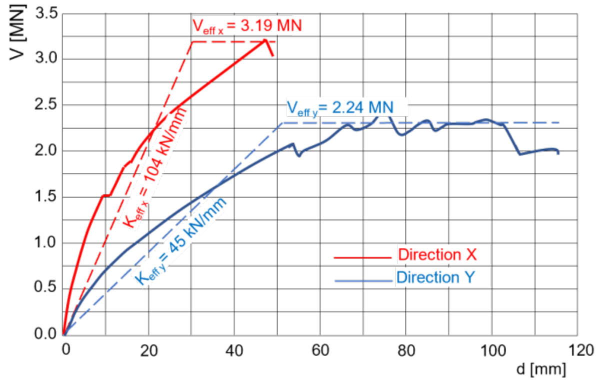


Fig. 10. Comparison of modal capacity curves in direction -X and +Y obtained by most significant analysis.

Altogether 24 analyses were performed and the capacity curves of the most significant ones, in -X and +Y are presented in the capacity curves in Fig. 9. The corresponding effective story stiffnesses (K_{eff}) and effective shear at the base of building (V_{eff}) were derived from the analysis results. As it can be seen from the values of periods (T) in table 2 and diagrams in Fig. 9 the stiffness and earthquake resistance of structure is much higher in the longitudinal direction (Y) due to the flexibility and ductility of the reinforced concrete frames creating the core of structure (Fig.7). The ductile mechanism of the structure response with sufficient level of resistance well justifies the selected strategy of structural strengthening introducing r.c. frames and lightweight, stiff CLT horizontal diaphragms and lightweight timber central dome.

The following tables 3 to 5 present the detail data of the response of structure. As it is presented, the repaired, strengthened and partially reconstructed building in each direction satisfies the demands of the Eurocode 8 (α parameters are higher than 1.0).

Table 3. Verification of structure seismic vulnerability

Limit state	PGA [m/s2]		α	
	Direction X	Direction Y	Direction X	Direction Y
Significant damage SD	1.062	1.713	4.721	7.613
Damage limitation DL	0.888	1.022	7.399	8.514

PGA: limit capacity acceleration, α=PGA/a_{gR}, a_{gR}: design ground acceleration at site

Table 4. The limit state parameters

Limit state	Direction X	Direction Y
SD	d_t = 7.7mm < d_m=36,6mm	d_t = 11.3mm < d_m=86,3mm
DL	S_d 3.5mm < d^*_y=26,2mm	S_d 5.4mm < d^*_y=46,1mm

d_t: the target displacement of the Multi Degree of Freedom (MDOF) system dt=d*t x Γ, d_m: the ultimate displacement of the Multi Degree of Freedom (MDOF), d^*_y: the yield displacement of the idealized SDOF

Table 5. Analysis parameters

Parameter	Direction X	Direction Y
Period of the equivalent system T*[s]	0.555	0.848
Mass of the equivalent system m*[t]	812.26	792.65
Total mass until achievement of a term of values w[t]	1537.38	1537.38
Ratio m*/w [%]	51.8	50.58
Modal participation factor Γ	1.17	1.12
Plasticization strength of the equivalent system F^*_y [MN]	2.73	2.01
Plasticization displacement of the equivalent system d^*_y [mm]	26.2	46.1
Ultimate displacement of the equivalent system d^*_u[mm]	41.8	103
Available ductility d^*_u/ d^*_y	1.60	2.23

In addition to seismic analysis, 3Muri program enables the static analysis. Load bearing cappacity of masonry is checked according to Eurocode 6. In herein describedcase, all walls and reinforced concrete element meets required cappacity as it is presented in Fig.11. In table below N_{ed} represents the design value of the applied axial force on the masonry pier, while N_{Rd}represents the resistance of the masonry pier to the applied force. All piers satisfy the requested criteria, since the ratio N_{ed} /N_{Rd}< 1.0.Parameter h_{ef} refers to the effective height of masonry pier and t_{ef} stands for the effective thickness of masonry element. The limit slendernes ratio h_{ef}/t_{ef}should not exceed the value of 20 for the unreinforced masonry. In our case the values are just slightly exceeded at some masonry piers.

Wall	Failed piers	Ned/NRd Max	hef/tef Max
1	0	0,45	15,10
2	0	0,69	15,10
3	0	0,62	20,26
4	0	0,68	15,10
5	0	0,45	15,10
6	0	0,15	7,05
7	0	0,16	7,05
8	0	0,15	7,05
9	0	0,36	20,26
10	0	0,38	20,26
11	0	0,48	12,62
12	0	0,46	15,10
13	0	0,66	15,10
14	0	0,65	15,10
15	0	0,46	15,10
16	0	0,38	20,26
22	0	0,40	20,26

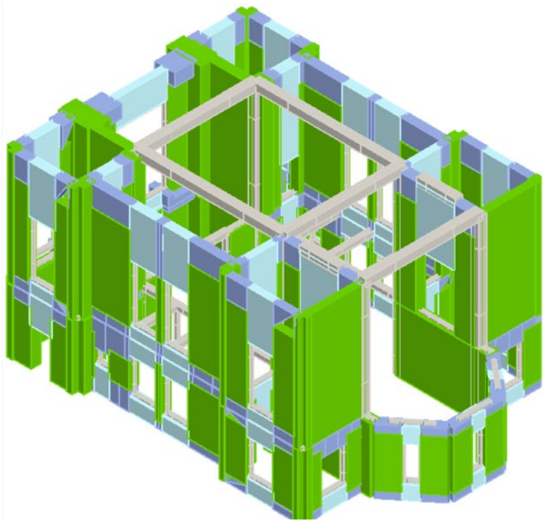


Fig. 11. Results of static analysis of structure

The distribution of damages at significant damage (SD) limit state due to action of earthquake action in longitudinal (X) and transversal (Y) direction is presented in Fig. 12 where the legend of diferent damage stages of structural elemnts is added. More the half of masonry piers and wals as well as all reinforced concrete columns and beams are undamaged. The rest of masonry pier suffered shear failures that did not jeopardize the stability and integrity of structure as whole. The global stability and integrity of the structure is provided by the strong inner reinforcedconcrete frames undamaged.

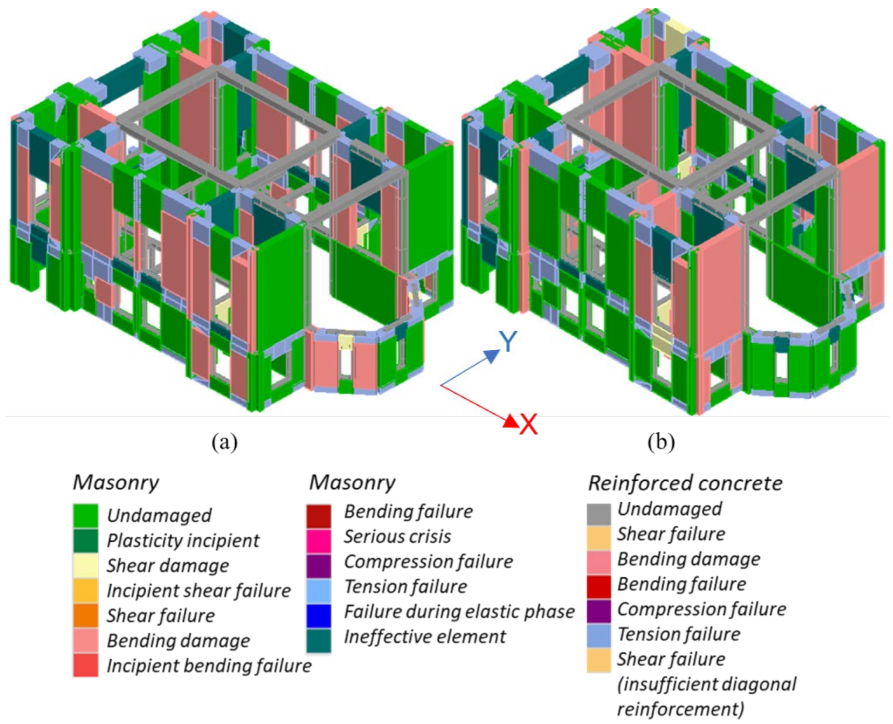


Fig. 12. Damage pattern of structural elements resulted from the seismic analysis at achieved story displacement d of 48.8 mm and base shear force V of 3.20 MN in X direction (a) and story displacement d of 115.0 mm and base shear force V of 2.39 MN in Y direction (b).

The presented damage pattern of structural elements provides information on the critical parts of building and its global response to earthquake action. This information is crucial for the design of structure as whole because the weak parts can be identified and strengthened if needed. However, in the presented case there is no need for further strengthening of structural element because in configuration as presented it fulfills the requirements of Eurocode 8 as justified by data in Table 3 above.

5 Conclusion

Presented case of post-earthquake design of heavily damaged historic masonry building located in Sisak, Croatia describes the strategy and results of heritage building retrofitting design. Following the conservator's guidelines and owner's requirements for the future use of building the concept of retrofitting took into consideration the preservation of heritage character of building. Thus, the building envelope constructed of unreinforced masonry (URM) was preserved and reconstructed following the original form of building erected by the end of 19th century. In the inner part of structure is placed the strong reinforced concrete frame that together with URM provides sufficient earthquake resistance according to Eurocode 8. In order to reduce the masses all floor structures were constructed of cross-laminated timber instead of reinforced concrete what reduced the total mass of structure by 9%.

Acknowledgment

The presented case of earthquake resistance assessment of repaired, strengthened and partially reconstructed building is a part of design documentation produced by PLANETARIS Ltd, Vodnikova 11, 10000 Zagreb, Croatia. The authors of this article contributed earthquake resistance assessment, while other involved experts, coordinated by the director of PLANETARIS Ltd. Natko Bilić provided architectural content, data derived from the site investigations and conservator's guidelines.

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The concept of risk and its measurement in the field of built heritage conservation: critical aspects and potential improvements

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Abstract. The term risk has been defined in different ways in various scientific areas. As a result, there is a certain confusion over the meaning and the use of the term. In order to understand better the variety of approaches to the concept of risk and consequently its measurement, representative studies, carried out by researchers and professionals, are considered. Which are the most important aspects that built heritage conservation adopted and developed and how these aspects have led to the use of different methods of assessment and evaluation of risks? Secondly, different methods of risk assessment and evaluation, adopted in various activities of the built heritage conservation process, are selected and analyzed. With the aim to highlight their strengths and limitations, a comparison is drawn, permitting us to have an overall picture of the available methods and at the same time to identify the eventual gaps and the critical aspects of the research/practice. Lastly, based on the acknowledgment of the limits and the problems of the various methods, suggestions for improvement are made.

Keywords: Risk Concept, Risk Analysis, Risk Assessment, Risk Management, Preventive Conservation, Built Heritage Conservation, Built Heritage Management.

1 Introduction

Over the last thirty years, preventive and planned conservation approaches to the built heritage management have been gaining ground in the European context. Research and policy have marked a shift from isolated and episodic restoration interventions to long term processes of constant care and local development. Management tools and practices such as periodic maintenance based on regular inspection surveys and systematic monitoring, information management, risk preparedness, as well as systemic projects, valorisation strategies, and people involvement practices, have emerged and have gradually been developed [1-3].

A paradigmatic approach is the Monumentenwacht model, based on the concept of supporting preventive conservation through a service of regular inspection surveys and the carrying out of minor, "first-aid", on-the-spot repairs. The organisation model, founded in the Netherlands in 1973 and subsequently in Belgium in 1991, has been studied and adapted to suit different statutory and cultural contexts by various European countries from the 90s onwards [4-9]. Undoubtedly, the European standard *Conservation of cultural property – Condition survey of immovable heritage* [10] follows the Monumentenwacht rationale and represents an attempt to implement preventive strategies.

In the Italian context, the definition of conservation as a long term process "ensured through consistent, coordinated and planned activities of study, prevention, maintenance, and restoration", offered by the Italian Cultural Heritage and Landscape Code since 2004 [11], represents a change of direction. The Italian approach to conservation is based on an integrated study of the cultural heritage and its environment, not only physical but also social-economic. The Pilot Project for the Planned Conservation of the Cultural Heritage in the Umbria region elaborated by Giovanni Urbani in 1975 [12], the setting up of the Risk Map project by the Central Restoration Institution in 1992 [13-16], the Guidelines for the Conservation Plan issued by the Lombardy region in 2003 [17], as well as the ten-year Cultural Districts project in Lombardy [18-20] represent the gradual steps and the considerable results achieved by implementing a preventive and planned approach to the built heritage conservation in Italy during the last decades [2, pp. 73-75].

What gains in importance in these examples is how to make rational decisions about cultural heritage conservation, or else how to make an efficient use of limited resources. The use of risk analysis, decision analysis, and risk management methods has been introduced in order to prioritise the activities, to reduce the costs and the losses and to increase the benefits and the quality of conservation results. Under this perspective, these approaches have focused on the relationships between cultural heritage and its environment, as well as their changes over time.

2 Risk concepts: definitions and general aspects

The term risk has been defined in different ways in the various fields and as a result, a certain confusion characterises the meaning and the use of the term. In order to understand better the variety of approaches to the concept of risk and consequently its measurement, different representative studies carried out by researchers and professionals have been considered. Firstly, the overview of different risk perspectives made by Ortwin Renn [21] and his proposal for their integration, secondly the overview provided by Douglas Hubbard [22] and his insistence on the importance of a scientific approach to risk management. Within this reference framework, the aim is to better frame the concept of risk and to understand the approach developed and the practices adopted in the field of the built cultural heritage.

2.1 Amplification of risk

The first study, carried out by Ortwin Renn, distinguishes seven approaches to the conception and assessment of risk evolved in the various academic fields: the actuarial approach; the toxicological and epidemiological approach; the engineering approach; the economic approach; the psychological approach; social theories of risk; and cultural theory of risk [21, p. 56].

As Renn underlines the diversity of these concepts depends on "the selection of the underlying base unit (i.e. operational definition), the choice of methodologies, the complexity of measures against risk, and the instrumental and social function of the risk perspective" [21, p. 56].

According to the analysis carried out by the author, the first three approaches can be grouped together as technical risk analyses. In short, "they anticipate potential physical harm to human beings or ecosystems, average these events over time and space, and use relative frequencies (observed or modelled) as a means to specify probabilities. The normative implication is obvious: since physical harm is perceived as an undesirable effect, technical risk analyses can be used to reveal, avoid, or modify the causes that lead to these unwanted effects. They can also be used to mitigate consequences, if causes are yet unknown, remote from human intervention or too complex to modify. Their instrumental functions in society are, therefore, oriented to risk sharing and risk reduction, through mitigation of consequences, standard setting, and improvements in the reliability and safety of technological systems" [21, p. 59].

Criticism about technical analyses comes from the social sciences and centres on the two following statements: the perception and evaluation of risks is a complex and multifaceted process that is determined by values and preferences – although it is not always acknowledged [21, p. 59; 23 pp. 3, 10]; the inclusion of complementary objectives within the goal of risk reduction requires participation by interest groups and the affected public [21, pp. 60, 77; 23, p. 10].

As stated by Renn [21, p. 77], the other perspectives on risk broaden the concept of risk, by including the interpretations of undesirable events and "socially constructed" realities, and by focusing on the evaluation of the risk context and the associations between the risk and social or cultural artifacts. Several contributions offered by influential researchers, such as Daniel Kahneman, Amos Tversky, Paul Slovic, Baruch Fischhoff, Sarah Lichtenstein, Roger Kasperson, and Mary Douglas, among others, bring out the limits of experts' knowledge and can help to enrich risk management [21, 23]. Thus, Renn [21, p.79] suggests the integration of the different perspectives and not their replacement, that is to say cultural and social considerations cannot supersede technical and economic considerations but should incorporate them in order to offer a frame "that assigns each perspective an appropriate place and function".

2.2 A scientific approach to risk management

Another author to have mapped out the current state of different perspectives on risks is Douglas W. Hubbard [22, pp. 55-93]. He proposed a division into four general groups: actuaries, war quants, economists, and management consultants. The taxonomy takes into consideration the types of problems they focus on and the methods they use. The author's scope is to analyse the problems faced by these diverse schools of thought and to propose methods to fix them. Criticism has focused on the one hand on the most popular, newer methods that "don't necessarily build on the foundation of earlier methods that have stood up to scientific and historical scrutiny. It's more like the rapid construction of mining towns in the American West during the Gold Rush, where nice facades are quickly erected with minimal attention to structural quality in the rest of the building. And anybody can put up a shingle saying he is a risk management expert" [22, p. 23]. On the other hand, the author denounces the fact that while the limits of the experts' knowledge have been studied to a large degree, and relatively simple techniques have been developed to overcome the difficulties, risk managers employ hardly any of these methods [22, pp. 96-97].

The last aspect faced by the author regards the challenges for risk management: "confusion regarding the concept of risk"; "completely avoidable human errors in subjective judgments of risk"; "entirely ineffectual but popular subjective scoring methods"; "misconceptions that block the use of better, existing methods"; "recurring errors in even the most sophisticated models"; "institutional factors"; and "unproductive incentive structures" [22, pp. 76-77].

In regard to the concept and the definition of risk the author distinguishes between risk and its related concept of uncertainty as well as the measurements of each [22, pp. 79-80]. As the author claims, this distinction not only represents the actual use of the terms in the insurance field and other areas of professions and research, but it corresponds also to the general use of the terms by the public [22, pp. 79-80].

The review offered by Hubbard [22, pp. 80-93] calls attention to several other definitions of risk (such as the Frank Knight's definition, risk as volatility, risk as a good thing, etc.) that "were mutually exclusive, contradicted common sense uses of the language, and defied even the academic literature available at the time" [22, p. 91]. Finally, the author argues that risk terminology has to be considered part of a broader field of decision analysis, and thus adds the required terms concerning "strict uncertainty", "risk/reward analysis" and "ignorance" [22, pp. 92-93].

2.3 Defining risk in the field of built heritage conservation

The definition of risk, that is the degree to which loss is likely to occur, as a combination of two principal, dominate components "hazard", and "vulnerability", is widely acceptable in the field of built heritage, at an international level [24, 25]. The former term regards the probability that a threat of a given intensity will occur in a particular place. Whereas the latter concerns the degree of loss associated with the particular hazard and related to the exposed system and its propensity to be damaged.

In regard to the two frameworks of risk perspectives discussed before, the following aspects emerge. Firstly, the approach to risk developed in the field of built heritage shares the same point of view with engineers, who model systems of components and their interactions. The vulnerability studies concerning historic buildings and constructive techniques draw attention on the complex interaction of different elements, materials and boundary conditions. For this reason, the assessment is based on a gradual knowledge process acquired through the combination of information gained from a variety of analyses.

The second aspect regards the intrinsically twofold character of the built heritage conservation. On the one hand, the safeguarding of the cultural values associated to the building materials and techniques and on the other hand, the guaranteeing of the necessary level of its technical performance. The buildings are not objects to contemplate but they have to stand up. They have to be safe, accessible, comfortable, energy efficient, secure, easy to look after, etc. [26-28]. In order to balance these two aspects and to determine compatible solutions (often alternatives that meet the performance level "equivalently"), it is required to define the possible alternatives, to identify and analyse their consequences, both risks and benefits, and then to select the most acceptable option. Under this perspective, the acceptable risk is the risk associated with the most acceptable alternative in a decision problem. Fischhoff et al. [29] state that this can have two implications: first, the most acceptable alternative may not be the one with the least risk, and second, the acceptable risk is situation specific, depending on the set of alternatives, consequences, values, and facts in the decision process.

3 Assessing and evaluating the risks to the built heritage

The implementation of the Disaster Risk Reduction DRR phase framework in the cultural heritage sector provided by the STORM – Safeguarding Cultural Heritage through Technical and Organisational Resources Management project makes clear the interconnection between the conservation activities and the risk assessment/management actions. Specifically, the different built heritage conservation procedures and actions have been analysed in terms of scale of application, main objectives, DRR phases, direct/indirect actions, and involved actors, both institutions and professionals [30, pp. 24-43].

Among the various approaches to the measurement of risk stand the common methods of expert's audit, stratification methods, weighted scores, calculus of preferences and probabilistic models [22, pp. 24-26]. Representative examples of the above categories of risk assessment methods are examined. The selection of the examples, as the table 1 illustrates, is based on two criteria: firstly, assessments that include different risk factors, and secondly, assessments carried out during different conservation activities, e.g. inspection survey, maintenance planning, documentation, intervention compatibility evaluation, and environmental monitoring/management.

Table 1. Examples selected for the analysis of risk assessment methods

Examples selected	Conservation activities	Risk factors considered	Risk assessment methods
Monumentenwacht model organisations	Inspection survey	Continuous/slow acting risk factors	Expert's audit
Pompeii maintenance planning project	Maintenance planning	Natural and human risk factors	Expert's audit
Risk map project	Documentation	Natural and human risk factors	Stratification method
EN 16883:2017	Project/intervention compatibility evaluation	Inappropriate project/intervention	Calculus of preferences
NICHE project	Environmental monitoring/ management	Indoor climate risk factors	Probabilistic model

3.1 Monumentenwacht organisations model: preventive conservation based on regular inspections

Despite the differences between the various European initiatives, the Monumentenwacht model, based on regular inspection and immediate repairs in order to avoid consequential damage, supports preventive conservation.

The inspections are usually carried out by a tandem of experts in the conservation sector and consist in examining the building both from the outside and inside, starting from the roofs, and arriving through the masonry structure to the foundations. As Lipovec and Van Balen [5, p. 196] describe "particular attention is given to critical points such as chimney pots, gutter eaves, openings. The examination is not limited to finding the parts most exposed to potential damage but also checking all the details, such as windows, doors, and metal or wooden decorations both inside and out. Paying equal attention to all parts of the building, functional and decorative, the Monumentenwacht service contributes to the preventive conservation process, established by the cultural values, and not just to the maintenance. In this way, the goal of providing the owner with a true "state of health" of the buildings, which is presented in the form of a report, is achieved. The final document, accompanied by photographs and recommendations for priority interventions, is useful both for the company that will carry out the works, and as a reference for the owner regarding problematic points and expenses".

Concerning the evaluation of the damages and the indication of risks and priorities, the Monumentenwacht inspection approach "relies on the existence of visible damage phenomena and qualitative analysis rather than a quantitative analytical and experimental approach. This analysis entails an inductive process based on the experience gained by analysing and comparing the behaviour of different structures with similar materials and construction techniques in similar environments" [31].

Considering the three types of risks proposed by Waller [32-33], the visible damage phenomena can be compared to the first type of mild/constant risks. In particular, the continuous monitoring of long-term structural damage accumulations is able to provide an early warning system for structural and safety assessments [31].

3.2 Preventive and planned conservation in Pompeii: constant planning based on monitoring and progressive experience/knowledge

The planned conservation project in Pompeii implements the Italian shift in conservation field, matured mainly in research studies and in the national heritage law, "from exclusively operational interventions to processes of study and control, to be implemented before, during, and after the strictly executive phases" [34].

The methodological approach, as described by Osanna and Rinaldi [34], is based on a process of three distinct, but related phases, i.e. inspection activity, execution phase, and critical synthesis, that is to say a critical evaluation of the interventions. The inspection activities, carried out by interdisciplinary teams of archaeologists, architects, restorers, and structural engineers, and the recording of the detected processes of degradation aim at identifying the critical aspects, without ignoring the complexity of the diagnostic phase, and to plan the short- and medium-term interventions. The assessment, based on visual and empirical observations, concerns the evaluation of the damage severity and its evolution process determining three urgency degrees.

Notwithstanding the difficulties in evaluating the decay progression and its speed – because of the interactions of the various decay processes, as well as the lack of information/documentation with regard to the history of the past interventions – the continuous monitoring of the archaeological park conditions and the daily practice of the operators have enabled on the one hand, the management of emergencies, and on the other, have improved the acquisition of knowledge and experience, necessary for the effectiveness of the maintenance planning.

What is more, the recording and the evaluation of the efficiency of the interventions over time can lead to the development of true expertise, or better as Shanteau argues [as cited in 35] "experience only leads to learning if a clear cause and effect link exists between action and consequences and it is possible to identify critical success factors", or rather "it is not having experiences that matters – it is what you learn from them".

3.3 Risk Map project: an advanced technological documentation tool for cultural heritage management

The Risk Map, initiated in 1992-96, is an ongoing project that regards the development of a geographic information system (GIS) concerning the cultural heritage management. From the nineties to the present, over 95.000 monuments on the national territory have been geo-referenced on vector maps and aerial orthophotos, as well as all the listed building restrictions issued from the year 1902 to 2005 have been collected in the system [36].

This database, accessible to various public technical and administrative bodies (research institutes, public agencies, and ministries), stores, organizes and manages data related to both the cultural heritage conditions and its environment. In this way, it contributes to the knowledge sharing and the examination of the various data relations necessary for the management of the emergencies, of the infrastructures and the territory, and for the protection of the cultural heritage [36-37].

In regard to the risk assessment, simple stratification methods such as risk maps (called also heat maps or risk matrices) use normally two or three ordinal scales which are multiplied together in order to get an aggregate score, e.g. likelihood and consequence or hazard, vulnerability and exposure. The Italian Risk Map in particular uses three different combinations of four indicators, hazard and exposure for the territorial risk, hazard and vulnerability for the individual risk, and local hazard and vulnerability for the local risk.

Moreover, the vulnerability assessment, in this case linked to the evaluation of the conservation state, is carried out through the evaluation of three criteria, gravity, extent and urgency for each type of damage and for each type of element. The overall vulnerability of the building is an average score of all its components and their damages [38]. As a result, the criticalities of single elements or limited areas are levelled down and consequently the priorities cannot be identified.

Scoring methods, both weighted scores and multiplicative matrices have been criticized as "worse than useless" [39]. Among the main problems they manifest, the fact that they have been developed separately from scientific methods in risk and decision analysis, and that they are "sources of error on their own as a result of unintended consequences of their structure" stand out [22].

Apart from the ineffective use of scoring methods, the vulnerability assessment linked directly to the evaluation of the state of conservation could be inadequate for two principal reasons. Firstly, because the presence of damage is not always equivalent to the expectation of damage, or better as Della Torre [40] underlines, for the prevention is more important the changeable relationship between object and its context and the analysis of scenarios that could give rise to processes that are not yet perceptible in their concrete effects. Secondly, as Michalski [41] argues "the danger is that one is endlessly fixing only urgent problems. Option C is a decision to fix the urgent situation in the short term (option A) at the same time as committing to a plan to fix the slower situation in the long-term (option B), no matter what. We may talk about the rights of future generations, but we may not have faced the implications of a moral arithmetic based on it. Option C is not simply saying do A plus B, it is saying that we may have to abandon some A type issues in order to ever get B started. Here, I believe the modelling of realistic outcomes, and not simply a response to urgency, will be crucial".

3.4 Guidelines for improving the energy performance of historic buildings: evaluation of decisions according to their risks

During the last years, the Multi-Criteria Decision Analysis (MCDA) has been applied in the field of cultural heritage. The presence of a large number of aspects and of diversified nature, often in conflict, and many of them difficult to be quantified has led to the application of multi-criteria techniques to the evaluation of the various alternative projects [42]. For example, for the selection of equivalent safety measures [43], accessibility measures [44], reuse alternatives and enhancement strategies [45-46], and more generally of possible compatible solutions with the building values.

What stands at the base of these methods is the idea to put in relation the characteristics of a project with the objectives and the preferences (i.e. the attributes or criteria) of the decision-maker. The procedure of selecting appropriate measures to improve the energy performance of a historic building proposed by the European standard EN 16883:2017 [47] is a practical application of multi-criteria decision analysis. The recommended criteria include the following categories: technical compatibility, heritage significance, economic viability, energy performance, indoor environmental quality, outdoor environmental impact, and use aspects. The different solutions are evaluated according to their performance scores, which indicate how well they meet the criteria. In this case, a five level scale of assessment has been proposed, in order to evaluate the effects of the measures and to identify the measures that best meet the needs of a building.

3.5 Environmental risk assessment for cultural heritage protection: a method based on the concepts of systems theory and probability

The new environmental risk assessment methodology for cultural heritage protection (NICHE) elaborated da Andretta et al. [48] regards the cultural heritage housed in museums, galleries, and archives. As stated by the authors, although the method concerns the works of art and focuses on the risks related to the microclimatic environment, its application to other types of risks (e.g. structural, related to usage, arising from natural disasters, infesting agents, technical malfunctions, etc.) can be easily developed. In detail, "all situations where the effects of the sources of risk on the targets of interest can be described with an S shaped function (for example, a Dose-Response Curve, a Probit or a Logit models) can be treated with the NICHE approach, grounded in the comparison with threshold reference values reported in the technical/scientific literature and norms" [48].

The elaborated methodology is grounded in the following definition of risk: "The risk (R) for the Targets of Interest (Ti), due to an Anomalous State (STa) of the System (S) which produces a Source of Risk (SoR) of Magnitude (Md), is given by the probability of an Adverse Effect (Ea) on (Ti) caused by the (SoR), i.e. R = Pr (Ea, Md)" [48, p.23]. As the author describes [48-49], this definition is based on the concepts of the systems theory and of the probability.

The implementation of the methodology concerned the Classense Library of Ravenna and in particular the results of environmental monitoring carried out in 2014 over two periods that were considered extreme. In particular, a certain number of halls of the Classense Library corresponds to the system. The paper-based materials represent the targets of interest, the chemical-physical changes and the degradation mechanisms effects are the possible adverse effects. The indoor microclimatic conditions are equivalent to the anomalous states. Finally, the magnitude is expressed by the difference between monitored data and threshold values reported by the reference norms [48].

Concerning the assessment methods of risk, the authors distinguish between "absolute" and "relative" methodologies, according to the approach to the determination of the unconditional and conditional probabilities. The former requires their exact determination whereas the latter elaborates a ranking of risks by applying the same method to different scenarios.

4 Comparison and evaluation of the risk assessment methods

The analysis of different examples has focused on the description of the risk assessment methods that are used, and the examination of their principal aspects. With the aim to highlight their strengths and limitations, a comparison is drawn based on their reliability, effectiveness, and openness to evaluation.

Henderson and Waller, in their paper about effective preservation decision strategies [35], discuss two different decision-making processes, the heuristic and the analytic-deliberative. The first one is based on intuitive processes, which are rapid and can be reliable. The second requires time to complete and can be described by an analytic deliberative model (e.g. the cultural property risk analysis model by Waller). The authors argue that each of these processes has its strengths and weaknesses, and their use depends on the available resources, especially time, the quality and the type of the data available, and the context in which decisions must be made. This kind of distinction can also be made here, between the first two case studies, the assessment method of which is based on experts' judgements, and the other three that build a model for the analysis and the assessment of risks.

In respect of reliability, or else the validity of the outcome of a method, in the case of the experts' judgement, lies mainly on the knowledge and the expertise of professionals and in particular their ability to identify indicators of risks [35]. In the case of Risk Map, the use of scoring methods, both weighted scores and multiplicative matrices, reduce the validity of the assessment results because of the irrational structure of their aggregation models. In the matter of the multi-criteria analysis, proposed by the Guidelines for improving the energy performance of historic buildings, the formulated objectives, i.e. the criteria and the weights selected for the assessment and the ranking of the various options, can affect adversely the reliability of the method in the context of built heritage if they are not coherent to the principles of conservation or they simplify complex questions. Finally, the validity of the probabilistic model of the environmental risk assessment, as Andretta et al. [48] argue, depends on the availability and the accuracy of the data.

Discussing the effectiveness of the different methods, or else their appropriateness for specific contexts, the following comments can be made. The need of making a rapid decision that is required in managing emergencies, or the need of a sensory judgement, essential for early detection of changes or signals of damage propagation call for regular inspections and continuous monitoring activities carried out by trained professionals. On the other hand, the restoring of data concerning the assessment of hazards, exposure and vulnerability – regardless the problematic risk aggregation methods, as well as the difficulties in keeping the information system updated owning to the required large amount of economic resources and time [50] – can be effective in the perspective of an enduring depository of the available knowledge. In regard to the multi-criteria analysis, the effective combination of technical data and cultural values seems to be appropriate in the context of the evaluation of the risk acceptability. As concerns the NICHE approach, the consideration of risks that can be described only by an S shaped function depends on the establishment of their acceptable limits.

The distinction between experts' judgements and analytical deliberative models, made at the beginning of this comparison [35], clarifies also the difference between tacit knowledge of experts that is not open to evaluation and the explicit scale of relating inputs to outcomes provided by the structure of the models that is available for critique. However, subjective inputs relied on experts' judgement are also required in the case of analytical models. In specific, the vulnerability assessment of the Risk map model, and the five-level scale of assessment proposed by the guidelines EN16883:2017 are based on experts' judgements. Moreover, the weights of the criteria in the latter are determined by the subjective preferences of the decision makers.

5 Proposals to improve risk assessment

The analysis and the comparison of the different methods highlighted the problems and advantages of each. With the aim to make better risk analysis, the various problems of the methods are discussed and suggestions for improvement are made.

With regard to the experts' judgements, in the context of regular inspections and continuous monitoring activities, the complex observation process made by the inspectors remains usually implicit, i.e. it is not explained, communicated or registered properly. As Della Torre [40] argues the condition survey is a typical secondary prevention practice, which entails tertiary prevention activities to avoid the propagation of damage, and primary prevention to improve behaviours and avoid problems caused by use, like loading, wear and tear, and indoor climate among others. Nevertheless, the shift in the conservation profession from restoration to preventive attitudes and practices is not immediate and still needs to be developed. For this reason, the distinction between condition assessment and risk assessment is of great importance. In fact, the identification of the most effective preventive measures cannot be linked directly to the condition of the building elements but requires a risk analysis based mainly on the complex interactions between the elements and within their environment. Hence, the description and the recording of the aspects associated with risks could clarify and explicate the reasoning behind the classification of the urgency of measures, allowing its review and evaluation.

As for the scoring methods and the ordinal scales in risk assessment, various researches [e.g. 22, 39, 51] highlight their limitations and argue that are not useful tools for risk assessment. While Cox [39] focuses on the mathematical properties of risk matrices and examines their limitations, Hubbard and Evans [51] identify and discuss the following four main problems. To begin with, scoring methods do not pay attention to the findings of psychological research on cognitive biases that are relevant to risk assessment and in particular to the assessment of likelihood (such as the effects of "overconfidence", "anchoring", "framing", and "inconsistency"). Another problem regards the variability in the interpretation of verbal labels that are used in ordinal scales either by different users or by the same user in different contexts. Moreover, the invalid inferences derived by treating ordinal scales as if they are ratio scales, such as distance or mass, are fallacious and harmful. The example of "star" ratings that are used by film critics is very characteristic, "two stars are simply better than one star, but not exactly twice as good. Four one-gallon containers of gasoline will pour exactly into one four-gallon gasoline tank, but Roger Ebert knows he would much rather watch one four-star movie than four one-star movies" [22, p. 119]. The last problem described by the two authors regards the exclusion of correlations among various risks and consequently their underestimation.

To avoid the problems assessed, Hubbard and Evans [51] emphasize mainly the need of quantitative methods that use explicit probabilities and magnitudes of losses, or else ratio scales, instead of using verbal or ordinal scales. Indicative and useful examples in this direction include the adoption of a common scale to convert the predicted deterioration into predicted loss of value proposed by Waller's Cultural Property Risk Analysis Model, or the aggregation of modelled risks proposed by the JCSS [52], as well as the model of Multi-Hazard Assessment of Vulnerability applied to historic buildings proposed by D'Ayala et al.[53].

Concerning methods such as multi-attribute utility theory (MAUT), or multi-criteria decision making (MCDM), as it was mentioned above, the evaluation and the ranking of the various decisions take into consideration their risks, in other words, risk analysis provides input to decision analysis [22, 54]. Moreover, these methods by taking into account tradeoffs become important for the risk management and the evaluation of the acceptable risk. Besides, the selection of the attributes and their weights brings greater transparency on the process of decision making. In order to increase the validity and the quality of the process and improve its outcomes two aspects should be considered, "what and whom to include on the one hand and what and how to select on the other hand" [M. Hajer, H. Wagernaar, A. Stirling, paraphrased by Renn, 55, p.49]. The "co-operative discourse" model proposed by Renn [55] for the involvement process of experts, stakeholders, and the public in risk governance integrates scientific expertise, rational decision-making, and public values. Specifically, the model combines selected formats of the three discourse types: epistemic discourse/group Delphi format, reflective discourse/value-tree analysis format, and participatory discourse/citizen panel format.

The last group of methods considered here are the probabilistic models of risks. Generally, the mathematical computation of losses and their magnitudes is regarded as the most scientific approach to quantitative risk assessment. Problems and errors related with subjective estimates, empirical testing of models, correlations, etc. have been raised by the research and improvements have been suggested and adopted [22].

6 Conclusions

Starting from the definition of risk in different scientific areas, the paper highlighted the two aspects of the concept of risk that built heritage conservation adopted and developed: the engineering approach based on the modelling of systems of components and their interactions within the environment, and the concept of compatibility based on the notion of the acceptable risk and its evaluation.

In regard to the different approaches to the assessment, the analysis notes that the methods vary from a qualitative to a quantitative approach to assessment, according to the scope of the analysis and the available resources. None of the approaches should be considered exhaustive. Each of these methods has its strengths and weaknesses and their effectiveness depends on the context, the conservation activity, or the management strategy. As Menoni [56] argues "risk assessment cannot be considered a monolithic tool, to be developed by experts and then delivered to decision makers who should make their decisions on its ground. Different types of policies and preventive strategies require different inputs, the ideal being experts working with and not for decision makers. The need to use a variety of tools, such as probabilistic risk assessment, scenario modelling, simulations differentiated not only according to the policy for which they are designed but also to the geographical scale and to the final users, require a rethinking of the entire matter, in order to better meet new and emerging demands".

The limits and the critical aspects of the methods concern mainly the rooted restoration attitudes vs preventive practices, the difficulties in comparing and aggregating diverse risks, as well as the difficulties in integrating cultural and technical issues. Suggestions for the improvement of the various methods are made by taking into consideration the need for the review/evaluation of a method, for reflective analysis, diffusion of methods that work better, and teamwork that includes both different specialists and the public. However, additional analysis should be carried out in order to monitor the results of their implementation over time and gather evidence of their efficacy.

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Cultural Heritage

International Law on Cultural Heritage: The Benefit of Updating the International Community's Classification of Perpetrators of Cultural Heritage Looting and Destruction

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Abstract. Since the Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict of 1954 (Hague Convention), the international community has committed to the protection and preservation of cultural heritage. Remaining one of the most central dedicated pieces of International Law on cultural heritage, the lack of updated International Law on the concept finding similar levels of success in obligating states and generating new norms regarding cultural heritage has exposed the age of the convention. Absent from the Hague Convention is a proper classification of perpetrators of cultural heritage crimes. In the past, perpetrators have been convicted of war crimes and crimes against humanity, yet convictions were linked with other egregious acts. The 2016 International Criminal Court Al-Mahdi Case and United Nations Security Council Resolution 2347 both declaring perpetrators of cultural heritage crimes are war criminals was a significant advancement, yet limited, particularly as war crimes cannot occur during times of peace and the difficulty of International Law's application of rules of war during non-international conflict. This research project argues that purposeful looting and destruction of cultural heritage can and ought to be considered a crime against humanity. Through this approach, a greater number of cultural heritage crime perpetrators can be held accountable. By educating civilians on the importance of cultural heritage and previous state commitments, increased pressure can be placed on governments to abide by previous international commitments, hold states accountable for actions or inactions, and facilitate further transdisciplinary efforts for cultural heritage protection and preservation.

Keywords: International Law. Cultural Heritage Protection, Cultural Heritage Crimes. War Crimes, Crimes Against Humanity, Amending International Law

1 Introduction

Molded by and ever influencing the practices of local, cultural, and global populations, cultural heritage is as much a part of humanity as it is an extension of it. Defined by the United Nations Educational, Scientific, and Cultural Organization (UNESCO), cultural heritage is both tangible and intangible, ranging from skeletal remains in museums and archaeological sites, artifacts, architectural and natural marvels, to language, oral history, rituals, song, dance, or anything with "outstanding value" to individual and shared histories, the arts and sciences, and anthropology [1]. Left behind by ancestral generations, cultural heritage is to be appreciated by present and future, local and global populations for socioeconomic, educational, and even political purposes. Without question, cultural heritage is an essential part of not just the originating culture, but to humanity itself, aspects of cultural heritage which are at times vital to the survival of cultural and ethnic groups socioeconomically and in providing "lessons from the past" for people around the world to learn from and appreciate.

Cultural heritage is a part of humanity, yet, unfortunately, just as people may lose their lives or homelands, they may lose part of their humanity and identity through the destruction and defilement of their cultural heritage. As such, the international community in seeking to show their general acknowledgment and agreement over the importance of cultural heritage on both the local and global scales have committed themselves through international conventions and treaties –International Law – over the protection and preservation of cultural heritage. While first mentioned in the Hague Convention With Respect to the Law and Customs of War on Land in 1899 as being afforded some protections as the property of a state [2], The Hague Convention for the Protection of Cultural Property in the Event of Armed Conflict of 1954 (referred to as the Hague Convention henceforth) was the first dedicated, monumental piece of International Law over the protection and preservation of cultural heritage, declaring that states are to provide safeguards to cultural properties, including archiving materials and increasing the presence of personnel to defend cultural properties when there is an apparent risk of war, and even outlining what obligations states have as occupying powers towards the cultural heritage of the occupied people [3].

2 Cracks in the Hague Convention

While the Hague Convention was groundbreaking for its time in delineating the necessity of protecting and preserving cultural heritage in a general manner with 133 states ratifying the convention, in the present day the Hague Convention has remained as the single most influential convention on cultural heritage with few other pieces of International Law finding the same level of success in generating norms and regulating the practices of states in the international community on this topic. New pieces of International Law on cultural heritage do not get the same level of support from states in the international community, even the Hague Convention's own protocols; the first which was created the same year as the original convention, 1954, and the second in 1999, both updating aspects of the original convention finding fewer and fewer state parties, 110 and 86 respectively [4]. Later attempts in International Law, in a similar manner, update aspects of the Hague Convention, notable pieces being: The Convention on the Means of Prohibiting and Preventing the Illicit Import, Export and Transfer of Ownership of Cultural Property of 1970 (referred to as the Convention on Illicit

Cultural Property Trade); The Convention Concerning the Protection of the World Cultural and Natural Heritage of 1972; and The Convention for the Safeguarding of the Intangible Cultural Heritage of 2003.

Yet, as the Hague Convention of 1954 has remained the most substantial piece of International Law regulating and obligating state action on cultural heritage, the flaws, cracks, and age of the convention have started to show as the dynamics of International Law, International Relations, war and conflict, and the human condition have evolved over the near 70 years since the original convention's inception. For one, the Hague Convention is focused on cultural "properties," that of tangible heritage rather than the intangible; although addressed in the Convention for the Safeguarding of the Intangible Cultural Heritage, its provisions are rather vague in the level of effort states must put in for means of safeguarding intangible heritage through educational, community fostering, or archiving means, likewise these being disconnected from other general provisions and obligations of states in the Hague Convention which focus on tangible heritage. Further, the convention is primarily concerned with how to handle cultural heritage during times of war with very little reference for how to secure and preserve cultural heritage during times of peace, only what states must do during peace time to prepare for situations that could lead to cultural heritage destruction during war. Furthermore, while there is consideration of non-international conflict, stating that parties involved in the war must be bound to some degree to the convention and its amendments, there is great difficulty when considering non-state actors and their potential abuse and destruction of cultural heritage outside contexts of war, non-state actors being a complex concept in International Law that cannot be adequately comprehended as non-state actors were not as prominent in the past as they are today. To rephrase, as International Law cannot properly define conflict between a state and non-state actors as a proper "war," International Law will subsequently not be able to easily obligate states to abide by their commitments for the protection and preservation of cultural heritage during times of war, especially when states may choose not to recognize or legitimize violence perpetrated by groups within their borders as an "armed conflict" as to not subject themselves to the rules of International Law during war, International Humanitarian Law (IHL), *jus in bello*, rather than their own criminal procedures [5].[1]

The cracks of the Hague Convention are not the fault of the convention itself so to say, but states in the international community that do not put in much effort to keep their commitments in line with the changing dynamics of International Relations, sometimes even completely violating their commitments and International Law itself, as has and continues to occur in occupied Cyprus by Turkey for a near half century, for example [6]. More often than not, it is the International Organizations (IOs) and Non-Governmental Organizations (NGOs) that pick up the lacking efforts of states, acting as 'norm entrepreneurs,' the term coined by Cass Sunstein, in generating new norms and

[1]International Human Rights Law and International Criminal Law somewhat picks up where International Law on IHL lacks in handling non-international conflict between state and non-state actors, yet it is not nearly as strong and influential of actions and norms as IHL. This is likewise dependent on whether the state wishes to hold an individual or group accountable for their actions in an international body which would bring recognition and some sort of legitimacy to the groups involved in the conflict rather than through local criminal procedure.

acting on their own to preserve and protect cultural heritage and act as disseminators. Despite the endeavors of the IOs and NGOs, however, without the involvement of states themselves, efforts will always be limited.

3 Classifying Perpetrators of Cultural Heritage Crimes Under International Law: Notable Attempts and Current Policy

Another flaw of the Hague Convention is that, while it does dictate those who breach the convention must find some sort of penal or disciplinary sanctions imposed upon them, there is no further mention of accountability present within the treaty, nor any means to classify perpetrators of cultural heritage looting and/or destruction; persecution of individuals is left to the criminal jurisdiction of the state. While individuals have been held as having engaged in crimes against humanity during the Nuremburg Trials or the International Criminal Tribunal of the Former Yugoslavia (ICTY), convictions including cultural heritage crimes[2] were always in conjunction with, an aside to, already egregious crimes including mass murder, ethnic, and religious cleansing [7,8]. Otherwise, attempts in the past to provide a proper legal classification for perpetrators of cultural heritage looting and destruction under International Law had been less than fruitful.

There have been multiple attempts to consider the destruction of cultural heritage as "cultural genocide," however this endeavor too has not been successful. Having originally coined the term "genocide" in 1944, prominent lawyer Raphael Lemkin had always considered the destruction of a people to be multifaceted, encapsulating both physical and cultural destruction, both intermingled and interdependent; emphasizing the integral role of the abuse of culture in acts of genocide [9,10]. Introduced into the drafting of the Convention on Genocide in 1948, however, the concept of cultural genocide was promptly pushed to the side with a significant split between the Western and Soviet Blocs. A quick summary of the opposition to the term is adequately represented by the Danish delegation's declaration at the time, stating that "It would show a lack of logic and of a sense of proportion to include in the same convention both mass murders in gas chambers and the closing of libraries" [11]. At a tense time during decolonization, Western states chose to leave the concept of cultural genocide for another time, possibly another convention, wanting to avoid any significant backlash considering their own difficult histories with the destruction of cultural heritage of indigenous groups in colonies or their own territories. This future deliberation of cultural genocide did not occur until 1993 with the Draft Report of the Working Group of the UN on Indigenous Populations where cultural genocide was again included in the draft but removed from the final work in 2007 with push back from a number of the same states that opposed the term's inclusion in the Genocide Convention, namely the United States

[2]For the purposes of this paper, cultural heritage crimes include tangible and intangible cultural heritage destruction, it is not simply limited to the looting and illicit trade of cultural resources and their removal from site contexts.

(US), Canada, New Zealand, and Australia, those sharing poor history with their indigenous populations [12,13].

To say the least, the international community has shown that the protection and preservation of cultural heritage is not their priority, nor finding a proper classification for perpetrators of cultural heritage crimes. These endeavors, as mentioned earlier, have typically been propelled by IOs and NGOs, and while there have been a number of small scale resolutions within states, including one by the Swedish Central Board of National Antiquities along with the Swedish Branches of both UNESCO and the NGO International Council on Monuments and Sites (ICOMOS) which states concretely that the deliberate destruction of cultural heritage must be considered a war crime and in cases of excelsis like in the Former Yugoslavia 'ethnocide,' previously mentioned in the same Rights of the Indigenous working paper yetwas removed along with 'cultural genocide' [14], an additional case involving the North Atlantic Treaty Organization (NATO) is of interest. The Final Communiqué of a NATO conference in Kraków, Poland in 1996 declares that the willful destruction of cultural heritage during military operations ought to be considered a war crime, and that the term "armed conflict" should be extended to include internal civil and armed conflicts for such provisions of cultural heritage protection, and provisions of other topics involving armed conflict, to apply [15,16].[3]

With the NATO declaration as well as resolutions by individual states, IOs, and NGOs acting as potential precedents and pushing norms as to how perpetrators of cultural heritage destruction ought to be considered, the Rome Statute in 1998 of the International Criminal Court (ICC) seems to further solidify that the deliberate destruction of cultural heritage during armed conflict, insofar as is under the ICC's authority, is to be considered a war crime. Specifically, Article 8(2)(e)(iv) dictates that "intentionally directing attacks against buildings dedicated to religion, education, art, science, or charitable purposes, historic monuments…" is to be considered a war crime; again there is a primary focus on tangible cultural heritage [17]. It was not until 2016, however, that this article of the Rome Statute was truly brought to light through the successful conviction of Ahmad Al-Faqi Al-Mahdi through the ICC for his role in directing cultural heritage destruction operations by the Ansar Dine militia during their conflict against the government in Mali in 2012. Convicted for war crimes in attacking historical and religious sites in Timbuktu, the international community has set a new precedent by convicting someone in an international court solely for cultural heritage crimes, clearly and officially declaring what perpetrators of cultural heritage destruction ought to be classified as: war criminals [18,19].

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[3]While the Final Communiqué of NATO on this topic in 1996 could be found, it should be noted that any official release of the document is nowhere to be found, neither in NATO's press releases, nor in that of any other involved organization at the time. Though there was a press release of NATO indicating that they would indeed be discussing this topic in Kraków, and while many organization websites and publications reference this document, their source to the ICOMOS page, ICOMOS having been involved in the NATO conference, is likewise unavailable and could not be found in internet archives. This could possibly have to do with the declaration that the definition of "armed conflict" be extended, something that would implicate obligations of states in International Law on a number of subjects not exclusive to matters of cultural heritage.

It must be noted, however, that while the Rome Statute has many state parties, 123, the decision by the ICC that the destruction of cultural heritage is to be considered a war crime is only binding on those ratifying states, not other non-party states in the international community. Yet, following the conviction of Al-Mahdi, the United Nations Security Council (UNSC) in 2017 adopted UNSC Resolution 2347 dictating that those responsible for the intentional destruction of cultural heritage must, circumstantially, be treated as war criminals [20]. It should be noted that unlike other pieces of International Law usually formed through multilateral treaties, conventions, and resolutions, International Law formed by the resolutions of the UNSC are binding on all states regardless of state consent; as a sovereign state, becoming a member of the UN and thus subscribing to the UN Charter obligates states to abide by the resolutions of the UNSC. As such, while the conviction of Al-Mahdi in the ICC concretely declaring deliberate cultural heritage destruction a war crime would not mean much for states not ratifying the Rome Statute, the resolution of the UNSC is not up to be questioned by states: the deliberate destruction of cultural heritage is a war crime.

While a tremendous step forward for the protection and preservation of cultural heritage, there are inherent and legal limitation in considering perpetrators of cultural heritage destruction as war criminals. For someone to be convicted as a war criminal, crimes must have been in violation of IHL, IHL only in effect during a state of war. Once again, the international community puts its emphasis on the protection and preservation of cultural heritage, and specifically the persecution of perpetrators of cultural heritage destruction, during times of war. As mentioned previously, armed conflict over the years has shifted away from interstate conflicts to primarily that of non-international conflict. The codification of IHL is most strongly defined in the four Geneva Conventions and its subsequent protocols, and while Common Article 3 and the Second Protocol of 1977 of the conventions focus on the role of non-international armed conflict, specifically how the parties involved in non-state conflict are subject to certain rules of war and IHL, there is a complicated threshold in order for the conflict to be deemed 'war' [21,22]. Article 1(2) of the Second Protocol of the Conventions states with clarity that the provisions involving non-international armed conflict shall not apply in a situation of "internal disturbances and tensions such as riots, isolated and sporadic acts of violence and other acts of a similar nature" [22]. Likewise, considering issues of sovereignty and intervention as expanded upon in Article 3(1) and Article 3(2), Médecins Sans Frontières describes that it may be in the interest of states to never classify their internal conflict as non-international armed conflict as to not give sovereignty to the groups fighting within their borders in order to retain their authority as a state and their jurisdiction over criminal procedures [23,5]. The central figures that have the greatest authority over declaring when a state is and is not in an armed conflict, a war, and when IHL applies, are the UN General Assembly and the UNSC, both of which would require adequate time to deliberate each situation.

Indeed, Al-Mahdi's conviction was through his involvement in a non-international conflict between a state and non-state actors, and thus while this would have been a case in which there would be difficulty in considering, under International Law, Mali having been at war, the situation in Mali near the start of conflict in 2012 was already internationally recognized as a proper armed conflict as opposed to simple "internal strife." With the eruption of internal conflict in Mali in January of 2012, two months later in March the government of Mali was overthrown by the armed forces of the country which suspended the constitution. Having condemned through multiple Presidential Speeches and Press Statements the forcible seizure of power in the country, the UNSC in its 2056th resolution on July 5th, 2012, declared that the parties involved in Mali must abide by IHL, IHL which is only applicable during times of war, *jus in bello* [24]. Following sanctions and threats of stronger sanctions by neighboring countries in the Economic Community of West African States, the Junta had stepped down leading to the election of Diouncounda Traoré, who in his inauguration stated he would "not hesitate to wage a total and relentless war" against non-state adversaries [25]. Furthermore, in January of 2013 the government of Mali had requested aid from foreign militaries to fight against rebels, including the French who had engaged in a military intervention for up until August 2022, solidifying the idea that there was no control of the rule of law in Mali at the time [26,27]. There is no question that at the time of Al-Mahdi's actions and conviction Mali was in a state of war, internationally recognized including by the UNSC, therefore in this case it would have been simple to consider an individual's or a group's egregious actions violating IHL as war crimes.

In other situations, however, how then can the international community hold perpetrators of cultural heritage looting and destruction accountable in a more adequate and potentially timely fashion, under International Law, in cases that are inside, outside, and sometimes in the grey zone of contexts of war and peace? It is argued that the only classification that holds the same if not more weight than war crimes would be "crimes against humanity," the term itself ever evolving along with International Law over time.[4] The term "crimes against humanity" has never been definitively defined in a dedicated piece of International Law, yet the Rome Statute of 1998 of the ICC has a rather robust definition. What is and is not a crime against humanity is ambiguous, again it is not definitively defined, yet a crime against humanity is nonetheless a widespread and systemic attack on a civilian population, either in times of peace or war. Specifically under the Rome Statute, crimes against humanity include but are not limited to: murder and extermination; enslavement; torture; rape and forced pregnancies (to dilute genetic pools); persecution against identifiable groups; as well as other inhumane acts meant to cause great suffering or serious injury to physical and/or mental health [17]. To commit a crime against humanity is to forcibly subjugate a people to the deprivation of their identity and/or humanity.

4 How and Why Cultural Heritage Crimes Can and Should be Considered Crimes Against Humanity

Cultural heritage crimes fit quite well under two of the outlined ways in which crimes against humanity can be committed, as described in the Rome Statute: Article 7(1)(h) "persecution against any identifiable group or collectivity on political, racial, national,

[4]"Crimes against peace" could also be a potential classification, yet those are only applicable during times of peace

ethnic, cultural, religious, gender… or other grounds that are universally recognized as impermissible under International Law;" and Article 7(1)(k) "other inhumane acts of a similar character intentionally causing great suffering, or serious injury to body or to mental or physical health" [17]. Quickly considering the role of cultural heritage, the loss and deprivation of cultural heritage which may be vital to a group of people will subsequently lead to the loss of the socioeconomic and educational value of that cultural heritage which would have been appreciated by both local and global groups, potentially leading to the victimization and marginalization of cultural, minority, and tribal groups. While this was most definitely the case in Mali by the Ansar Dine militia, this was also common practice of the Islamic State (ISIS) which had destroyed cultural grounds to displace populations in Iraq and Syria, and additionally desecrated such sites and their cultural significance without physically "destroying" them, like the executions held in the ancient ruins of Palmyra in Syria [28]. Likewise, from a mental state alone, the destruction of cultural heritage, aside from marginalizing groups, through the purpose of victimization causes significant anguish and demoralization, as occurred with the destruction of the Bamiyan Buddha statues in Afghanistan in 2001 by the Taliban, subjugating by force local civilians to destroy their own heritage, their history, facing death or otherwise [29]. Even in Al-Mahdi's ICC case was the concept pushed that the destruction of cultural heritage causes "irreparable damage to the human persons in his or her body, mind, soul and identity" [30].

As what constitutes a crime against humanity has been left somewhat ambiguous, it is not outlandish, on the contrary entirely possible and feasible for the destruction and mass looting of cultural heritage to fit under the phrase. The destruction of cultural heritage has already in the past been considered a crime against humanity in the Nuremburg Trials or the ICTY, although as mentioned this was typically in conjunction with other crimes. Even the ICC in its releasing of the July 2021 policy on cultural heritage states that "crimes against or affecting cultural heritage are often committed in the context of an attack against a civilian population," and that "they may themselves amount to crimes against humanity" [31].

The ICC's description of what constitutes a crime against humanity in regards to cultural heritage destruction is dense and complicated, referring to multiple case precedents where the International Law on the subject of crimes against humanity, under the court's authority and jurisdiction, portrays its ambiguous nature. Considering the contextual elements of crimes against humanity, for example, an attack must have been committed against a civilian population and in furtherance of a state or organization policy, the attack being widespread or systemic [32]. The court has specified in the past that if an attack "is planned, directed or organized – as opposed to spontaneous or isolated acts of violence," the state or organization policy criteria will be satisfied, and that likewise a "systemic" attack is one that refers to a certain level of planning [33]. Further, the "policy" of an attack refers simply to the intent of a state or organization to either take or deliberately forgo action against or protecting a population; "policy" need not be a formal plan [34]. Furthermore, the term "widespread" refers to the "large-scale nature" of an attack; an attack need not be both widespread and systemic [35,36]. Likewise of note is how the ICC observes a "civilian population," the term also ambiguous in International Law, in the context of crimes against humanity, whereby they declare a civilian population does not specify any nationality, ethnicity, or distinguishing features; crimes against humanity are able to be conducted against people of the same nationality as the perpetrators, the stateless, or those of other affiliations [37]. Attacks on civilian populations in the context of cultural heritage crimes, however, in order to constitute a crime against humanity must show that the civilian population was the primary, as opposed to incidental, target of an attack [38].[5] The ICC in its policy description additionally outlines how cultural heritage crimes easily fit in the context of other ways in which crimes against humanity can be committed, vis-à-vis their connection with other crimes [31].

What is vital in considering cultural heritage destruction and looting as a crime against humanity rather than a war crime is, again, its greater applicability in being able to convict perpetrators for actions regardless of whether in a state of peace or war. A hypothetical example of where this would be of use is, say, a group having staged a large-scale attack on the Metropolitan Museum in New York City, leading to the destruction and/or theft of multiple exhibits or the museum itself. In such a case, it would be near impossible to consider perpetrators as war criminals, as there is no state of war in New York, but it would be possible to consider the event a crime against humanity. Even if there is no focus on a specific culture or exhibit, the contents of the museum are a part of the cultural heritage of humanity. Such an attack would be targeting the history and the cultural heritage of humanity's ancestors, but furthermore would be targeting the civilian population of New York which holds the Metropolitan Museum as a large part of the cultural heritage of the city, removing a valuable socioeconomic resource for New York and blocking educational research efforts using such cultural resources from both the city and the entire world; even if the primary purpose is for profit of perpetrators, the target of such a widescale attack, the victims, are the civilian population.

Leaving aside hopefully inconceivable hypotheticals and moving to actual examples of cultural heritage destruction, the Istanbul Pogrom in the 1950s is most certainly a relevant case between the destruction of tangible and intangible cultural heritage and crimes against humanity, with specific emphasis on the ICC's observation of the term. The bombing of a Turkish consulate in Thessaloniki, Greece, falsely and purposefully blaming the Greeks despite having been a conspiracy of the Turkish government at the time [39], led to the series of state sponsored riots against the Greek ethnic minority seeking to have them ousted from their places of heritage. While the number of deaths is not in the thousands as one might associate when thinking of crimes against humanity, amidst the chaos, it is believed roughly 37 Greeks were killed, their homes raided and businesses ransacked, Greeks, as well as some Armenians and Jews, chased through the streets beaten and/or raped, churches destroyed, and Christians "Islamized" by subjecting men and priests to genital mutilation and torture [39]. Although already considered by some another Greek Genocide, Turkey at the time could not have been

[5]A distinction should be noted between the *target* of an attack and the *purpose* of an attack.The purpose of such an attack may be for a multitude of reasons not delineated by the court, but could conceivably include personal profit or victimization, as a few examples.Further, the ICC states that in targeting a civilian population, the "sufficient amount" of civilian targets to deem an attack a crime against humanity will be deemed appropriate by the court in each case.

considered to be in a state of war and thus having conducted war crimes when systematically attacking and forcing the exodus of the Greek ethnic minority, yet it could easily be considered a crime against humanity. All the crimes committed against the Greek ethnic minority during the pogrom is most definitely associated with the destruction of the intangible cultural heritage of the minority in Turkey following their exodus as refugees, studying and education in the Greek language and the practice of their faith, beliefs, rituals, and traditions slowly but surely dying out in the country as the population of the ethnic minority had declined from 110,000 as of the signing of the Treaty of Lausanne in 1923 to roughly 2,500 people as of 2006 [40].[6]

Looking at another example, the large-scale raid on the Mallawi Museum in Minya Egypt in August 2013 accused by the Ministry of Antiquities to have been conducted by the supporters of the ousted former president Morsi of the Muslim Brotherhood led to the destruction and theft of over 1,000 cultural resources [41,42,43]. Amidst the chaos following the coup d'état in July of 2013, it is difficult to claim there was a state of war in Egypt at the time, but equally difficult in calling it a time of peace. By considering cultural heritage destruction and theft a crime against humanity, it is reiterated that there would be no need for extensive deliberation over whether there is a state of war or peace when seeking to convict perpetrators for their cultural heritage crimes, in this case where it was certainly targeted against the Egyptian people and robbing them, quite literally, of their heritage as well as socioeconomically damaging the city of Minya and its people; the only pieces to this case up for debate and questioning is whether to accept the Egyptian government's accusation at the time that this was an orchestrated event by political opponents, as well as one's definition of how large-scale the attack was and its symbolic magnitude.

It is believed that the above properly illustrates how crimes against cultural heritage can properly fit under the umbrella of "crimes against humanity." Aside from the potential of holding additional people accountable for their actions under International Law, one may ask what the point is of changing the classification of perpetrators of cultural heritage looting and destruction from the term war crimes, especially to a different term that many states may be unlikely to support. It is argued that, even if state governments would not support the use of the term crime against humanity when referencing cultural heritage looting and destruction, the recognition as such by individual people, activist groups, NGOs, and IOs can push norms for something that is already agreed upon by the ICC. The beliefs of the Danish delegation when discussing the Genocide Convention shows that some state governments in the international community do not place as much emphasis on their past commitments to the protection and preservation of cultural heritage. This can be illustrated easily when looking at the UK's policy on the illicit trade of stolen cultural properties, where after having left the European

[6]It is acknowledged that the Istanbul Pogrom is another situation in which cultural heritage crimes are committed alongside other egregious actions, thus such cultural heritage crimes would not have alone been considered cases of crimes against humanity or war crimes, it would be part of a collective of other crimes. Yet, this case exemplifies that even state governments can target a civilian population be it their own citizens or otherwise and destroy both their tangible and intangible cultural heritage, even while not in a state of war, such actions befitting the definition of crimes against humanity.

Union and no longer being subject to the supranational organization's policies and regulations on cultural resource trade the government had decided there should be no licensing requirements for the trade of cultural materials, and that anyone caught with stollen materials cannot be convicted if they are, or claim to be, ignorant of the fact they are in possession of stolen resources [44,45]. A second illustration is Turkey's violations of various pieces of International Law despite their commitments to the Hague Convention, for example, detailing their obligations as an occupying power, considering their occupation of Cyprus for the past near half century, and various resolutions by the UNSC, as was mentioned earlier [6].

By acting as norm entrepreneurs, pushing norms that the theft and destruction of cultural heritage can and should be considered, circumstantially,[7] a crime against humanity, citizens can pressure their respective governments to have greater accountability for their actions or lack thereof. A potential case where one could have been, under International Law, fitting the criteria of having committed a crime against humanity through the destruction of cultural heritage site contexts and looting is that of Aydın Dikmen, the "official" archaeologist of the occupied territory of Northern Cyprus by the Turkish government. Warned of whenever the military planned to blow up any cultural sites and monuments so he may take "things which matter," through Dikmen's efforts in his large scale, occupied-territory wide looting operations in Northern Cyprus, an unknown but certainly countless amount of stolen Cypriot cultural materials have been found all over the world, from the US, UK, Netherlands, to even Japan, some worth tens of millions of dollars [46,47,48]. With an unknown amount of cultural properties removed from their sites of contexts, the Greek Cypriot population clearly having been targeted through the looting and destruction of Orthodox Churches, Dikmen is a case of one who could have been convicted of crimes against humanity for destruction and looting of cultural heritage. Dikmen would have been subject to International Law had Germany ratified the Convention on Illicit Cultural Property Trade, as Dikmen was living in Germany, which would have obligated Germany to extradite him and subject him to Cypriot Courts. Instead, Dikmen was sued by the Cypriot government through German courts and was fined a measly €266 thousand, pennies compared to his millions in profit through illicit art and cultural resource trade, if the fine was ever paid, never even facing jail time [48,49].

5 Conclusion

Although it may have been unlikely to convict someone like Dikmen of having committed a crime against humanity for his role in directing cultural heritage looting

[7]It is improper, and to an extent unethical, to consider all destruction of cultural heritage as a crime against humanity. If a researcher studying an artifact were to break the piece through their carelessness, such an event cannot hold weight to the scale of a crime against humanity. The same can be said about someone who takes a piece of pottery from a burial ground. When saying "circumstantially," there is meant to be some sense of scale and intent as described by the ICC's policy on cultural heritage, likewise in the same fashion the UNSC states perpetrators of cultural heritage crimes must "circumstantially" be deemed war criminals.

campaigns in occupied Cyprus, or even a war criminal as the UNSC still deems the Cyprus situation an occupation which under International Law is considered armed conflict, if citizens, NGOs, IOs, and even some states were to recognize that such actions fit under the umbrella "crime against humanity," at the very least conversations would garner. By considering such actions as just relating to war crimes and leaving the rest to local criminal procedure when at a time of peace, where as shown even in western democracies such laws on cultural heritage are lacking, there is little room for states at peace to have any accountability for failing to hold perpetrators accountable or harboring such criminals within their borders. Take the case of Dikmen, if the destruction and looting of cultural heritage is considered a crime against humanity, as is circumstantially already recognized as such in International Law through the ICC and previous convictions through the Nuremburg Trials or the ICTY, would the German people easily accept that their government is allowing such a perpetrator to essentially walk off with his profits, without even having been extradited to the courts of the country he committed his crimes? Would the people accept that their country, such as the UK or the Netherlands which have become hubs for the illicit art and cultural heritage theft trade where neither of which have ratified the Convention on Illicit Cultural Property Trade, is indifferent to and at times facilitates such crimes against cultural heritage, crimes against humanity? It is believed that, no, some citizens may be indifferent, but others will not accept such actions or inaction of their democratic governments, nor want one having conducted crimes against humanity within their borders unpunished. If they do not accept such actions or lack thereof, they would be able to apply greater pressure on their representatives as well as potentially work with NGOs, IOs, and those in different states to bring about a real normative and legal change for the betterment of cultural heritage protection and preservation, that which is humanity's cultural heritage.

Considering cultural heritage looting and destruction as a crime against humanity would be, more than anything else, an educational approach to the preservation and protection of cultural heritage. By being classified as a crime against humanity, people around the world would come to a mutual understanding, not only of situations of cultural heritage looting and destruction and their own governments' actions or indifference to International Law andinternational commitments and obligations – forcing people to pay attention to what is occurring both around them and the world, – but of the global significance of cultural heritage; its uniqueness and non-renewability, how people benefit from it and how it offers the entire world lessons from the past, as well as the obligations of the people of today to provide safeguards and ensure generations are able to appreciate humanity's cultural heritage in the future. Through greater education and educational opportunities on the importance of cultural heritage as well as the violations of International Law by some governments around the world and their lacking efforts to protect and preserve cultural heritage in line with previously made international commitments, it can be hoped that transdisciplinary efforts at the local, national, regional, and international levels can find new vigor for the betterment of cultural heritage. Such efforts, of course, would find benefit by having a global, common, mutual understanding of how to classify perpetrators of cultural heritage crimes in a manner that in a more widespread fashion can hold such individuals accountable, potentially deter further crimes, and pressure governments to engage in further efforts for the protection and preservation of cultural heritage, the term that seems to be the most feasible being "crimes against humanity."

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Seismic-Energy Combined Retrofit Systems of Historical Buildings: The Use of Light Metal Exoskeletons

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Abstract. The current trend in retrofitting existing buildings is mainly seen under the environmental aspect, giving little attention to seismic issues. Contrary, recent European Union's policies in this field are based on integrated approaches aimed at improving both energy and earthquake performances. Therefore, the so-called seismic coats have been launched on the building market. In this framework, the design of a new system for seismic-environmental requalification of existing constructions made of masonry or reinforced concrete is presented and illustrated in the present paper through the application of a cold-formed steel framed structure. This system is provided with both insulation panels, used to provide energy benefits, and a X-bracing system, employed to absorb part of the seismic forces to preserve the existing structure from damage. In the current research work, firstly, a description of the coat's components is presented. Secondly, the anti-seismic solution has been used to reinforce RC frames and its effectiveness has been proved by refined mechanical analyses in the non-linear field. Finally, the comparison of performances of examined structural system before and after the intervention has been made to evaluate the benefits provided by the proposed coating system under a seismic viewpoint.

Keywords: Seismic upgrading, Seismic-Energy Coat, RC frame, Light Exoskeletons, Cold-Formed Steel.

1 Introduction

Italian legislation identifies two main interventions to be executed for increasing seismic performances of buildings: upgrading interventions, when the seismic safety factor ζE, intended as the capacity acceleration over the demand acceleration ratio, augments of at least 0.10, and retrofitting interventions, when the ζ_E factor assumes unitary value as per new constructions. Multiples are the types of interventions to be executed and they differ from each other based on the typological and structural differences of the buildings they are designed to fit on [1][2][3][4]. Their proven validity derived from years of scientific tests and applications showing good results in applicability and flexibility of use. It is clear that the study of new techniques must first pass through test and evaluation phases. The retrofit of existing structures strongly depends on their degree of damage, which can be attributed to age, corrosive actions, material or anthropogenic degradation, etc. For this reason, it is necessary to carry out experiments on a diversified pool of structures on which various types of interventions can be applied. Structures are often created from scratch with particular characteristics of simulated deterioration, which never perfectly correspond to the real state of a structure aged over time. The availability of structures already completed in an advanced state of decay would be a valuable opportunity for studying such retrofit interventions. In previous years, the European Community decided to reduce steel production and, as a consequence, many production plants were abandoned over time. In the Bagnoli area of Naples hosting the ILVA industrial complex, which extended over a densely populated, touristic area close to the coastline, production of steel was done. Therefore, it was one of the first production areas to be decommissioned and partially demolished. Part of the buildings located there were then subjected to protection restrictions, as they are evidence of the value of industrial engineering of the 60s and 70s. The remaining part of the built-up, purely made of reinforced concrete, were preserved for their precious use as "samples" on which to carry out tests and research, becoming a huge open-field research laboratory. Thus, the ILVA-IDEM (ILVA IntelligentDEMolition) [5] program was born in collaboration between the University of Naples Federico II and many participating subjects. Most of the RC structures placed in the ILVA area were built before 1980 when Naples was not yet considered seismic territory. Consequently, they were made of one-direction moment resisting frames, mainly designed to withstand gravity loads (Gravity Load Design - GLD). It must also be stated that for these RC structures, located close to both a highly industrial area and the sea, the atmospheric environment was highly harmful, leading to both corrosion damage to steel bars and concrete carbonatation. This scenario is particularly suited for application of retrofit or upgrading interventions , since they would be evaluated on already degraded structures resulting from years of exposure to particularly aggressive environments. The current memory is framed in this context, focusing the attention on the use of a cold-formed steel framed exoskeleton for strengthening and stiffening an existing RC frame. This framed structure represents one of the sub-structures (modules) of the ILVA-IDEM building after cutting operation at floor levels. The reinforcing technique herein presented is the Resisto 5.9 system, a seismic-energy technological coating designed by the Progetto Sisma company, that improves both seismic performance and energy efficiency of existing masonry [6][7]and RC[6]. A 2D frame is selected from the modules of the 3D office building under exam and assessed with and without the proposed reinforcing system by means of two structural software, namely Abaqus and Pro_Sap. The purpose of this evaluation is to study the contribution of the coating system for seismic upgrading of the structure. The first software, Abaqus, allows to precisely build the system with all its peculiarities, including connections and non-linear laws of materials, providing very accurate results. Contrary, Pro_Sap is a commercial type of FEM software mainly used in the professional practice, that allows to perform seismic analyses on both new and existing structures. The aim of the work is to compare the output results deriving from the two programs to highlight the capacity of the simpler software to effectively simulate the seismic behaviour of he investigated RC frame.

2 The structure under investigation

2.1 The Office Building

The original building was built in the 1970s and it served as an office complex (**Fig. 1**). A framed structure with brick infill walls, designed to resist only vertical loads, was built on two levels with overall plane dimensions of 41.60 m x 6.50 m and height of 6.60 m. It was made of a single bay in the transversal direction and 12 bays in the longitudinal direction (**Fig. 2**) [7][8][11].


(a) (b)

Fig. 1. Side view of the original building: north-east (a) and north-west (b) facades.

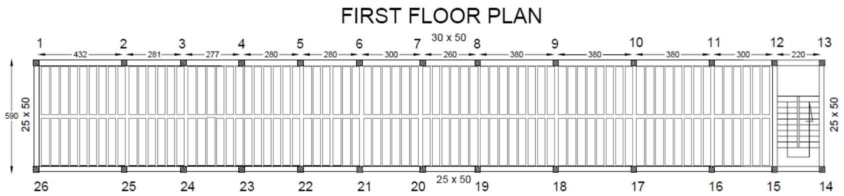
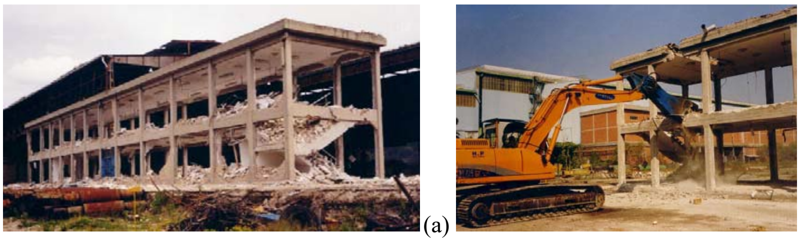


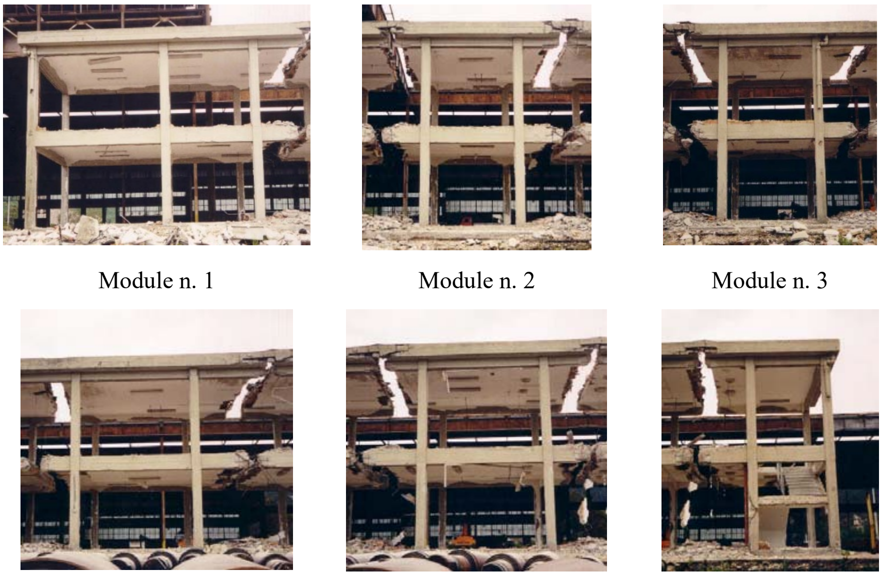
Fig. 2. Plan configuration of the building at the first level.

The structure was then stripped of the infill components, leaving only the bare frame with the 12 spans (**Fig. 3**). By cutting the beams at the floor levels, 6 modules were derived (**Fig. 4**). The first and sixth modules had different characteristics: the module n.1 consisted of three transverse column alignments and two unequal bays in the longitudinal direction, while the n.6 one was occupied by the staircase. Instead, the modules from the second to the fifth were the same in terms of geometry and structural elements.



(a) (b)

Fig. 3. Bare frame (a) and cutting of the floors for the definition of the structural modules (b).



Module n. 1 Module n. 2 Module n. 3

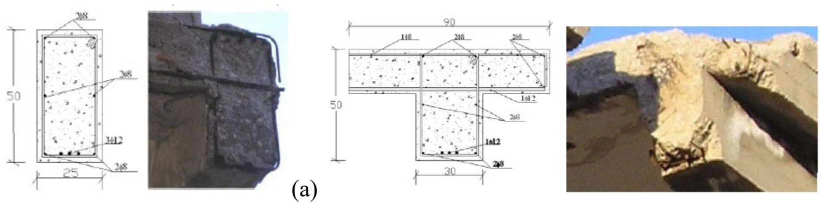
Module n. 4 Module n. 5 Module n. 6

Fig. 4. Modules obtained from the infill demolition and floor cutting phases.

2.2 The Structural Module n.5

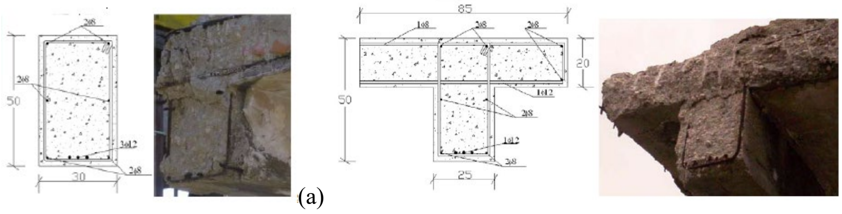
The analyses herein presented refer to the module n.5 (**Fig. 5**) of the built complex, which has been selected due to the homogeneity of characteristics with most of the building modules, except than those with numbers 1 and 6. The geometric configuration of this module is characterized by a rectangular shape measuring 6.30 x 5.90 m and developing on two storeys with heights of 3.55m and 6.81m at first and second floor, respectively. The thickness of the floor is 24 cm and 20 cm, respectively, at the first and second floors. Both floors have a central transverse joist and are supported, at the first level, by emerging rectangular beams (30 x 50 cm and 25 x 50 cm) placed along the longitudinal direction, while at the second level, the beams have a T cross-section of equal width and the same height of the first level beam members. In the transverse direction, the lateral resistance is essentially provided by the columns, which have a square section of 30 x 30cm and are reinforced with four longitudinal steel bars, Φ12, placed in the section corners. Stirrups Φ8 are placed in the columns every 300 mm. The foundation structure is composed of two inverted T-beams placed in the longitudinal direction (**Fig. 7Fig.**).

Fig. 5. General view of the module n.5.



(a) (b)

Fig. 6. Right side of beam sections at first (a) and second (b) level.



(a) (b)

Fig. 7. Left side of beam sections at first (a) and second (b) level.

2.3 The Seismic-Energy Integrated Coat

The Resisto 5.9 system [5] is a technological coating solution allowing for the improvement of seismic performance of existing buildings, also combining their energy efficiency through the integrated insulating package (**Fig. 8**).

The reinforcement of the existing structure is performed by integrative steel structural elements collaborating on the surface. Particularly, the system is made up of steel elements suitably connected to each other and to the RC frame.

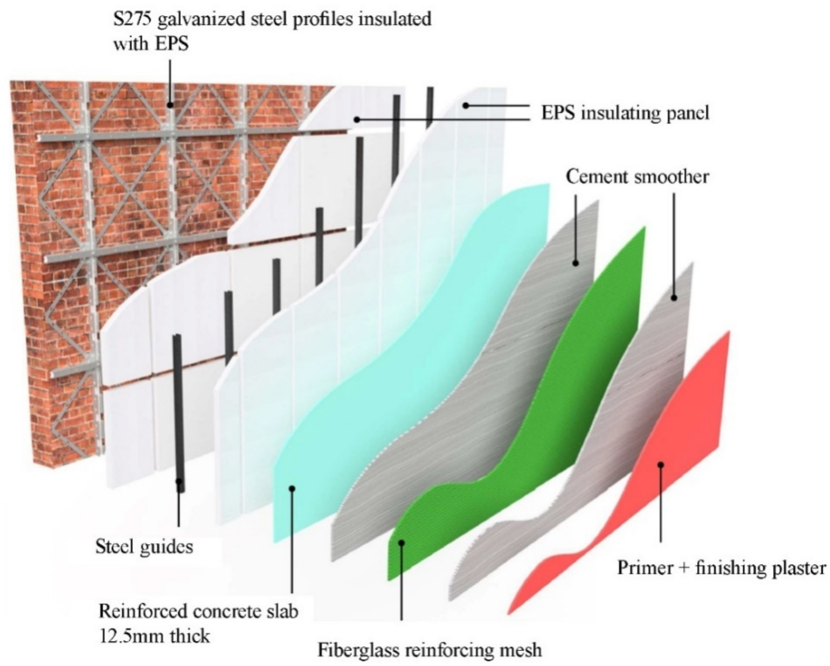


Fig. 8. Layers of the Resisto 5.9 system.

The metal profiles (**Fig. 9**) have a hollow rectangular cross-sections with dimensions of 60 mm x 40 mm and 50 mm x 25 mm and thickness of 3 mm. They are made of galvanized S275GD+Zsteel (yield strength f_y = 275MPa and failure strength f_u = 430 MPa). Three mm thick cold-formed plates with side length of 50 mm complete the system by acting as a connection between vertical and horizontal members and as an anchor point for the bracing. The elements are positioned in adhesion on the external surface of the wall, placed side by side and connected to the structure's surface through anchors with regular pitch. The anchoring must be of the chemical type, made by injection of a specific resin into holes of suitable diameter and depth and subsequent insertion of class 8.8 threaded steel rods. Each profile is connected to the adjacent one/s to ensure continuity of the reinforcing elements according to vertical, horizontal and bracing directions: shaped pre-galvanized steel plates allow for the union between profiles and bracings through class 8.8 galvanized steel bolts. From a structural point of view, the Resisto 5.9 system is aimed at the seismic upgrading/retrofit of buildings pursuant to sections 8.4.2 and 8.4.3 of the NTC 2018 standard [8], which deals with global interventions aiming at improving or retrofitting the entire structural organism. The system can also be used as a local intervention pursuant to section 8.4.1 of the NTC 2018 standard [8], which concerns interventions on single portions or single elements in order to contribute to the reduction of the structure vulnerability towards local mechanisms/kinematics. In this paper the effect that this system offers towards the seismic upgrading of an existing RC structure, without analyzing the energy issues evaluated in another context [4], is evaluated.

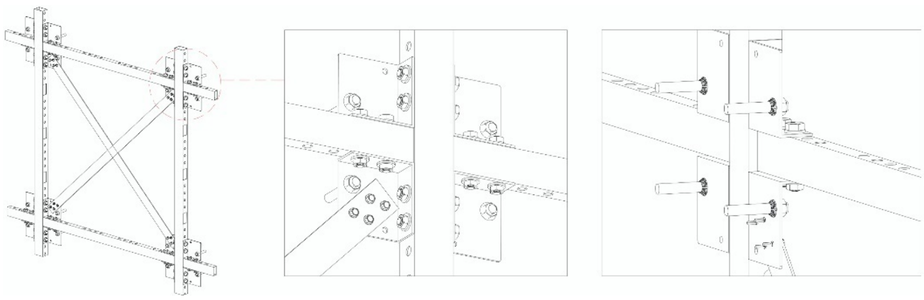


Fig. 9. Components of the Resisto 5.9 system.

2.4 Framework of FEM Modeling

The modeling of the RC structure under examination was carried out with the aid of the softwares Abaqus and Pro_Sap [9] [10] by creating a two-storey 2D frame model. The motivation of this choice is to be found in the research of the contribution of the Resisto 5.9 coating system on a 2D frame undisturbed by the dynamics of the rest of the structure. The RC frame, previously presented in this paper as module n. 5 (see 0), was submitted to non-linear static analyses with and without the seismic coating in order to evaluate the contribution in terms of seismic contribution provided by the reinforcement with the proposed system. Three structural models were built: a control frame without reinforcement (RC Frame), a reinforced frame with the seismic coat only linked to the RC structure (RC Frame + Resisto NOT Fixed) and a reinforced frame where the vertical members of the seismic coat are fixed to the foundation structures (RC Frame + Resisto Fixed). To make a more realistic comparison between the two softwares, in Pro_Sap it was decided to model only the first level of the reference frame where seismic forces are experimentally applied. For this reason, the presence of the upper floor was considered by applying equivalent concentrated loads at the head of the columns, as presented in Section 4.4. To obtain objectively correct results deriving from different modelling approaches through the two used programs, it is necessary to start from input data compatible with the state of the materials being analyzed. For this reason, reference to the experimental mechanical characterization of structural materials was done considering in the FEM models the measurement units shown in **Table 1**.

Table 1. Measurement units of the International System.

SI (mm)						
mm	N	tonne (10^3 kg)	s	MPa (N/mm^2)	mJ (10^{-3} J)	tonne/mm^3

2.5 Mechanical Characterization of Materials

The investigations on materials carried out on the structural RCmodule under examination are part of the whole mechanical characterization performed within the ILVA-IDEM project [3], which saw destructive and non-destructive tests to obtain the necessary information on concrete and steel samples extracted from the members (**Fig. 10**).

The use of several samples allows to derive the average resistances of the various structural materials which were subsequently used as mechanical parameters in the numerical analyses carried out (**Table 2** and **Table 3**) [11].

Fig. 10. Extraction of cylindrical cores from module n.6.

Table 2. Concrete samples' mechanical properties.

Specimens n.	Unit weight (kg/m^3)	Elastic modulus (MPa)	Strength (MPa)
1	2244	17692.0	20.5
2	-	16666.7	21.0
3	2235	16129.2	19.9
Average	2239	16829.3	20.5

Table 3. Rebar samples' mechanical properties.

Specimens n.	Φ (mm)	Length (mm)	Yielding load (kN)	Ultimate load (kN)	Ultimate stress (MPa)	Yielding Stress (MPa)
1	8	1040	29.0	33.0	656.5	576.9
2	8	975	-	41.0	815.7	-
3	8	500	23.1	33.4	664.5	459.6
Average					712.2	518.25
4	10	558	39.5	59.2	753.8	502.9
5	10	520	38.9	58.8	748.7	495.3
6	10	485	-	62.7	798.3	-
Average					766.9	499.1
7	12	850	44.1	73.8	652.5	389.9
8	12	570	53.1	82.2	726.8	469.5
9	12	860	53.0	79.0	698.5	468.6
Average					692.6	442.7

The recording of experimental data on materials serves to calibrate the mathematical model to ensure correct monitoring of the interventions to be performed. In this framework, the absence of an adequate degree of knowledge can lead to considerable variations in the results, as evidenced in [12] and [13]. Therefore, in order to implement a valid theoretical model of the substructures under study, the National Seismic Service of the Civil Protection Department, in collaboration with the University of Chieti/Pescara, performed dynamic tests on the structure with modal identification and subsequent calibration of results in the FE model of the module to test the reliability of the mechanical characterization [14]. In the following the mechanical parameters of materials used for modelling the RC module in the Abaqus CAE and Pro-Sap programs are reported.

Abaqus Mechanical Parameters. The data obtained from the analyses conducted on the structural samples under examination led to the definition of the mechanical parameters necessary to accurately model the non-linear behavior of the materials. The data tables related to each material are shown below. In particular, a Concrete Damage Plasticity model was used for the concrete (**Table 4**), which is based on the formulations regarding the yield functions proposed by Lubliner et al. [15]. To define B450C steel of rebars, data from tests carried out on site specimens were entered (**Table 3**). The properties of steel members of the Resisto 5.9 coating ssystem were defined in **Table 5**.

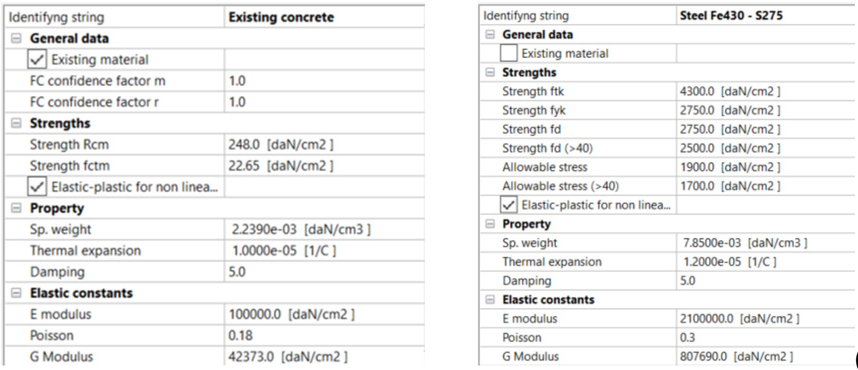
Table 4. Concrete's mechanical parameters.

		Density		
Mass Density	2.239E-009			
		Elastic		
Young's Modulus	Poisson's Ratio			
10000	0.18			
		Concrete Damage Plasticity		
Dilation Angle	Eccentricity	Fb0/fc0	k	Viscosity Parameter
40	0.1	1.16	0.667	0.0001
		Tensile Behaviour		
Yield Stress	Fracture Energy			
1.1	0.6			

Table 5. Mechanical properties of the Resisto 5.9 system steel members.

		Density
Mass Density	7.85E-009	
		Elastic
Young's Modulus	Poisson's Ratio	
210000	0.3	
		Plastic
Yield Stress	Plastic strain	
275	0	
430	0.19	

Pro_Sap Mechanical Parameters. According to on site-inspections, the concrete has a compressive strength of 24.8 N/mm^2 (**Fig. 11a**), steel rebars for concrete have a yielding strength of 450 N/mm^2 (B450C) and steel of the Resisto 5.9 system's profiles has a yielding strength of 275 N/mm^2 (**Fig. 11b**).



Identifyng string	Existing concrete
General data	
Existing material (checked)	
FC confidence factor m	1.0
FC confidence factor r	1.0
Strengths	
Strength Rcm	248.0 [daN/cm2]
Strength fctm	22.65 [daN/cm2]
Elastic-plastic for non linea... (checked)	
Property	
Sp. weight	2.2390e-03 [daN/cm3]
Thermal expansion	1.0000e-05 [1/C]
Damping	5.0
Elastic constants	
E modulus	100000.0 [daN/cm2]
Poisson	0.18
G Modulus	42373.0 [daN/cm2]

(a)

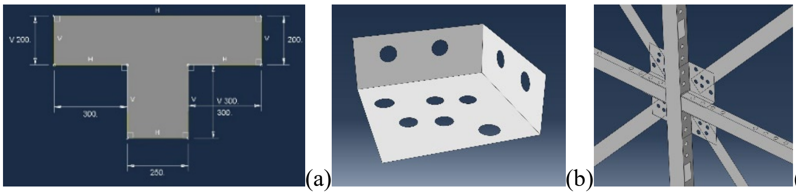
Identifyng string	Steel Fe430 - S275
General data	
Existing material	
Strengths	
Strength ftk	4300.0 [daN/cm2]
Strength fyk	2750.0 [daN/cm2]
Strength fd	2750.0 [daN/cm2]
Strength fd (>40)	2500.0 [daN/cm2]
Allowable stress	1900.0 [daN/cm2]
Allowable stress (>40)	1700.0 [daN/cm2]
Elastic-plastic for non linea... (checked)	
Property	
Sp. weight	7.8500e-03 [daN/cm3]
Thermal expansion	1.2000e-05 [1/C]
Damping	5.0
Elastic constants	
E modulus	2100000.0 [daN/cm2]
Poisson	0.3
G Modulus	807690.0 [daN/cm2]

(b)

Fig. 11. Materials implemented in the Pro_Sap software: existing concrete (a) and steel of the seismic coat elements (b).

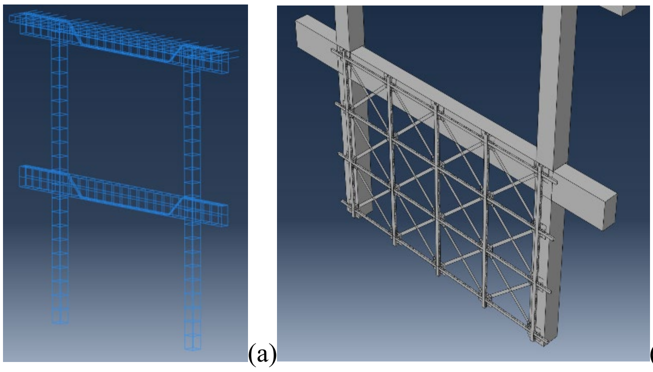
2.6 Modeling Process in Abaqus CAE

The modeling of the three-dimensional elements facing the structure under examination was carried out using the "part" command of the Abaqus CAE software. The concrete elements were modelled as homogeneous solid elements (**Fig. 12a**), while longitudinal rebars and stirrups were modelled as beam elements with their proper cross-sections. Finally, the cold-formed steel parts of the Resisto 5.9 coat were modelled through "shell" elements by assigning the relative thickness to each section (**Fig. 12b** and **c**). After individual elements of both the RC structure and the coating system were modelled, by using the "assembly" module of the program the entire model was constructed putting each element in the right position thanks to the translate and rotate commands (**Fig. 13**).



(a) (b) (c)

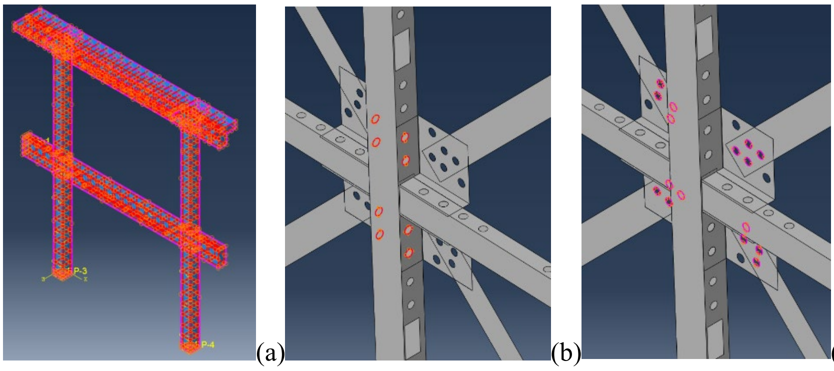
Fig. 13. Dimensions of the RC T beam (a), the Resisto 5.9 gusset plate (b) and 3D view of the bracing system of the coating system (c).



(a) (b)

Fig. 13. Assembly of rebars and stirrups of the RC structure members (a) and the Resisto 5.9 system mounted on the RC frame (b).

Interactions and boundary conditions. Once the model was assembled, the propaedeutic step for the analysis was the regulation of the interactions among elements together with assignment of constraint conditions. Abaqus is not able to understand automatically the interaction among elements; for this reason, these interactions, such as for example the "embedded" interaction between the RC members and their rebars, were defined in the program. These constraints regulate the symbiotic behaviour of steel and concrete by simulating perfect adherence between the two materials (**Fig. 14**). The subsequent interactions concerned the application of the exoskeleton on the RC frame and the relationships between the exoskeleton's components itself, such as braces, vertical members and horizontal ones. These last interactions were regulated by the "tie" command between gusset plates and members and between gusset plates and braces to simulate the behavior of a bolted connection without defects (**Fig. 14**).



(a) (b) (c)

Fig. 14. Embedded rebars (a), tie between plate and members (b) and tie between plate and braces (c).

As for the boundary conditions, two conditions were set up: full restraints at the base of the pillars and gravitational loads on the floors (**Fig. 15a**). In the constraint conditions, a controlled displacement constraint was also set on the first level beam in order to perform a controlled-displacement push-over analysis (**Fig. 15Fig.b**). No stress was applied to the exoskeleton of the Resisto coat, except than its own weight. This expedient makes possible to keep the analyses on thebare RC frame and the stiffened frame perfectly comparable to each other, so to read the upgrading done by the Resisto 5.9 system.

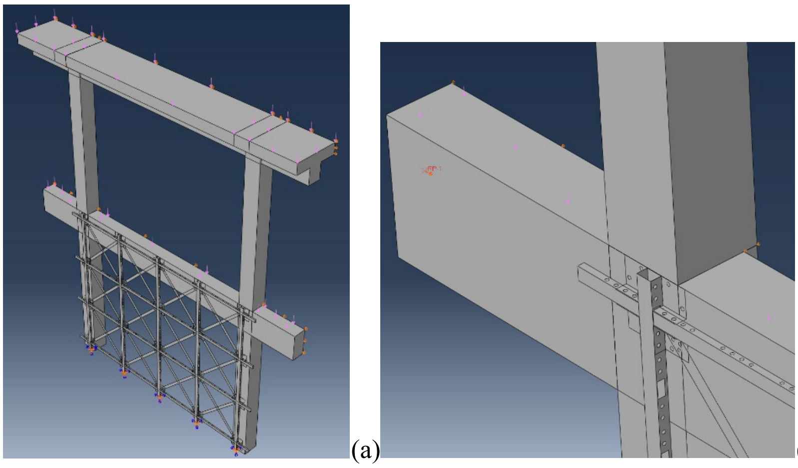

(a) (b)

Fig. 15. Boundary conditions of the composite structure (a) and displacement applied to the C beam for pushover analysis purpose (b).

Meshing. A necessary phase for the correct analysis execution is the accurate choice of the mesh [16] [17]. The evaluations herein performed to define the optimal mesh, which were found to balance the best accuracy degree of results towards the elaboration time, are omitted for the sake of conciseness.

Fig. shows the difference in terms of mesh size among various elements, where the densest discretization was used in the Resisto 5.9 parts to have more detailed information on their behaviour.

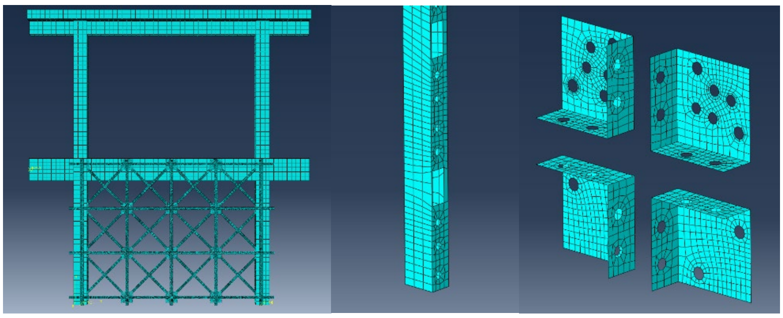


Fig. 16. Different components of the structure after meshing operation.

2.7 Modeling Process in Pro_Sap

The model of the composite RC frame –coating system structure was also built in the Pro_Sap finite element environment by implementing the geometrical and mechanical parameters already introduced in previous Sections 0 and 0. Leaving aside the detailed description of the elements constituting the system, as it was already introduced in the relevant section, in the following only the way they were implemented in the calculation software is shown.

Beams (25x50 cm cross-section) and columns (30x30 cm cross-section) of the RC frame were modelled as D2 elements, i.e. one-dimensional elements defined by two nodes, to which the property of non-linear beams were assigned. In all three models, fixed boundary conditions were assigned to the RC columns. Horizontal members (2.5x5 cm hollow rectangular cross-section with thickness of 3 mm) and vertical members (4x6 cm hollow rectangular cross-section with thickness of 3 mm) of the reinforcement system were modelled as D2 elements as well. They were placed one after another with a pitch of 1 m and were fixed at any intersection between RC columns and beams by means of 15 cm links having property of infinitely stiff material. The bracing diagonals (0.3x5 cm cross-section) were modelled as non-linear trusses resisting only to axial forces. A M3 node release was assigned to steel horizontal and vertical members to simulate the constraint conditions. Only in the third model (RC frame + Resisto 5.9 fixed at the base) fixed boundary conditions were assigned at the base of the vertical members. **Fig. 17** and **Fig. 18** show the solid and wireframe graphics, respectively, of the three FEM models under study.

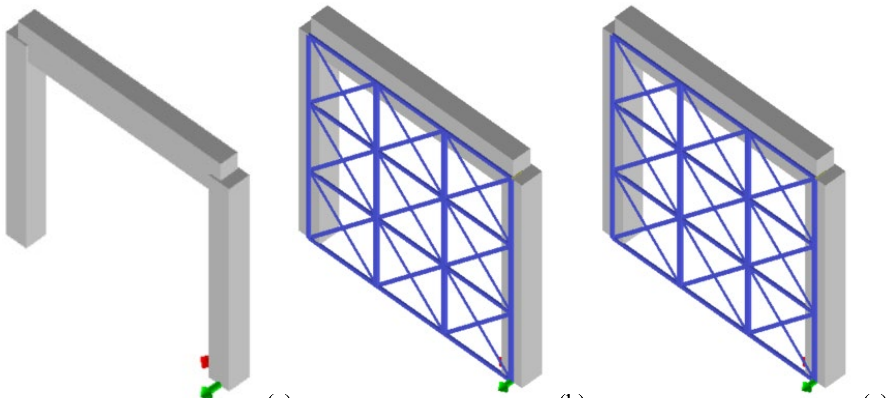
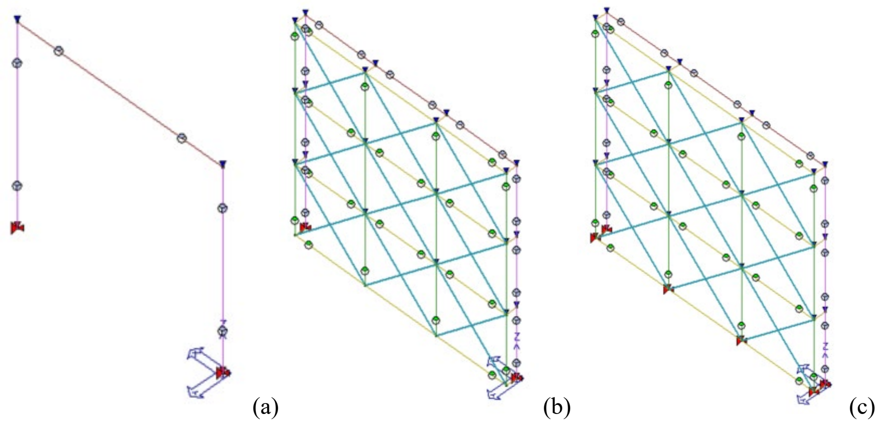

(a) (b) (c)

Fig. 17. Solidview of the three FEM models: RC Frame (a), RC Frame + Resisto NOT Fixed in Foundation (b) and RC Frame + Resisto Fixed in Foundation (c).



(a) (b) (c)

Fig. 18. Wireframe graphic of the three models: RC Frame (a), RC Frame + Resisto NOT Fixed in foundation (b) and RC Frame + Resisto Fixed in foundation (c).

Finally, loads were applied. Dead loads of the structural elements were automatically calculated by the software. The first floor load was manually applied as global distributed load on the RC beam with a value of 14.5 kN/m. The presence of the upper level of the RC frame was considered by applying a nodal load of 44.28 kN at the top of each column.

2.8 FEM models and seismic test on the bare RC frame

The three different FEM models already presented in Section 0 (RC Frame; RC Frame + Resisto NOT Fixed in Foundation; RC Frame + Resisto Fixed in Foundation) were tested under static non-linear analyses. As far as the push-over curves are concerned, the master joints to be monitored for plotting the capacity curve was chosen in the middle of the end cross-section of the first level beam. To compare the performance of different retrofit solution, the necessary first step was the analysis of the experimental data coming from the lateral test performed within the ILVA-IDEM campaign on the bare RC frame. This test was conducted adopting a cyclic loading history with variable load steps stopped before occurrence of any hinge in the RC members. Therefore, the diagram of **Fig. 19Fig.** shows only the trend of a foreseeable behavioral response of the frame having an initial branch determined experimentally and a subsequent perfectly plastic behaviour not investigated in the full-scale test.

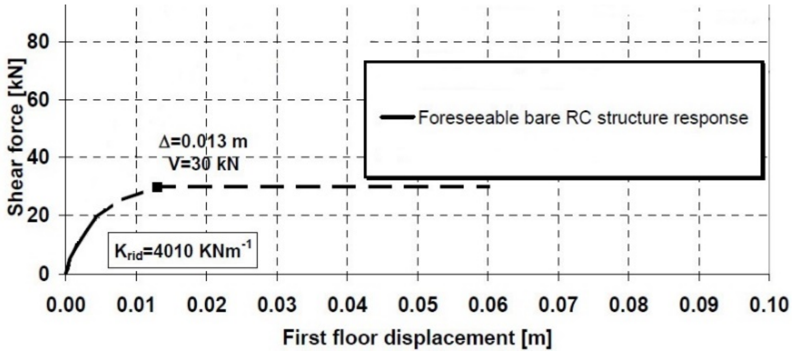


Fig. 19. Foreseeable structure response of the bare RC frame.

2.9 Abaqus CAE analysis results

From the analyses carried out with the ABAQUS program on the bare RC it can be seen that plastic hinges started when concrete degraded and they largely developed at a displacement of 5cm. Yielding of rebars starts at 3cm of displacement and was localized at both pillar bases, also extending to the areas corresponding to the nodes. The active yielding state of concrete and rebars is displayed in **Fig. 20**.

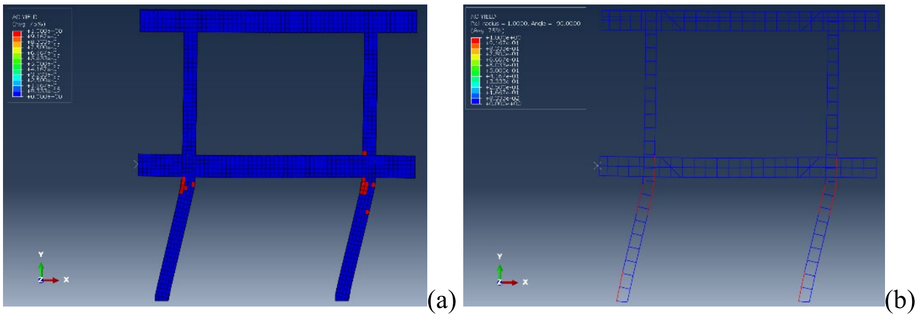


Fig. 20. Concrete(a) and rebar(b)active yield states.

The curve obtained from pushover analysis is represented in **Fig. 21**, where it is compared with the experimental curve previously illustrated. It can be observed that the first branch of the numerical curve fits very well the initial branch of the experimental curve. This confirms the validity of the FEM model implemented, which can be therefore used for subsequent analyses aiming at retrofitting the studied bare RC frame.

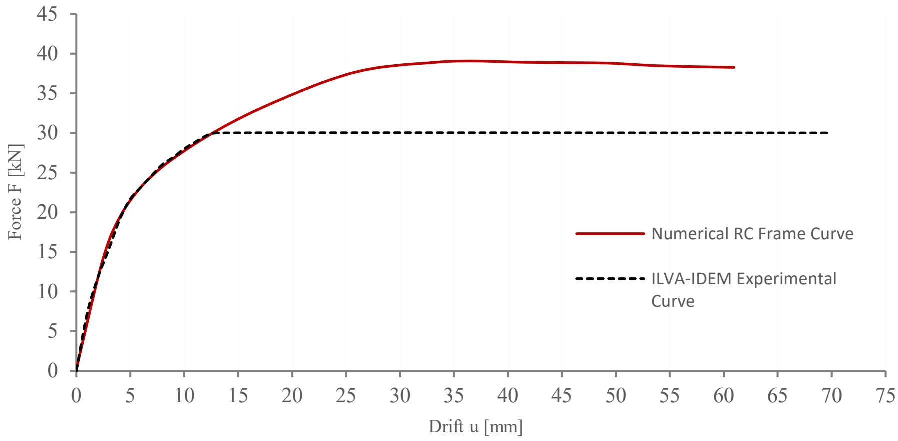
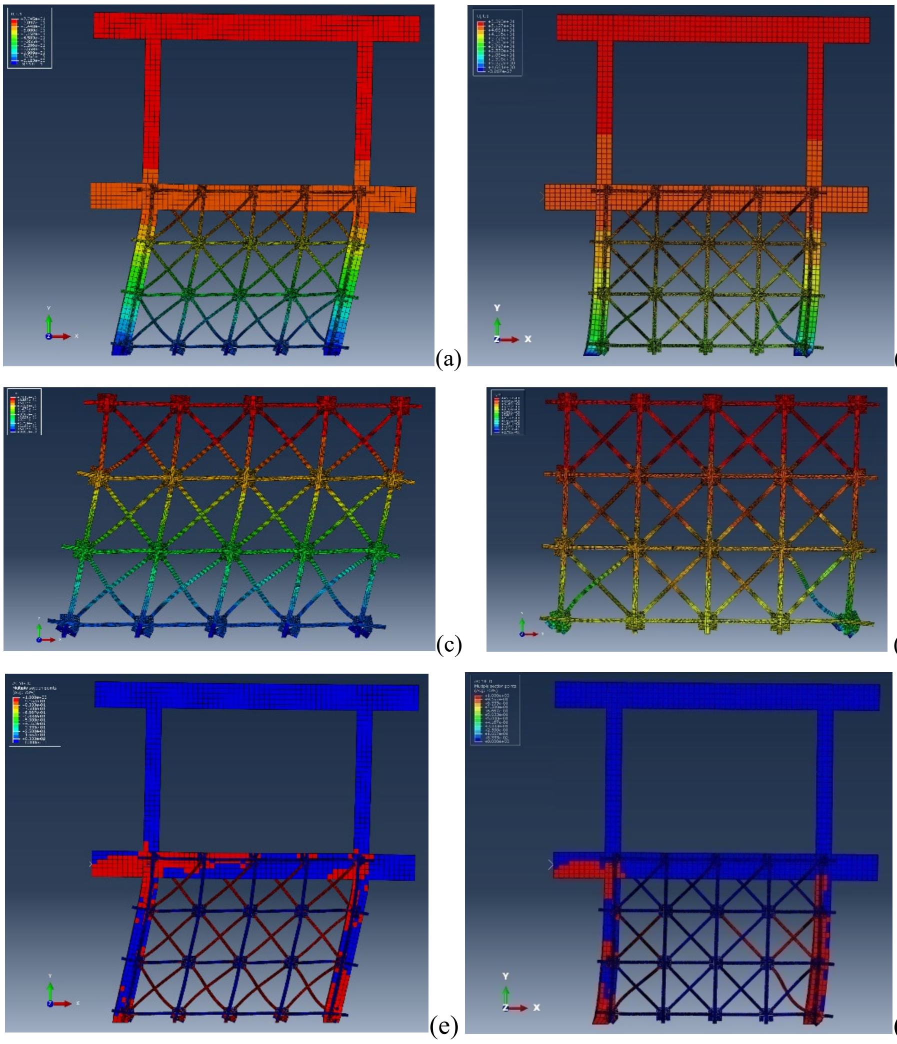


Fig. 21. Numerical and experimental pushover curves on the bare RC frame.

The Resisto 5.9 system allowed to reduce the distribution of stresses in the RCframe with an evident beneficial impact to increase the structural stiffness. This issue can be found in the distribution of active yielding state in the two different models (Resisto NOT Fixed in Foundation and Resisto Fixed in Foundation) compared to that of the bare RC frame. The Fixed model showed the greatest drift with the bracing system reaching yielding state (**Fig. 22Fig.e** and **g**). In this model, a displacement of 70 mm in the first storey beam was attained (**Fig. 22a**), while the non-Fixed model reached at the same point a displacement of about 50 mm (**Fig. 22b**). The drift obtained with the Resisto 5.9 system is also shown in **Fig. 22**Σφάλμα! Το αρχείο προέλευσης της αναφοράς δεν βρέθηκε.**c** and **d**, where it is noticed that in the fixed model the entire exoskeleton reached the largest drifts under lateral loads. In particular, the top end of the beam showed a displacement of about 51mm. On the other end, the non-fixed model did not absorb a significant amount of load. In fact, few bracing elements reached the yielding point (**Fig. 22f** and **h**). In this case, the bottom end of the exoskeleton moved with the RC frame of about 35mm, while the top end shifted of about 50 mm. This means that the differential displacement in the exoskeleton was about 15 mm. Finally, it should be noted that in the non-fixed model the analysis failed to converge at a displacement of about 40mm because of an excessive deformation of the components. Nonetheless, this FEM model presented a different failure mechanism, with break age of concrete at the column bases rather than at the column tops.



(a) (b) (c) (d) (e) (f)

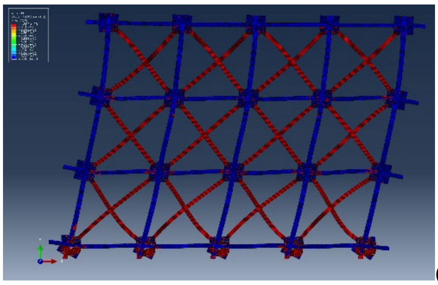
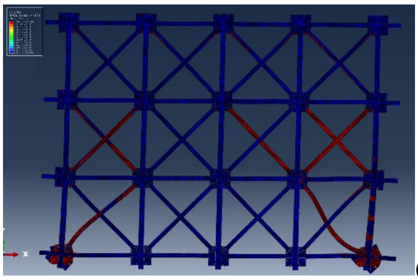

(g)

(h)

Fig. 22.RC Frame + Resisto 5.9 Fixed deformed state (a), RC Frame + Resisto 5.9 NOT Fixed deformed state (b), Resisto 5.9 Fixed deformed state(c), Resisto 5.9 NOT Fixed deformed state (d), RC Frame + Resisto 5.9 Fixed active yield state (e), RC Frame + Resisto 5.9 NOT Fixed active yield state (f), Resisto 5.9 Fixed active yield state (g), Resisto 5.9 NOT Fixed active yield state (h).

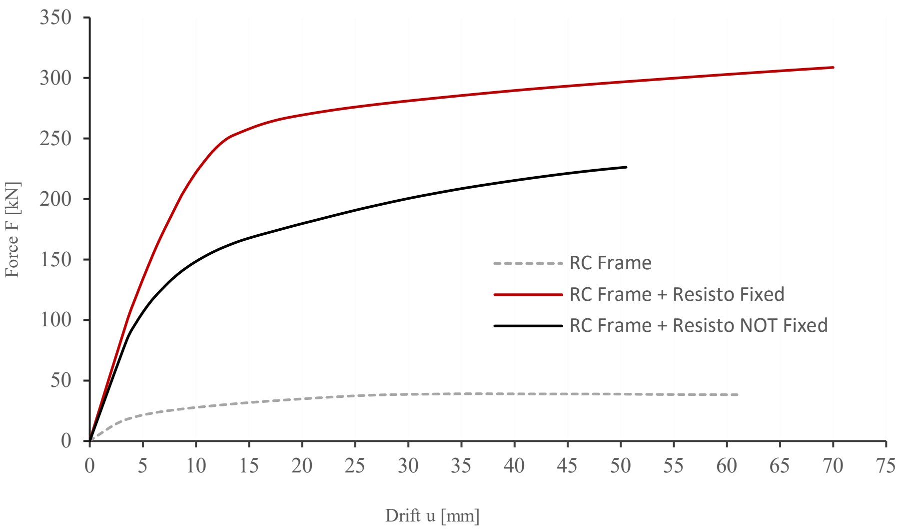


Fig. 23. Abaqus pushover curves of the three structural models.

The different behaviour of the two retrofitted FEM models compared to that of the bare RC frame is accurately represented in the pushover curves of **Fig. 23**. Even if the non-fixed model has a worse behavior than the fixed one, it allowed the entire frame to reach stiffness K and maximum force F greater than those of the frame without Resisto 5.9. The improving capabilities of the Resisto 5.9 system are displayed from **Table 6** to **Table 8**.

Table 6. Displacement (U), Force (F) and Stiffness (K) obtained from the Abaqus pushover curves.

ID Model	U [mm]	F [kN]	K [N/mm]
Experimental RC Frame	13	30	5294.80
Numerical RC Frame	70	39.07	5294.80
RC Frame + Resisto 5.9 Not Fixed	50	226.28	23966.76
RC Frame + Resisto 5.9 Fixed	70	308.72	25358.62

Table 7. Percentage increases of the parameters of the numerical RC frame compared to the experimentally tested RC frame.

ID Model	U [mm]	F [kN]	K [N/mm]
Experimental RC Frame	-	-	-
Numerical RC Frame	-	30%	-

Table 8. Percentage increases of the parameters of the reinforced RC frame compared to the unreinforced RC frame.

ID Model	U [mm]	F [kN]	K [N/mm]
RC Frame	-	-	-
RC Frame + Resisto 5.9 Not Fixed	-	479%	353%
RC Frame + Resisto 5.9 Fixed	-	690%	379%
Fixed – Not Fixed	-	36%	6%

Since the analyses herein presented were conducted in a displacement-controlled mode, the displacement variation (Δ%) appears of unnecessary utility. Contrary, in terms of maximum seismic force, the Resisto Not Fixed model was much more resistant (479%) than the bare RC Frame. At the same time, the Resisto Fixed model exhibited a maximum strength very larger than the bare RC Frameone (690%). Percentage differences in terms of stiffness K showed how the Resisto System positively impacts on the investigated RC structure. In particular, an improvement of 353% for the Not Fixed model and 379% for the Fixed one was registered. As a conclusion, the Fixed solution showed a better response than the Not Fixed one both in terms of maximum force (+36%) and stiffness (+6%) due to the different plastic behavior of the two FEM models previously presented.

2.10 Pro_Sap analysis results

The three frames were assessed by means of push-over analyses with concentrated plasticity models. The Pro_Sap software calculates the limit capacity of plastic hinges according to the assigned sections, materials and load cases. A horizontal force, calculated with a triangular distribution was considered to evaluate the in-plane behaviour of the frames. The pushover curves plot the seismic force (Fb) and the corresponding displacement of the control point (dc) that was assumed at the head of the column. The analyses were performed according to the factors illustrated in **Fig. 24**.

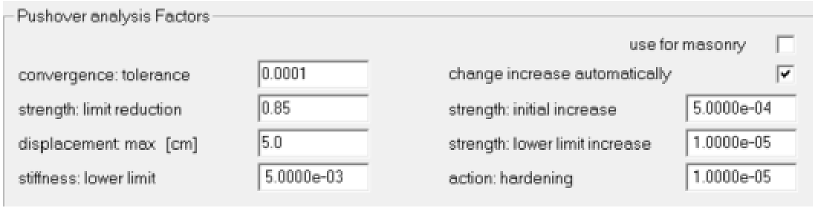


Fig. 24. Pushover analysis factors assigned in the Pro_Sap software.

The comparison between the experimental curve and the numerical curve of the RC frame calculated by means of the Pro_Sap software is shown in **Fig. 25**, where it is apparent that the two curves showed the same stiffness, but different maximum force.

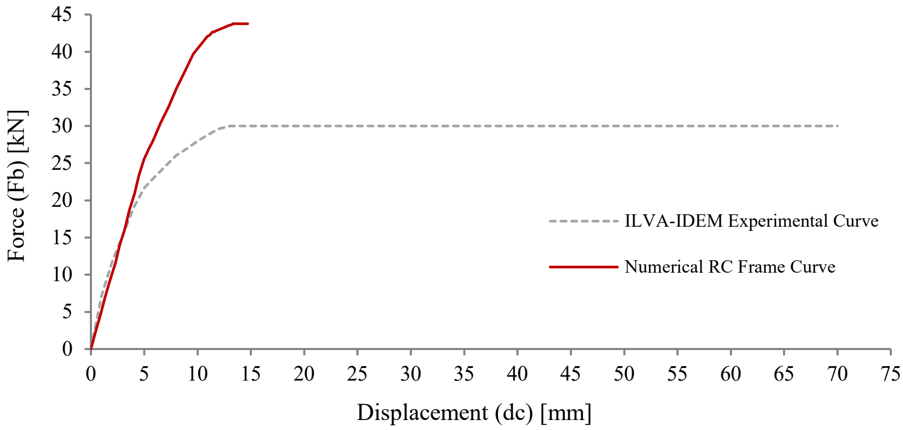


Fig. 25. Comparison between experimental curve and numerical one in Pro_Sap environment referred to the RC Frame.

The results of the pushover curves are depicted in **Fig. 26** and in **Table 9** in terms of maximum force ($F_{b,\, max}$), ultimate displacement ($d_{c,\, U}$), elastic displacement (d_y*) and stiffness (K*) of the equivalent bilinear curve, and ductility ($\mu = d_{c,\, U}/d_y$*).

The application of the seismic coating at the first level of the RC frame led to a significant increase of resistance and ultimate displacement, corresponding to equally high increases in stiffness and ductility. The percentage increases of each parameter, compared to the control frame (RC frame) are illustrated in **Table 10**.

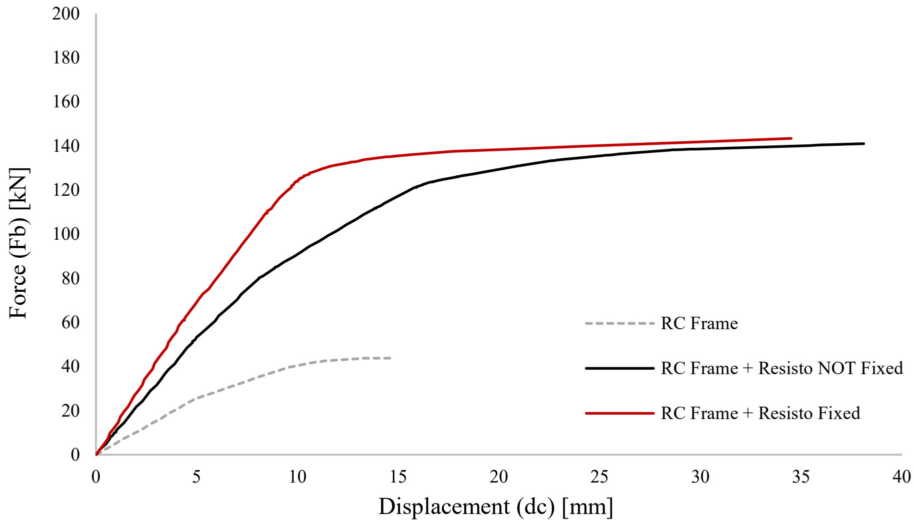


Fig. 26. Pushover curves of the three models calculated with Pro_Sap Software.

Table 9. Results of pushover curves of the three models in Pro_Sap software.

ID model	$F_{b,max}$ [kN]	$d_{c,U}$ [mm]	d_y* [mm]	K* [N/mm]	μ [-]
RC Frame	43.76	14.7	8	5033.5	1.8
RC Frame + Resisto NOT Fixed	141.00	38.1	13.7	9576.4	2.8
RC Frame + Resisto Fixed	143.40	34.5	10.2	13310	3.4

Table 10. Percentage increases of maximum force, ultimate displacement, stiffness, and ductility of the reinforced frames compared to the control one.

ID model	ΔFb, max	Δdc, U	ΔK*	Δμ
RC Frame	-	-	-	-
RC Frame + Resisto NOT Fixed	+222%	+159%	+90%	+51%
RC Frame + Resisto Fixed	+228%	+135%	+164%	+84%

Therefore, the seismic behavior of the RC frame was considerably improved thanks to the application of the seismic coating. The fixed boundary conditions (RC Frame + Resisto Fixed) showed a better response to the seismic action in terms of stiffness and ductility with percentage increases of 39% and 22%, respectively, compared to the not fixed solution (RC Frame + Resisto NOT Fixed).

The step-by-step control of the results also allowed to follow the damage evolution of each structural element. In the sections of the RC beam and columns where plastic hinges were assigned, it was possible to assess when plasticization occurred (i.e., the applied moment exceeded the ultimate moment). The results are illustrated in **Fig 27** for each model with a colored dot representing a plastic rotation value.

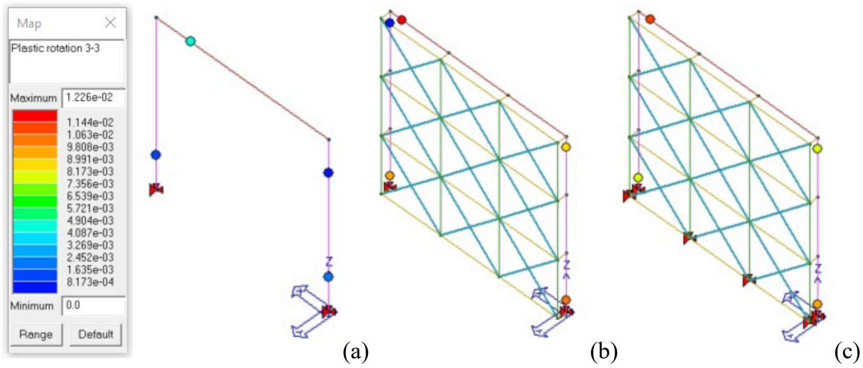


Fig. 27. Plastic rotations of RC elements for the three models: RC Frame (a), RC Frame + Resisto NOT Fixed (b) and RC Frame + Resisto Fixed (c).

2.11 Comparison between Abaqus and Pro_Sap results

The comparison between the pushover curves obtained from Abaqus and Pro_Sap for the three models is illustrated in **Fig 28**.

The unreinforced RC frame curve showed the same stiffness for both software with a significantly lower ultimate displacement in Pro_Sap. Both software displayed an increase in base shear and stiffness due to the application of the seismic coating, which is 40-50% higher in Abaqus then in Pro_Sap. Moreover, Abaqus results show a greater increase in maximum force due to the fixed boundary conditions with a percentage increase of 36%, rather than the increment of 2% of Pro_Sap's. The differences were found in the necessary approximations made by a more commercial software like Pro_Sap that manages a limited number of information compared to Abaqus. Some approximations are dependent from the way the software handle the mechanical parameters. Abaqus allows a more precise parametrization of properties, such as plastic behaviour, hardening in high deformations, micro-fracture and so on. This feature allows the software to investigate a higher field of plastic deformations that Pro_Sap limitedly consider due to its restricted list of editable mechanical parameters. Nonetheless a numerical comparison of the results is described in **Table 11 Table**in terms of maximum force (F) and stiffness (K).

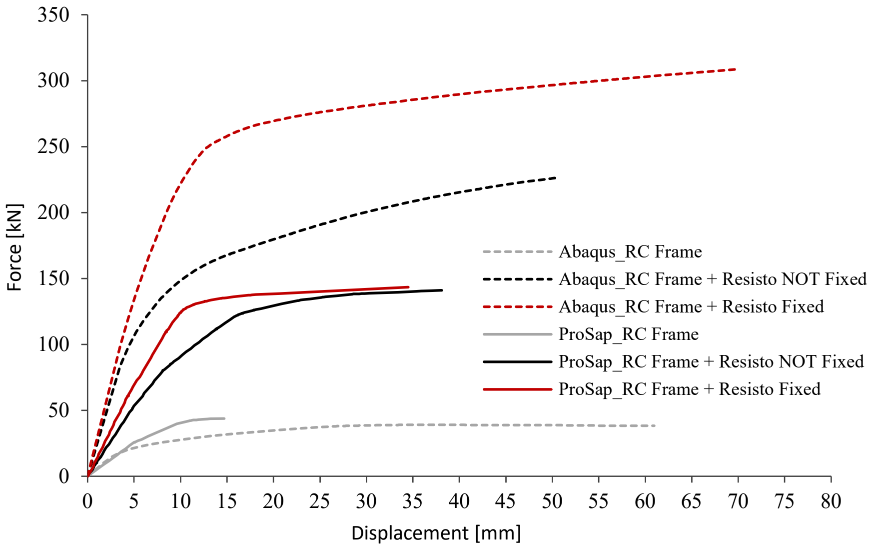


Fig. 28. Comparison between Abaqus and Pro_Sap pushover curves of the three structural models.

Table 11. Percentage increases of maximum force and stiffness in the Abaqus models compared to the Pro_Sap ones.

ID model	ΔFmax	ΔK
RC Frame	-12.00%	+4.94%
RC Frame + Resisto NOT Fixed	+37.69%	+60.04%
RC Frame + Resisto Fixed	+53.55%	+47.51%

3 Conclusions

The research focused on investigating the application of a cold-formed steel framed exoskeleton to a RC frame extrapolated from an existing building. A plane frame was assessed with and without the reinforcement by means of two structural softwares, namely Abaqus CAE and Pro_Sap, with the purpose of evaluating the contribution of the seismic coating system and finding the most efficient method to implement the reinforcement in a calculation software. The comparison between these two programs was made with the purpose of assessing the differences in the results of the structures' seismic behaviour, having modelled the same structural sample with two of the most widely used structural softwares. Three structural models were built with the same characteristics in both softwares: a control frame without reinforcement (RC Frame), a reinforced frame with the seismic coat only linked to the RC structure (RC Frame +

Resisto NOT Fixed) and a reinforced frame where the vertical members of the seismic coat are fixed to the foundation structures (RC Frame + Resisto Fixed).

The analyses were carried out by means of a pushover test in both software. The results showed that the seismic coating system provided a significant improvement of seismic performances to the RC frame, especially for the solution with vertical members linked to the foundation system. The contribute of the un-fixed solution (RC Frame + Resisto Not Fixed) was an increase in base shear (479% Abaqus CAE and 222% in Pro_Sap), ultimate displacement (159% in Pro_Sap) and stiffness (353% Abaqus CAE and 90% in Pro_Sap) compared to the RC frame without reinforcement. The fixed solution (RC Frame + Resisto Fixed) showed a better behavior leading to an increase in base shear (690% Abaqus CAE and 228% in Pro_Sap), ultimate displacement (135% in Pro_Sap) and stiffness (379% Abaqus CAE and 164% in Pro_Sap) compared to the RC frame without reinforcement.

The comparison between the results provided from both software showed that, even if the structures were modelled using the same geometrical, mechanical, and loading conditions, the seismic performances obtained from a more commercial calculation software (Pro_Sap) are significantly worse than the ones obtained from a more accurate software such as Abaqus CAE. Abaqus pushover curves showed higher values of base shear, displacement and stiffness for the reinforced models, suggesting that further analysis should be performed to reduce the gap between these results. However, the necessary approximations of a commercial software allowed to reach the seismic upgrading of the structure by applying the seismic coating system, even if leading to an improvement of the seismic behavior, on the safe side, lower than its potential.

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Seismic investigation and upgrading of disused industrial buildings: a case study

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Abstract. In this paper, the evaluation of the seismic behaviour and the consolidation plan of a former industrial building are described.
After a short introduction regarding the value of industrial architecture, discovered only in the late '70s of the past century, and the necessity to intervene on this heritage, most of the time abandoned, the case study has been introduced. It is a former tobacco industry placed in a small village in the outskirt of Salerno, in the South Italy.
Firstly, the historical evolution of the property has been reconstructed. Then, the main structural and architectonical features of the building have been illustrated. After this knowledge phase, the seismic behaviour has been evaluated with regard both to local and global mechanisms. Based on the obtained results, retrofitting operations have been hypothesized to allow for the new functionalization and the reuse of the building.
In conclusion, the effectiveness of the consolidating interventions has been demonstrated by repeating the pushover analyses, whose results have enabled the complete seismic upgrading of the former tobacco industry.

Keywords: Industrial buildings, Tobacco factory, Pushover analyses, Retrofitting operation, Seismic upgrading.

1 Introduction

In Italy, most of the existing buildings were erected without any seismic criteria, since realization was made before the first national seismic regulations.

Among these structures, built to resist only to gravity loads, there were industrial edifices. A huge part of them, especially those built with a mixed structure (masonry and reinforced concrete), came back to the early '30s of 20th century, whereas the ones made of steel structure dated back around 1980s. [1]

However, both typologies seriously suffered seismic actions, as demonstrated by two recent earthquakes occurred in L'Aquila in 2009 and in the Emilia – Romagna region in 2012. In those occasions, seismic events highlighted not only the vulnerability of historical centres with their ancient buildings, but also the susceptibility of industrial constructions to undergo significant damages and failures [2].

Consequently, the Italian Project DPC-ReLUIS set up, in the period between 2019 and 2021, the CARTIS-GL form so to characterize, from typological and structural viewpoints, large span buildings on Italian territory[3, 4].

The form is divided into four parts that start from general information, like the consistency of the territory, and arrive to specific data, like the geometrical and structural features of the examined building. The collected data with the CARTIS form allow to obtain some important outcome, such as the prevailing construction period, covered area, number of floors, height, etc. of a set of industrial buildings in the studied area.

The interest in studying industrial areas and buildings was born in 1950 in England, where in the previous century the industrial revolution began. In Italy, this interest arrived later, mainly in ‘70s, when industry started to be considered as identity of the population. Thanks to an increasing interest on the factory buildings, in that decades, the “industrial archaeology” concept was born and many researchers began to study these particular architectures characterized by long spans [5, 6, 7, 8] after their abandonment due to the failure of industrial societies aiming at recovering purpose through reuse of their spaces for events and exhibitions.

On the basis of these premises, our work focused its attention on the study of a former tobacco industry abandoned after the bankrupt of the owner society. This industrial building is placed in a small village in the outskirt of Salerno in South Italy.

Starting from the description of the area where the building is located, firstly, the crack pattern achieved from in-situ visual surveys was defined and, then, its seismic behaviour was predicted by carrying out nonlinear analyses through the TreMuri computer program. Based on the results, recovery interventions were defined and the analyses on the retrofitted building was performed to evaluate their positive effect on the structure seismic behaviour.

2 The former tobacco factory: the case study

2.1 Placement and historical evolution

The case study herein introduced is a former tobacco factory placed in Cafasso - Borgo Nuovo, a small village, with less than 1000 inhabitants, in the municipality of Capaccio, within the province of Salerno in South Italy.

The municipality belongs to the Sele Plain, a very large flat area which extends for about 500 km^2. In **Fig. 1** the placement of the examined structure is observed.

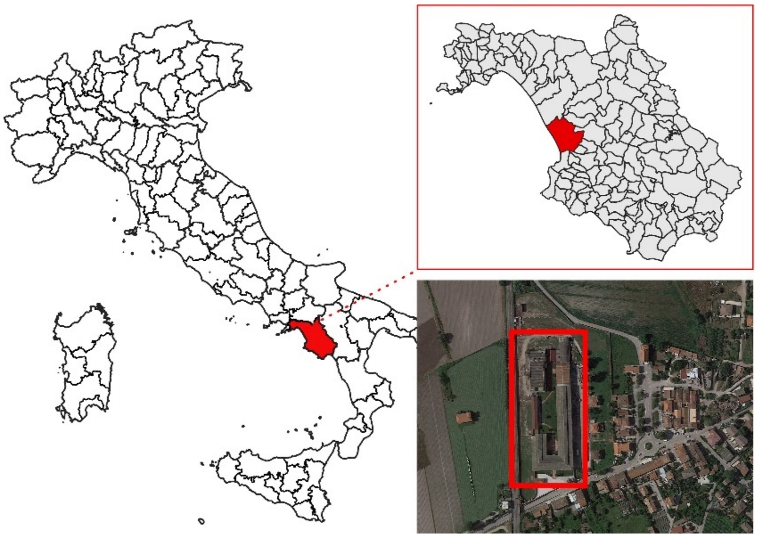


Fig. 1. Placement of the case study

The case study belongs to a network of other buildings having equivalent use spread in the Sele Plain, like the Farina or Fiocche tobacco factory. Most of them (except than the Carillia structure) was disused and abandoned in the '90s and now they are in a very advanced state of decay [9].

In **Fig. 2** a scheme of this factories network in the outskirt of Salerno is depicted.

These constructions have similar geometry distinguished by long spans and modest height. Their structures were realized with either load bearing masonry or reinforced concrete structures. Generally, the facades are characterized by a regular scan of openings useful for lighting of internal spaces and their ventilation.

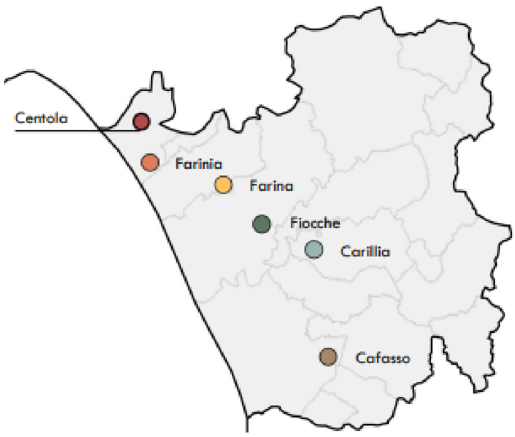


Fig. 2. Network of tobacco industries in the municipality of Capaccio (Salerno)

The case study named "Luigi Razza tobacco industry", also known as "Cafasso tobacco factory", was erected in a large property where about 26 structures dating back to different time periods were built.

The case study building takes its name from Luigi Razza, the last owner. Before his death, in 1935 he bought the property from Gaetano Bonvicini, who started the edification with the house of director and stables (Buildings with nr. 1 – 2 – 3 and 4 – 5 – 6, respectively, of **Fig. 3**).

Fig. 3. The first buildings in the property (Late '20s)

In 1943, the property became a war warehouse and then returned to the Industrial Agricultural Society of Salerno a few years later until the '60s when the estate was sold to another tobacco industry society, and it was expanded with the construction of several houses for workers and dryers (Buildings nr. 9 – 15 and 24, respectively, of **Fig. 4**). In the early '70s, the entire area was sold to private entrepreneurs, who failed their activities in 2002.

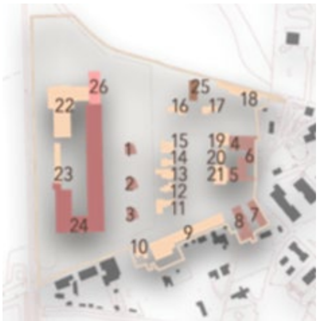


Fig. 4. A map of the property in the late '90s

Despite the efforts of Capaccio municipality, which tried to buy the grounds and its buildings, since 2020 the property is in abandoned state. In 2021, however, the procedure of remediation for the presence of asbestos is launched and the same municipality manages to win the lease for the organization of events and exhibitions.

Between the various and numerous buildings existing in the lot, in this work our attention is on the structure that one time hosted the dryers. Its main features are described in the following section.

2.2 Structural and architectural features of the former tobacco industry

The building under study, which within the large area examined is the one intended to the dryers' function when it was active. The drying phase in the processing of tobacco consisted in hanging the leaves on wooden structures, generally the gratings placed under the covers, to allow them to dry before the next production stages. **Fig. 5** shows a three-dimensional view of the edifice.

Fig. 5. A three-dimensional view of the building

It is articulated into three "arms" that, due to their configuration, individuate an internal courtyard. The structure reaches a maximum height of about 15m. **Fig. 6** reports the ground floor plan of the building.

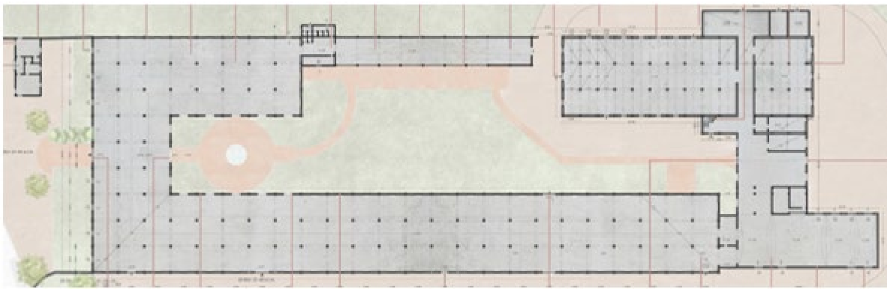


Fig. 6. Ground floor layout

Its structure is of mixed type, composed of masonry and reinforced concrete (**Fig. 7**), the external masonry is realized with solid bricks, and it is interrupted by reinforced concrete pillars, placed at about 6 m each other, which develop from the ground to the building top (**Fig. 8**).

Internally, due to the old use required for the tobacco manufacturing, there are not vertical divisions, but only pillars which mark the spaces dividing them into standard modules.

There are not even internal horizontal floors, but only the roof structure having a double pitch configuration made of corrugated sheet metal placed so to replace the previous asbestos panels. This roof is sustained by a grid of wooden beams. (**Fig. 9**) The facades are characterized by a series of rectangular opening. Some of them have been closed with solid bricks after the abandonment of the factory in order to avoid the entrance of strangers (**Fig. 10**). All these features are highlighted in the following photographic documentation.

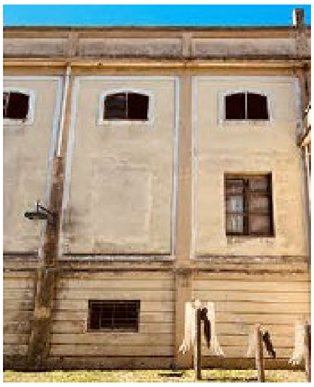


Fig. 7. Alternation of masonry walls and pillars on the façade

Fig. 8. Reinforced concrete pillar

Fig. 9. The structure of the roof

Fig. 10. Closure of the opening at ground floor

2.3 State of decay: the crack pattern

Due to the abandonment occurred at the beginning of the 20th century, the building under examination shows different types of injuries and failures, that could be grouped into four categories:

- Crushing of masonry walls;
- Poor connection among adjacent walls;
- Decay of wooden elements;
- Decay of reinforced concrete pillars.

With the regard to the first type of damage, at the base of the external masonry walls it is possible to individuate crushing phenomena. These could be related to the age of materials and the decay of the mortar. In some points of walls orthogonal to each other, there are a lack of connection between them, which give rise to the absence of the so-called “box-effect”. As a consequence, the structure could suffer local mechanisms. like overturning phenomenon [10].

Due to the humidity, numerous wooden elements of the roof grid are deteriorated. Instead, other elements show vertical lesions due to the loads increase during time.

Finally, some problems are found in reinforced concrete pillars, which exhibit in some parts the detachment of the concrete cover. As a result, the steel reinforcement bars are exposed and rusty. In **Fig. 11** the four typologies of damages above described are illustrated.

a) b) c) d)

Fig. 11. Injuries on the case study: a) Crushing of masonry walls, b) Poor connection between adjacent walls, c) Decay of wooden beams, d) Detachment of the cover concrete from the pillars

3 Seismic behaviour evaluation

3.1 Method

In order to evaluate the seismic behaviour of the dryers of the former tobacco factory, the TreMuri computer program, a calculation software developed by the STA.DATA company, is used. It is a software based on the Frame by Macro-Elements (FME) numerical modelling technique, where each masonry panel is composed of three macro-elements, namely piers, spandrels and rigid nodes. The first are placed next to the openings, the spandrels are above and under the openings, and rigid nodes, considered as infinitely igid, are at the intersection between piers and spandrels.

TreMuri program, which was extensively used in various literature works [11, 12], is herein used for the evaluation of the non – linear behaviour of the inspected masonry structure. The global analysis gives back the pushover (or capacity) curve, which is identified through the base shear-displacement diagram. According to the current Italian technical code [13, 14] in order to carry on the pushover analyses, two distributions of inertia forces must be considered as follows:

- Distribution proportional to the static forces (Group 1);
- Uniform distribution of forces, which is derived from a uniform distribution of accelerations over the height of the construction (Group 2).

3.2 Evaluation of local mechanisms

Before evaluating global behaviour of the tobacco fabric under study, it has been studied its tendency towards local mechanisms.

They are also known as first-way mechanisms, and they are defined as failure modes involving structurally independent parts of masonry named macro-elements experiencing behaviour outside their own plane. Among them, we recognize partial/total overturning and vertical/horizontal bending phenomena.

Generally, these failures interested structures which do not show the so-called "box – effect" due to a lack of connection either between vertical walls and horizontal floors or between two adjacent orthogonal masonry panels [15, 16, 17].

These local mechanisms have been assessed through the TreMuri software, used also in the next step for global analysis. The evaluation is based on the limit analysis method, that consider the masonry as a series of rigid macro-elements having unlimited compressive strength, but zero tensile resistance.

For each considered mechanism, the portion of masonry is transformed into a kinematic chain (unstable system), with the identification of rigid bodies capable of rotating or sliding among them.

Verifications have been conducted with reference to the Life Safety Limit State. They are satisfied if the spectral seismic acceleration of activation of the kinematics a^*_0 is greater than the peak ground seismic acceleration $a_{0,min}$:

$$a_0^* \geq a_{0,min} \tag{1}$$

In the case of ground floor constraint, a_0^* is calculated as follows :

$$a_0^* = \frac{\alpha_0 \cdot g}{e^* \cdot F_C} \tag{2}$$

in which:

α_0 is the multiplier of the seismic action causing the collapse, obtained through the principle of virtual works;

g is the gravity acceleration;

$e^*$is the participating mass fraction related to the first vibration mode;

Fc is the confidence factor (in this case assumed equal to 1,35).

$$a_{0,min} = \frac{S_e(0)}{q} \tag{3}$$

where:

$S_e\,(0)$ is the ordinate of the elastic spectrum;

q is the behaviour factor.

Contrary, for masonry walls having hinge at a certain altitude, the following expression is used:

$$a_{0,min} = \frac{S_e(T_1) \cdot \psi(Z) \cdot \Upsilon}{q} \tag{4}$$

where:

- $S_e\,(T_1)$ is the ordinate of the elastic spectrum, which depends on the first vibration period T1;

- ψ is the first vibration mode in the considered direction;
- γ is the modal participation coefficient;
- q is the behaviour factor.

For the former dryers of tobacco factory, only the overturning phenomenon, considering both partial and global types, are evaluated.

In **Table 1Table** and **Table 2Table**, the achieved results obtained analysing the perimeter walls of the structure are summarised. It is seen that the structure has a high vulnerability towards local mechanisms, since all analyses are not verified.

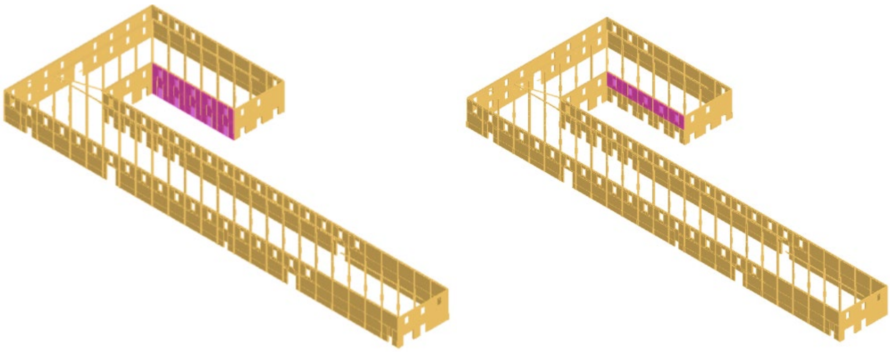
Table 1. Results of evaluation of local mechanisms – Global type

Wall	Constraint	a_0^*	$a_{0,min}$	Check Result
-	-	[m/s²]	[m/s²]	[-]
1	Ground	0,4931	1,4171	Not Verified
2	Ground	0,0178	1,4171	Not Verified
3	Ground	0,5017	1,4171	Not Verified
4	Ground	0,5465	1,4171	Not Verified
5	Ground	0,4991	1,4171	Not Verified
6	Ground	0,5430	1,4171	Not Verified
7	Ground	0,5509	1,4171	Not Verified
8	Ground	0,5501	1,4171	Not Verified

Table 2. Results of evaluation of local mechanisms – Partial type

Wall	Constraint	a_0^*	$a_{0,min}$	Check Result
-	-	[m/s²]	[m/s²]	[-]
1	First-floor base	1,0950	2,5777	Not Verified
2	First-floor base	1,1248	2,5777	Not Verified
3	First-floor base	1,1793	2,5777	Not Verified
4	First-floor base	1,1806	2,5777	Not Verified
5	First-floor base	1,1332	2,5777	Not Verified
6	First-floor base	1,1799	2,5777	Not Verified
7	First-floor base	1,1104	2,5777	Not Verified
8	First-floor base	0,7632	2,5777	Not Verified

Fig. 12 represents one of the same perimeter walls (Wall nr. 3) analysed for the evaluation of the global overturning mechanism and the partial one.



a) b)

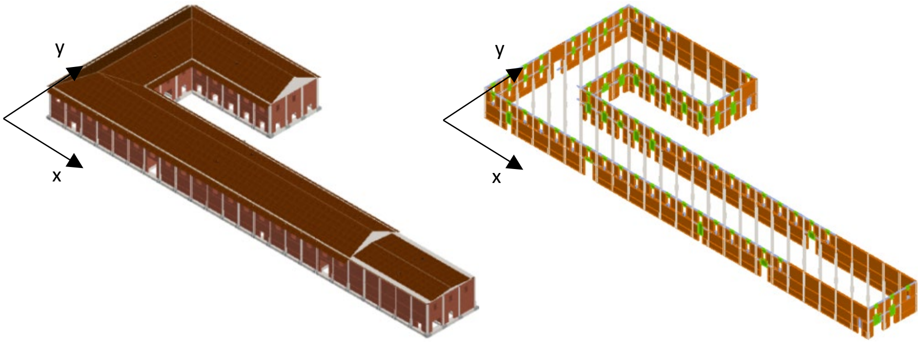
Fig. 12. Wall 3: a) Global overturning; b) Partial overturning

3.3 Pushover analyses

Once the evaluation of local mechanisms is done, pushover analyses are carried out in order to evaluate the global behaviour of the structure.

After geometrical modelling of the structure is executed, the properties of materials are defined selecting the lowest level of knowledge (LC1) according to the current Italian legislation. Therefore, the minimum values for resistance and medium ones for elastic modules are assumed for masonry. Finally, the roof structure is modelled over the masonry structure.

After the 3D model is generated, the mesh dividing each masonry panel in the three above-mentioned macro-elements is created. A view of both the three – dimensional model and the meshed one of the building is depicted in **Fig. 13**.



a) b)

Fig. 13. Macro-elements modelling of the investigated structure:
(a) Three – dimensional model; (b) Meshed model

Firstly, modal analysis is performed and a first vibration period in y direction, equal to 0,57 s is achieved.

Subsequently, after the subsoil category type C is defined, pushover analyses monitoring the displacement of a “control node” at the roof level are performed. The results of the two worst analyses are shown in **Table 3**, where the seismic safety factor at Life Safety Limit State, intended as the ratio between the capacity acceleration and the demand one, is provided in each analysis direction.

Table 3. Results of pushover analyses

Nr.	Seismic direction	Seismic load	Eccentricity	α_{SLV}
16	-X	Modal distribution	-269,8	1,681
20	+Y	Modal distribution	-719,8	0,625

In **Fig. 14**, the main damage and failure mechanisms of masonry macro-elements are illustrated on the three-dimensional model of the building for the analysis in direction y.

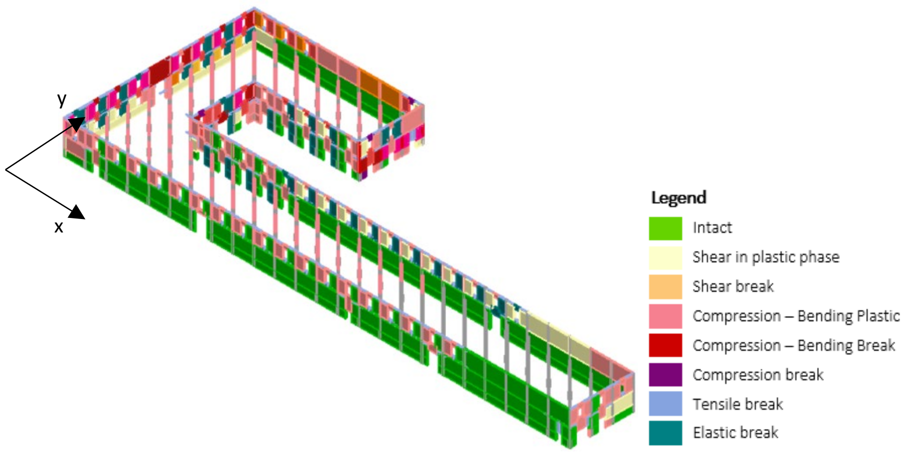


Fig. 14. Damage mechanisms of the structure loaded in direction y

As it is observed from the above figure, the main mechanisms affecting masonry piers are the shear failure (yellow elements) and compression – bending (pink elements) phenomena. Most of RC pillars undergo plastic behaviour under compression – bending actions (pink elements).

4 Retrofitting plan

4.1 Interventions

Following the analysis phase which underlined the deficient seismic behaviour of the building, especially in y direction, and its high vulnerability towards overturning phenomena, various consolidating operations are hypothesized aiming at the building reuse. In particular, based on the intentions of the municipality of Capaccio, the structure could be used for exhibitions and other events connected to the food industry.

The retrofitting plan foresees some specific interventions that are described as follows.

Metal chains

The first operation consists of the insertion of metal chains to contrast the overturning phenomena due to the lack of effective connections among orthogonal walls.

These chains, having circular cross-section with diameter of 20 mm and placed every 5/6 meters, arefirstly designed through the "Tie beams calculation" software, that allows to get the chain diameter, and then verified by means of "Kinematic Analysis" modulus of the TreMuri program. This latter calculation tool provides not only the verification of the local mechanism, but also the checks towards the following failure mechanisms:

– Masonry punching

The punching resistance of masonry in the anchoring zones is given by the following formula:

$$\tau_{pun} = f_v \cdot [2 \cdot (b + t) + 2 \cdot (a + t)] \cdot t \quad (5)$$

where:

- t: thickness of the masonry;
- b: width of the plate;
- a: height of the plate;
- fv: shear design resistance of the masonry.

– Anchor penetration

The penetration of the anchor in the masonry is given when the compressive strength of the masonry subjected to the contact pressure of the plate is exceeded. This resistance is given by the following formula:

$$\tau_{pen} = f_d \cdot a \cdot b \quad (6)$$

being f_d the design compressive resistance of the masonry.

– Chain yield strength

The verification of the chain is done by using the following expression:

$$\tau = f_y \cdot \frac{\Phi^2 \cdot \pi}{4} \quad (7)$$

where:

- Φ is the diameter of the metal chain;
- fy is the design tensile resistance of the chain.

Scuci and Cuci technique

Another intervention planned on the masonry walls is the scuci and cuci technique.

Thanks to this operation, the damaged stones are replaced with new ones of the same material in order to ensure a better organization and duration over the time of the masonry apparatus.

As a first step, the plaster covering the masonry (if present) and the damaged stones are removed. After, there is the cleaning of the masonry by removing debris and dust. Finally, the new blocks are inserted using a zero or slightly expansive shrinkage grout.

Re – styling of the joints

A further consolidating operation on the masonry apparatus foresees the re – styling of the joints using mortar having a similar chemical composition to the pre-existing one, so to avoid unsuccessful operations.

New steel frames around openings

Since the design idea includes the elimination of masonry brick walls used for the closure of openings after the abandonment of the structure, in order to restore the resistance and the stiffness of the structure, steel frames are hypothesized to be inserted around openings. They are made up of two steel columns per side and two beams of HEB type.

All the profiles are connected to the masonry walls by chemical anchors.

Interventions on the reinforced concrete elements

This category includes two types of operations. The first intervention consists of the enlargement of the cross-section of some pillars showing failures from pushover analyses. Existing pillars have cross-sections of 46x46 cm at the base and 36x36 cm at the top. These elements are reinforced to reach a final cross-section of 50x50 cm.

The second intervention is the reconstruction of the concrete cover in most cases detached due to the age of materials and the lack of maintenance over the time. Both operations can be performed according to the following phases:

- Removal of the degraded concrete;
- Removal of dust and debris and subsequent washing;
- Application of protective paints for steel bars;
- Placement of new steel bars for the reinforcement;
- Concrete casting in the first operation, reconstruction of the concrete cover in the second case.

Replacement of the roof

Since the current roof made of corrugated metal sheets is a temporary structure placed after the removal of the previous one realized in asbestos, its replacement is foreseen with a new “cold type” structure so to get a ventilation space between the coverage layers. Proceeding from the inside outwards, the new roofing structures is composed of wooden plank, vapour barrier, rock fibre panels for thermal insulation, waterproof coating, air space and final coverage.

4.2 Pushover analyses after interventions

After the planned retrofitting operations above described, reported in **Fig. 15**, are inserted in the TreMuri calculation model, both local (linear) and global (non-linear) seismic analyses are repeated.

From one side, local checks confirm the contrast of overturning phenomena thanks to the insertion of metal chains in the structure.

From the other side, global analyses show the effectiveness of the consolidating interventions. Indeed, all the 24 pushover analyses are verified in both analysis directions. The worst analysis results are depicted in **Table 4Table**, where it is noticed that, being the alfa coefficient greater than the unit in both analysis directions, the planned consolidation interventions allow the building to be completely retrofitted from seismic point of view.

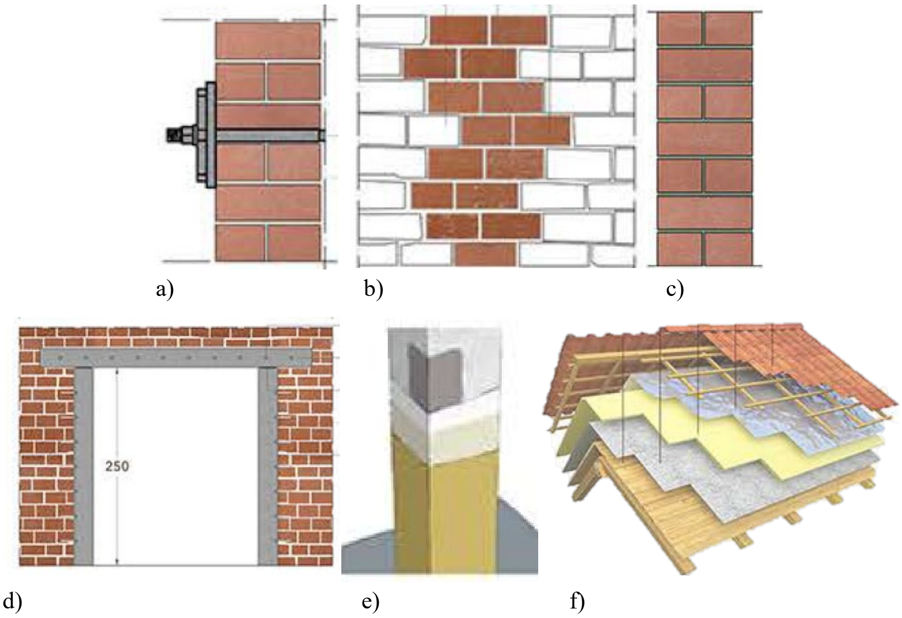


Fig. 15. Schematic representation of planned retrofitting operations: (a) Insertion of metal chain; (b) "Scuci and cuci" technique; (c) Re-styling of joints; (d) Steel frame around door; (e) Reinforcement of thereinforced concrete pillar; (f) New roof.

Table 4. Results of the two worst pushover analyses

Nr.	Seismic direction	Seismic load	Eccentricity	α_{SLV}
11	+X	Modal distribution	269,8	1,712
20	+Y	Modal distribution	-719,8	1,25

5 Conclusions

The work dealt with the seismic behaviour assessment and retrofit of a former tobacco industry located in the small village of Cafasso - Borgo Nuovo, in the province of Salerno of Southern Italy. Since interest in industrial archaeology began in the last decades of 21st century, the interest towards industrial buildings, which represent a huge heritage evidence of both the industrial revolution and the change of architecture adapted to new spaces and materials, is strongly felt by researchers and designers.

The case study is a typical example of this new way of doing architecture. The building has a mixed masonry-reinforced concrete structure, and it was abandoned after the bankruptcy of the industrial society in 2002. As a result, it is in a very advanced state of decay with widespread crushing phenomena of masonry walls and concrete cover spalling in the pillars.

In the current work, after the knowledge phase and the crack pattern survey of the building, its seismic behaviour with respect to both local and global mechanisms was evaluated. The unsatisfactory analysis results deriving from this assessment phase required the planification of anti-seismic interventions of different type, aimed to both enable overturning mechanisms and reinforce in terms of strength, stiffness and ductility the original structure, with the final goal to ensure its requalification and reuse.

The planned consolidation interventions proved their effectiveness, since local mechanisms were avoided by inserting metal chains and pushover analyses, thanks to operations on masonry walls, RC pillars and roofing structure, provided seismic safety factors greater than one in both analysis directions, allowing the former tobacco factory to be completely retrofitted from seismic viewpoint.

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Extensive Restorations of Arched Stone Bridges: the Examples of Plaka Bridge in Greece and Stari Most in Bosnia and Herzegovina

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Abstract. In the last thirty years, Europe has experienced two major destructions of important monuments of its cultural heritage. They are both related to the collapse of stone-built, arched bridges, which were closely linked to the history and evolution of the bridging areas.

In 1993, the historic Mostar Bridge (Bosnia and Herzegovina), built in 1566 by the Ottoman architect Mimar Hajrudin, almost completely collapsed, bridging the Neretva River. The cause of the collapse was the relentless bombardement of Mostar during the Yugoslav war (1992-1995).In 2015, the entire central arch and almost 90% of the eastern pier of Plaka Bridge in Tzoumerka collapsed, following extreme weather events and a rise in the level of the Arachthos River. The bridge was erected in 1866 by master builder Kostas Bekas. The restoration of these bridges were complex, high-tech projects, and posed great challenges, being global innovations.

This article gives a brief presentation of the two bridges and analyzes the administrative and technical framework for their restoration. The purpose of this article is to compare and evaluate common and non-common features of the two projects, since the innovative ways of restoring them can be methodological models for the restoration of similar structures.

Keywords: Arched Stone Bridge, Masonry Structure, Monument, Procedure-Framework, Restoration.

1 Introduction

A wide variety of arched stone bridges have been documented in the Balkan Peninsula, built mainly in the 18th and 19th centuries or even earlier [1]. More than 500 characteristic examples of such historical structures have been recorded just in the Epirus Region of northwestern Greece [2]. They were erected from local building materials [3] during the pre-industrial era, in order to overcome important communication and transportation obstacles. The relevant bridges often became points of reference for the areas they served. In this way, they were intertwined with the local traditions of the people, constituting great witnesses of the history and the eternal evolution of the lives of their inhabitants.

Some of these bridges exist as cultural heritage monuments in a local or supra-local level. While many of the elements of the world's cultural heritage are at high risk of destruction due to natural processes and human activities, many of them have already been destroyed especially in recent years.

Related structures are subject to a number of interdependent wear factors. The change in loading conditions throughout their lifetime [4] is a key risk factor for maintaining their structural integrity and in some cases requires appropriate measures for their preservation [5]. Deterioration of bridge construction materials, due to natural aging and wear mechanisms [4], in some cases exacerbated by the use of incompatible restoration materials, is an issue that needs to be considered, as building materials are interrelated with conservation status and response of the structure as a whole. Climate change also plays an important role in the degradation processes, as extreme temperature changes as well as extreme rainfall greatly affect and accelerate the progressive degradation of building materials [5], especially considering the wet environments in which bridges are built, receiving (extreme many times) seasonal fluctuations in river flows. Also, the destructive fury of man can be an additional factor of deterioration.

Research related to the conservation of historic arched stone bridges is on the one hand, of utmost importance for their preservation as cultural assets, and on the other hand, it proves to be significantly difficult, as each one of them is unique. Features such as: the number of arches and their shape, the dimensions of the arch and the piers [4], the building materials and the filling materials used [6], the construction method and the differentiation of construction techniques depending on the building period and region, the characteristics of the river, the environmental conditions of the area they bridge and the loads they have to carry [5], contribute to this. For this reason, it is necessary in many cases of preservation of similar monuments to apply an interdisciplinary approach [7], which will integrate and merge data from more than one field of research interest. Usually a multidisciplinary team, to be determined in relation to the type and scale of the operation, should work together from the first steps of a restoration project [8].

In 1566the construction of the single-arch, stone-built bridge Stari Most in the city of Mostar (in Bosnia and Herzegovina) was completed, which spans the Neretva River. Exactly three hundred years later, in 1866, the Arachthos River (in Epirus, Greece) was bridged, at Plaka, similarly with a stone-built single-arched bridge.

Plaka Bridge in Ioannina (after the collapse of the Korakos bridge) is the largest single-arched bridge in the Balkans, designated by the Greek State as a historical monument (1971) and a work of art “in need of special protection” (1972). The Bridge of Mostar (Stari Most) was included in the list of world cultural heritage monuments by UNESCO, one year after its restoration (2005).

Both bridges suffered significant losses for different reasons. Plaka Bridge (Fig.1) collapsed in a significant part (Fig.2), on February 1, 2015, after heavy rainfalls in the area.

Fig. 1. Plaka Bridge (downstream view), August 2014.

Fig. 2. Plaka Bridge (downstream view), May 2015.(Image source: © Ch. Giannelos)

Stari Most (Fig. 3) was destroyed on November 9, 1993 (Fig. 4) due to bombardement by Croatian forces, during the war in Yugoslavia.

Both bridges have for different reasons each, great importance for the local population and beyond. Since Plaka Bridge is not just a monument of cultural heritage and popular architecture. It is a symbolic element intertwined with historical events of Greece. Its significant size and the particularity of its construction make it a high-tech work, while its overall image and its relationship with the special beautiful natural landscape that surrounds it, and contribute to its characterization as a work of art with artistic and aesthetic value [7]. While Stari Most was designated by UNESCO as a World Heritage Site not only because of its architectural value but also because of its great symbolic importance for the multinational community of Mostar [9].

Thus, in both cases, it was decided to restore the bridges, which has been successfully completed.

Fig. 3. Stari Most complex before the bombardement, August 1989. (Image source: © A.Pašić)

Fig. 4. The surviving abutments of Stari Most after the bombardement, December 1993. (Image source: © A. Pašić)

The restoration of the two bridges, apart from being an important technical work, raised the theoretical issue in relation to the correctness (in terms of the accepted principles of restoration) of reconstructing a large part of them. This matter was dealt with in both cases in the same way, given the great importance (from a historical, social, political, religious point of view, etc., as the case may be) of the two bridges.

For both bridges, their restoration was decided and carried out following precisely the historical structural system and using practically the same structural materials.

Despite their differences, both projects are complex and required the synergy of many factors to be carried out. Indeed, for the restoration of Plaka Bridge, three Ministries collaborated (Ministry of Culture and Sports-MoCS, Ministry of Infrastructure and Transport-MoIT and Ministry of Economy and Development-MoED), the National Technical University of Athens (NTUA), the Epirus Region andt he Municipality of North Tzoumerka, the Technical Chamber of Greece/Department of Epirus (TCG/DE), two Contracting Companies and at least four Research Offices [10].

The restoration of Stari Most bridge complex was made possible thanks to the cooperation of the city of Mostar, UNESCO, the World Bank, the World Monuments Fund and other donors (states and institutions). Among the donor countries are Italy, the Netherlands, Croatia and Turkey. Also, the European Union (through the Council of Europe Development Bank), the World Monuments Fund (WMF) and the Aga Khan Foundation for Culture [11].

The loss of the two bridges over a large area, allowed the exhaustive documentation of the monuments, which contributed to their scientific restoration.

In this paper, administrative and technical issues are presented, which were a necessary and important factor in the success of these complex projects and concern the framework, methodology and cost of the restorations.

Through the presentation of the restoration projects of the two bridges, as well as through the comparison of the procedures followed, it is possible to draw essential conclusions regarding large-scale interventions in cultural heritage structures.

The methodology followed in this work is related to a bibliographic research regarding the context of restoration of Stari Most, while regarding the project of the Plaka Bridge the author of this text was directly involved in the restoration, due to his position (routing of the commissioning process and project supervision).

2 Plaka Bridge

2.1 Brief description of the bridge

Plaka Bridge is geographically located in the settlement of Raftanaioi, of the Municipality of North Tzoumerka, of the Regional Unity of Ioannina. It was part of the road network connecting Tzoumerkochoria with Arta and Ioannina, and the old Municipalities of Pramanta with Katsanochoria (Fig.5), which are separated by the Arachthos River very close to its confluence with the Raftanitikos stream.

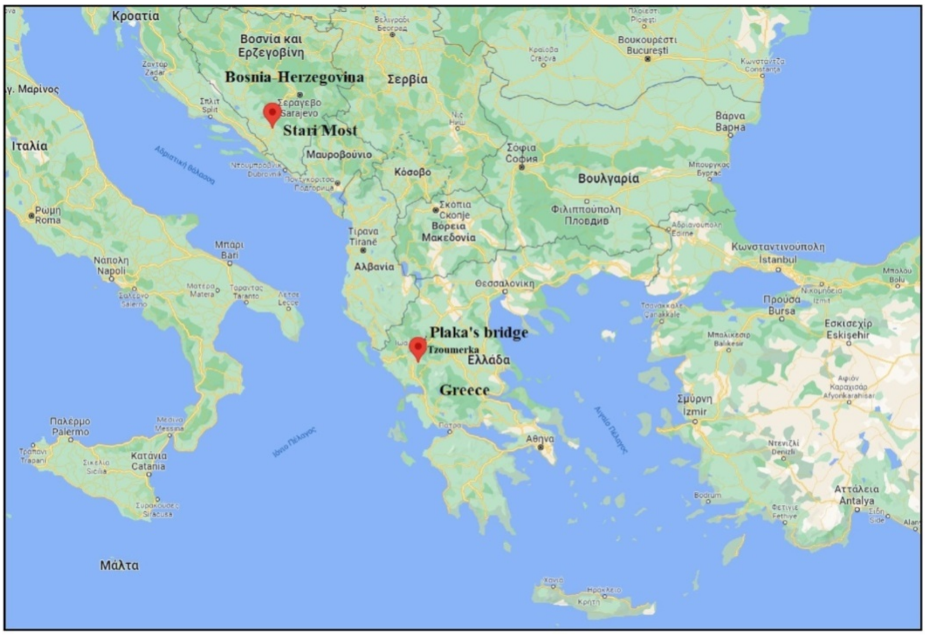

Fig. 5. Positioning Plaka Bridge and Stari Most. (Image source: © google.com/maps)

Plaka Bridge is the largest single-arched bridge in the Balkans [10]. It has been designated as a work of art in need of special protection[1] and has been declared as a historic preserved monument[2].

After the initial failed attempt in 1863, the bridge was rebuilt in 1866 by the Tzoumerkioti master builder from Pramanta, Kostas Bekas [12], and was preserved until 2015 (Fig.1). The bridge worked beneficially for the people of Tzoumerka, since it was a vital necessity for the commercial communication of the region with Arta, from the time of its construction until 1881, the year in which most villages in the region gained their freedom from the Turkish yoke, after their annexation to the Greek State [12, 13], according to the Treaty of Berlin.

It consists of the central arch (Fig.1 and Fig. 11) that has a free opening of about 40m, a height of about 20m and two false-arches, the eastern arch with an opening of 6.6m and the western arch with an opening of 5.2m. The total length at the level of the parapets is 72m. Its width is 4.5m on the eastern and 5.0m on the western pedestal, decreasing progressively towards the piers, remaining constant only along the central arch, which is 3.7m wide at its bottom.

The central part of the bridge consists of two arches: the main (interior) and the second (exterior) which is built above the main. The construction is of very good quality

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[1]With Decision no. 22676/17.2.1971 (Government Gazette 162/B΄) of the Minister of the Presidency of the Government.
[2]With Decision no. 10062/934/12.7.1972 (Government Gazette 621/B΄) of the Minister of Culture and Sciences.

with slab-like, roughly hewn stones, 9~12cm wide and their average weight is 80kg. The thickness of the joints is exemplarily very small 3~7mm [7].

In the main arch, around 450 worked vault stones appear in each arch, similarly in the auxiliary and eight times more stones (but smaller) in the thickness between the two sides. The total number of stones in the main arch is estimated at approximately 9,000 pieces. The rest of the structure contains about 12,000 fine stones on the surface, while ten times more were the stones of the inner filling. The stonework had a volume of about 1,500m^3, of which 300m^3 was only for the central arch, the weight of which amounted to 4,000 tons together with the parapets and the deck [7].

Apart from the stones and mortars, the structure contained a large amount of timber, formed into superimposed lattices and two systems of metal reinforcements [transverse system (arpizes) and longitudinal system of metal links][7].

2.2 The Collapse of the Bridge

On February 1, 2015, the largest part of Plaka Bridge collapsed, after heavy rainfalls and a large rise in the water level in Arachthos River, due to extensive scouring of the eastern pier [7, 14]. It completely collapsed the central arch and almost 90% of the eastern pedestal (Fig.6).

Fig. 6. Surviving sections of Plaka Bridge, September 2018. Left: part of east abutment and the Customs building. Right: West abutment and piers body.

The investigations carried out by the scientific staff of the NTUA included - among others - the architectural documentation of the bridge, the documentation of the supporting body (including the structural materials and the wooden and metal elements which were easily identified and recorded due to the collapse) and the study of its pathology [7].

A geotechnical survey, investigation of the hydraulic elements of the river, as well as numerical simulation and analyzes of the monument were also carried out. All these elements, which confirmed the sufficiency of the integrity of the bridge against the actions exerted on it and gave a convincing explanation in principle for the causes of its collapse, served as the basis for taking - from a technical point of view - the decision to restore it.

The main cause of the collapse was the undermining of the foundation of the eastern pier [7, 14].

2.3 Procedures of the Administrative Framework of Rehabilitation

After the collapse (2015) and until the completion of the restoration of the bridge (2020), actions were implemented both by the central and regional administration, as well as by the local government, with the assistance of the NTUA, as well as technical companies. The following is a summary calendar of the main relevant actions and decisions:

- On February 5, 2015, an autopsy was carried out by a scientific team of the NTUA and a meeting in the Region of Epirus. The condition of the bridge was ascertained and preliminary proposals were formulated for its restoration.
- On February 18, 2015, a Project Group was formed by the NTUA to study the restoration of Plaka Bridge.
- On August 10, 2015, the 1st Programmatic Cultural Development Agreement (PCDA) was signed, for the implementation of the preliminary works of the restoration, with the MoCS, the Region of Epirus, the Municipality of North Tzoumerka, the NTUA and the TCG/DE as parties. The Region of Epirus was designated as the implementing body and the subject of the contract, among other things, was the work of retrieving the fallen sections and the work of strengthening the surviving sections of the bridge. The 1st PCDA was implemented in three phases and was completed on July 13, 2018.Part of the work and research of the 1st PCDA was carried out with the sponsorship of the company “Terna SA”, which provided the necessary equipment and technical staff. The company “Kalliergos OTM SA” prepared the Foundation Study of the Eastern Pier.
- On July 11, 2016a Decision of the Minister of Culture was issued approving the specifications and directions for the restoration of the Bridge.
- On June 15, 2017 the 2ndPCDAwas signed for the implementation of the project “Fastening, Restoration, Rehabilitation, Highlighting of the Arachthos Bridge in Plaka”, with the MoED, the MoCS, the MoIT, the Region of Epirus, the Municipality of North Tzoumerka, the NTUA and the TCG/DE.
- The object of the 2ndPCDA was the restoration of the bridge, its protection from the local erosion of the river, the shaping of the surrounding area, the restoration of the landscape and its promotion, in order to enable the integration of the monument into cultural, social and economic life of Epirus, to contribute to the preservation of the architectural memory-history of the region and to be an important pole of attraction for getting to know the place and its history.In order to deal with special scientific issues of the PCDA, an eleven-member Scientific Committee of the Project was established under the responsibility of the NTUA.
- On January 31, 2018 the Minister of Culture & Sports, with her Decision, approved the studies of the project, which were prepared by the MoIT (Directorate of Road Infrastructure) with technical consultants Kalliergos OTM SA and Ch. Takos.

- On September 18, 2018 the relevant contract was signed and the implementation of the project was undertaken by the construction company Nirikos Techniki SA. The cost of the project, including all studies, as well as the costs of the two PCDA's, amounted to €6,150,000.00 [10].
- On August 18, 2020 the restoration of the monument was completed.

2.4 Rehabilitation Framework

The restoration project of Plaka Bridge was complex, high-tech and the first (almost) complete restoration of a work of art and a listed monument in Greece.

The interventions related to the purely technical part of the restoration framework, in general, were the repairs and reinforcements of the surviving sections, the restoration of the sections that fell in February 2015 and general works on the deck, parapets and the surrounding area, which had directly related to the bridge.

The basic planning principles for the interventions emerged from the NTUA Project (2016), as approved by the Central Council of New Monuments (CCNM), were harmonized with the decisions of the Scientific Committee and are related to [7]:

- the performance of the initial engraving of the bridge with the shaped parapets and without the unintended deformations noted during the life of the bridge, according to the restoration study,
- the similarity to the historical structural materials,
- the maintenance of the historical construction method, but with different auxiliary means (molds-scaffolding) and
- the preservation of the metal links and application of wooden eschars, for historical reasons.

2.5 Restoration Methodology

The restoration work of the bridge (2ndPCDA) was divided into seven groups [10]:
Group 1. Execution of preliminary works of Western Access.
Group 2. Restoration of Western Access.
Group 3. Execution of preliminary works of Eastern Access.
Group 4. Restoration of Eastern Access.
Group 5. Restoration of Central Arch.
Group 6. Work to complete the restoration of the Monument.
Group 7. Retrieving a fragment of the collapsed arch from the riverbed.

The subject of the 1st and 2nd group was related to the implementation of the preliminary works and the restoration of the western access, while the 3rdand 4thgroup were related to the implementation of the preliminary works and the restoration of the eastern access. Based on these, all the necessary works were carried out, which related both to the preparations for the implementation of the main restoration works of the bridge accesses, as well as the works related to the realization of the restoration of the eastern and western access.

Thus, in the context of group 1 and 3, works were carried out such as: a) installation of a trigonometric network around the perimeter of the bridge, b) application of the arrangements of the river course and waterproofing and protection measures on a case-by-case basis, c) cleaning of the existing stonework from plants and deforestation of trees and bushes at the edges of the accesses, d) installation of a system for monitoring movements and measuring the width of cracks, e) construction of the piles and the header support of the formwork and f) construction and installation of the mold and its support scaffold.

In the context of groups 2 and 4, works were carried out, indicatively, such as: a) removal of the upstream parapet and part of the deck in the area of the western arch, as well as old grouting of the surface of the walls, b) sealing of wall cracks and the salvaged part of the arch with grouting and new grouting of their surfaces, c) restoration of western abutment walls in contact with the rock and construction of the trunk of the eastern pier, with the corresponding part of the springing line of the central arch, d) repair of spandrel walls and construction of the filling material between the spandrel walls of accesses, e) restoration of the base of the deck, f) repair of the wing wall of the western pier and g) installation of transverse system.

The 5th group, most important from a technical point of view, was the guide of the restoration of the central arch of the bridge. Within the context of the group in question, the pales and the pale cap of the central arch mold were manufactured. The mold and its support scaffolding were installed.

The 6th group was related to general works to complete the restoration, while the 7th group was related to the retrieval of a large fragment of the collapsed arch from the river bed.

2.6 Restoration Materials

According to the Scientific Committee, the new structural materials had to be as close as possible to the historical materials [7]. In addition to the stones, mortars and grouts as well as the metal elements that were incorporated into the project, chestnut wood was used.

- Stones. The NTUA scientific team proposed to use generally stones from the same rock as that of the historical structure, which is found in the wider area of the bridge [7]. The restoration study of the monument suggested that, under certain conditions, some of the stones of the historical structure that fell and were collected could be used in the internal filling of the bridge or in sections without much stress. Based on the architectural documentation study, the use of three types of stones was foreseen: flagstones, masonry stones and porolits [15]. Finally, the stones from which the bridge was built came from a quarry in the Dafnoula area of Ioannina [10].
- Mortars – grouts. For the mortars, since it was not possible to apply them exactly the same as the historical ones, compositions with similar physical characteristics were proposed by the NTUA [5, 16], confirmed by the MoCS(Directorate of Research and Technical Support of Restoration Studies and Projects) [17] and adopted be the MoIT (Directorate of Road Infrastructure), fulfilling the requirements of developing the desired strength in a reasonable time. Because the location of the operation is heavily stressed by the flow of the river, the choice of mortar and grout was based on the rapid development of high strength and high durability. Lime-pozzolan compositions were provided for mortars and grouts.

For crack grouts, lime-pozzolan compositions combining rapid hardening with better cohesion were considered [5, 16, 17].

- Metal elements. As mentioned above, the specifications set for the restoration required the preservation of the metal links (transverse and longitudinal) of the historical construction. Two types of metal reinforcements were applied to the bridge, in the piers and in the central arch [18].
  Industrial steel was used in the historical construction of the piers. Transverse metal connectors (*arpizes*) were used on the inner part of the central arch of the bridge. For wedging the anchors, nails with curved ends (*giftokarfa*) were sometimes used [18, 19].
  The new metal elements installed on Plaka Bridge were titanium, which was used for the construction of the arpizes, as well as stainless steel, which was used for the construction of the metal grids, the metal links of the eastern pier and the metal trusses [10]. It was not possible to re-use lead in the anchor holes and simultaneously reuse the best-preserved links.
- Wooden elements. The wooden grids of the historical construction, which were preserved during the restoration, are divided into two categories: horizontal and radial grids [18, 20]. From the fallen fragments, but also from the salvaged part of the western arch in which the holes are preserved in the positions of the now disintegrated timbers, the existence of four horizontal eschars was documented [18, 20]. The horizontal grids were made of fir wood, while the radial grates of oak wood. The material used for the construction of the new grids is chestnut wood.

3 Stari Most

3.1 Brief description of the bridge

Stari Most (Old Bridge) built at an altitude of about 60m, is geographically located in the southeast part of the city of Mostar (Fig.5), which owes its name to it. On both sides of the bridge rise its towers, called Mostari, i.e. guardians of the bridge. It stretches over the Neretva River and connects the Bosnian-populated eastern part of the city with the Croat-populated western part. For centuries it has been considered a symbol of bridging the East with the West, not only the Christian world with the Islamic world but also the Catholic Croats with the Orthodox Serbs. Today, the reconstructed bridge is a symbol of reconciliation, international cooperation and of the coexistence of diverse cultural, ethnic and religious communities [11]. While, locally it has become a symbol of pride and identity for the people of Mostar [21].

The bridge was built in 1566 [9, 22, 23] by Mimar Hajrudin, the disciple of the Ottoman architect Kodza Mimar Sinan [24], by order of Sultan Suleiman the Magnificent. Stari Most built in the Ottoman era went through many changes and renovations. Most modifications took place in the period following the fall of the Turkish Empire [25]. According to the records kept in the Sarajevo National Museum, the construction of the Old Bridge started in 1557 and was completed nine years later [25]. The chronological information about the beginning and end of bridge construction work cannot be considered fully reliable as historic records with different data are also available.

In addition to the bridge, the Stari Most complex also includes a set of buildings consisting of three towers, two mosques and other medieval structures (Fig.8) [11].A crossing already existed at this location in Mostar before the Otoman Empire, as confirmed by archeological investigations during which authentic remains of a wooden bridge were identified [9, 25].

On July 15, 2005, the bridge and the neighboring historic buildings were classified by UNESCO as a world heritage site, not only because of their architectural value but also because of their great symbolic importance [11].

The bearing arch (Fig.3 and Fig. 12), which is the most important part of the bridge, has the form of a humbled semicircle and is sharp-edged. Its total opening on the upstream side is 28.71m, while on the downstream side it is 28.62m. Its width ranges from 3.95 to 4.05m and its height is 12.06m [25]. The height from the lowest (dry) level of the Neretva River ranges from 19.0.m to 21.00m and the curvature of its interior is almost circular. It consists of approximately 1,100 pieces of stone. None of the stones used had the same dimensions. The dimensions of the average of these are: 0.40m x0.80m x1.00m [24].

3.2 The bombardement of the Bridge

The bridge was destroyed 10 days after the second siege of Mostar by Croatian forces, which began on 9 November 1993 during the 1992-1995 war in Yugoslavia [26].

According to the finding of the International Tribunal for the former Yugoslavia "the bridge was intentionally destroyed by the Croatian Defense Council"[3] and the bombardement of the bridge was seen as a symbolic act of ethnic cleansing in multi-ethnic Bosnia and Herzegovina [9].

A temporary suspension bridge was built in the place of the historical bridge after the end of the war, in order to restore the communication of the areas of Mostar on both sides of the river (Fig.7).

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[3]Indictment of the International Criminal Tribunal for the former Yugoslavia (www.icty.org/x/cases/prlic/ind/en/prl-ii040304e.htm).

3.3 Procedures of the Administrative Framework of Rehabilitation

The government of Bosnia and Herzegovina requested in 1998 from the international community the financing of the rehabilitation. The following is a summary calendar of the main actions of the restoration project:

- On July 13, 1998 UNESCO, the World Bank, the World Monuments Fund and the Aga Khan Foundation for Culture entered into a partnership to oversee the restoration work.
  According to the Commission for the Preservation of National Monuments of Bosnia and Herzegovina, the cost of the project amounted to approximately 15million euros[4]. The provision of resources from various sources is as follows: 4million came from a World Bank loan to the aforementioned partnership. 7.6million collected as donations from Italy (3million), the Netherlands (2million), Croatia (0.6million), Turkey (1million) and the Council of Europe Development Bank (1million). The city of Mostar invested 2million in the bridge restoration project [11].
- On April 17, 2000 the preparation of the required restoration studies begins, which were completed in 2001. The design of Stari Most was developed in 2000 and 2001. Step by step, the design documents, the drawings and the calculations were checked and approved by an International Commission of Experts, named ICE [27].
  The control of the project, from a scientific point of view, was assigned to an international group of expert scientists, under the auspices of UNESCO, in order to ensure the historical correctness, integrity and coherence of the project. The implementation of the project was undertaken by the Turkish company "ER-BU Construction & Trade Collective Company of Ankara", which bid less in an international tender. The supervision of the works was conducted by the private company Omega Engineering, based in Dubrovnik [28].
- On June 7, 2001 took place the start of restoration work.
- On July 23, 2004 took place the official reopening of the bridge.

[4]See also The World Bank: Document of The World Bank, Implementation Completion Report No. 32713, June 22, 2005. Bosnia-Herzegovina Cultural Heritage Pilot (2005).

Fig.7. View of the temporary suspension bridge, February 1995.(Image source: © A. Pašić)

3.4 Rehabilitation Framework

The restoration project was complex and particularly difficult, since it consisted the first (almost) complete restoration of a stone-built bridge worldwide.

The restoration involved actions ranging from saving the historical parts of the bridge, researching the historical materials, defining the final restoration plan, to the final reconstruction and preservation of the structure [23].

The design, performed in a period of almost one year time, allowed keeping the structure unchanged for what concerned the construction materials, the construction techniques and the exact geometry, "even if characterised by ordinary irregularities" [25].

There were many companies and institutions involved in the preparation of research, preliminary and final studies for the reconstruction of the historic bridge complex. Among them are included both the Italian company "General Engineering WorkGroup" which prepared the Architectural Documentation Study of the Bridge, and the Department of Civil Engineering of the University of Florence which prepared the Static Rehabilitation Study as well as the Hydraulic Study (www.mostarbridge.org; structurae.net/en/structures/mostar-bridge).The German company "Landesgewerbanstalt Bayern-LGA Historical Bridges Group" was responsible for defining the new structural materials [25].

The project of the monumental restoration of Mostar concerned the restoration of the historical bridge complex and in particular the restoration (Fig.8): a) the bridge itself, b) the Tara tower, the smaller Herceguša tower, the mosque of Sultan Selim and two buildings of trade, on the east bank of the Neretva River and c) the Halebija tower, the outpost (Caradak) and a commercial structure between the tower and the bridge, on the west bank.

The fact of the total destruction of the central arch of the historical bridge made possible the archaeological investigation, including its architectural documentation through the recording of its structural details.

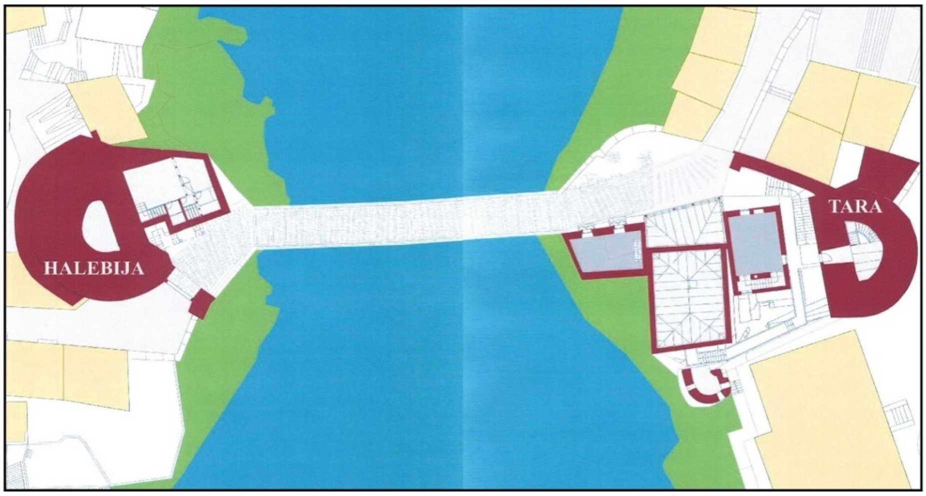

Fig. 8. View of the bridge complex (Image source: © A. Pašić)

3.5 Restoration Methodology

The bridge restoration process was divided into eighteen Phases. The order of implementation of each of them was strict and the most important of their tasks are related to [25, 29]:

- The temporary reinforcement and stabilization of the salvaged walls.
- Partial removals-deconstructions of the salvaged parts of the bridge and deck with detailed documentation and numbering of the deconstructed parts.
- The erection of a metal structure to support the construction of the arch, during which work was carried out to support the scaffolding and temporary bridging with a float.
- The assembly of the wooden mold.
- The construction of the arch and the keystone installation. The arch is structured by 111 rows of mudstones with a depth of 3.95m (from 3.92 to 3.97m) and a height of 0.80m. Each row includes 2 to 5 arch stones (average row is 3 to 4). The total number of arch stones of the arch amounted to 456 pieces and their total volume amounted to 145m^3.
- The construction of the intermediate reinforcing masonry, with the parallel construction of the lower cornice and the side spandrel walls.
- The decentering of the arch.
- The completion of the construction of the spandrel walls and the dismantling of the scaffolding.

- The construction of the upper cornice and parapets.
- The waterproofing of the bridge using a suitable type of mortar which also formed the basis of the deck floor in combination with the construction of new ones and the reconstruction of the historical elements of the deck.

3.6 Restoration Materials

A main requirement of UNESCO was the use of authentic materials and construction techniques whenever possible. That is, a new project had to be implemented, the same in every detail as the old one. Thus, the bridge was restored in a way identical to the way the historical one had been constructed. Although the construction was made with new materials, there was a significant percentage of incorporation of the historical materials.

- Stones: From August to November 21, 1997, UN forces in Bosnia and Herzegovina recovered stone sections of the damaged bridge from the Neretva River [11]. From the total of 456 arch stones, 162 pieces were recovered from the river, 24 pieces of stones from the cornice, 44 pieces of stones of the spandrels and 19 pieces of stones of the parapet were also recovered [27].
  It is a fact that the architectural beauty of the monument is due to the sophisticated plot of large and different sized stone elements with thin joints, 5~8mm thick, which were extracted from a quarry in the area south of Mostar called Mukoša [24]. Most of the stone elements of the bridge, such as the arch, cornices, spandrels and parapets were constructed from tenelija rock (Category I), which is a local oolitic limestone [22, 24, 25]. The deck and stone slabs above the cells were constructed with hard, calcareous and light colored marble with the local name krecnjak [9].
- Mortars – grouts. During the restoration, mortars of different types and compositions were used throughout the structure, which had increased elasticity and sealing characteristics. The mortar used as a foundation was a mixture of hydrated lime and sand from the Neretva River. For the composition of the mortars were also used: artificial pozzolan, hydraulic lime, mineral aggregates and water [23, 25].
  After the completion of the restoration works of the external rescued walls, remedial works and works of grouting the cracks of the internal walls were carried out. Grouting was implemented both in the wing walls and in the rocky foundation of the bridge. The grouting was implemented by pressing limestone grout (lime emulsions). The purpose was to strengthen the walls by reducing the internal cavities created over the years, ensuring better contact with the bearing layer [25].
- Metal elements. The stone elements of the bridge were strengthened through the use of metal connectors made of forged iron, and were placed at the level of the connecting joints following different assembly methods. The metal connectors had flared ends and after their installation, molten lead was poured into the slots to finalize their assembly. The railing was similarly constructed of wrought iron [23]. The total amount of molten lead with which the arch was "reinforced" amounted to 30 tons, which was 10% of the total weight of the arch of 300 tons [25]. The metal connectors incorporated into the project consisted of nearly 1,700

anchorage elements [25] and 810 dowels (www.mostarbridge.org), and were applied to the stone elements through slots that were deliberately carved with their bottoms slightly widened in order to avoid disconnection.

The metal connectors had flared ends and after their installation, molten lead was poured into the slots to finalize their assembly. The railing was similarly constructed of wrought iron [23].

The metal elements, combined with the use of mortar, allowed for a fairly efficient connection system that was implemented extensively in the arch stones, where three different groups of links were adopted to better bind the entire structure. Most of the reinforcing metal links remain protected in the inner parts of the slots to prevent them from oxidizing.

4 Discussion

For different reasons, at different periods of time, vast sections of the two bridges collapsed and the governments of Greece[5] and Bosnia and Herzegovina immediately decided to restore them.

The analysis attempted in this article highlights important similarities in dealing with the two projects of total restoration of stone-built bridges. The administrative framework for organizing the actions, the agencies involved, the financial object, the methodology, the prioritization of the implementation of all the required actions and the times in which they were achieved, show this conclusion in an emphatic way.

The Stari Most project was a global innovation, from every point of view. For the first time, international organizations, cultural and educational institutions, countries, and private companies collaborated to make it work in the best possible way. The restoration of Plaka Bridge was a complex, high-tech project, and was a great challenge, as it involved the first almost complete restoration of a work of art and a preserved monument in Greece. Central, regional and local administration, a university institution and the TCG collaborated on the rehabilitation procedures and framework.

The two bridges were fasten and restored to their historical form using the same stones, similar mortars and following the same methods as their historical constructions. The historical correctness, integrity and coherence of the projects were ensured for the restoration of Plaka Bridge by the Greek scientific community and management by the central administration, while for the restoration of Stari Most, by the international community of specialist scientists and management by the Unesco.

The restoration of Stari Most lasted 37 months (June 7, 2001 to July 23, 2004), while the main contract for the restoration of Plaka Bridge lasted 27 months. Both restorations were special trials because of the multi-participation, but mainly because of the deviation from ordinary. The loss of the two bridges over a large area allowed the exhaustive documentation of the monuments, which contributed to their scientific restoration.

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[5]The fact that Plaka Bridge was a cultural monument of a supralocal nature, combined with the fact that Greek society has a living relationship with its cultural heritage, led to the almost universal demand for its restoration (over 85%), and even in a period of fiscal crisis for the country [30].

The restoration of the bridges included many common phases: from the rescue of the historical parts, the research of the historical materials, the determination of the final restoration plan, the final restoration and also the preservation of the structures. The bridge restoration works were similar both in terms of their type and the order in which they were carried out. The reinforcement of the remaining sections, the dismantling-deconstruction of the fragile material, the setting up of the metal scaffolding and the wooden moulding, the way of building the arches, the building of the masonry, the pedestals, the process of de-arching with the necessary monitoring of the phenomenon of movements-deformations, the completion of the construction of the spandrel walls, cobblestones and parapets were implemented in a similar sequence both in Mostar and in Plaka.

The materials used in both cases were similar. The stones incorporated into the projects came from the surrounding areas. In both cases, similar to the historical ones were used, however new types of mortars-grouts, which had increased elasticity, sealing characteristics and strength. The imperfections of the historical construction as well as the deformations due to stress of the two bridges were not repeated in the restorations.

However, there are three differences between the two projects. Plaka Bridge was a more demanding project in terms of dimensions compared to Stari Most. In practice, less than 400m^3 of stones were required in total for the restoration of Stari Most, while for the restoration at Plaka, at least 800m^3 of general stones, 4,000 pieces of arch stones and 102 pieces of stone keys were incorporated into the project [10].

Also, the level of difficulty of the projects related to the field conditions was certainly higher in the Plaka area, since the work had to take place in the Arachtos River, with intense rainfalls and (almost) flooding (Fig.9). On the contrary, the location of Stari Most as well as the field conditions in Mostar favored the avoidance of unforeseen situations during the progress of the works (Fig.10).

The third difference concerns the significant percentage of incorporation of historical materials (mainly stones) in the bridge in Mostar. The differences are exhausted in the use of structural materials, a matter directly intertwined with the historical construction technique of the bridges. In the case of the bridge in Mostar the main connecting material was most the metal elements and less the masonry mortar, while in Plaka was the opposite.

Fig. 9. Conditions in the area of the restoration project in Plaka, November 2019.[6]
(Image source: ©Nirikos Techniki SA)

Fig. 10. Conditions in the area of the restoration project in Mostar, September 1997.
(Image source: © A. Pašić)

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[6] Photo on the left comes from a surveillance camera installed on the eastern slope (upstream view), where the large elevation of the water level can be seen, and the crest of the wing wall can be seen marginally. There have been cases where the supply has "disappeared" the wing wall. Photo on the right shows a landslide of part of the eastern slope after heavy rainfalls. The upstream wing wall can be seen again, as well as the Customs building.

5 Conclusions

The present work has shown that the implementation of projects of similar size and importance, such as the restoration of the two historical bridges, require an interdisciplinary approach in order to deal with their complexity in a more comprehensive way, but at the same time to respond the research questions posed on a case-by-case basis in a more rational way. It is also clear that the management of complex projects of extensive restorations requires the simultaneous cooperation of various agencies and organizations, in conjunction with the academic, scientific, research and technical communities.

Moreover, the restorations of Plaka Bridge and Stari Most are, by world standards, pilot projects. Both the innovative ways of restoring the bridge in Mostar and the one in Plaka can be methodological models for the restoration of similar monuments, which have suffered damage-destruction of a similar magnitude.

Plaka Bridge, built in 1866, was closely linked to the history and evolution of the place and in particular to the villages of Tzoumerka, whose inhabitants it served, contributing decisively to the survival of the local communities, in times of significant communication difficulties. It is again an elegant work of uppermost beauty that shows the technical intelligence of the old bridge builders of Epirus, being an important element of the cultural identity and life of the place (Fig.11).

Stari Most, built in 1566, has been considered for centuries a symbol of bridging the East and the West, not only the Christian world with the Islamic world, but also the Catholic Croats with the Orthodox Serbs. The restoration of the bridge in Mostar (Fig. 12) had an additional goal, to lead to the restoration of emotional bridges, between Croats, Serbs and Muslims, to the reconciliation of the inhabitants of Mostar, who are so different from every point of view[7]. The restoration of the historic bridge of Mostar is a symbol of the restoration of the country from the civil war, the reconciliation and reunification of the multi-ethnic communities and by extension the multi-ethnic and multi-religious Bosnian society [9].

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[7]See also Radulovic, A.: The Question of authenticity in recoveries in post-conflict zones, In Proceedings of the 2nd International Conference on Best Practices in World Heritage, People and Communities, 29 April-2 May 2015. Menorca, Spain (2015**).**

Fig. 11. Plaka Bridge after restoration (downstream view), August 2021.

Fig. 12. Stari Most after restoration (downstream view), September 2006.
(Image source: © A. Pašić)

Anyway, the specialized use of authentic materials, the particular morphological characteristics, their aesthetic value, as well as their importance both for the forest-rural landscape of Tzoumerka, and for the urban landscape of Mostar, they are both established as recognizable reference points of cultural heritage, and as national and international symbols and achievements of human potential.

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A code of action for the responsible conservation of squares in historic cities through the experience of northern Greece

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Abstract. The historic cities of northern Greece came to include squares as a result of modernizing urban interventions. Up until the late 19th century, the structure of social life under Byzantine and Ottoman rule made them unnecessary, with very few exceptions. It was only in the last years of Ottoman rule, and mainly under the Greek administration, after 1912, that they began to be properly integrated into the urban layout, as a symbol of modernization. In either case, they suffered considerable degradation after the Second World War and it was only in the 1980s that their historical significance began to be acknowledged. Hence, multiple conservation initiatives started to unfold, which currently allow for an appraisal, and in its wake, for the drafting of a code for optimum future action.

The present paper pursues these two goals, through two separate focuses: firstly, on the procedural, and secondly, on the technical segment of contemporary care for a characteristic selection of six squares in four historic cities of northern Greece. As concerns the technical segment, it is addressed in terms of the distribution of functions in and around the squares, and the design of the latter and the surrounding fronts.

Keywords: Squares, historic cities, northern Greece, functions, design.

1 Introduction

Currently subdivided into the regions of Macedonia and Thrace, the northern part of Greece encompasses a considerable number of cities whose history spans well over a century. Among them, Thessaloniki stands out as the oldest, having been founded in the early 4th century BC, while others, such as Veria, Xanthi, and Kastoria, date to Hellenistic, Late Roman, and Early Byzantine times, respectively. Remarkably, even in cases of such a long presence, the urban layout came to include open spaces for the convergence of circulation routes and social interaction only as of the late 19th century, and more systematically, after 1912, as modernizing urban interventions. Nowadays, however, they play a vital role in the shaping of the historical profile of the respective cities. In this context, since the 1980s, multiple conservation initiatives have unfolded, aiming to enhance their special character. These initiatives allow for an appraisal, which in turn can produce a set of guidelines for optimum future action.

The present paper aims to conduct this appraisal, and in its wake, draw a code of action for the responsible conservation of squares, at primarily national and secondly international level. To achieve this goal, a systematic review, analysis, and evaluation of the conservation care that has been shown so far in a characteristic selection of six squares in the aforementioned four historic cities will be pursued, addressing, on one hand, the procedural, and on the other, the technical issues involved. The material for this task was provided by archival and on-site research, coupled with personal experience from related work on behalf of the Hellenic Ministry of Culture.

2 The evolution of squares in the historic cities of northern Greece

The northern part of Greece was until the early 20th century part of the Ottoman Empire. A highly centralized state, the latter came to occupy the current regions of Macedonia and Thrace for nearly five centuries, in the course of which their cities were broken up into autonomous neighborhoods, inhabited by clusters of people sharing common religion or origin. The overall sense of a community was absent, an event which coupled with the minimal margin for independent action by the local authorities, made open communal spaces unnecessary, and hence, non-existent [1].

Nonetheless, very few, yet notable exceptions did occur. In the center of the introverted living quarters, small courtyards are known to have provided access to the neighborhood's major edifice, the religious building, in addition to offering space for the outdoor activities of its inhabitants. The inner courtyard of the Jewish quarter of Veria (contemporary Barbouta Square), is a most characteristic example, set in the center of a compact triangular layout of houses, which incorporates, at one corner, the Synagogue [2] - (see Fig. 1). On the other hand, a similarly triangular open area in the Doltso district of Kastoria (contemporary Emmanouil Brothers Square) provided the necessary space for the open-air bazaars that supplied the inhabitants of the surrounding, highly secluded Christian sector of the city with basic goods [3] - (see Fig. 2).

In the last decades of Ottoman rule, the granting of property and development rights to communities other rather the ruling Muslim, part of an overdue quest for modernization, allowed certain Christian clusters to flourish and erect memorable communal buildings, next to major churches. In certain cases, this activity was combined with the arrangement of the edifices around a small open space, which facilitated projection in the cityscape, while also fostering a sense of community among the inhabitants of the surrounding quarter. This was the case of the open area west of the old Metropolitan Church of Xanthi (contemporary Metropolis Square), which was surrounded by two schools and the metropolitan residence, between 1839 - 1897 [4] - (see Fig. 3).

With the incorporation, firstly of Macedonia (1913), and secondly of Thrace (1920), in the modern Greek state, proper squares began to emerge in the historic cities of both. In an attempt to signify a new era, far from their Ottoman past, the Greek administration promoted modernization according to western standards, including the provision of large open spaces, as points of reference for circulation and social interaction. Hence, in sharp contrast to their previous absence, squares claimed prominence in the numerous urban plans that were drawn up in the Interwar period, their most celebrated manifestations being met in the capital city of northern Greece, Thessaloniki.

The complete redesign of the historic center of the latter, after the devastating fire of 1917, produced a layout of streets around a newly established network of squares. Among them, Aristotelous Square functioned as the city's social center, next to the sea, at the start of a homonymous vertical civic axis, in combination with a unique manifestation of regulated design of the surrounding facades, in the neo-byzantine style [5, 6] - (see Fig. 4). At a short distance to the northwest, again next to the sea, Eleftherias Square assumed a major role in the city's economic life [5, 7] - (see Fig. 5), while further north, Emporiou Square served as an important hub for commercial activities [5] - (see Fig. 6).

Either originating in the very few open spaces of the Ottoman era or the multiple modernization efforts of the Interwar years, the squares of the historic cities of northern Greece suffered considerable degradation in the first decades after the Second World War, a result of tight development and unprecedented increase of traffic on their perimeter. It was only in the 1980s that their contribution to the historical profile of the respective cities began to be acknowledged, leading to the emergence of steadily multiplying initiatives for their enhancement [8]. These initiatives are comprehensively illustrated in the already distinguished six squares, a characteristic selection also in terms of type, size, and conservation needs, which therefore proves an ideal basis for an overall evaluation, through two separate focuses: firstly, on the procedural, and secondly, on the technical segment of contemporary care.

3 The procedural segment of contemporary care

The preparation of projects for the conservation of the squares of the historic cities of northern Greece is the responsibility exclusively of the local authorities. In the case of the selected six squares, the latter began to produce conservation plans in the late 1990s (Barbouta Square, 1995 - 1997), followed by the bulk of the hitherto completed projects over the next two decades (Metropolis Square, first phase, early 2000s; Aristotelous Square, 2006; Emmanouil Brothers Square, early 2010s; Emporiou Square, 2012 - 2013; Eleftherias Square, 2015; Metropolis Square, second phase, 2017; Emmanouil Brothers Square, redesign, 2021).[1]

[1]Dating based on the information provided by the Technical Services of the respective municipalities, in the archives of which one can locate the complete projects.

Fig. 1. Barbouta Square.

Fig. 2. Emmanouil Brothers Square.

Fig. 3. Metropolis Square.

Fig. 4. Aristotelous Square.

Fig. 5. Eleftherias Square.

Fig. 6. Emporiou Square.

The above initiatives attest to an undisputed interest of the local administrations in the enhancement of the form and function of the six squares, to the benefit, not only of the residents of the respective cities but also of the visitors and tourists. Yet compared to the wider European context, this interest proves rather delayed, not to mention inconsistent with a complete approach to the whole issue. The focus on the specific squares was not the result of a definition of priorities in the wake of a review and appraisal of the conservation needs of all the squares of the four historic cities. Moreover, the drafting of the projects was initiated not so much upon acknowledgment of a vital prerequisite for optimum preservation, but rather on the occasion of combined funding by the European Union and national resources being made available for related works.

As concerns the preparation of the projects, a notable issue is firstly identified in the composition of the respective planning teams. The involvement of professionals from multiple disciplines, particularly engineering, landscaping, and heritage management, does not prove firmly established. Of the hitherto completed plans, merely three were drafted on the basis of interdisciplinary cooperation (Aristotelous Square, Emporiou Square, Eleftherias Square), thus leaving a major requirement on hold.

Also noteworthy is the fact that a significant portion of the projects, namely three of them, were shaped in the wake of architectural competitions, a beneficial tool for optimum enhancement that allows contributions from independent planners. Regrettably, though, in the case of Emporiou Square and Aristotelous Square, the municipal authority chose to ignore the award-winning project in the earlier national (1994) and international architectural competition (1997), respectively. On the other hand, as concerns Eleftherias Square, the proposal that received the first prize (2013) was transformed into a complete project, which luckily secured funding. Yet shortly after the commencement of works, it was canceled by the local authority, on the grounds of the pursuit of a more profitable exploitation of the respective terrain, through the additional construction of an underground parking lot.

Worth adding is that, with the project of 2006 having not been implemented so far, the conservation of Aristotelous Square was recently addressed through yet another architectural competition (2021), whose award-winning project is expected to produce a complete plan shortly. Yet the intermediate distance is most likely to prove considerably longer. The competition's jury was not staffed with representatives of the state bodies charged with the protection of the area, namely the supervising services of the Ministry of Culture and Sports, and the Ministry of the Interior. Hence, with crucial reserves over the prizewinning proposal already being expressed by both, its transformation into a feasible prospect appears, to say the least, rather distant.[2]

Another major issue about the hitherto followed procedures is the overall absence of consultation with the wider public. Even though the legislation defining the responsibilities of the local authorities called for consideration of the views of the local population on all matters of common interest, as early as 2006 [9], none of the projects completed thereafter followed this rule. A minor exception is witnessed only in the case of

[2]See documents: (a) 469151/09-02-2023, of the Ministry of Culture and Sports/Service of Modern Monuments and Technical Works of Central Macedonia, and (b) 643/16-02-2023, of the Ministry of the Interior/Department of Traditional Settlements and Listed Buildings.

Emmanouil Brothers Square. Merely two years ago (2022), the local authority initiated consultation, yet just in terms of the accommodation of the tables and seats of a nearby restaurant, and not the overall treatment of the square.[3]

The scope of the so far drafted projects is a last matter that deserves attention. To begin with, though all six squares form part of wider historic ensembles, it was only in two of them that conservation was pursued, not in isolation, but in the framework of a plan for the entire wider setting, an obvious prerequisite for optimum enhancement. These are Barbouta Square (in the framework of a project for the entire network of communal spaces of the old districts of Veria) and Emporiou Square (in the framework of a complete project for the wider Chrimatistiriou Square district of Thessaloniki).

In the case of Aristotelous Square (part of the homonymous civic axis), Emmanouil Brothers Square (part of the network of communal spaces of the historic center of Kastoria), and Eleftherias Square (part of the network of communal spaces of the historic center of Thessaloniki), an isolated approach was favored, with a hopeful reversal in terms of Aristotelous Square in the near future, through the recent architectural competition that addressed the entire homonymous axis (2021). Lastly, as concerns Metropolis Square, a wider focus was initially adopted, yet in the second and main phase of works, the latter was abandoned. Hence, as in the other three cases, basic dissimilarities occurred, namely in the paving materials and urban equipment, with a negative impact on the enhancement of both the squares and the wider setting.

A second point of interest in terms of the selected scope is that, so far, all projects have dealt, exclusively, with the functional layout and overall shaping of the terrain of the squares, ignoring the equally vital distribution of functions and shaping of the fronts on their perimeter. To this day, no plan has been drafted in conjunction with a set of standards for the last two issues, thus allowing both to be regulated by building and planning rules for wider sections of the urban fabric, which are largely inconsistent with the special conservation needs of the squares. Hence, considerable room for incompatible action arises, with the only prospect of halting being the independent definition of standards by the state services charged with historic ensemble protection. Such is the case of Aristotelous Square, where the shaping of the surrounding fronts is subject to restrictions that were separately enforced, in 1983, as part of the protection of the surrounding buildings as listed assets by the Ministry of the Interior [10].

4 The technical segment of contemporary care

Apart from the procedural issues, the conservation of the selected squares proves ardently linked to technical issues, namely the distribution of functions in and around the squares' terrain, and the design of the latter and the surrounding fronts. Each is of special importance for optimum enhancement and will therefore be discussed separately, as follows.

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[3] See document 21414/30-05-2022 of the Municipality of Kastoria/Directorate of Financial Services.

Fig. 7. Aristotelous Square, facing the sea.

Fig. 8. Metropolis Square, view from the east section to the west parking lot.

Fig. 9. Metropolis Square, view with the street to the east.

4.1 Distribution of functions in the squares

As concerns the arrangement of functions in the terrain of the squares, one needs to note that, in their initial realization, all six spaces were meant to serve as open areas for social interaction and relaxation, fully accessible by pedestrians and capable of hosting outdoor events. In their present state, three of them continue to display this capacity, though to a varied degree.

Barbouta Square remains an open area, fully accessible to walkers and convenient for festivities (see Fig. 1). The same applies to Emmanouil Brothers Square and Aristotelous Square, except that considerable portions on the perimeter of the former, and two large surfaces along the long sides of the latter have been taken up by the tables and seats of surrounding cafes and restaurants (see Fig. 7). In Aristotelous Square, this development has caused significant disturbance to pedestrian movement, a result of the exaggerated size and irregularity of the occupied spaces. Substantial confinement and clear delimitation are hence necessary, as already prescribed in the 2006 conservation project, and hopefully, in the wake of its cancellation, in the upcoming plan after the architectural competition of 2021.

A rather intermediate case, Metropolis Square is cut up by a street in two open areas (see Fig. 8). Similarly to Barbouta Square, the east one is fully accessible to walkers and ideal for outdoor events. Yet in sharp contrast, the west portion has been transformed into a parking lot, a most incompatible alteration, which ought to have been averted, along with the introduction of the street in between, regardless of its overall light traffic load.

Regrettably, such alterations are also witnessed in the remaining two cases, not to mention to a much greater degree. In Emporiou Square, in the wake of the initial measures for the COVID-19 pandemic, the entire open space has been occupied by the tables and seats of the surrounding cafes and restaurants, leaving no more than a narrow path for walkers attempting to pass through (see Fig. 6). Even worse, after the cancellation of the conservation project of 2015, Eleftherias Square, already partially overlapped by a bus terminal, was transformed, in its remaining part, into a parking lot, which hinders all pedestrian movement, to say nothing of social interaction and relaxation (see Fig. 5). Both cases reflect wholly incompatible choices, which render imperative a complete and unconditional recovery of open space. A recovery already ideally prescribed, in terms of Eleftherias Square, in the 2015 enhancement plan, which promoted the creation of a fully accessible urban park, honoring the major events that marked the history of the square and Thessaloniki itself, chief among them the initial assembly and humiliation of the city's Jewish community by the Nazis, in 1942.

4.2 Distribution of functions around the squares

In addressing the arrangement of functions around the terrain of the squares, it is essential to note that, with the exception of the introverted -hence inaccessible to vehicles- Barbouta Square, from the very start, the remaining five spaces have been either bordered by streets on all sides (Aristotelous, Eleftherias, Emmanouil Brothers, and Metropolis Squares) or placed on the intersection of streets (Emporiou Square). Hence, with the increase in vehicle traffic in recent years, the adjacent streets nowadays emerge as possible obstacles to the squares' enhancement.

Fortunately, this concern has been so far met with considerable positive action. In the case of Emmanouil Brothers Square and Metropolis Square, the traffic load was reduced to a minimum, primarily by narrowing the vehicle routes to the least required width and by laying them with relatively rough and uneven setts (see Fig. 9). On the other hand, from very early on, the streets bordering the long sides of Aristotelous Square were converted into pedestrian lanes (see Fig. 7), as was, more recently, the picturesque Aghiou Mina street that leads to Emporiou Square, in conjunction with a confinement of the width of the remaining vehicle routes to an absolute minimum.

Clearly beneficial, both in terms of the enhancement of the squares and the meeting of contemporary needs, the above interventions leave only two major issues to be resolved. The first is the elimination of car parking around Emmanouil Brothers Square and Metropolis Square (see Fig. 3), a degrading factor that could be eradicated with the installation of discreet bollards. The second is the facilitation of pedestrian access to Aristotelous Square and Eleftherias Square, given their immediate adjacency with streets of heavy traffic load.

With a new conservation project for the former currently underway and the one completed for the latter in 2015 proposing merely the establishment of pedestrian crossings at selected points, an adequate solution for the two squares remains to be reached, given the large flow of walkers to both, and in particular from Thessaloniki's immensely popular seafront. If optimum enhancement is to be achieved for the city's two most prominent and historically significant open spaces, drastic approaches ought to be considered, possibly involving the conversion of the avenue bordering the squares from the side of the sea into a pedestrian route, or even the relocation of the avenue below ground, leaving a fully open terrain for the numerous scrollers.

Except for the streets, the selected squares are bordered by buildings, whose functions reflect greatly on the preservation of the special character of the respective spaces. Solid proof to this remark is foremostly provided by Barbouta Square, Metropolis Square, and Aristotelous Square. In all three of them, the surrounding edifices have largely retained their original functions, both communal (religious and educational) and private (residential, office, and recreational), with the mere exception of the fully compatible conversion of certain of Barbouta's houses into boutique hotels. Hence, the genuine spirit of the three spaces has remained basically untouched and easily identifiable, particularly the striking tranquility of the introverted Barbouta Square (see Fig. 10) and the lively atmosphere of the iconic Aristotelous Square (see Fig. 11).

The same does not apply in the case of the remaining three squares, mainly as a result of the recent multiplication of originally non-existent or far fewer recreational uses on their perimeter. In Emmanouil Brothers Square and Eleftherias Square, the current balance between the initially dominant functions on the ground floor of the surrounding buildings (residential and financial - traveling, respectively) and recreation remains in favor of the former, yet with the prospect of a reversal being imminent. Hence, specific rules need to be set, also covering the uses of the upper floors, where, for the time being, no substantial deviation from the original functional schemes (residential and financial - office - hotel, respectively) is noted. Such care is much more urgently required for

Emporiou Square, where recreation has already prevailed over the initially dominant commercial uses on the ground floor, while hotels are gradually erasing the offices and workshops on the upper floors, thus depriving the square of its genuine, commercial context (see Figs. 12, 13).

4.3 Design of the squares

To begin a discussion of the design of the six squares, one must first exclude Eleftherias Square, since its present use as a bus terminal and parking lot has established an overall disposition that is totally alien to that of a square (see Fig. 5). Secondly, it is important to note that the remaining five spaces have not preserved to this day any original features. Hence, their design is a case of entirely contemporary shaping, with two major points of reference, namely historical essence and modern needs.

To this end, the five squares display, at present, a largely common disposition: a flat terrain, with a clear central space, surrounded by features for rest (see Figs. 1 - 4, 6). Though barely notable, this arrangement does feature two beneficial characteristics. By remaining free, the central area allows unrestricted views of the surrounding building fronts, and in the case of Aristotelous Square, of the sea and the imposing Mount Olympus, the highest mountain of Greece, which was intended to serve as a focal point from the very start (see Fig. 7). On the other hand, the central spaces prove easily accessible from the perimeter of the squares, except for the barriers set by the equipment of nearby cafes and restaurants on the long sides of Aristotelous Square, and the merely two points of entry in Barbouta Square. The latter constitute, however, an original specificity, whose preservation has underlined the site's introverted character.

Upon further observation, one notes that, apart from Aristotelous Square, the terrain of the remaining spaces is laid with a limited number of hard materials, either traditional (stones, setts) or modern (cast paving), yet wholly sympathetic, in plain patterns (see Figs. 1, 2, 9). Hence, from the aesthetic viewpoint, a fully compatible result is achieved, along with a positive minimization of the ecological imprint, due to the local origin of the selected means. By contrast, Aristotelous Square has attracted over the years a wide variety of mostly incompatible modern materials, in a truly unbalanced composition (see Fig. 14), which needs to be reconsidered, if a substantial contribution to the enhancement of Thessaloniki's most prominent open space is to be secured.

A major issue as concerns the paving of the squares is that it occupies almost their entire surface. Greenery and water features prove unexpectedly absent, given the local climate (cold winters and particularly hot summers), with limited exceptions: the relatively small grass plots and scarce trees of Aristotelous Square (see Fig. 7), and the barely adequate trees on the perimeter of Barbouta Square, Emporiou Square, and Emmanouil Brothers Square (see Figs. 1, 2, 6), in the case of the latter with an incomprehensible diminishment pending, under the most recent of conservation projects to be completed for the six squares (see Fig. 15). Hence, a confinement of hard surfaces in favor of vegetation and water proves necessary, yet without erasing the central open area and obstructing the view of the surrounding fronts and landscape features.

Fig. 10. Barbouta Square.

Fig. 11. Aristotelous Square.

Fig. 12. Typical building on the perimeter of Emporiou Square in the 1980s, with shops on the ground floor and offices further up.

Fig. 13. The same building today, with a cafe - restaurant on the ground floor and a hotel on the upper stories.

Fig. 14. Aristotelous Square, with four distinct types of paving.

Fig. 15. Redesign of Emmanouil Brothers Square, 2021.

Another crucial chapter in the design of the squares is urban equipment. Expect for Emporiou Square, the selected spaces display a beneficial installation of a minimum of elements (benches, tree tubs, bollards, light posts, litter bins, and occasionally drinking fountains), which could be slightly expanded (tree seats, cycle racks, and educational features). The hitherto installed items are of rather plain, yet conventional form, leaving the ideal alternative of specially designed elements inactive. In addition, an unnecessary introduction of two separate types of a single feature is noted in certain spaces, namely two types of light posts in Aristotelous Square, and two types of sitting posts in Emmanouil Brothers Square and Metropolis Square (see Fig. 8).

Emporiou Square displays a more refined and uniform picture, being the only one so far to accommodate specially designed benches, carefully regulated lighting, and unique microclimate enhancement features (see Fig. 6). Worth noting, though, is that lighting has not been determined in conjunction with the lighting of the perimetric facades. Moreover, the scale and disposition of the microclimate enhancement features, namely a huge dome-like frame supporting a fan and a low-height water curtain, have caused irreparable aesthetic damage, in addition to obstructing the observation of the surrounding fronts (see Fig. 16). At the same time, the square is cluttered with the freely deployed furniture of the surrounding cafes and restaurants, an assembly of multiple, disparate, and largely incompatible features, which is also met at Aristotelous Square and Emmanouil Brothers Square. The adoption of a wider perspective as concerns lighting, and the introduction of discreet bioclimatic features and limited recreation equipment of common, plain, and elegant form is, therefore, a vital necessity, along with a clear delineation of the areas to be occupied by the latter.

A positive aspect in the hitherto pursued designs is the overall arrangement of wiring in underground channels, rather than on overground posts, which would have caused significant aesthetic disturbance. On the other hand, a notable deficiency is identified in the absence of substantial care for the needs of people with disabilities. Apart from the peripheral incorporation of tactile paving in Emporiou Square, the remaining spaces have nothing more to offer than a flat terrain, suitably even only in Aristotelous Square and Emmanouil Brothers Square.

On the whole, if a case of truly outstanding design, with a beneficial impact on the site's historic significance and the city's contemporary needs, was to be identified, that would certainly be the regrettably unrealized project of 2015 for Eleftherias Square. Its plan for a walkable green surface at the center of the square, complemented by plain paving, carefully arranged trees, simple, elegant, and mostly specially designed urban equipment, discreet bioclimatic features, aids for the blind, and subtle reminders of the square's exceptional history would have created a truly coveted space in the historic center of Thessaloniki (see Fig. 17).

4.4 Design of the surrounding fronts

The shaping of the surrounding fronts plays a vital role in the overall effort to highlight the special character of a square. In the case of the selected six spaces, this task is confined to the treatment of existing facades, as none is bordered by empty plots, which would additionally set forth the issue of sensitive modern development.

To be more precise, the surrounding fronts are composed of the facades, on one hand of historic buildings, most already listed, and on the other, modern structures, largely of minimal aesthetic interest. As regards the former, one notes an overall preservation of their distinctive form and separate features, particularly in Barbouta Square, Metropolis Square, and Emmanouil Brothers Square (see Fig. 18). The latter actually displays the only notable deficiency among them, namely limited dispersion of disfiguring wiring, air-conditioning units, and restaurant signs. As regards the remaining three squares, additional concern is justified, as on the ground floor, the accommodated shops, cafes, and restaurants have opted for highly distinguishable, yet equally disturbing design, in terms of coloring, texture, and added equipment (see Fig. 19). In both cases, the restoration of the morphological unity of the respective fronts ought to be promoted, along with all necessary maintenance works and care for lighting enhancement, which is currently limited.

As concerns the surrounding modern structures, Aristotelous Square gathers none. In Barbouta Square, Metropolis Square, and Emmanouil Brothers Square, a positive establishment of relatively moderate fronts is noted, with a considerable margin for improvement (removal of disfiguring shelters, signs, and mechanical units). In Eleftherias Square and Emporiou Square, a similar situation remains to be witnessed, due to the vivid morphological disruption caused by the shops, cafes, and restaurants on the ground floor and the free deployment of signs and air-conditioning units on the upper floors (see Fig. 20). Hence, substantial remedial action needs to be taken, a task resting entirely with the respective owners, as are the necessary works on the historic buildings, which in absence of special subsidy schemes and collective conscience, are all too often disregarded.

Fig. 16. Emporiou Square, view below the domed frame.

Fig. 17. Redesign proposal for Eleftherias Square, 2015.

Fig. 18. Metropolis Square, with view of the surrounding building fronts.

Fig. 19. Emporiou Square, view of the impact of recreation on a listed building.

Fig. 20. Eleftherias Square, view of the fronts of surrounding modern buildings.

5 Conclusions

The preceding appraisal of the hitherto displayed care for the selected six squares has highlighted a wide array of successes and weaknesses, which allow for a set of guidelines to be set, in the form of a code of action for the responsible conservation of the squares of the historic cities of northern Greece, and possibly the wider European context, as follows:

1) The conservation of the squares requires sustained care, starting with a review and appraisal of the needs of all the open communal spaces of the historic city, and passing on to the preparation of conservation projects, regardless of the availability or not of funding. These projects ought to be drafted through interdisciplinary cooperation, ideally following the award-winning proposals of architectural competitions, and in consultation with the state services charged with historic buildings and sites protection, and the general public.
2) The conservation project should initially address the characteristics and needs of the square's wider setting, in all its possibly multiple manifestations (historic center, civic axis, residential neighborhood). Upon focusing on the square itself, it should deal, not only with the functional and morphological arrangement of its terrain but also with the disposition of the uses and the shaping of the fronts on its perimeter.
3) The functional layout of the square's terrain ought to provide for an open area that is fully and unconditionally accessible by pedestrians, eliminating vehicle circulation and parking, in addition to clearly defining appropriately sized plots for the outdoor segment of recreational uses. If the square is bordered by streets, steps should be taken to facilitate pedestrian access, including the relocation of vehicle routes, even below ground, and their transformation into pedestrian lanes, or at least the reduction of vehicle traffic to an absolute minimum. The surrounding buildings need to preserve their original functions, with conversions conducted to the extent that the genuine spirit of the place remains untouched.

4) The design of the square's terrain ought to preserve all noteworthy original features. If no such elements have survived, a clear central space should be established, enjoying easy access from its perimeter and combining sympathetic paving (preferably of local materials) with greenery and water features in a balanced whole, which will reflect the local climate and allow unrestricted views of the surrounding fronts and landscape features. Moreover, the square ought to be furnished with all appropriate, yet not unnecessarily multiple urban equipment, preferably specially designed, in plain, elegant, and discreet forms, along with care for microclimate enhancement, facilitation of enjoyment by people with disabilities, underground wiring, carefully regulated lighting, in conjunction with the lighting of the perimetric facades, and deployment of the least required, uniform outdoor furniture by surrounding recreational functions.
5) The morphological unity of the fronts of the historic buildings surrounding the square ought to be fully preserved and highlighted, along with the establishment of a moderate aesthetic impact by the perimetric modern structures. To this end, next to the conduct of necessary conservation and lighting enhancement works, the adoption of compatible design by shops and recreation firms on the ground floor and the absence of disfiguring features on the upper floors (e.g. shelters, signs, wiring, and mechanical units) needs to be secured.

As with conservation itself, the application of the above code should rest with the local authorities, notwithstanding the need for a supplementary promotion of special subsidy schemes, and above all, collective sensitivity for the preservation of the squares' historic significance and simultaneous adjustment to contemporary needs.

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Historic adjacent concrete buildings strengthened by cable-ties under seismic pounding effects: A stochastic approach considering uncertain input parameters

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Abstract. Cultural Heritage structures include existing old industrial framed reinforced concrete (RC) buildings. The present study deals with a stochastic numerical treatment for the pounding problem concerning the seismic interaction between historic adjacent framed structures strengthened by cable-ties (tension-only bracings) when the input parameters are uncertain. This problem concerns here the unilateral contact between neighbouring structures during earthquakes and is considered as an inequality problem of dynamic structural contact mechanics. The Monte Carlo method is used for treating the uncertainty concerning input parameters. The purpose here is to estimate numerically and to control actively the influence of the cable-ties on the seismic response of the adjacent structures. Finally, in a practical case of two seismically interacting historic framed reinforced concrete (RC) structures, the effectiveness of the proposed methodology is shown.

Keywords: Historic RC Structures, Seismic pounding effects, Upgrading by Cable-ties, Seismic Sequences, Input Parameters Uncertainty, Monte Carlo method.

1 Introduction

The recent built Cultural Heritage (CH) includes, besides the usual historic monumental structures (churches, monasteries, old masonry buildings etc.), also existing old industrial buildings of reinforced concrete (RC), e.g. old factory premises framed structures, see e.g. [1]. In systems of such historic structures, the case of the seismic interaction (pounding) between adjacent structures or structural parts can become a crucial problem [2-9]. It is reminded that pounding concerns the seismic interaction between adjacent structures, e.g. neighboring buildings in city centers constructed in contact when the so-called “continuous” building system is allowed to be applied. On the common contact interface, during an earthquake excitation, appear at each time-moment either compressive stresses or relative removal displacements (separating gaps) only. These requirements result to inequality conditions in the mathematical problem formulation [10]. Moreover, pounding can cause significant strength degradation and damages on adjacent structures.

In order to overcome the above strength degradation effects, various repairing and strengthening procedures can be used for the seismic upgrading of existing RC buildings [8, 11-12]. Certainly this upgrading of Cultural Heritage structures must be realized by using materials and methods in the context of the sustainable structures [13]. Among the rehabilitation procedures, cable-like members (tension-only bracings) can be used as a first strengthening and repairing procedure [14-17].

Tention-ties have been used effectively in monastery buildings and churches arches. The ties-strengthening approach has the advantages of "cleaner" and "more lenient" operation, avoiding as much as possible the unmaking, the digging, the extensive concreting and "nuisance" functionality of the existing building. These benefits hold also for Cultural Heritage RC structures. It is emphasized that the (tension-only) ties can undertake tension but buckle and become slack and structurally ineffective when subjected to a sufficiently large compressive force. Thus, the governing conditions in the mathematical problem formulation take equality as well as an inequality form and the problem becomes a highly nonlinear one. As concerns the numerical treatment, non-convex optimization algorithms are generally required, see details in [10, 18-21].

Concerning the numerical analysis of such existing old Cultural Heritage RC structural systems, many uncertainties for input parameters must be taken into account. These mainly concern the holding properties of the old materials that had been used for the building of such structures, e.g. the remaining strength of the concrete and steel, as well as the cracking effects etc. Therefore, an appropriate estimation of the input parameters and use of probabilistic methods must be performed. For the quantification of such uncertainties, probabilistic methods have been proposed [22-26].

As concerns the current seismic upgrading of existing RC structures, modern seismic design codes adopt exclusively the use of the isolated and rare ‘design earthquake’, whereas the influence of repeated earthquake phenomena is ignored. But as the results of recent research have shown [27], seismic sequences generally require increased ductility design demands in comparison with single isolated seismic events. Especially for the seismic damage due to multiple earthquakes and to pounding this is accumulated and so it is higher than that for single seismic events, see [7, 27-28].

In the present research study, a computational probabilistic approach is developed for the seismic analysis of Cultural Heritage adjacent existing industrial RC framed-buildings. These structures are subjected to seismic sequences and are to be strengthened by cable-ties elements in order to reduce the pounding effects. Special attention is given for the estimation of the uncertainties concerning structural input parameters. Souncertain-but-bounded input parameters [29] are considered and treated by using Monte Carlo techniques [30-32]. Damage indices are computed for the seismic assessment of such historic and industrial RC structures [33-34]. Finally, an application is presented for a simple typical example of an industrial RC system strengthened by bracing ties in order to reduce pounding effects under seismic sequences.

2 The Stochastic Method of Analysis

A stochastic seismic analysis of Cultural Heritage existing RC framed-buildings has been recently presented [26]. This methodology proposed in [26] is followed herein. As well-known, see e.g. [30-32], Monte Carlo simulation is simply a repeated process of generating deterministic solutions to a given problem. Each solution corresponds to a set of deterministic input values of the underlying random variables. A statistical analysis of the so obtained simulated solutions is then performed. Thus the computational methodology consists of solving first the deterministic problem any times for each set of the random input variables and finally realizing a statistical analysis.

2.1 Numerical Treatment of the Deterministic Problem

The mathematical formulation and solution of the deterministic problem concerning the seismic analysis of existing RC adjacent frame-buildings strengthened by ties has been recently developed in [16]. Briefly, a double discretization, in space and time, is used. So, first, the structural system is discretized in space by using frame finite elements. Non-linear behavior is considered as lumped at the two ends of the RC frame elements, where plastic hinges can be developed. Pin-jointed bar elements are used for the cable-elements (tension-only). The unilateral behavior of these tie-elements and the non-linear behavior of the RC structural elements can include loosening, elastoplastic or/and elastoplastic-softening-fracturing and unloading - reloading effects. All these non-linear characteristics, concerning the ends of frame elements, the cable constitutive law and the unilateral contact, can be expressed mathematically by the subdifferential relation [18-19]:

$$s_i\,(d_i) \in \hat{\partial}\, S_i(d_i) \,. \tag{1}$$

Here s_i and d_i are generalized stress and deformation quantities. For the case of tie-elements, these quantities are the tensile force (in [kN]) and the elongation (in [m]), respectively, of the i-th cable element. $\hat{\partial}$ is the generalized gradient and S_i is the super-potential function, see Panagiotopoulos [18] and [19].

For the numerical treatment of the problem, the cable-elements and the unilateral-contact are taken into account. Thus, the dynamic equilibrium for the structural system of two adjacent structures (A) and (B) is written in matrix notation:

$$\mathbf{M_A \ddot{u}_A} + \mathbf{C_A(\dot{u}_A)} + \mathbf{K_A(u_A)} = \mathbf{f_A} + \mathbf{T_A s_A} + \mathbf{Bp} \,. \tag{2A}$$

$$\mathbf{M_B \ddot{u}_B} + \mathbf{C_B(\dot{u}_B)} + \mathbf{K_B(u_B)} = \mathbf{f_B} + \mathbf{T_B s_B} - \mathbf{Bp} \,. \tag{2B}$$

$$\mathbf{p} = \mathbf{p}_N + \mathbf{p}_T. \tag{3}$$

Here $\mathbf{s}_A$ and $\mathbf{s}_B$ are the cable elements stress vectors for the two adjacent structures (A) and (B), respectively; $\mathbf{p}$ is the contact elements stress vector and $\mathbf{T_A}$, $\mathbf{T_B}$ and $\mathbf{B}$are transformation matrices. The pounding stress vector $\mathbf{p}$ is decomposed to the vectors $\mathbf{p}_N$, of the normal, and $\mathbf{p}_T$ of the tangential interaction forces between structures (A) and

(B). By $\mathbf{u}_L$ and $\mathbf{f}_L$ are denoted the displacement vector for the structure *L=A, B* and the load time dependent vector, respectively. The damping and stiffness terms, $\mathbf{C}(\dot{\mathbf{u}})$ and $\mathbf{K}(\mathbf{u})$, respectively, concern the general non-linear case. Dots over symbols denote derivatives with respect to time. For the case of ground seismic excitation $\mathbf{x}_g$, the loading history terms $\mathbf{f}_L$ become

$$\mathbf{f}_L = -\mathbf{M}_L \, \mathbf{r}_L \, \ddot{\mathbf{x}}_g \, . \tag{4}$$

where $\mathbf{r}_L$ is the vector of stereostatic displacements.

The above relations (1)-(4), combined with the initial conditions, provide the problem formulation, where, for given $\mathbf{f}_L$, the vectors $\mathbf{u}_A$, $\mathbf{u}_B$, $\mathbf{p}$ and $\mathbf{s}_A$, $\mathbf{s}_B$ have to be computed.

For the computational treatment of the problem, the structural analysis software Ruaumoko [35]is applied hereafter as in details described in [16]. The decision about a possible strengthening for an existing RC structure, damaged by a seismic event, can be taken after a relevant assessment. This can be obtained by evaluating suitable damage indices. The focus herein is on the overall structural damage index DI_G after Park/Ang, as in details is described in [33, 34].

The global damage assessment index is obtained as a weighted average of the local damage index at the section ends of each structural element or at each cable element. First the modified [34] *local* damage index DI_L is computed by the following relation:

$$DI_L = \frac{\mu_m - \mu_y}{\mu_u - \mu_y} + \frac{\beta}{F_y d_u} E_T \tag{5}$$

where: μ_m is the maximum ductility attained during the load history, μ_u the ultimate ductility capacity of the section or element, μ_y the yield ductility, β a strength degrading parameter, F_y the yield force of the section or element, E_T the dissipated hysteretic energy, and d_u the ultimate generalized deformation.

Next, the dissipated energy E_T is chosen as the weighting function and the *global* damage index DI_G is computed by using the following relation:

$$DI_G = \frac{\sum_{i=1}^{n} DI_{Li} E_i}{\sum_{i=1}^{n} E_i} \tag{6}$$

where: DI_{Li} is the local damage index after Park/Ang at location i, E_i is the energy dissipated at location i and n is the number of locations at which the local damage is computed.

2.2 Numerical Treatment of the Probabilistic Problem

In order to calculate the random characteristics of the considered cultural Heritage RC system, the Monte Carlo simulation is used following [26]. As well-known, see e.g. [30-32], the· main element of a Monte Carlo simulation procedure is the generation of random numbers from a specified distribution. Systematic and efficient methods for generating such random numbers from several common probability distributions are available. The random variable simulation is implemented herein by using the technique of Latin Hypercube Sampling (LHS) [23-25]. The generated basic design variables are treated as a sample of experimental observations and used for the system deterministic analysis to obtain a simulated solution as in subsection 2.1. is described. As the generation of the basic design variables is repeated, more simulated solutions can be determined. Finally, a statistical analysis of the obtained simulated solutions is performed.

In more details, a set of values of the basic design input variables can be generated according to their corresponding probability distributions by using statistical sampling techniques. As concerns the uncertain-but-bounded input parameters [29] for the stochastic analysis, these are estimated here by using available upper and lower bounds, denoted as U_B and L_B respectively. So, a mean value (average) is estimated as $(U_B + L_B)/2$ and a deviation amplitude as $(U_B - L_B)/2$.

Such design variables for the herein considered RC buildings are the uncertain quantities describing the backbone diagrams of non-linear constitutive laws, e.g. plastic-hinges behavior, and the spatial variation of input parameters for old building materials. Concerning the plastic hinges in the end sections of the frame structural elements, a typical normalized moment- normalized rotation backbone is shown in Figure 1, see [24]. This backbone hardens after a yield moment M_y, having a non-negative slope of $a_h$up to a corner normalized rotation (or rotational ductility) μ_c where the negative stiffness segment starts. The drop, at a slope of a_c, is arrested by the residual plateau appearing at normalized height r that abruptly ends at the ultimate rotational ductility μ_u. The normalized rotation is the rotational ductility $\mu=\theta/\theta^{yield}$.

The above six backbone parameters in Fig. 1, namely $a_h, a_c, \mu_c, r, \mu_u$ and $a_{My}, = M/M_y$ are assumed to vary independently from each other according to a truncated Normal distribution. Typical distribution properties for these uncertain-but-bounded parameters concerning plastic hinges according to [24] are given in Table 1. The table values concern the mean value, the coefficient of variation (COV) and the upper and lower bounds of the truncated Normal distribution.

As regards the random variation of input parameters for the old materials, which had been used for the building of old RC structures, their input estimations concern mainly the remaining strength of the concrete and the steel and the elasticity modulus. According to JCSS (Joint Committee Structural Safety), see [22], concrete strength and elasticity modulus follow the Normal distribution, whereas the steel strength follows the Lognormal distribution.

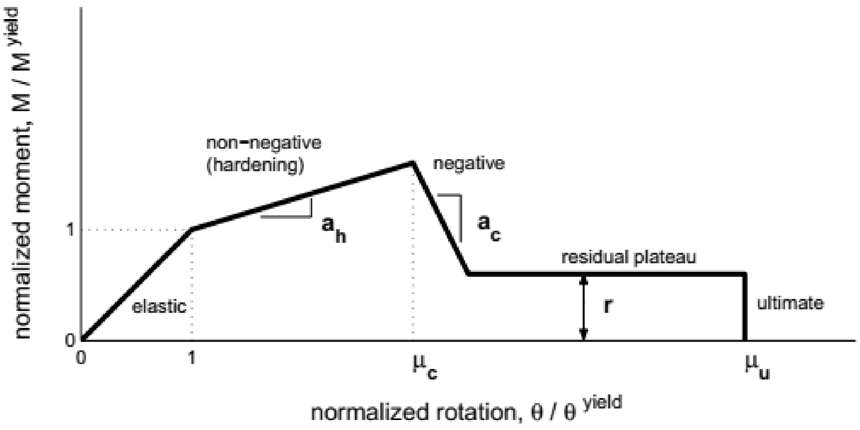

Fig. 1. Representative moment-rotation backbone diagramme for plastic hinges [24].

Table 1. Uncertain-but-bounded parameters for a typical plastic hinge

	Mean	COV	L_B (min)	U_B (max)	Distr. type
a_{My},	1.0	20%	0.80	1.20	Normal-tr.
a_h	0.1	40%	0.06	0.14	Normal-tr.
μ_c	3.0	40%	1.80	4.20	Normal-tr.
a_c	-0.5	40%	-0.70	-0.30	Normal-tr.
r	0.5	40%	0.30	0.70	Normal-tr.
μ_u	6.0	40%	3.60	8.40	Normal-tr.

3 Numerical Example

3.1 Description and modelling of the considered Cultural Heritage RC structural system

The investigated Cultural Heritage old industrial reinforced concrete systems shown in Fig. 2. This system is a 2-D "mixed" system of two adjacent reinforced concrete (RC) structures, the frame (A) and the shear wall (B). The frame (A) is to be upgraded by ties. The system will be subjected to a multiple ground seismic excitation.

The shear wall (B) has an orthogonal opening of 2mx3m. The frame beams are of rectangular section 30/60 (width/height, in cm), with section inertia moment I_B and have a total vertical distributed load 30 KN/m (each beam). The frame columns, with section inertia moment I_C, have section dimensions, in cm: 30/30. The thickness of the shear wall (B) is 20cm. The structures are parts of two adjacent buildings, which initially were designed and constructed independently in different time periods.

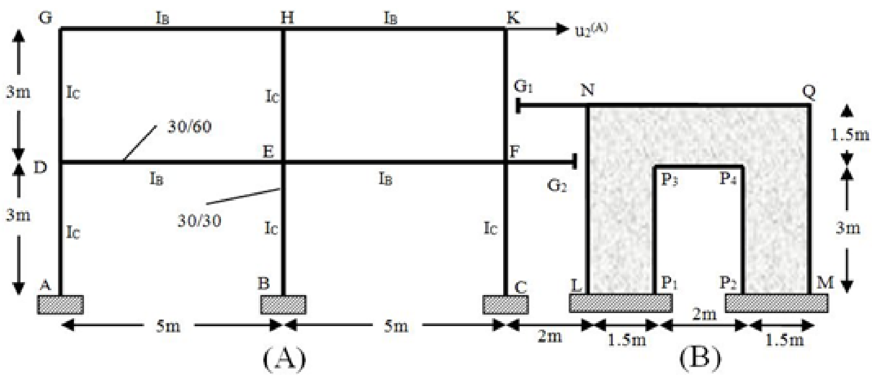

Fig. 2. The initial system of the RC structures (A) and (B), without cable-strengthening and with two possible unilateral contacts on G_1 and G_2**.**

Due to connections shown in Fig. 1, pounding is expected to take place on frame column FK (point G_1) and on shear wall part LN (point G_2) of structures (A) and (B), respectively. The gaps on G_1 and G_2 are taken initially as zero. The system of the seismically interacting RC structures (A) and (B) has been subjected to various extremal actions (seismic, environmental etc.). So, corrosion and cracking have been taken place, which have caused a strength and stiffness degradation. The effective stiffness of the concrete members are estimated according to [36-37]. The so resulted reduction for the section inertia moments I_C and I_B was estimated to be 20% for the internal column BH and the shear wall (B), 40% for the external columns AG and CK, and 60% for the frame beams.

As concerns the discretization in space by using finite elements, for the RC frame (A) the usual 2-D frame elements are used (see the Manual of Ruaumoko code, [35]). For the shear RC wall (B), use is made of the displacement-compatible plane stress model proposed and applied in [38]. This model is a quadrilateral plane stress one with 8 nodes totally. Of them, the 4 nodes are the corner ones and the 4 others on the side middles. Each node has three degrees of freedom. So, the displacement vector of each node i has two translational components, u_{ix} and u_{iy} , and one rotational component θ_{iz}. This formulation allows the connection of the plane stress elements with the frame elements. Concerning the shear wall (B), 6 square elements with dimensions 1.5mx1.5m and one orthogonal element with dimensions 2.0mx1.5m are used.

In order to rehabilitate seismically the system, the initial RC frame (A) of Fig. 2 is strengthened by four (4) steel cables (tension-only bracing elements) as shown in Fig. 3. The cable-bracing scheme of Fig. 3, with 4 cable-elements in frame (A), is denoted as S4. The strengthening cable members have a cross-sectional area $F_r = 20$ cm^{2}and are of steel class S1400/1600 with elasticity modulus $E_s = 210$ GPa. The cable constitutive law concerning the unilateral (slackness), hysteretic, fracturing, unloading-reloading etc. behavior, has been developed in [16].

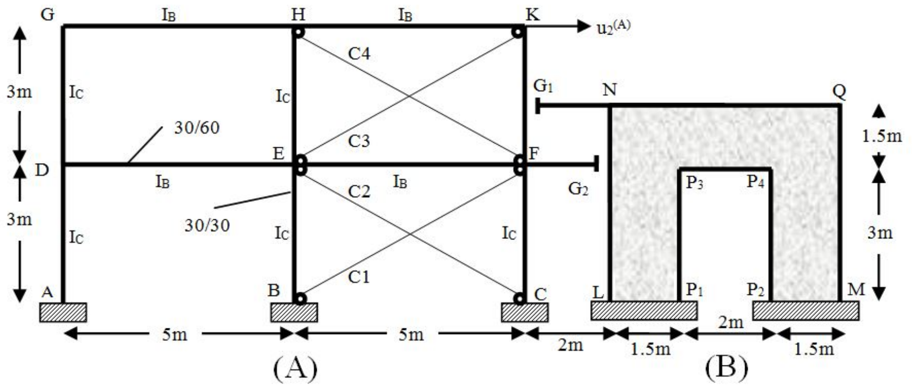

Fig. 3. The S4 system with 4 diagonal strengthening cables in frame (A).

Using Ruaumoko software [35], the columns and the beams of the frame are modelled by prismatic frame RC elements. Nonlinearity at the two ends of the RC frame structural elements is idealized by using one-component plastic hinge models, following the Takeda hysteresis rule. Interaction curves (M-N) for the critical cross-sections of the examined RC frame have been computed.

For the modelling of the cable (tension-only bracing) elements, the Ruaumoko"Bi-linear with Slackness Hysteresis Rule"IHYST = 5 shown in Fig. 4 is considered (see Fig. 33 in the Manual of Ruaumoko code, [35]), taking into account also the Ruaumoko"Degrading Strength Rule" shown in Fig. 5 (see Fig. 48 in the Manual of Ruaumoko code, [35]).

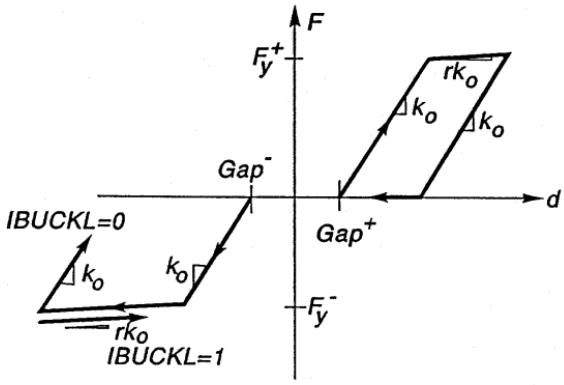

Fig. 4. The Bilinear with Slackness Hysteresis RuleIHYST = 5
|in Ruaumoko code, see Carr [35].

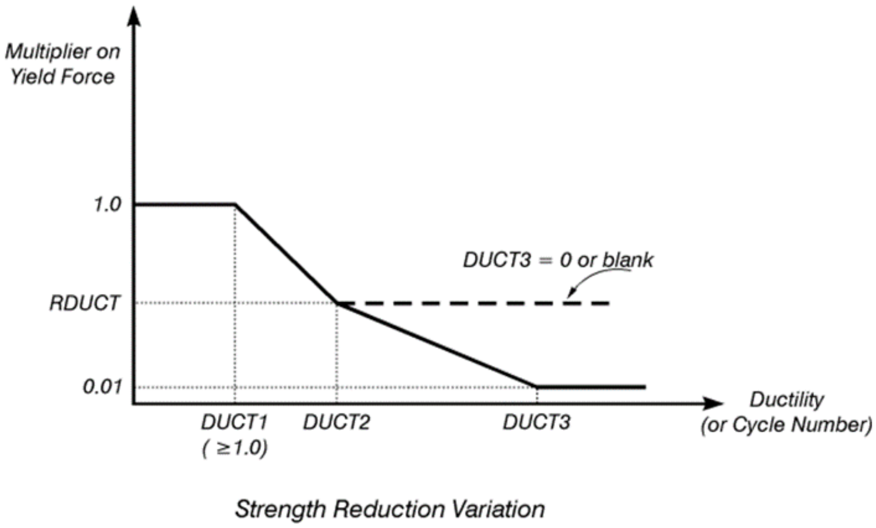

Fig. 5. The RuaumokoDegrading Strength Rule, see Carr [35].

Further, investigations presented in [39, 40] and shown in Figures 6, 7 and 8 are taken into account. In more details, in the paper [39], concerning the seismic behaviour of cross-braced frames, the diagonal tension-only bracings were taken as being effective only when in tension and were modelled as 'bilinear with slackness' with a large value of slackness being given for the compressive direction so that a compressive stiffness would never occur, see Figure 6. In the paper [40], representative shake table test results for the El Centro 1940 N-Searthquake excitation include the Fig. 7 concerning "Stress-strain hysteresis loops for tension-only braces" and the Fig. 8 concerning a typical force time-history for tension-only braces.

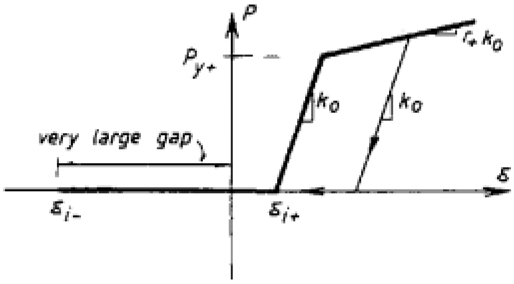

Fig. 6. Bilinear hysteresis model for tention-ties with a large value of initial slackness in compression, see [39].

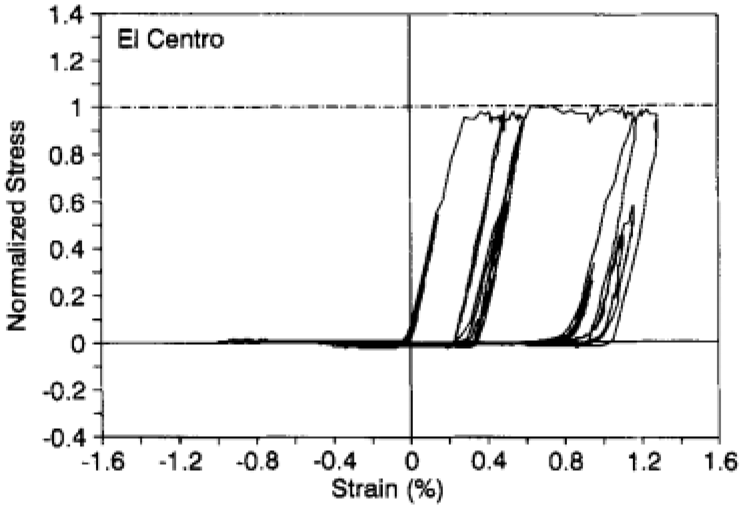

Fig. 7. Stress-strain hysteresis loops for tension-only braces, see [40].

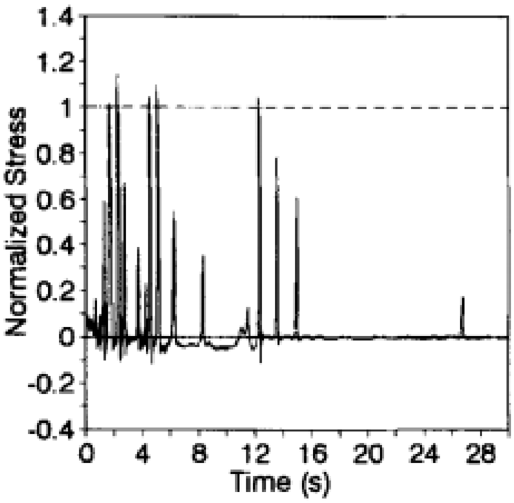

Fig. 8. Typical force time-history fortension-only braces, see [40].

Taking into account all the above considerations and [41], the constitutive law of cable-elements presented in [16] and shown in Fig. 9 is finally used herein.

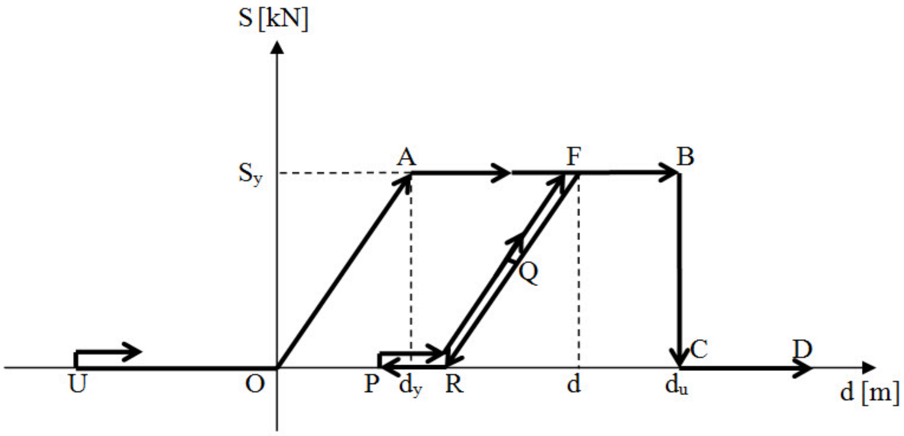

Fig. 9. The diagramme for the constitutive law of cable-elements, see [16].

The unilateral contacts in G1 and G2 are modelled by using the Contact-Element of the Ruaumoko library [35], and by applying the procedure presented in [7], see Fig. 10.

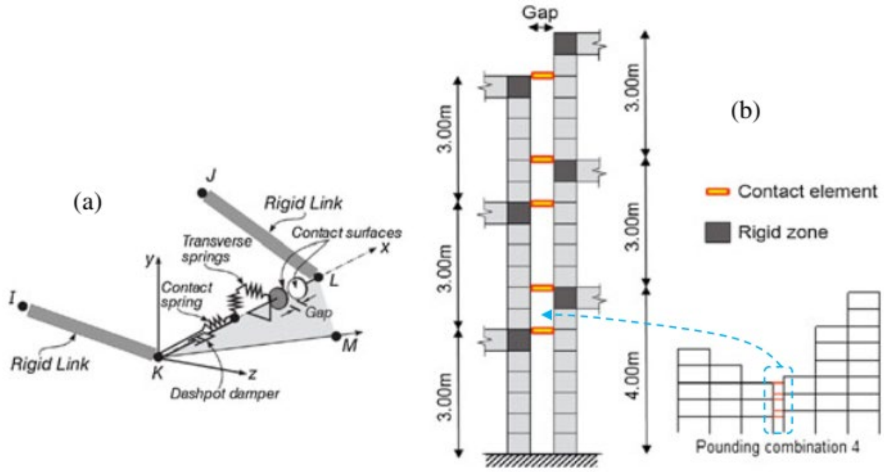

Fig. 10. (a) RuaumokoContact Element (from [35]),
(b) Modelling of structures interface , see [7].

The concrete class of the initial old system is estimated to be C12/15. According to JCSS (Joint Committee Structural Safety), see [22], concrete strength and elasticity modulus follow a Normal probability density distribution (pdf) and the steel strength follows the Lognormal distribution. So the statistical characteristics of the input random variables concerning the old building materials are estimated to be as shown in Table 2. By COV is denoted the coefficient of variation. The mean/median values of the random variables correspond to the best estimates employed in the deterministic model according to Greek codes, see KANEPE [36]. On the contrary, the input variables concerning the steel of the bracing ties (new material) are considered as deterministic ones.

Table 2. Statistical data for the old building materials treated as random variables

	Distribution	mean	COV
Compressive strength of concrete	Normal	12.0 MPa	15%
Yield strength of steel	Lognormal	191.3 MPa	10%
Initial elasticity modulus of concrete	Normal	26.0 GPA	8%
Initial elasticity modulus of steel	Normal	200 GPA	4%

3.2 Seismic Sequences Input and some Representative Probabilistic Results

In Table 3 three typical real seismic sequence are reported, which have been downloaded from the strong motion database of the Pacific Earthquake Engineering Research (PEER) Center, see [27, 28]. The systemsS0 and S4 are considered to be subjected to the Coalinga seismic sequence of the Table 3.

Table 3. Multiple earthquakes data

No	Seismic sequence	Date (Time)	Magnitude (M_L)	Recorded PGA(g)	Normalized PGA(g)
1	Coalinga	1983/07/22 (02:39)	6.0	0.605	0.165
		1983/07/25 (22:31)	5.3	0.733	0.200
2	Imperial Valley	1979/10/15 (23:16)	6.6	0.221	0.200
		1979/10/15 (23:19)	5.2	0.211	0.191
3	Whittier Narrows	1987/10/01 (14:42)	5.9	0.204	0.192
		1987/10/04 (10:59)	5.3	0.212	0.200

The proposed numerical procedure is applied by using 250 Monte Carlo samples. Some representative results of the numerical investigation concerning the systems S0 and S4, for the sequence of Coalinga seismic events only, are presented in Table 4.

Table 4. Representative response quantities for the systems S0 and S4

SYSTEM	EVENTS	DI_G	DI_L	IMPACT-G_1 [kN]	IMPACT-G_2 [kN]	u_{top} [mm]
(1)	(2)	(3)	(4)	(5)	(6)	(7)
S0	E_1	0.204	0.238	-116.7	-42.8	-36.8
	E_2	0.288	0.264	-170.8	-85.7	-51.8
	E_1+E_2	0.394	0.378	-363.7	-159.8	-75.7
	COV	27.8%	32.1%	27.2%	29.2%	31.4%
S4	E_1	0.028	0.119	-221.4	-324.8	-17.3
	E_2	0.108	0.137	-262.8	-329.1	-29.1
	E_1+E_2	0.110	0.149	-337.3	-348.2	-33.2
	COV	22.8%	25.2%	23.8%	26.1%	28.4%

In column (2) of the Table 4, the Event E_1 corresponds to Coalinga seismic event of 0.605g PGA, and Event E_2 to 0.733g PGA, (g=9.81m/sec^2). The sequence of events E_1 and E_2 is denoted as Event (E_1+ E_2). The coefficient of variation COV concerns the Event (E_1+ $E_{2.}$).

In table columns (3)-(7) the mean values of the shown quantities and the COV concerning the Event (E_1+ E_2) are given. So, in table column (3) the Global Damage Indices DI_G and in table column (4) the Local Damage Index DI_L for the bending behavior of the element FK in frame (A) are given. Next, the maximum compressive impact-contact forces on the pounding regions G1 and G2 are given in the table columns (5) and (6), respectively. Finally, in the table column (7), the maximum horizontal top displacement $u_{top} = u_2^{(A)}$ of the second frame floor is given.

As the table values show, multiple earthquakes generally increase, in an accumulative way, the response quantities, e.g. critical displacements and damage indices. On the other hand, the strengthening of the frame (A) by 4 X-tie bracings (system S4 of Fig. 3) improves the response behaviour against seismic sequences. So, the mean values of the maximum horizontal top displacement $u_{top} = u_2^{(A)}$ of the second frame floor in S4 are smaller in comparison to ones of S0. These values can be further reduced by a parametric investigation of the cable-ties characteristics, e.g. by increasing their cross-sectional area $F_r$or investigating alternate cable-strengthening schemes.

4 Concluding Remarks

A stochastic computational approach has been presented, which can be effectively used for the probabilistic numerical investigation of the seismic inelastic behaviour of adjacent Cultural Heritage old RC framed structures. These structures are strengthened by cable elements in order to reduce pounding effects. This is proven by the results of a typical numerical example concerning the seismic response of a system subjected to multiple earthquakes. The probabilistic treatment of the uncertain-but-bounded input parameters is effectively realized by using Monte Carlo simulation. Finally, by using computed damage indices, the optimal cable-bracing scheme to reduce pounding effects can be selected in a parametric way among investigated alternative cable-strengthening schemes.

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(Technological) Globalization and Anthropogenic Heritage: Objects and the Distinct Nature of Culture

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Abstract. The concepts of culture and civilization have been directly linked to the process of social construction since the dawn of human history. A philosophy of civilization presupposes a history of human evolution that would seek to highlight humanity's achievements through which we have reached the modern age. Now, even more so after the middle of the 20th century, the relationship between material civilization and technology has also been emphasized in the context of the protection of a "global cultural heritage". In this article, we will initially focus on the influence of the anthropogenic object heritage on the evolution of societies, arguing that it determines our collective experience and social memory to an important extent. We believe that such an analysis could beneficially contribute to a more meaningful understanding of a crucial topic of our modern technological era, an era that combines the clash of civilizations with globalization. We propose that the vision of a culture as a common possession of all humanity presupposes the respect of each country's right to possess and care after its own cultural tokens.

Keywords: Heritage, Material Civilization, Globalization, Culture.

1 Introduction: "Heritage" as a diachronic concept

Everything that enters the human world, either by itself or by man's effort, becomes part of the human condition. The objectivity of the world, its being independent from human activity in general, and the human condition complement each other. Because human existence is a dependent existence, it would be impossible without things, and things would turn into a pile of unrelated objects, into a non-world, if the determining elements of human existence didn't exist (Arendt, 1986 [1958]: 22).

Everything that is left to us from the previous inhabitants of this earth, either made by themselves or simply identified by them (that is, they have found it and it now constitutes a "material" which plays a key role in our lived environment), is included in what we call heritage (or historical heritage). This handover is an event that, one could say, inevitably happens and will keep happening without the mediation of any guarantor or other interfering agent. Thus, we could emphasize, with no exaggeration, that this handover is clearly a passive, predetermined action. Also, as a general rule, all people are, jointly, its recipients. We are not in a position to choose, in the first place, what we receive from the past as part of our inheritance nor can anybody conceal from his successors, and take with him in another world, the majority of the elements which constitute the facts of the material reality that surrounded them.

The presence, in the here and now, of the material elements of the past is the undeniable fact of their diachronicity and, in contrast to historical references to past events and to subjective interpretations and views, which constitute the history of a place, stands also for the possibility of their recognition as "living" evidence of eras past.

But what truly drives us towards dealing, to a lesser or larger extent, with the remnants of the past (supposing we have agreed we have the right to)? What makes our heritage stand out and take its place as such, within the context of our present situation? In times which have been characterized as postmodern, in an era of great changes and of frantic pace, the technological phenomenon tends to change, even as a working hypothesis, the basic characteristics of our way of life.

And yet, how is it possible to understand older creations today and evaluate the works of people we do not know? Do we have to do it, acting critically and, thus, selectively, or are we obligated to respect their life cycle by simply acting as impartial witnesses who observe, without intervening, their gradual degeneration?

These questions are not unequivocally defined, nor can they possibly be answered in a definitive and absolute way. They can only help us articulate our inquiry and perhaps lead us to clearly defined loci of discourse. For they are connected to crucial concepts which have been interpreted in various ways, through the lens of things such as history, the past, memory, tradition, progress and the built environment. These interpretations clearly co-shape the identity of a period of human history by explaining as well as justifying, to some extent, a series of human actions and behaviours.

2 Natural and Anthropogenic Heritage

The proposition that "heritage" is as old as humanity itself (Lowenthal, 1998: 1) should not be considered an overstatement. Even prehistoric humans have left us evidence of their lives. We have indications, at the very least, of the way they used to find their food, processed natural objects to make tools, carved a piece of stone and placed it in a spot on the ground to honour a lost companion, or for any other reason we cannot exactly comprehend. Dealing with heritage inevitably concerns us all. Whether we are interested in its protection or are ultimately indifferent to it, no one can overlook the fact that, at one point in time, we have all dealt with the material version of times past. This, however, does not mean that everyone has the same assumed representations of the elements of the past, nor do they benefit from and consider everything they perceive in the same way (Kokkinos, 2016).

We have already deliberately limited the scope of heritage. And, so far, we have only hinted to its two major categories. The term "heritage" consists of natural and anthropogenic heritage. Natural heritage, which is directly connected to the wider ecological issues, will not concern us here as it is a special, distinctly separate, field of research.

Of course, this does not mean that the two fields have no common characteristics, that, in many cases, they do not require common examination tools or that they do not fit into relatively similar ways of interpretation, or even evaluation, and that they are not connected and interdependent, interacting with each other. It is also a given that knowledge in the field of natural heritage has a lot to offer to those who attempt to approach the other component of heritage.

By making this distinction, we have basically pointed to one of the main parameters of human nature, one that uniquely characterizes the human species and separates it not only from the natural environment but also from all other organic forms. We have pointed out to its ability to decisively shape and, by using its intellect and memory, process the natural space in which it lives, to a degree not only quantitatively greater but also qualitatively more complicated than anything the other members of the animal kingdom can do. By separating natural and anthropogenic heritage, we have also denoted man's natural ability to not only construct but also create. Humanity and construction are two intertwining concepts; without constant creative intervention in the external environment, it would have been impossible for us to reach the present social arrangements. These creations, which over time accumulate in the, basically elementary, human "toolkit", as a result of human manufacturing skills and the craftsmanship to transform the matter that Homo Sapiens firstly encountered two billion years ago, comprise what we call the anthropogenic (manmade) environment. Precisely this anthropogenic environment constitutes a part of what every generation inherits and what every generation bequeaths to the next, having added or removed a part, this process being the result of human innovation and the application of new inventions, and is essentially a product of humanity's handling of the state of things it inherited (Kokkinos, 2013a; 2013b).

3 Categories of Anthropogenic Heritage

We have decided to focus our interest to what has remained in the world in which we live and whose cause of existence is man. Given that matter is perishable and that every material entity has a limited life span, the fact that such constructions have *remained* means two things: either that their life limit –after which they cannot continue to exist as structured constructions that manifest even their original form– has not yet expired, or, on the other hand, that we were interested in some of them and have decided to protect them and extend that limit for a number of reasons. In this way, we choose to protect certain constructions of the past while we are not pay the same attention to others, and so we are creating categories. In our time, we have already seen several examples of this, and we are informed daily of even more cases that schematically describe this situation. Elements of the past are not given any consideration while the preservation of others is a matter of national or even global priority.

We have already mentioned prehistoric man and the tangible, material evidence he has left us, which we are trying to preserve by initially considering their intrinsic value as material objects. However, their material properties are not the only ones we have to appreciate and report. In the same context, we have to ask ourselves the same question when we face a cave drawing or the characteristic images carved on a stone by prehistoric people in their attempt to portray situations of their times and their world. In the first case we are dealing with what remains of the past as an object, along with all the meanings it may suggest. In the second case we also have the handing down, by means of visualization, of an idea that is much more difficult to decipher and understand as such. These are two categories of heritage that, despite the fact that they both originate from man, the first belongs to the heritage of objects while the second refers to that of ideas. These categories define two separate worlds: the real, tangible world of objects, and the immaterial world of ideas. The anthropogenic heritage has been, in this way, divided into the heritage of objects and the heritage of ideas (Faulkner, 1978; Kokkinos, 2004).

This general reference to objects leads us to the next classification. There are objects that date back several centuries and their archaeological value as historical evidence is, in most cases, undeniable. They have real value as sources of first-hand interpretation for the approach of periods of human history, as evidence to support already known information or even refute existing theories. There are also those objects that are considered works of art, even if no one can irrefutably claim that such a characterization can withstand the test of time and remain safe from criticism. However, over time, some works have been registered in the cultural inventory of a region, a country or a state, or even recognized as parts of a universal cultural heritage (which constitutes one of the arguments employed by the governments of countries that insist on keeping parts of other countries' heritage, many times illegally, far from their original environment). Finally, various material constructions have captured man's interest because they are specimens that are capable to communicate and transfer to next generations the skills and techniques of people from the past. They are important signs of different times that actively project their presence in the here and now and demand, in a sense, the continuation of their existence.

Perhaps a central problem now becomes apparent; that is, what can be included in the previous categories of anthropogenic heritage (see Table 1) is not known in advance as it does not depend on a predetermined process. What is of value to one man as a work of art can be totally worthless to another and, according to this man's opinion, not really worthy of protection. On the other hand, this signifying process plays an important role in the development of every social formation (Kokkinos, 2012).

Table 1. Heritage

HERITAGE		
NATURAL	ANTHROPOGENIC	
	HERITAGE OF OBJECTS	HERITAGE OF IDEAS
	1. CLASSICAL WORKS OF ART 2. HISTORICAL EVIDENCE 3. SKILLS-TECHNIQUES EVIDENCE	1. CULTURE (CUSTOMS-CODES OF COMMUNICATION) 2. PHILOSOPHY 3. SCIENCE-TECHNOLOGY-ENGINEERING

4 The "imprinted experience" and the "external world"

The world in which we nowadays live is more of an anthropogenic, artificial (manmade), world than a natural world. By this we mean that human intervention has been definitely drastic and crucial and is constantly intensified. This "external world", which changes constantly, affects and determines, to a larger or smaller extent, human behaviour through man's tendency to behave as an adaptive system. People's goals, on various levels, define the contact between their internal and external environment. Man's relationship with the environment changed radically with the great upheaval following the "industrial revolution". With the population's confluence in large urban centres, the artificial environment was overwhelmingly enlarged against nature. Technological progress led societies into a dense network of new media and complex processes which altered not only the way of life, but also the very psyche of their members (Kontaratos [ed.], 1971; Koulermos [ed.], 1971).

To the extent that man is effectively adaptive, his behaviour reflects mainly the characteristics of the external environment (illuminated by his goals) and reveals only a few limiting properties of his "internal environment", the normal mechanism that makes a person capable of thought. The "adaptation" of thoughts into the form of environmental problems is limited by only a few "inherent" characteristics of thinking people. Everything else involved in thought behaviour and problem-solving behaviour is artificial: it is taught and improved through devising improved plans and storing them into memory (Simon, 1999 [1981]: 90-91). Therefore, we should consider the world of objects as a crucial component of human continuity as well as being a defining feature for the shaping of our perception for our entire lives. A material product is undoubtedly standing before us. It combines, on one hand, the current perception formed by common taste as well as by the needs, authentic or inauthentic, of social dynamics, while, on the other hand, offers an outlet to people's concentrated desire to contribute to the developing situation, by externalizing amorphous ideas and assumptions about it (Kokkinos, 2006). Furthermore, it allows man to "converse" with social reality, even though a conversation with every one of his fellow men would be impossible. Man, as a creator, aims, through his tangible constructions, to stop the perpetual flow of time, to underline existence-defining moments and pass on to next generations the elements that, according to his views, should not be forgotten. By imprinting his experience on matter, he wants to express his own perception of reality, perhaps even match the mental component of his own microcosm with the general social reference in a context, which is characterized strongly by the factors of multiculturalism and globalization.

5 Towards a Global (?) Cultural Heritage

Multiculturalism, as a descriptive term, suggests the existence of more than one, culturally heterogeneous, social formations or groups. As a modern problem, the term "multiculturalism" refers to the nexus of practical problems and judicial-political dilemmas posed by the fact of the coexistence of culturally diversified social groups, when manifested in the context of an organizationally unified political structure, in which a group that expresses a single cultural version is prominent (Paparrigopoulos, 1999: 2-3). If the members of each group publicly identify with the predominant characteristics, practices and values of an "official" social practice, then there is a risk that partial structures (racial, cultural, etc.) will gain the predominance against the universal human identity. On the other hand, a part of the individuals' uniqueness stems from the ways in which they integrate, reflect and modify their cultural heritage (Gutmann [ed.], 1997 [1994]: 43-44) as well as that of those with whom they come into contact.

"Recognition" and "identity" are two concepts whose signification within the social sphere is attributed to the age of modernity. We refer to the recognition of every man's difference from any other and to the respect of his identity, regardless of all kinds of discrimination (racial, national, religious, etc.). In the premodern era, contact with an extra-human source was sufficient enough to fulfil one's existence and led to a, certainly relative, distinction of the ego. From the 18th century onwards, the established social situation is put under examination. A first development was the questioning of the various hereditary titles and offices. Thus, the changes in the qualitative search of personal autonomy became apparent, within a certain social setting.

So, the term "multiculturalism", which encompasses and highlights the concepts of recognition and identity as well as related issues, was included in the vocabulary of those societies whose population was either born from migration or colonization, and consists of citizens of various nationalities, religious and racial backgrounds etc. (the example of the U.S.A. being the most iconic). We come across it for the first time in the revised edition of the *Oxford English Dictionary*, as late as in 1989. Of course, the first mentions of the term appear already in the 1970s, in books published in Canada and Australia. The aim of this dynamic is the creation of a political and social movement for the equal recognition of all collective identities within the context of a democratic rule of law. This claim does not primarily aim towards the levelling of the social life conditions but towards the protection of the integrity of the forms of life and traditions to which these groups belong (Habermas, 1994: 50-51). And it is no coincidence that this kind of actions are linked to what has been happening over the last decades: waves of migration, civil conflicts and state partitioning.

The opposing force to the demand for multicultural societies, together with all their implications, is, in a way, the well-known debate about "globalism" and the "clash of civilizations" that should come in order to clear the universal landscape[1]. The triumph of the West, which was ceremoniously "announced" in 1989[2], and the unification of the world around a global market (which will be regulated by certain western countries) and the omnipotence of a small group of leaders is the predominant characteristic of our era. A few years earlier, Samuel P. Huntington placed at the heart of his thought the concept of civilization in order to highlight the fact that the boundaries of nation states had already been compromised. The theory of the clash of civilizations, the division of the world into opposing cultural camps,[3] overestimates the cultural factor in politics, in an era when ways of life have approached each other, on a global scale, and cultural differences are diminishing, in an unprecedented degree, even though they remain important. This overestimation intends to redefine the appropriate opposing poles and the formation of spheres of influence.

6 Addendum

Globalization means, in a general sense, that we are all co-dependent (Bauman, 2001). In our times, several situations, that would otherwise develop separately, are connected and interact and this is a condition that defines them from the beginning and throughout their course. It is an essential characteristic of the economy, culture, politics, and therefore our entire social life. Nowadays, it is a historical fact (Castells, 1999), as it is backed by the major changes in the scientific and technological field and especially in the field of computers and communications (Vergopoulos, 1999; Harvey, 1996). Therefore, globalization decisively influences our notions of culture and civilization (Held, 1995; Wiredu, 1995; Hebdige, 1990; King, 1990). What is of interest to us here is that it provides arguments to those who support the perpetuation of the stay of important monuments away from the place in which they were originally created. The term "global cultural heritage", when combined with the views we saw formally expressed, as part of state policy, suggests a great threat to actions taken in the name of recognition and respect of identity, in the context of autonomous societies. It seems that

[1]We associate the "clash of civilizations" with "globalization" because we believe they essentially aim for the same thing: the ideological-politicaldominanceofagroupofcountriesattheexpenseoftherestofthe world, in the first case by utilizing national-cultural characteristics while in the second by acting on the basis of economic-technological superiority.

[2]For Fukuyama, *History has ended* and the dialectic that fueled its wars and revolution sceasedto exist, as the western "democratic model" triumphed and there is now no rival. This simplistic position was originally introduced in 1989. See, Fukuyama, 1993 [1992].

[3]See, Huntington, 1998 [1996]. Huntington's book, published in 1996, was based on his original article ("The Class of Civilizations?") published in the summer of 1993 in *Foreign Affairs*. This theory has also been strongly criticized, while the recent war in Afghanistan resulted in its resurfacing in the spotlight. See, for example, Huntington et al, 1998.

it is not at all unlikely that issues which concern, or should concern, the internal affairs of individual countries, have been raised to the sphere of central political decisions and the overall planning of global governance by a group of powerful governments.

7 Conclusions

Artifacts play an important role in determining the cultural content of each era. This a posteriori claim places modern societies against their present and proclaims them as configurative forces of History. At the same time, it commits them, in a way, to the duration, the development and the continuity of their own civilization. This issue emerges not only when we examine personal activity, the attitude of each citizen of each country, but also when we see the collective practices, the universal politics, through various ways and forms. Thus, it is connected with decisions and conditions that are formulated on the institutional level and which each of us must fulfill or oppose. We believe that the beginning and the development of the function of memory are interwoven with the material environment. Discourse over objects becomes a means by which people exchange evaluations and views concerning the notions of time, memory, history, progress and human solidarity. The promotion or concealment of previous eras, which correspond to material testimonies, are interconnected with the process of memory and indeed not with quantitative performance, i.e. with numbers and statistics that leave no room for different interpretations, but with a qualitative status, i.e. judgments that have to do with ideological/political interpretations. This is so because the various constructions of human connect, in a unique, unidentified and irrelevant to positivist views way, the senses with material substance. If material substance is to be processed and consumed immediately, there would be neither semiotics nor memory.

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The use of restored monuments for the exhibition of contemporary artworks: where is (preventive) conservation?

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Abstract. The key issue raised in this paper concerns the absence of an institutional framework for the operation of the buildings with the condition of preventive conservation of the modern collections. The main interest of curators focuses on the restoration of the monument in order to be "functional" and accessible rather than to the provision of facilities that will prevent the deterioration of contemporary works (two-dimensional paintings, in-situ installations, sculptures, video projections, etc.). Secondly, the monuments cannot always provide possibilities for a controlled microclimate. The fact that the exhibits are modern, made of technologically advanced or recycled materials - sometimes not original ones but replicas - should not preclude the practical application of preventive conservation measures. After all, it is proven that the establishment of an exhibition regulation is necessary regardless of the bioclimatic design of the buildings.

Keywords: bioclimatic design, preventive conservation, contemporary art.

1 The problem of funding for preventive or remedial art conservation measures

The need for low cost sustainable solutions

In recent years there has been a dominant principle for contemporary conservation practice that prevention is better than the cure of collections; According to Eastop (2011) the “Ethos” of current conservation practices is preventive conservation which seeks to reduce the effect of material and environmental changes on collections by responding to their causes rather than to their effects. In some cases, even the rationale for replicating or re fabrication a contemporary artwork is a strategy instead of conservation due to its degradation [1].

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As Sakellariou remarks, these measures of preventive conservation relate to the development and improvement of the services of curators or collection managers [2]. As he states, in the case of preventive conservation there is always a problem of economy resources and funding proposals even at the most subsidized institutions which lack the premises, equipment and conservators so as to support preventive conservation projects (**Fig. 1**.)

Fig. 1. A fully digitally controlled microclimate inside the National Gallery of Athens funded by the Stavros Niarchos Foundation (credits: K. Stoupathis, 2021).

As preventive conservation measures also require a lot of expenses, complex strategies have to be followed in the cases of historical buildings as those are not intended for museums or exhibition spaces. Thus, they host old and modern collections of historical, artistic and even religious value. The expertise of a professional in the field of preventive conservation is very important because he prepares scientific reports of the museum environment, assesses any factors that threaten the collection in relation to the building and makes decisions about any endogenous or exogenous factors that may place the art objects at risk. "Especially in cases where old buildings are not restored but left in a state of abandonment there is instability of their internal environment which provokes the artworks´ deterioration. Additionally to this, Brooks adopts a communicative approach as expresses the opinion that besides practical issues there are initiatives for museums to communicate conservation in public through exhibitions which offer the intriguing spectacle of the possibility of slowing down natural decay to which all objects (and humans) are subject [3]. Golfomitsou also points out, that in some cases, artworks existing in material form may be replaced or reproduced instead of being conserved. Besides, the sources of a museum funding may be diverse. Reduced funding leads to a diminishing of resources such as museum jobs and a reduction of supplies and this leads museums to hire conservation managers who are authorized to make decisions in relation to what needs to be conserved and what resources are required [4].

Taking all the aforementioned into account it is clearly understood in the scientific community of museum professionals that the application of the already tested methods of preventive conservation takes precedence over any other conservation and restoration considering that preventing is better than any conservation treatment.

2 Where do contemporary art exhibitions take place?

Types of cultural spaces and monuments that host contemporary art

Historical buildings are the most important to manage due to their design peculiarities given that conservators must combine the optimal conditions for the protection of (contemporary) objects as well as the preservation of their architectural shell and the comfort of their visitors. A detailed and analytical design of their internal environment is required which is defined as “bioclimatic design”. In the case of historical buildings, modifications and restoration interventions are not always easy to apply as Stamatopoulou mentions [5], the expanded concept of the museum includes every cultural space, talking about a)a general categorization of buildings that house art collections and manage human culture, b)buildings that have been built from the beginning for museum use and therefore own the required structural specifications and c)buildings that have been reused and whose original construction state did not respond to the aim of a museum or of a cultural venue **(Fig. 2)**

However, the role of the Museum building is achieved through a meticulous, detailed and analytical bioclimatic design; the goal of the design of the internal environment of the building monument is firstly to optimize the internal environment to balance the preventive conservation needs regarding the requirements of the collection. Secondly it depends on the type of objects displayed such as paintings, mixed media installations, organic collections made of fragile and ephemeral materials that are difficult to preserve. Thirdly there is always the question of knowing-how can this monument support the museological context of the curator-museologist and enhance the interpretation of the artworks by its visitors.

Stamatopoulou categorizes such buildings, according to the control of their internal environment into four categories as: a)unmodified buildings that have not undergone electromechanical construction interventions or any preservation of their internal microclimate, b)adapted monuments whose external environment has been measured in order to achieve a microclimate control of relative humidity, temperature, etc., c)old buildings as monuments with construction defects made of inappropriate paint materials, d)buildings constructed as spaces for cultural use.

We should also not forget outside open-air exhibitions in parks/gardens, urban blocks or in the metro stations, underground, etc.

Fig. 2: View from a restored wooden roof, old house and studio of A. Mylona that was converted in a contemporary art museum. Besides the installation of an inverter-type air conditioner there are artificial and natural light sources (credits: K. Stoupathis, 2022).

3 Recommendations for the control of microclimate in public spaces

Authorities of a contemporary arts conservator

In the case of contemporary art that is publicly exhibited, the famous archaeological sites and monuments that host it are charged with historical memories, are reverently browsed and need to be well preserved [6]. Besides monuments, changing views on preventive conservation on artworks have occurred: As Kuhne and Kirch [7] explain, contemporary exhibitions may take place even in demolished or undamaged buildings which may have undergone renovation or past restorations (**Fig. 3)**.

Fig. 3: A site specific light installation placed onto the “Old Tobacco Factory” of Athens during “Portals” exhibition: sun-light immerses from a crystal roof (credits: K. Stoupathis, 2021).

So, new materials and material combinations of contemporary artworks are a challenge for the conservator. For example, a thorny problem is the broad spectrum of new media art which after a few years of aging require more up to date forms of conservation, or copying a visual work of art to other storage media instead of conserving it may alter the way we treat or protect collections. But in contrast to this holistic perception of art meaning and art aging, Gwynne mentions that “a contemporary artwork in its infancy...some artworks are fabricated with the understanding and the requirement that the materials must evolve or be replaced over time” [8].

Regarding preventive conservation, the climatic conditions of the (urban/rular) area where the old masonry, museum or gallery is situated need to be evaluated and the construction characteristics of the building or past restorations be examined -in order to achieve a stable climate control for the preservation state before making use of any collections displayed. For example developments and discussions are well underway in many contemporary institutions which have introduced new forms of display concerning involving art-installations, events and actions where the viewer interacts with the contemporary collection [9]. To any practical dilemmas of the conservator should someone add further, any lack of previous preservation reports of the monument. Concerning the architectural science, laboratorial or “in situ” tests must take place in order to evaluate the present condition of the walls, openings, renders and pointing mortars. As far as Restoration is concerned these experts have to make decisions about keeping any interventions of architects as they are, repair or substitute them [10]. Also, in order to improve the quality of the atmospheric conditions and to control the internal environment of a building, special attention is attributed to the existence of its thermal zones as each monument is internally characterized by thermal zones based on the thermal data-energy resources or energy losses.

Moreover, major changes in museum practices in relation to internal conditions were made by following Thompson's recommendations which focused on limiting any environmental fluctuations in the museum environment instead of struggling to retain stable microclimate conditions; Thus, Thomson in 1978, concluded that a preventive conservation framework should be created by defining fluctuations in the range of +, -, 4-5 R.H %, achieved by air conditioning system. For it is more crucial to maintain these environmental changes rather than knowing in detail the effects of small degradation phenomena on the objects. Additionally, a well designed museum environmental control would include along with regulated R.H.% and Temperature, adequate filtration to absorb most of the harmful particulate matter (such as soot from industrial venues that host exhibitions). In urban spaces damaging pollutants penetrate through the doors, windows or contamination brought in by the public. As Stolow remarks, high density can also raise carbon dioxide levels, ammonia in galleries through the openings and floors [11].

Finally, for the proper operation of the air conditioning system, the appropriate control condition sensors must be placed: a modern solution for the control of the indoor environment is by the telemetric method where the sensors in each area of the exhibition are connected to a transmitter which is then connected directly via network to a computer and thus one can have (in real time and from a distance) all the records of the environmental conditions [12].

4 Ethical issues: Should the old monuments look like white cubes?

The "white-cube" phenomenon of a gallery or museum

– Despite the microclimate control, as far as the aesthetics of the exhibition spaces are concerned there's too much talk about the white-cube phenomenon in contemporary exhibitions. For many art critics have raised concerns that the new, most outlandish Art Museum designs upstage the art inside, mentioning that this may be explained due to their futuristic appearance in contrast to the architectural characteristics of historic buildings; On my opinion, this may be disappointing as far as collection-care is concerned.

– On the one hand as O΄ Doherty mentions, there is the "white cube" space which instead of an old exhibiting practice provides with an opportunity to see not the artworks but the space first. As we assume this means that there may be no interest in the preventive conservation as there is a limited period of time that artworks are displayed or their deterioration timeline may be neglected. So, in order to manifest ideas and for preventive conservation rules the artworks are well mounted in galleries, hung but scattered for study. The easel picture is seen like a portable window that penetrates the walls of the building with deep space [13]. For Smithson, a vacant white room where the work of art exhibited is still a submission to the neutral, a kind of aesthetic convalescence, curable or incurable waiting to be consumed by society [14].

- On the other hand, Kyung and Cerasi argue that the white-painted rooms free of all visual distractions except the contemporary artworks have become a standard so widely accepted, due to contemporary Art Museums ability to tarnish into global tourist destinations-this has often made them into a pretext for ambitious architecture and urban investments. This state of withdrawal from the world outside allowed museums to emerge as spaces apart for reflection as symbols of personal and collective transformation through a higher deal. Moreover, the monuments´ openings and windows were banished for the "time passage" disappeared -not for preventive conservation-as "the idea was to allow the viewer to focus on one work at the time and to maximize purely aesthetic contemplation" [15].
- Along with these post-modern statements mentioned for the inner exhibiting areas we should further consider Riegl´s theory for the modern cult of monuments or his statement for the renewal value of a monument where interventions of restorers through stylistic additions may alter the forms or colors of it like a "newly created work" [16]. He states that, these artistic but historical monuments may be misunderstood in terms of our human conception as the artistic value of a monument is no longer commemorative but a contemporary value that should be seriously taken into account before preservation or restoration. Despite the "age value" he refers to the "historical" (that does not concern the preservation of any traces of age, disintegration or other changes caused by nature's impact on the monument) but that the present state should be maintained and stop the progression of future decay. Moreover, an old building still in use should be restored without endangering the visitors but in respect to its original stylistic unity. After all, environmental sensitivity becomes extremely important to museologists who collaborate with conservators. Many curators and designers are often loath to sacrifice Aesthetics for the sustainability of the environment: In contemporary exhibitions all designers are looking for processes and materials that are environmentally friendly and decrease energy consumption inside the monument, inner or outdoor space of area used **(Fig. 4).**
- Despite the control of light -radiation in the internal part of a building which is crucial for the preventive conservation of artworks as task of a conservator, the hot or bright lights used by exhibition designers are an enormous energy drain, plus the large amount of energy involved in installations and prints that influence the quality of the air through harmful volatile compounds and difficult to dispose chemicals [17].

Fig. 4. An installation of S.Antonakos at the Ampelokipoi Metro station of Athens which is partially in contact with external environment conditions, deposits and immersive sun light (credits: K. Stoupathis 2015).

5 Why not preventive conservation in contemporary art exhibitions in historical venues?

What lies beyond this rhetorical question

This paper is an extension of a recent survey as far as it fills the gap regarding the establishment of a legal code of ethics concerning the necessity of preventive conservation. A Code of Conduct has to be firmly applied in various monuments, that are being reused for contemporary art exhibitions. Due to the problem of the restoration of the architectural form of the monuments in relation to the conservation and exhibition requirements of contemporary collections; in particular the question of the re-use of historical buildings or abandoned spaces in the cloistered city seems to be a familiar practice of curators, in the context of:

a) Organizing periodical, visual exhibitions including alternative non-restored monuments such as neoclassical houses, old schools, factories, abandoned venues,
b) Following a contemporary trend/advance of postmodern times, in the service of curation due to limited expenses, art exhibitions in monuments that are free of cost and available, open-air buildings and outdoor art-happenings where preventive conservation is impossible to apply,

c) Selecting buildings with specifications that match with the museological concepts and ideas or initiatives of the curators for cultural exhibitions.

Thus, it sees that the curators of the exhibitions do not pay any attention to the factor of the preventive conservation of art. The main reason is that often the museological concept of a periodical exhibition- as well as the short period of time it lasts, play a

very important role in the lack of provision of preventive conservation measures **(Fig. 5).**

Fig. 5: Cement interventions and aluminum air tubes on the inner walls at the old Stock Exchange Hall of Athens in "Agora" 2013 exhibition: M. Babousis paper artworks were lit by fluorescent tubes and there was no light radiation control. (credits: K. Stoupathis, 2013).

They also choose the old building that is consistent with the idea they have in their mind or according to the thematic units that make up a museum exhibition. They clearly collaborate with artists who hang artworks, or create site-specific installations, improv-isation ally and empirically. In some cases the kind of the contemporary art exhibition enhances (only) the investigation of literature and archival research of these "expanded interiors" by the curator. As Huber remarks any archaeological, archival and historical analysis of the buildings, its wall paintings, architecture and design has to be related contemporary practice and movements even at art performances [18]. The key issue raised here is sustainability which concerns the absence of an institutional framework for the operation of such buildings with the condition of preventive conservation of the modern/contemporary collections. Despite this, the urban fabric has in relation to all natural phenomena its own impact on Aesthetics [19].

It is obvious that the main interest of the curators´ focuses on the restoration of the monuments in order to be functional and accessible for the public, rather than to the provision of facilities and air conditioning units that will control the microclimate in the exhibition space. Taken for granted that in most cases curators are not familiar with preventive conservation principles due to their educational background they display the artworks in indoor climate conditions, something which does not exclusively prevent contemporary artworks from deteriorating **(Fig. 6).**

Fig. 6: The "NuKUmori washi Kimono" paper Art installation by M. Papatzelou, displayed near an open window at the "Red House" of Chalkida city. As mentioned on the floor, the perfume is an important material of the artwork (credits: K. Stoupathis, 2023).

Additionally, to this, these monuments cannot provide possibilities for the total control of their microclimate. The fact that the exhibits are contemporary, made of technologically advanced (sometimes recycled materials) or even replicas being displayed, should not preclude the practical application of preventive conservation measures. In fact, professionals in the field of culture need to establish new cultural recommendations and comply with new regulations for the energy saving operation of those buildings: an updated code of conduct based on the most environmentally friendly and money-saving measures. So, one would wonder, if it is of extreme importance to institutionalize the recordings of micro-climate conditions in a monument that will host collections before they are even incorporated. As Duilio, Moyano and Gomez suggest "conservation literature and standards recommend to perform long term monitoring on a building instead of following rigid and arbitrary conditions" [20]. My opinion is that we have to redefine the interior space, the monument itself on both formal, practical and conceptual levels, besides the set-pointing of the ideal environmental conditions.

More specifically, all cultural managers and museum professionals should improve a close dialogue-even with the artists- in order to facilitate new paths for the exploration of historical monuments´ relevance for contemporary art making, towards sustainability. As Macdonald and Goncalves suggest, in cases of concrete structures an ethical issue is "to balance best practices for repair, treatment and maintenance with conservation needs through compromises that require understanding of their long term consequences" [21].

Due to these important issues mentioned research tools such as significance assessment and risk analysis, architectural reports of the preservation state of the buildings or mock ups of treatment materials should be applied prior to hosting these exhibitions. Environmental parameters such as the monuments´ energy losses, the inappropriate building materials, the lack of air conditioning units, infrastructure or anti acid supports on the art exhibits or the polluted by fumes atmosphere, do not provide protection from the threats of collections. On the contrary, they place them at risk.

6 Conclusions

The need for preventive conservation enables museum professionals and mostly conservators to struggle with obstacles of limited resources. There are also problems of funding preventive conservation projects and arguing with curators, stakeholders or architects when trying to safeguard art and retain the artists intents.

Beyond the rhetoric question "where is preventive conservation?" another problem exists: the necessity of the detailed establishment of a professional code of conduct for curators and conservators where preventive conservation measures will be strictly applied, especially written for contemporary art when displayed in old monuments. The bioclimatic design of a monument, is extremely important for the sustainability of most urban buildings, while in some cases contemporary artworks deteriorate either exposed to a non-controlled microclimate or due to human neglect.

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Protection and enhancement of the historical and architectural heritage in times of peace on apparently distant war wounds. Some cases in Cagliari (Italy) between restorations, current problems and future prospects

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Abstract. The most recent conflicts in the European territory have focused the attention on the question of the protection of heritage after the war event, which now not appears in Italy as a distant problem, both temporally and geographically. The study here proposed examines the case of the city of Cagliari, the regional capital of Sardinia (Italy), which is centrally located in the Mediterranean. The city appears to be an interesting and complete model due to the variety of cases that can be found here. It seems interesting how the typology of property has (or has not) often led to a reconstruction method.

Historical cartography and images was compared with the current state; it is possible to observe the results of the buildings reconstruction (or part of the building) or urban void generated, to identify the main unsolved problems.

The problems generated by the Second World War bombings, were examined eighty years after the end of the conflict. We therefore want to understand what the approach to reconstruction in relation to the different intended uses of the assets and their architectural quality was, in the various decades, from the post-war period until today.

Furthermore, it is interesting to examine whether the interventions were carried out in accordance with the regulations and / or with cultural indications that have followed, by comparing the local issue with the national one. This occasion appears to be useful to reflect on the results of the damages of the city, where they remain severely compensable.

Keywords: restoration, damage, war.

1 Introduction

The overcoming of the "scientific restoration" with the transition to the "critical restoration" was a result for concrete operational needs after the traumatic event of the Second World War. The criteria of scientific restoration were inadequate towards the innumerable damages and vast gaps of parts of the architecture in the city during World War II, and everywhere in Italy there was a necessity of reconstruction in a very complex scenario. More specifically, the aspects developed "in times of peace" contained in the Athens Restoration Charter (1931), such as the anastylosis, permitted in archaeological contexts the contribution of new technologies on consolidation. In particular, the reinforced concrete masks these interventions to maintain the historical aspect of the architecture, with pays more attention in the "most picturesque" areas of the city, and a rare minimum integration in the buildings, to avoid "artistic forgeries" or "historical forgeries".

The debates and the approaches for reconstruction essentially follow two main strands: the reconstruction to totally delete the trauma that occurred, or the reconstruction to return to a prior state of the event getting back the lost assets. In other words, the reconstruction often takes place through two different approaches and "a perfect reconstruction of a historic building in its pre-war condition and, conversely, the complete destruction of the ruin almost always appear out of place and out of time" [1]. A further solution is the one of not-reconstruction. It is known that towards war destruction, the reconstruction of the monument "hic et nunc" is recurrent, by using historical images making this operation presupposed anastylosis, although the reintegrated material was often conspicuous (an operation that Giovannoni himself approved, considering the circumstances). Obviously, this is justifiable by the emotionality that characterizes the community, upset by the traumatic event [2]. Throughout Italy, the reconstruction in civil architecture is accompanied by a widespread phenomenon of building speculation in the logic of maximum profit, followed by the highly interesting debates that intellectuals develop on the case of the most important monuments. Despite the relative simplicity of the architecture of Cagliari, the example examined here reflects, as we'll show, what happens throughout Italy. The reconstruction plan, minimally implemented, will try to find a balance between the economy of the intervention and innovative solutions for the city, in order to restore and modernize the most damaged areas, but avoiding the loss of numerous historic architectures, previously planned to be demolished and rebuilt.

Referring to the classification of De Angelis d'Ossat [3] damaged buildings can belong to three different categories depending on whether the damage suffered is: minor, major, seriously damaged or destroyed (similar classification can be individuated in the historical cartography made immediately of the end of Second World War). This different intensity of damage should give rise to different attitudes. It is interesting to see how the damage estimated as slight will not always involve the minimum intervention and often the choices adopted do not depend on the feasibility of safeguarding the architectural heritage.

2 The city of Cagliari: historical background and general overview of the events during World War II

Due to its central location within the Mediterranean, the city of Cagliari has always been an active protagonist of trade, economic and consequently war interests. Undoubtedly a strategic site, as evidenced by the presence of Phoenician-Punic settlements, the notable necropolis of Tuvixeddu, which followed the Roman domination which defined the road structure that still characterizes the organization of the contemporary city [4]. The genesis of the city, according to specialists, can be referred to the Marina district due to its proximity to the port [5]. The current urban conformation takes shape (obviously taking into account the changes that have occurred over time) in the medieval period, when Sardinia was divided into four Giudicati, one of which was that of Kalaris. According to the literature, the presence of a Castro Calari was already documented in the year 1002, referable to the presence of a fortified castle [6]. It would be the Castello district. The Stampace district, which stands at the base of the Castle, is described as an adjacent area, at the service of the Castle itself, inhabited by craftsmen and workers, also surrounded by walls and towers [6]. Its shape remained almost unchanged until the beginning of the 19th century when the widespread desire was to tear down the walls that defined its perimeter, and the need to be part of a new modern post-industrial culture was strong enough to influence changes in the urban layout of the district, the result of which is a complex reading of its architectural vicissitudes, between the dense historical agglomeration, the nineteenth-century expansion, the railway and its appurtenances [5]. With the construction of the convent of San Domenico, surrounded by orchards and gardens, the last of the historic districts of the city was created, precisely Villanova, developed starting from scattered cores with a peasant vocation, whose perimeter was defined by the fortification of the Pisans.

Its road and architectural structure is distinguished from other cities due to the unique arrangement in an irregular checkerboard pattern [6]. Its expansion is the most consistent due to the early demolition of parts of the walls that bordered this historic district, which took place between the 15th and 16th centuries (Fig. 1) [7].

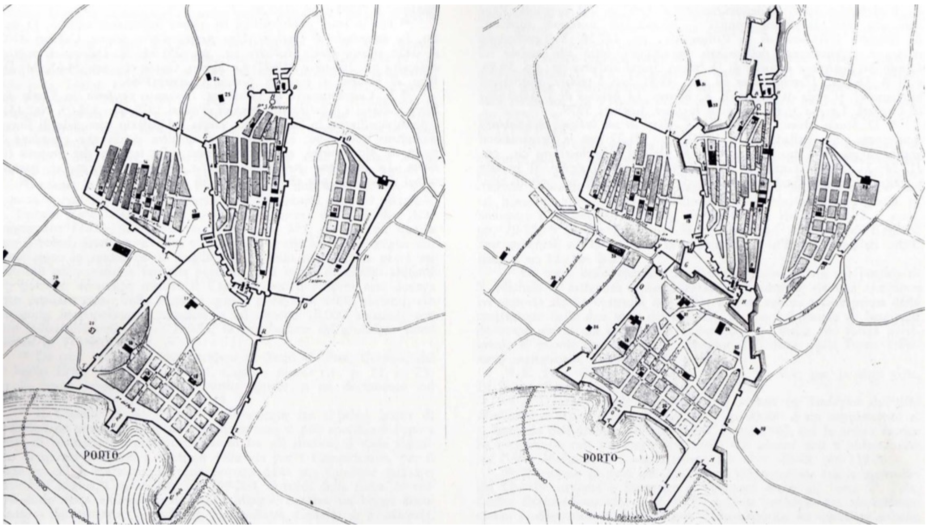

Fig. 1. Cagliari in XIV-XV century (left) and XVI century (right) [6].

The urban conformation of Castello district is defined and fossilized within the perimeter of the fortification walls (which here were not demolished even after the unification of Italy) which therefore, limited its expansion and guaranteed the conservation of the historical fabric. The bombings of 1943 changed this balance, given that many of the representative buildings, such as the town hall, were also moved to the lower part of the city between the districts of Stampace and Marina [5]. The latter, in the same period, progressively increases its expansion and, by the end of the seventeenth century, it will reach the consistency that it will maintain until the modern era [6].

Due to war strategies, the city of Cagliari finds itself playing a central role in the Italian panorama. In the aftermath of the outbreak of the Second World War, air and naval defense outposts were set up in Sardinia in order to intercept the Allies transits (and who had consolidated their presence in North Africa) through the Mediterranean Sea. The initial enthusiasm vanished as the months went by and the bombing intensified [8]. The first test took place on 16th of June 1940 when French planes bombed the Elmas airport [9]. When the British bombed the city of Cagliari twice in June 1942, there was still a widespread belief that the war would have spared Sardinia. However, in February 1943, in the frame of twelve days, the city and neighboring towns were shaken by heavy bombings with the consequent loss of hundreds of citizens and the devastation of a huge number of buildings. On 7th of February the Elmas airport was hit first; on the 17th of February the bombs exploded between via Nuoro, viale Bonaria, viale Diaz, the church of San Michele a Stampace, Castello, and the railway station, where there was a real massacre. The goal was to isolate the city from the rest of the island. On February 26th, 50 tons of bombs were dropped on the city of Cagliari on Castello, Stampace, and Bonaria (a district bordering Villanova). The scenario described following the attacks on the central districts of the city on 28th of February includes gutted buildings, compromised road, railway and port infrastructures, churches and convents reduced to rubble. After the bombings of other emblematic buildings, such as the civic market, the town hall, Palazzo Villamarina, the headquarters of the police station and again the railway station in via Roma were hit. On March 31st, the largest formation ever seen up to that moment was deployed on the Mediterranean Sea [10], in order to attack the port of Cagliari and the nearby airports of Monserrato, Decimomannu and Villacidro. The bombs also hit numerous houses in the Marina district, the Piazza del Carmine and the respective church. Following definitive massacre that took place on May 13th, the city was reduced to a pile of rubble, after the districts of Stampace, Castello, Marina and Villanova, the convent and church of San Domenico, Santa Caterina, Santa Lucia were heavily hit.

By the end of May, 75% of the buildings had been destroyed [8]. Presumably, the attacks were targeted on buildings of a significant and monumental nature, both civil and religious, such as the churches of San Giuseppe, Sant'Anna, the Bastion of San Remy, Palazzo Valdès, Vivanet, the Civic Theatre [11]. The heavy attacks on the city of Cagliari were part of the strategy designed by the Allies to mislead Hitler and the German state, convincing him that the imminent ground invasion would take place in Sardinia after the fall of the bases in North Africa. The British army produced a series of false documents which ended up in Axis hands. The strategy was successful and, the Fuhrer was convinced that the attacks would be against Sardinia and the Peloponnese and this allowed the Allies to land in Sicily without hindrance [12]. The census of war damage to the urban layout, particularly in the districts of Marina, Castello and Stampace, returned the image of the devastation of the bombings. Damage affected the 36% of the buildings, out of which 862 were destroyed, 574 were heavily damaged, and 1073 slightly affected. In addition to that, roads and infrastructure were impacted [13]. The damage was so intense that some authors consider it to be among the most bombed cities in Italy during the Second World War [14].

3 Post-war reconstruction in Cagliari: operational approaches adopted

The events described in the previous paragraph illustrate the violence of the assaults against Cagliari in 1943: after the conflict, the city returned to the citizens deeply changed and in some cases mutilated. The destruction of the urban center required an immediate action which led to various outcomes.

In a preventative perspective, starting from the months immediately before the outbreak of war, new directives in the field of heritage protection had been issued, on a national scale, in order to limit the disastrous consequences of bombardments on built heritage. [15]

This activity required a significant commitment in terms of financial and human resources, directing huge funds for the record of heritage through surveys, cataloging and photographic collection of the existing monuments. The material produced during these activities could have represented a very relevant image of the original state of the places, even in the interest of a restoration process that often assumed a less rigorous nature. The reconstruction process started before the end of the war, according to an emergency approach aimed at healing the psychological and material wounds inflicted by the conflict: the citizens themselves were engaged in clearing the rubble that remained of their city, determined to re-appropriate the urban spaces of everyday life. It should be noted that only a similar circumstance could have allowed the reconstruction of the city in such a short time.

Fig. 2. Palazzo Vivanet [www.sardegnageoportale.it]

Fig. 3. Scuola Satta [www.sardegnageoportale.it]

The need to restore the essential services led to restoration activities often carried out by non - specialized personnel and without a preventive specialist evaluation of the reconstruction criteria, just as the debate on the theory of restoration spread among the specialists of the sector on a national level. Even in the island context, the reconstructive issue is proposed in all its complexity, although the damage was less relevant compared to the other national realities.

Only in a few case we can see an interesting attention for restoration: for example the intervention on “Palazzo Vivanet” and the “Scuola Satta”, on the facades of these buildings the reconstruction of damaged parts using different materials is clearly visible, in full compliance with the criterion of recognizability of the intervention.

On the contrary, the monumental nature of the building would have suggested the stylistic restoration of the symbolic element of Saint Remy Bastion, subjected to an operation that still today makes it difficult to identify the additions. [16]

In Cagliari, the most important legislation about reconstruction was the "Piano di Ricostruzione", approved in 1947 and written in continuity with the instructions derived by the previous urban plan (1941) and the "Piano Costa" (1891). The explicit goal of the plan was to take advantage of military destruction in order to improve the services, the viability and hygienic conditions of the city and, in particular, of the historical districts. In fact, the intervention often started from speculative intensions related to the possibility of obtaining a greater income from the edification of the urban voids resulting from bombardments [13].

The war events carried aftermath overall the districts of the historic center of Cagliari, however the violence of the bombings has defined different situations.

Private buildings were often abandoned after the destruction and replaced by demolitions or contemporary architecture; even in via Roma itself, the institutional headquarter of Cagliari, the facades where scarred by the devastations of the bombs.

Beyond the damages on monuments, some major scars affected the urban tissue of all the four historical districts of the city (Villanova, Stampace, Castello and Marina).

In particular, in the Castello district some open wounds in the consolidated city have never found a solution suitable for Cagliari [17]. For instance, the monumental ruin of Palazzo Aymerich and the near Portico Laconi, between via La Marmora and via dei Genovesi, were destroyed by the bombs in 1943 and pending a musealization project since then.

Piazza Palazzo represents another unresolved area of the historical city center, a proper urban void, whose current configuration comes from the violence of bombardments: the main square in Castello district, already headquarter of the Palazzo di Città, and known for its valuable architecture, such as Palazzo Reale, Palazzo Arcivescovile and the Cathedral of Cagliari. The area is bordered to the north by the massive buttresses of the destroyed buildings, configuring an area almost crystallized in time and used as a parking because of immediate need rather than a defined planning idea [18]. Not even the religious buildings (although protected by specific symbols and preventive security measures [19]) survived the attacks of Second World War undamaged. Immediately after the bombardments, the superintendent Raffaello Delogu had to undertake a hard reconstruction process, dealing with the lack of human and economic resources available, as well as with the opposing opinions of the authorities. Delogu's proposals had to compare with the opinion of Sottocommissione Ministeriale, often chaired by eminent personalities like Roberto Pane [20].

Although the documentation stored in the archives about reconstructive operations appears to have shortcomings and gaps because of the emergential nature of actions, are known some works carried out by Raffaello Delogu. These works were led in order to guarantee the air defence of monuments (1940 - 1941) and the first interventions (1943 - 1946) and were carried out with workers and funds from the Genio Civile.

Interventions related to the clearing of rubble, recovery and consolidation involved the churches devoted to San Domenico, Santa Caterina, Sant'Anna, Sant'Eulalia, Sant'Agostino, San Saturnino, San Giuseppe and the Carmine church; several restoration works interested Palazzo del Governo, Bastione di Santa Croce, the church of San Michele, the church of Sant'Anna, the church of Sant'Agostino, the church of Sant'Eulalia and the Carmine church [21].

Of the church dedicated to Sant'Anna in Stampace only the facade and the bell towers remained, so Delogu used the photographic documents to establish a constructive dialogue with the Ministry, identifying the war damage as a chance to clear the building from the incongruous decorative motifs, according to the latest restoration theories [20].

The restoration of the Carmine church was characterized by a contrasting position of the Ministry. After the collapse, Delogu suggested a reconstruction of the building using the material present in situ. The Direzione Generale impeded both the reconstruction of the building and the replacement of the surviving elements, directing the project towards a modern construction [21].

Even the church of San Domenico, in the Villanova district, was affected by the bombings: the theme of the reconstruction opened a heated debate in the community, divided between a truthful reconstruction and an ex novo construction.

Despite an initial propensity to settle the surviving ruins in a garden area and to construct the church elsewhere, the church still lies in the same site, characterized by the features determined by the architect Raffaello Fagnoni in 1952.

A different approach was adopted towards the Santi Giorgio e Caterina church, initially located in Marina district and subsequently rebuilt, with different forms and styles, in Monte Urpinu.

The " how it was and where it was" reconstruction was not pratical because of the damage severity, so the project was directed to a new construction, different from the old one. The religious emblem from the originary church, the only element saved from destruction, is preserved and visible on the new façade [21].

In other cases the protection has left some open issues within the urban space, where some religious ruins remain, such us the ruins of Santa Chiara monastery, the Santa Lucia church in Marina district and the San Francesco cloister. The monastery of Santa Chiara was damaged so much that only the perimeter walls and part of the arches of the cloister were preserved, and the destruction is still perfectly visible to all the visitors [22].

However, the Santa Lucia church in Marina district represents an emblematic case of ruin mistakenly attributed to the outcome of bombardments, which actually hit very slightly the building, but deriving from a demolition project already assumed in the

Piano Cima and carried out only in 1947 [13]. The referred project included the construction of a never realized square. Similarly, in the Stampace district the San Francesco church was demolished by the Municipality's decision in order to ensure some unbuilt areas to be used for construction [23]. In recently years, the site and its evocative ruins have been involved in several valorization projects soon abandoned.

4 A reinterpretation of the largest war wounds of the city's architecture: some indirect damage of World War II after seventy years

The city of Cagliari, as previously mentioned, suffered considerable damages overall, so many that it is often considered as one of the most damaged among Italian cities. [24] Going into the detail of the deficiencies that the bombings generated in the city, we can generally point out not only a large amount of affected areas -for which a design solution for the reconstruction should have been found- but also the intensity of the damage.

Wounds that were never totally healed: *"the bombings of World War II caused gaps and stretch marks in the urban fabric, ancient and modern, increasing the number of "wounds" in the body of the city, and opening the long period of a difficult reconstruction, still unfinished"* [25]. And it is interesting to observe how such damages have generated critical situations in the architecture, which lead to various phenomena of vulnerability of the buildings, as indirect war damages, that can be observed after almost 70 years.

In the analysis here presented, some emblematic situations of current criticality in the architecture of the city have been investigated, by relating the critical areas currently encountered to the estimated damages in the post-war period and reported in the historical cartography "*Census of the destruction caused by war events*" [26], by identifying current critical issues or resolved situations, and by focusing in particular on the areas surveyed as the most damaged.

The cartography shows, with different colors, various gradations of damage and the buildings are classified as follows:

1. buildings damaged for a percentage between 76% and 100%;
2. buildings damaged for a percentage between 26% and 75%;
3. buildings damaged for a percentage between 1% and 25%.

For a need of synthesis, the investigated area corresponds to the historical center of the city, thus the expansion areas are excluded. Each of the three categories corresponds to a damage that we will define:

- high damage (corresponding to the previous point 1);
- medium damage (corresponding to point 2);
- slight damage (corresponding to point 3).

The attention was mainly focused on the areas with high damage.

To these three categories is added a white area, where the damage was zero. In this regard, the data reported here may be inaccurate in estimating the undamaged areas (due to the complexity of certain assessments of existing buildings and urban voids, during the war time). However, in general, we can estimate that from a total area of the historic center of approximately 650,000 m^2, approximately 43% of the buildings was undamaged, while the remaining 57% was variously damaged: 18% had suffered from serious damage, the 14% medium damage and 25% light damage.

The nearest neighbourhood to the port (Marina) appears to be the part of the city with the lowest number of undamaged buildings; moreover, here we find the highest percentage of the "buildings with high damage" category. It must be said that, beyond the statistics, the scars and the outcomes of the transformations of the historic fabric are visible throughout the historic residential buildings of the city. It should be noted that the city however covered a limited area if compared to other Italian cities: we are talking about a town which at that time covered an area of about 2 km2 with its built-up area, to give an idea, less than ¼ of the surface of Palermo. In other words, the whole town was close to one of the military targets, for example, of the port. The damage does not seem to focus on specific areas, but rather widespread and punctual because of the armaments used. The reconstruction responds to functional and economic needs, rather than adequate cultural approaches and planned operations, with rare exceptions. To simplify, we have examined each quartier and their main wounds -directly or indirectly connected to the war event- that the city still retains in its historical buildings.

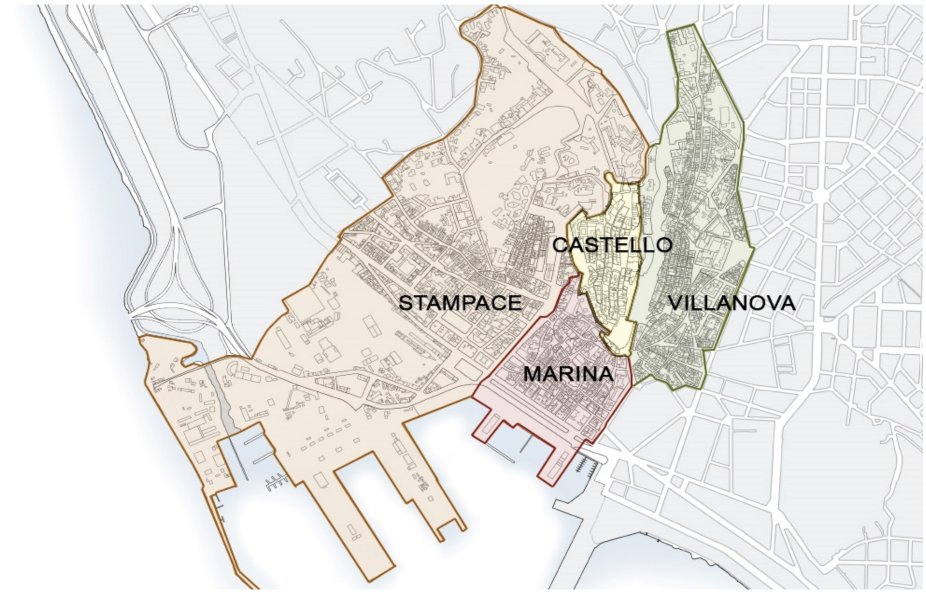

Fig. 4. The historical neighborhoods in Cagliari [LACHE Archive]

4.1 The neighborhood of Marina

In the neighborhood of Marina, the census of the damage done after the world conflict end records: only on the 29% of the built area, there were buildings not affected by damage; so, the bill was high, given that 71% of the surface of the city blocks had buildings that had suffered damage of varying intensity [27], as reported in the table below.

Table 1. Intensity of damage in the neighborhood of Marina.

intensity of the damage	square meters of surface	Percentage of the area damage versus the area of neighborhood
High	**25'347,1**	22%
Medium	**18’227,5**	16%
Slight	**37’348,3**	33%
Zero	**33'272,9**	29%

Starting from this analysis, comparing with the areas that are identified as public spaces in the Masterplan of the historical center of the city in force today [28], we can find a few areas in which there seems to be a correlation between the high level of damage suffered and the generation of spaces that have not been rebuilt.

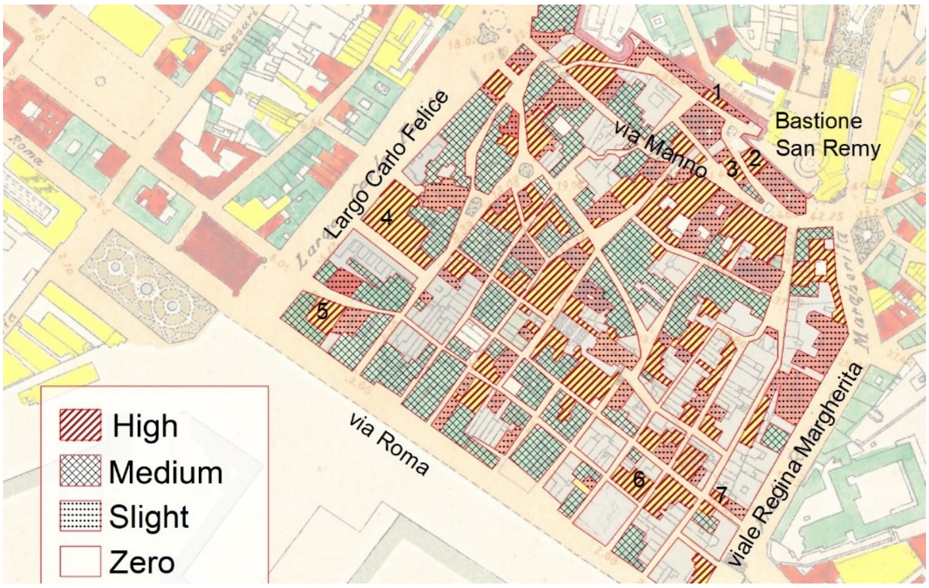

Fig. 5. The II war damage in the neighborhood of Marina (synthesis of historical cartography)

Starting from this analysis, comparing with the areas identified as public spaces, we can find a few areas in which there seems to be a similarity between the sustained high damage and the generation of spaces that have not been rebuilt. Later, it is examined how the reconstruction of some heavily damaged buildings was made.

For example, we notice that areas adjacent to the Bastion San Remy (classified with high damage), remain empty, and are now used for public parking. In the case of the urban void, in Via Spano (fig.5, n.1), the result of the bombing is visible in the stratigraphy of the walls, as the signs are visible both on the ramparts and in the adjacent houses: wall thickenings, buttresses, spurs, but also walled windows, reparations walls, partial reconstructions of masonry and discontinuity of the molded frame of the bastion, are well observable features that report what happened.

The result is the presence of an urban emptiness, a vulnerability for other buildings, which has not found a total resolution with the adopted measures: it is observed in fact that the buttress appears here not to be sufficient to ensure the balance to the architectural building that was not thought to constitute the head of the block. Obviously, there is a correlation between the fissuring framework that is present today and the damage caused by the bombings occurred 80 years ago: we can call this the "indirect damage". The buttress in the facade in front of the urban void has a lower height than the building itself, and this generates a particular criticality on the upper floor, where clearly there is a disconnection of the joints with hinge on the interfloor. It is not a coincidence that the lintel of the upper door, close to the cantonal, is propped up while, with further distance from the cantonal, the instability appears to be less and less worrying. (fig. 6)

Fig. 6. A building in front of empty urban

Similarly to this case, there are other occasions where the high damage of the building results in the maintenance of an urban void to give space to a parking area: for example, this is true for the area on Via S. Eulalia, in front of the steps leading to the homonymous church. Next to his staircase, a further urban void now hosts a small sports field.

On "Manno street" (via Manno), the gap is filled by a new single-level building (fig.5, n.3), which responds to the needs of the street and its mainly commercial use. In this road there are lots of buildings that replace the destroyed ones, both if the damage was considered of high or medium intensity. But the whole neighborhood appears to be dotted with new architectures, which simply respond to housing and functional needs, often with poor architectural quality and rarely interacting with the historic building style.

On other occasions the need for particular public buildings will make it necessary to operate in such a way that both the areas with highly damaged buildings and the less damaged ones are sacrificed: this is, for example, the case of the “Regional Palace” ("Palazzo della Regione"), built in this area because was partly affected by urban voids caused by the bombs (Fig.5, n.6 and Fig. 7). In 1963 the process for the rebuilding began, and its first solution was rejected by the municipality due to the limitation the view of the Castle, until the end of the 1988, when the present building was inaugurated. The block behind, also affected by damage classified partially as high and medium, will give space to a volume which, once again, hosts parking spaces.

Reconstruction solutions often do not guarantee the safeguarding of the heritage that could still exist: new buildings often do not relate to the historical context, but instead, as mentioned before, they seem to respond to purely functional needs, even where there is the presence of monumental buildings, not simply residential ones.

Fig. 7. Palazzo della Regione (www.sardegnageoportale.it)

This is the case, for example, of the “Banca d'Italia” building, in “Largo Carlo Felice”, which was built on a highly damaged area, but which does not consider either the presence of the near church of Sant'Agostino [29], nor what re-emerged in the area from archaeological excavations [30] (Fig.5, n.4).

Similar assessments can be made about the building in front of it, which, even worse, doesn’t appear to have been a reconstruction needed for the high level of post-war damage.

But the list of new buildings that struggle to relate to the historic fabric could be longer: the gap created on via Sardegna, next to the "Rinascente building" (built in the late 1920s, in a neo-mannerist style, with elegant marble cladding) is just one emblematic example (Fig.5, n.5).

Generally, we can observe how the post-war reconstruction has therefore paid less attention to the historical fabric, although what was planned in the reconstruction plan in this area and not implemented if not minimally, could have create a bigger loss of the historical architecture, particularly in the area mentioned here, where various blocks had to be totally removed to make space for new public housing buildings. [31]

4.2 The neighborhood of Castello

In the neighborhood of Castello, the census of the damage of the world conflict records as reported in the table below:

Table 2. Intensity of damage in the neighborhood of Castello.

intensity of the damage	square meters of surface	Percentage of the area damage versus the area of neighborhood
High	**11'310,2**	12%
Medium	**18'117,6**	19%
Slight	**20'114,9**	22%
Zero	**43'374,4**	47%

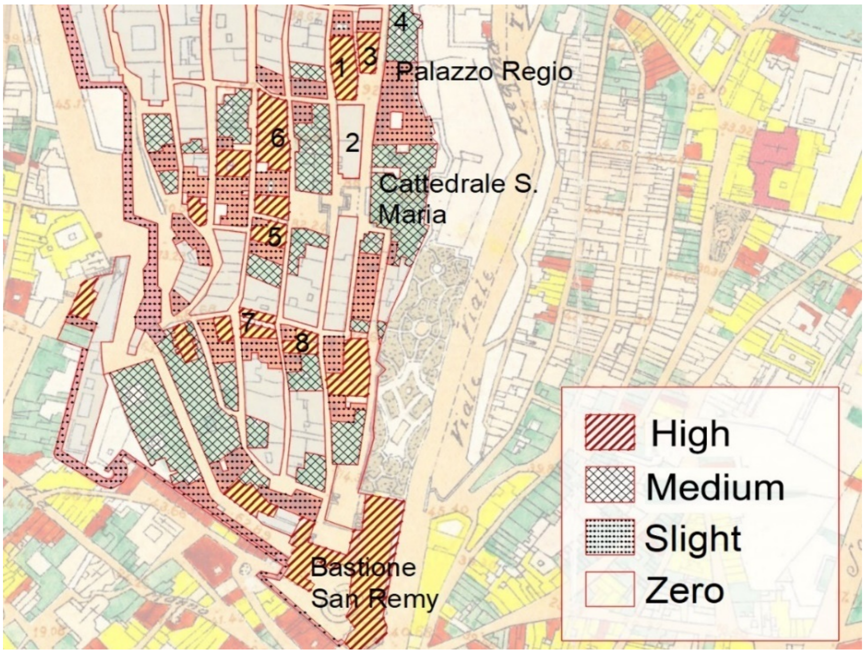

Fig. 8. The II war damage in the neighborhood of Castello (synthesis of historical cartography)

The case of Bastioni San Remy (fig.9) is emblematic, considering the monumentality of this architecture. The structure, built between 1896 and 1902, was classified as highly damaged by war bombing. Observing the historical images, the main elevation on Viale Regina Margherita was affected by a partial collapse: we can see the total loss of the central arch and part of the stairs on its right side. After the inevitable debate on the method of reconstruction, the gap was compensated, and without any distinction, the missing part was rebuilt in the years 1946-1948.

Fig. 9. Bastioni San Remy: before 1943, after damage, today (1th photo by https://www.sardegnadigitallibrary.it/ and 2th by http://www.sardegnasotterranea.org/)

In this area the current problems do not derive directly from war damages: there are no static instabilities. However, there is a lack of a general strategy for the redevelopment of the center, now less and less inhabited and, consequently habitable: it is an area of marginality, where it is impossible to overcome the problem of continuous vandalism. Architecture often not valuable, creates uncomfortable situations whose consequences are also reflected in the architecture of value.

In other situations, the generated gaps are the occasion to create parking spaces (e.g. fig.8, n.1-3-6), a need that causes demolitions for the expansion on blocks without damage in other areas (e.g. fig.8, n.2) where buildings for public use and of great importance, such as the cathedral or Palazzo Regio, need to be reached by vehicles. Among these monuments are not lacking of attention to restoration, we find situations that are far from be resolved, such as buildings in a state of ruin like some of the constructions in the parking area on the north side (fig. 8) or, not far from the Cathedral, other buildings in a partial state of ruins and with a few parking lots (e.g. fig.8, nbs. 6, 7, 8); among them there are also buildings of a certain value, such as Palazzo Aymerich (Fig.8, n.7), the noble residence of a wealthy family of the city, which covers an area of approximately 670 m^2. Another one, Palazzo Asquer (Fig.8 front of n.5) was partly rebuilt, and its instability can be traced back to these two phases.

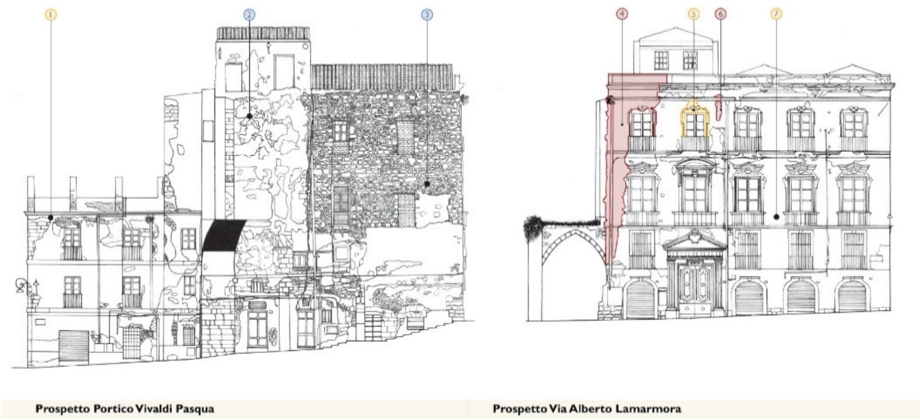

Fig. 10. Geometric survey of Palazzo Asquer [LACHE Archive]

Beyond the numerous cases that it could be mentioned, it is interesting to observe how overall the building transformation here seems to be more limited with the introduction of new dissonant architectures, probably due to the different needs of the neighborhood (where parking areas and squares are more needed than houses).

4.3 The neighborhood of Villanova

In the neighborhood of Villanova, during the II World War, the buildings were damaged as reported on the table below. The situation in the Villanova district (an example of which is shown in figure 11) appears to be not very dissimilar from the adjacent district, although the number of highly damaged buildings is slightly higher, and the figure relating to average damage is lower.

The historical images give back the complete picture of the damage which seems sometimes to have been overcome by erasing traces and reconstructing both the structure and the finishes in every detail. This is the case, for example, of Palazzo Valdes (on the map, fig.11, n.1 and Fig. 12), a prestigious building, built in two phases, first in 1894 and enlarged in 1905 [32]. We observe how the gap generated by the collapses affected a large portion of the building, particularly interesting for its geometry, with a curvilinear solution to connect the main and side elevations, in the decorative pattern attributable for the most part to the Art Nouveau style.

Table 3. Intensity of damage in the neighborhood of Villanova.

intensity of the damage	square meters of surface	Percentage of the area damage versus the area of neighborhood
High	**49’967,7**	20%
Medium	**20’964,8**	9%
Slight	**56’010,3**	23%
Zero	**117'562,3**	48%

There was no desire to denounce the rebuilt part, but today everything is unique and damaged by disfiguring writings on the base: this is the result of a failure to overcome the overall redevelopment of the city, which is also reflected in the most prestigious buildings. Another example of war damage in valuable architecture partially rebuilt is the convent of San Domenico (fig.11, n.2). The blocks near it or near the other church present here, the Church of San Vincenzo de' Paoli, are almost all highly damaged (fig.11, nn.3 -4). They are most of all unbuilt spaces, private courtyards, parking lots and small green areas, according to the needs of the church building complex. Not far from there (n.2) a new building was built, for the nursery school (fig.11, n.5).

For needs of synthesis, in general it can be observed throughout the district, where the housing need is a priority, the recurrence of complete replacements of the historic architecture with new buildings, and even here, they do not seek any integration with the historic fabric. Reference is made to the buildings on via Garibaldi and all around, even more because the real estate value is increased by the intended use of the ground floors in this commercial street. The situation on via XX Settembre is comparable, probably encouraged for being a border area, near the less compact city of expansion.

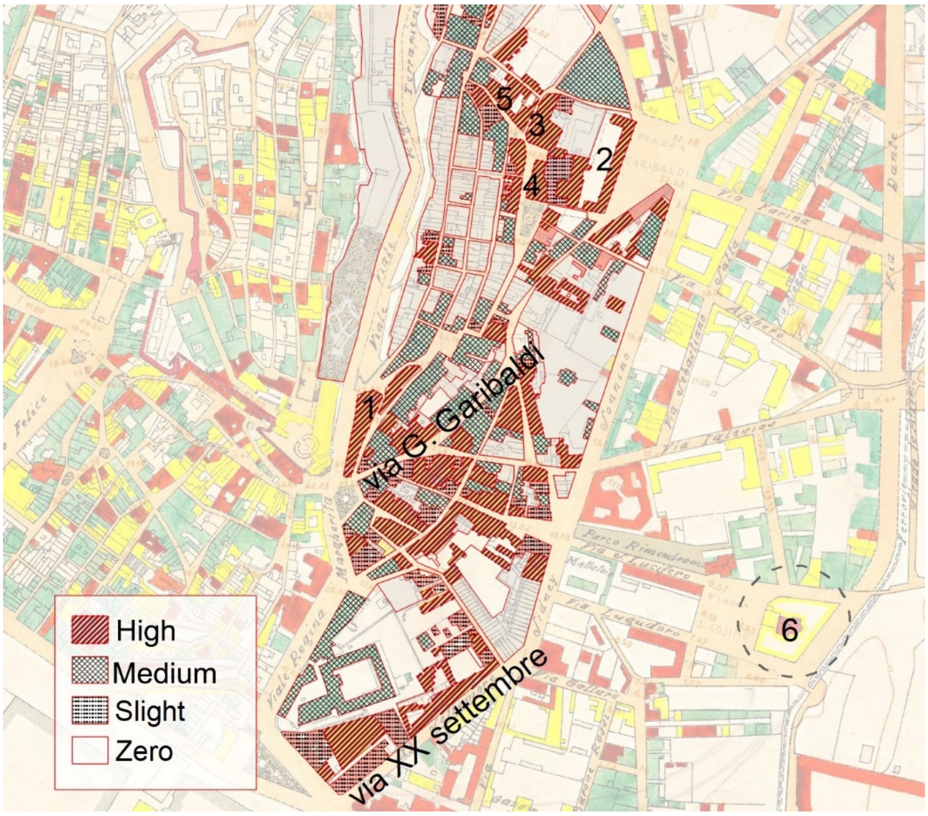

Fig. 11. The II war damage in the neighborhood of Villanova (synthesis of historical cartography)

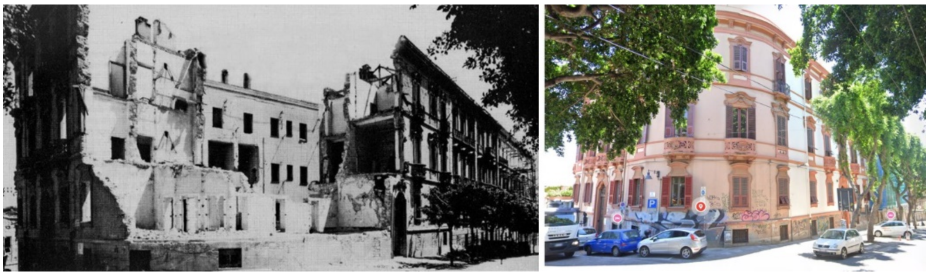

Fig. 12. Palazzo Valdes, Image after the 1943 bombing [https://www.cagliariperimmagini.it/] and the building today [google maps] images consultation date 05.01.2022

Finally, the Basilica of San Saturnino, of Byzantine foundation, dating back to the 5th/6th century (fig.11, n.6) and located near this district, is worthy of mention. Already incorporated into the historic city since the beginning of the twentieth century, it suffered some war damages, and since then, a whole series of restorations have taken place, leaving many critical unresolved issues. Although we could discuss a lot about this, it is interesting to observe how it underwent several collapses, despite the implementation of precautions to point out the damages (the collapse interested the barrel vault of the main nave, the large arch between the apse semi-dome and the central nave, and part of the side naves, except for the masonry). This was the opportunity not only to rebuild what had been lost, but a whole series of interventions led to the demolition of the eighteenth-century walls that blocked the large arches. From here arose a whole series of interventions that concentrated between the 70s and 90s, to find a solution for closing these large arches. The result is the positioning of large windows, which later will become the main cause of the vulnerability of the factory, generating degradation linked to excessive temperature and incorrect internal solar radiation, an issue still unresolved [33].

4.4 The neighborhood of Stampace

In the neighborhood of Stampace, during the II Word War conflict, the buildings was damage as reported on the table below.

Table 4. Intensity of damage in the neighborhood of Stampace.

intensity of the damage	square meters of surface	Percentage of the area damage versus the area of neighborhood
High	**29’262,7**	16%
Medium	**33’125,4**	18%
Slight	**47’152,9**	25%
Zero	**77’278,8**	41%

The Church of Sant'Anna [34] (fig.13, n.1) was highly damaged, as well as the block facing its right side: the church was restored while, in the other block, historical buildings were totally eliminated, and about in 1/3 of the surface new palaces without any architectural value were built. The remaining area has urban voids, where we find spontaneous green, with no serviceability, and also extended to the part of the block on which the structures surveyed as free of damage. The entire northern part of the district is characterized by new buildings (architectures which can be dated from the second half of the last century), which do not attempt to harmonize with the context, but only respond to functional needs. A different synthesis must be made for monumental buildings, such as the Post Office, in Piazza del Carmine (n.2) [35]. The building, built between 1926 and 1932, reveals no sign of this page of history. On the contrary, Palazzo Vivanet (fig.2 paragraph 3) clearly demonstrates the compensation for the gap. This last example, therefore, shows generally missing sensitivity that appears during any intervention of reconstruction carried out in the city.

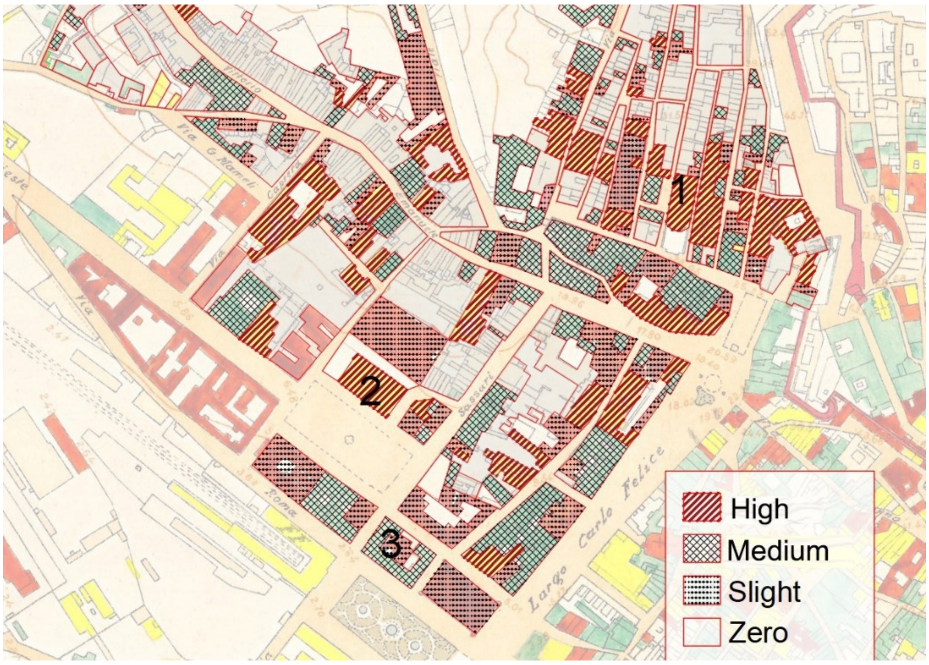

Fig. 13. The II war damage in the neighborhood of Stampace (synthesis of historical cartography)

5 Conclusions

The study reported here has allowed us to observe some problems of the city examined, which can be connected to the war fought 70 years ago.

The problems encountered are linked to aspects concerning both qualitative features of the architecture and spaces, and structural questions of buildings close to some urban voids. These are the result of gaps directly or indirectly connected to the bombs, as their presence constituted a pretext for the abandonment of the historic architecture which resulted either in a collapse without restoration, or in new architecture, but rarely ended up in high quality improvements in a panorama of redemption and better rebirth for the city that was emerging from the war conflict.

The problems that can still be found today in the historic center of the city reflect the difficulties that were already present before the war, and which worsened during the conflict, such as the lack of infrastructure or the lack of resources. Just think of the threshold of the 80s, when there were still 60% of residential buildings without architectural features, considered habitable according to Italian legislation but that were houses often with precarious hygienic-sanitary conditions. [13]

On the other hand, there is a cultural aspect, which denotes incompatibility between interventions and the use of architecture: the newly built or the "unbuilt" are solutions that often do not meet the criteria of conservation and enhancement of the historic city. The recurrence of the problems generated by the devastation of war, Restoring or

Abandoning [36], along with their social consequences, is still reflected in the current difficulties of a non-redeveloped historical center with high housing standards and services. A better strategy of redevelopment of the historic center, would perhaps make it possible to reverse the trend of depopulation of areas, by making them be more attractive.

Based on this initial analysis, it appears necessary to find design solutions on various aspects, such as:

- for urban voids there is a necessity to important integrations to solve the structural problems in some buildings;
- it appears necessary to encourage good practices in life also for residents (such as stopping the use of the car inside the historic center), and to integrate services to solve the parking problem for everyone, also for potential future residents;
- to improve the historic architecture, preserving what is still valuable and reducing, as far as possible, the negative aspects of the buildings (both historic and recent);
- to think about various categories of inhabitants that can generate a real and sustainable economy for the city;
- to think about the needs of the inhabitants and design spaces for useful services for the residents, to get a good quality of life (do not use the center as a container for consumption).

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Analysis of the Spatial Distribution of Traditional Villages in Guizhou

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Abstract. Guizhou's traditional villages are gradually disappearing as rural urbanization accelerates. However, there has been little in-depth research into how village dwellers are coping with spatial changes caused by resource relocation and modernization. Prior to that, it is critical to determine the villages' distribution characteristics and geographic features. This study focuses on the spatial distribution characteristics of Guizhou traditional villages using the software ArcGIS. The findings show that (1) Guizhou Province's traditional village distribution is "dual-core" intensive. (2) The topography of Guizhou Province is characterized by a "high in the west, low in the east" trend. In Guizhou Province's western and central zones, there are very few traditional villages with higher altitudes beyond Anshun City. (3) The slope analysis of this study shows that the slope of these two regions, Qiandongnan and Tongren with densely populated villages, are diametrically opposed.

Keywords: Distribution Characteristics, Geographic Features, Traditional Villages, ArcGIS.

1 Introduction

Chinese traditional villages, previously known as ancient villages, are villages built earlier than the founding of the Republic of China. The customary declaration "ancient village" was changed to "traditional village" in September 2012 by the decision of the first meeting of the Traditional Village Protection and Development Expert Committee. Traditional villages are the most meaningful legacy of Chinese farming civilization, containing rich historical information and cultural landscapes.

As a consequence, village research projects centered on revitalization, development, and cultural inheritance have emerged as a prominent theme. Simultaneously, with the strengthening of the research, theories from other related disciplines, such as history, anthropology, sociology, and so on, began to be incorporated into village research. This was especially true in Guizhou province. With the discovery of more traditional villages, there is one issue we must consider and resolve: the majority of traditional villages in Guizhou are located in the mountains, which has some drawbacks. For instance, education and medical facilities are insufficient, economic conditions are subpar, and population loss is severe. The ultimate source of these flaws is the fact that village space design is unacceptably comprehensive.

Since then, this paper has used ArcGIS as a research tool to analyze and summarize the spatial distribution characteristics and geographic features of traditional villages in Guizhou. Meanwhile, it can serve as the foundation for proposing a widespread spatial optimization design strategy for Guizhou traditional villages and laying the groundwork for future research on Guizhou traditional villages.

2 The State of the Art

The phrase "village" was derived from the Latin word "villa" in the 15th century. It is a community made up of a cluster of houses that is larger than a hamlet but smaller than a town. It is occasionally termed as "rural area" or "rural settlement" in research. Griffith Taylor published *Urban Geography* in 1949, which outlined typical settlements on each of the seven continents as well as their size and pattern changes[1]. This is a more in-depth book on villages around the world than previous studies. At the same time, there were other books published that provided more detailed information about villages.In 1963, Maretzki explained the Taira's development history in terms of economy, politics, religion, education, and social organization[2]. Lewis also established a typical life cycle in Tepoztlan, with the basis of village history and other specifications[3]. With the proliferation of information, basic research in the village became densely packed, and it progressed to the stage of classification and comparison. In order to achieve astable development, a portion of the research conducted classification studies on village population[4], residence scale[5], cultivated landmass[6], and so on. Studies also compared the differences between several villages with similar characteristics to investigate the reasons for the formation[7]. Village research has also advanced rapidly as a result of the advancement of computer technology. Scholars began to investigate the village's cultural characteristics from the viewpoints of cultural protection[8], tourism development[9], and spatial layout[10], as well as the village's environmental characteristics from the perspectives of architectural soundscape[11], light environment[12], and thermal environment[13].

The term "Chinese traditional villages" was coined around this time. The majority of these villages have kept their original architectural and spatial patterns. Every traditional village has a unique feature due to geographical and cultural differences. For example, villages in Fujian have Hakka buildings [14], while villages on the Loess Plateau have cave dwellings[15] and villages in Guizhou have stilted buildings[16]. The study of traditional villages in Guizhou began when the academic community became interested in this topic in general. However, because of the complex terrain, research was more difficult, and subsequent development was slower than in other regions. Guizhou is the site of numerous ethnic festivals, each having its own cultural connotations and presentation style. Using the Guizhou Miao Sisters' Festival as an example, early research focused on the festival process[17] and clothing characteristics[18]; the festival's development history[19] and social value[20] were gradually recognized in the subsequent period; after the simplicity of public transit and the emergence of tourism, studies on the festival's impact can be separated into music[21], handicrafts[22], and economy[23], etc. Rural development study is concerned relatively late, and the theoretical level was primarily focused on the assessment of the spatial distribution of traditional villages in Guizhou, specifically on various spatial attributes such as public space[24], indoor space[25], and cultural space[26]. The findings of interdisciplinary research are based on the user's past[27], ongoing[28], and potential future[29] behavioral activities. Due to the huge large differences between individuals in Guizhou's traditional villages, there is still a relative lack of overall sorting and comparative research on them.

Spatial distribution is a dispersion of geographic observations that represent the values of a particular phenomenon's or characteristic's behavior across many locations on the Earth's surface[30]. It was first mentioned in geography research. It also can be used in various disciplines such as anthropology, economics, medicine, architecture, and so on. In *Anthropology, Space, and Geographic Information Systems*, Mark Aldenderfer discussed the concept of geographic information systems in relation to anthropological inquiry[31]. Combes and Overman investigated the spatial distribution of economic activities in the European Union in order to describe available data, present descriptive evidence, and consider the nature of agglomeration and dispersion[32]. Researchers monitor dengue vectors and viruses using satellite imagery and statistical models in the paper *Dengue vectors and their spatial distribution*[33]. The village spatial distribution studies were conducted in various locations around the world, particularly in China[34] and other Asian countries[35]. Academics can evaluate the effects of spatial distribution from topographic factors[36], cultural features[37], and development direction[38] based on its characteristics. In the meantime, several methodologies can be used. Xu established the evaluation model using Geographical Detector and Absorbent Hygiene Product methods to provide a reference for the precise development and protection of minority villages[39]. In Greece, Sevenant used a geographical information system to investigate the relationship between settlement patterns, land use zoning, and landscape visibility[40]. Carrão evaluated the relative usefulness of MODIS imagery data with high spectral and temporal resolutions for land cover classification[41].

Existing studies provide a solid foundation for the subsequent stage, although there are some inconsistencies. To begin with, when compared to other plains provinces, Guizhou Province has more distinct village characteristics and relatively more basic research but does not previously emphasize the advantages of its terrain. Second, increased research data allows for more precise analysis results. A total of 1352 new villages were added to the traditional village lists of the sixth batch, which was announced in 2022. Guizhou Province has 33 new ones, the majority of which are in Anshun. At the same time, the findings of this study should be generalizable enough to assist governments at all levels in allocating resources wisely.

3 Research Material

3.1 Overview of the Study Area

Guizhou Province (103°36′ E-109°35′ E, 24°37′ N-29°13′ N) is in the southwest part of China (see Fig. 1). The land area is 176,167 square kilometers, accounting for 1.8% of the total in the country. Guizhou Province is located in the Yunnan-Guizhou Plateau's eastern region. The province's landforms can be broadly classified into three types: plateau mountains, hills, and basins, with mountains and hills accounting for 92.5% of the total area. From the first batch to the present, the total number of Chinese traditional villages is 8171. Guizhou has 757 traditional villages (see Fig. 1), ranking second in China, with Yunnan province having the most. Qiandongnan prefecture ranks first in Guizhou province for the number of traditional villages, and Table 1 shows the statistics on the number of traditional Chinese villages in Guizhou.

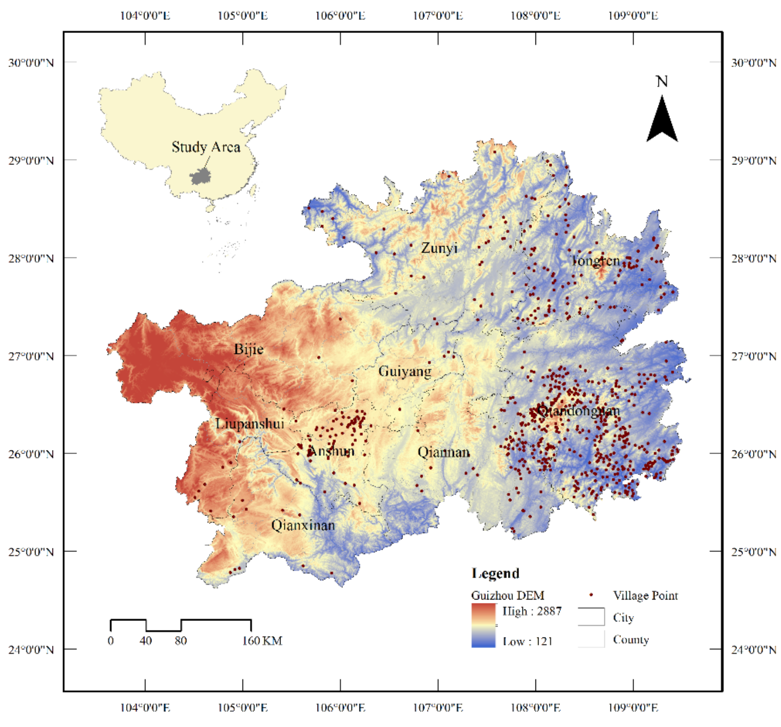

Fig. 1. Location of Guizhou province and 757 traditional villages, and Guizhou digital elevation model (DEM).

Table 1. Statistics on the number of traditional Chinese villages in batches 1-6 of each city in Guizhou Province.

Batches	Qian dong nan	Tong ren	An shun	Qian nan	Zun yi	Liu pan shui	Qian xi nan	Gui yang	Bi jie	Total
1	60	12	4	7	3	-	1	3	-	90
2	165	29	3	1	3	-	-	-	1	202
3	51	33	27	8	7	5	3	-	-	134
4	33	25	22	20	12	4	3	-	-	119
5	100	11	11	32	14	1	4	4	2	179
6	6	4	11	10	1	1	-	-	-	33
Total	415	114	78	78	40	11	11	7	3	757

3.2 Data Sources

The subjects of this study are 757 traditional villages at the national level in Guizhou province, with data sourced from the Traditional Chinese Villages Digital Museum (http://www.dmctv.cn, sourced on December 15, 2022). To facilitate research, villages can be decimated into points from a macro perspective. The geographic information database of traditional villages in Guizhou was created using ArcMap 10.8 after counting the latitude and longitude information of the villages. It also contains Guizhou digital elevation model (DEM) data from Geospatial Data Cloud (http://www.gscloud.cn, accessed on December 18, 2022) and Guizhou province boundary data from National Catalogue Service For Geographic Information (http://www.webmap.cn, accessed on December 18, 2022).

4 Methodology

4.1 Average Nearest Neighbor Analysis

In ArcGIS, the average nearest neighbor tool calculates the nearest neighbor index based on the average distance between each feature and its nearest neighboring feature. The following are the formulas:

$$R = \frac{D_O}{D_E} \tag{1}$$

$$D_O = \frac{1}{n} \times \sum_{i=1}^{n} d_i \tag{2}$$

$$D_E = \frac{0.5}{\sqrt{n/A}} \tag{3}$$

Where R is the average nearest neighbor, D_O is the observed mean distance between each feature and its nearest neighbor, and D_E is the expected mean distance for the features given in a random pattern. And where n is the total number of research objects, d_i is the nearest neighbor distance for point i, A is the area for research scope. When $R = 1$, traditional villages are randomly distributed throughout space; when $R < 1$ traditional villages tend to cluster spatially; and when $R > 1$ traditional villages are uniformly distributed spatially.

4.2 Thiessen Polygons Analysis

There is only one point input feature in each Thiessen polygon (Voronoi diagram). The location of a Thiessen polygon is closer to its associated point than any other point input feature. Since then, Guizhou traditional village points' distribution can be assessed. Following the GIS analysis, Excel can be used to calculate the coefficient of variation(C_V), which is the ratio of the graphic standard deviation to the mean deviation. The following is the formula:

$$C_V = \frac{R}{S} \times 100\% \tag{4}$$

Where R is the graphic standard deviation, and S is the graphic mean deviation. When $C_V < 33\%$, traditional villages are evenly distributed; when $33\% < C_V < 64\%$ it means that traditional villages are randomly distributed; when $C_V > 64\%$, it means that traditional villages are clustered and distributed.

4.3 Kernel Density Analysis

Kernel density analysis is a non-parametric method for estimating a random variable's probability density function using kernels as weights. It can assist in evaluating the spatial distribution characteristics from the perspective of the overall scope of research, and it can be more intuitive to discover the unique layout of traditional villages in Guizhou. The formula is as follows:

$$f(x) = \frac{1}{nh}\sum_{i=1}^{n} k\left(\frac{x - x_i}{h}\right) \tag{5}$$

Where n is the total number of traditional villages in Guizhou, h is the search radius for research scope, $k(\ )$ is the kernel smoothing function, and x_i is a random sample from an unknown distribution. The higher the kernel density, the more traditional villages per unit area, and the denser the distribution. The lower the kernel density, the fewer traditional villages per unit area, and the distribution is dispersed.

5 Result and Discussion

5.1 Guizhou Traditional Villages Distribution Characters

From an overall perspective. In ArcMap 10.8, the average nearest neighbor tool can be used to justify distribution type based on the latitude and longitude of the points. The final output of it returns five values: Observed Mean Distance (D_O), Expected Mean Distance(D_E), Nearest Neighbor Index (R), z-score (standard deviation), and p-value (probability). Its output (see Fig. 2) indicates that this result cannot be shown randomly due to $z < -2.58$ and $p < 0.01$. In the meantime, $R \approx 0.68 < 1$ implies that the distribution of Guizhou traditional villages is clustered. This finding also provided evidence for the next steps.

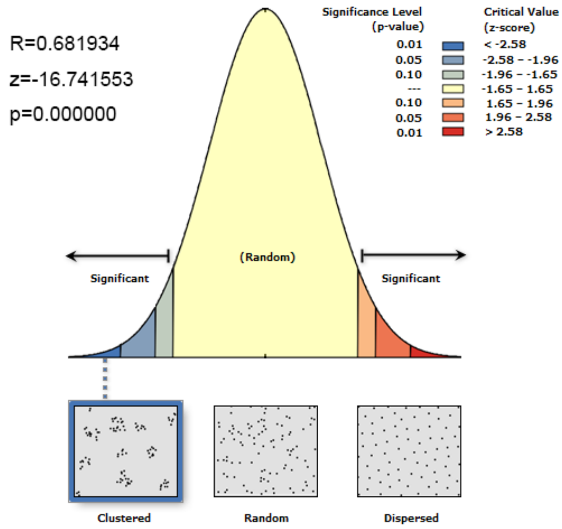

Fig. 2. Average nearest neighbor index of Guizhou traditional villages.

From a regional perspective. The tool of Thiessen polygons analysis can show the distribution from the regional level through the Voronoi diagram (see Fig. 3). The figure illustrates that graphics distribution in Qiandongnan and Anshun is highly imploded, whereas it in Tongren is relatively uniform. Although there are fewer villages in Anshun than in Qiandongnan, they are more inextricably distributed and have the highest C_V when combined with Table 2. However, in Guiyang, Qianxinan, and Bijie, their C_V is less than 64%, and the distribution of villages is more random. As a result, when selecting specific case studies in the future, traditional villages in these three cities should be avoided.

Table 2. Statistics on C_V of traditional villages in Guizhou Province.

City	Graphic Standard Deviation (km²)	Graphic Mean Deviation (km²)	C_V (%)
Bijie	2148.5556	5221.5499	41.15
Qianxinan	522.3809	1188.0009	43.97
Guiyang	1001.9074	1593.8608	62.86
Tongren	143.0454	187.3407	76.36
Zunyi	661.0724	801.3753	82.49
Liupanshui	3441.2394	2066.5219	166.52
Qiannan	376.3887	222.0990	169.47
Qiandongnan	127.6533	73.6184	173.40
Anshun	465.8271	213.0041	218.69

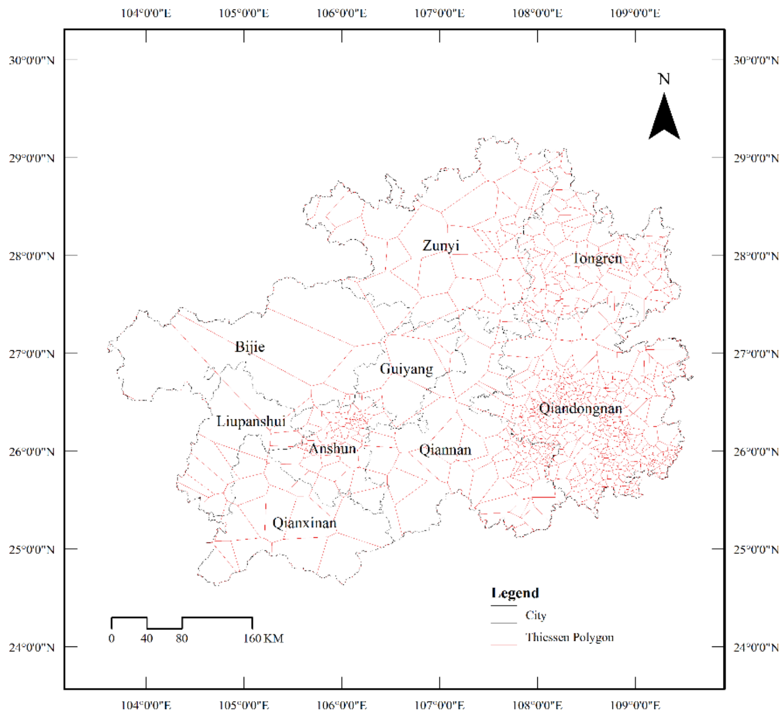

Fig. 3. Thiessen polygons analysis of Guizhou traditional villages.

From the villages' density perspective. TheKernel density analysis tool is used for analyzing the distribution density of all these village points in Guizhou. The outcome shows (see Fig. 4) that traditional villages in Guizhou are densely distributed in a "dual-core" pattern. To come up with, it is a concentrated area, with Qiandongnan prefecture at its heart. It has the most number of traditional villages in Guizhou Province, with 415, far outnumbering other cities. The second sub-core agglomeration area is Anshun. Despite having 78 traditional villages and ranking third in Guizhou Province, Anshun's distribution is denser when compared to Tongren City (ranked second) and Qiannan prefecture (tied for third). Furthermore, the distribution of Tongren City is relatively dense in other regions.

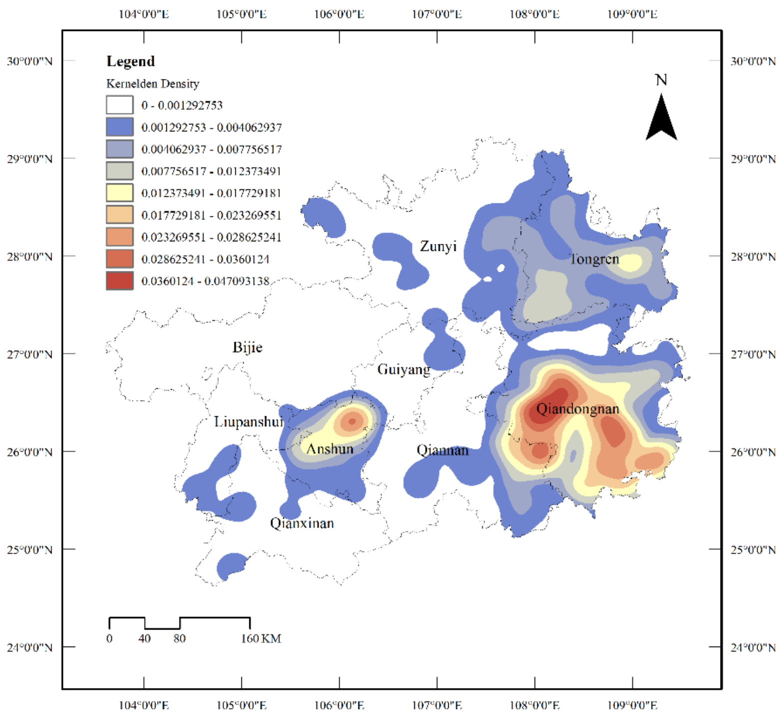

Fig. 4. Kernel density analysis of Guizhou traditional villages.

5.2 Guizhou Traditional Villages Geographic Features

About altitude. From the DEM of Guizhou province (see Fig. 1), it is easy to find that the topography of Guizhou Province exhibits a "high in the west and low in the east" trend. The western part of Guizhou sits on the Yunnan-Guizhou Plateau, with a maximum elevation of 2887 meters. Beyond Anshun City, there are very few traditional villages with higher altitudes in Guizhou Province's western and central zones. The eastern section is lower in average altitude, with the lowest point being 121 meters. Local high-altitude areas have emerged in Qiandongnan and Tongren. Traditional villages in this area are dispersed outwards, with the high-altitude area serving as the focal point.

About slope and aspect. ArcMap 10.8 includes a 3D analysis tool that displays slope and aspect based on the DEM. The slope analysis (see Fig. 5) of this study shows that the slope of these two regions, Qiandongnan and Tongren with densely populated villages, are diametrically opposed. Qiandongnan has a comparatively high overall slope, whereas Anshun has a relatively low one. These two locations can be chosen for comparative study in the future to explore the possible impacts of the allocation. However, due to space constraints, the analysis results of the aspect do not have an obvious trend and will not be described in detail.

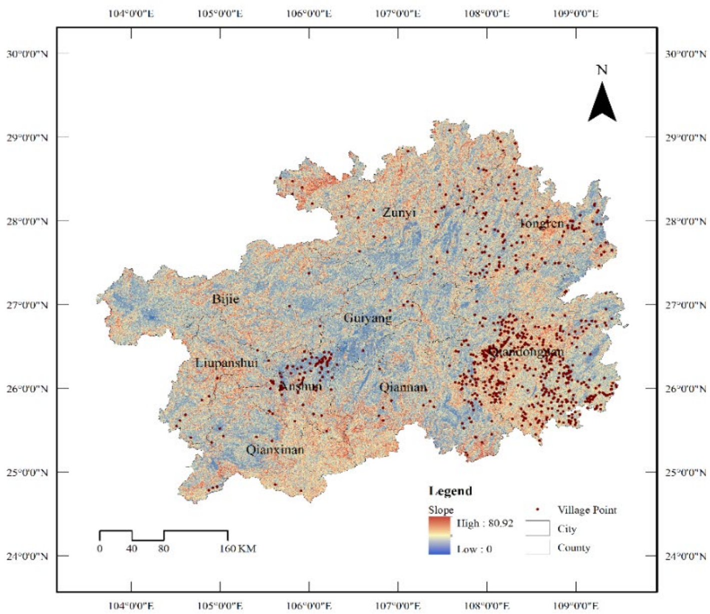

Fig. 6. Slope analysis of Guizhou traditional villages.

6 Conclusion

According to the observations of this project's analysis, the distribution of traditional villages in Guizhou Province is "dual-core" intensive. Traditional villages in

Qiandongnan prefecture are the most tightly distributed, with low altitude and high slope terrain characteristics; Anshun City is the second densest center, with a high altitude but a gentle slope; Tongren City has relatively more villages than the other cities, and the villages are relatively dense, with more gentle terrain features.

As a result, in the subsequent research, geographical factors and human factors, as well as other factors that affect the distribution of villages, should be combined and analyzed in an attempt to establish a scientific and reasonable consideration system for influencing factors, so that designers can propose design strategies corresponding to traditional villages in Guizhou.

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Aspects of Significance in the "Dark Heritage" of Thessaloniki, Greece[1]

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Abstract. Located in the north of Greece and boasting an uninterrupted history of over 2.300 years, Thessaloniki has a wide array of architectural monuments to display. Hellenistic residences, Roman administrative centers, Byzantine churches, and Ottoman communal buildings have shaped for decades the city's historical profile, leaving limited space for a nonetheless widely acknowledged architectural grouping, namely its "dark heritage".
Comprising buildings and sites that have over the years been related by the local community to rare phenomena and curious events, Thessaloniki's "heritage of darkness" fascinates the imagination of its residents, in addition to providing a frequent subject for the writings of local journalists and researchers, and a focal point in the work of the services and bodies involved in monument protection. The above players evidently evaluate its constituents in different manners, thus leading to the emergence of multiple aspects of significance in the appraisal of the city's "dark heritage".
Entering a hitherto untouched -on a scholarly basis- domain, this paper aims to identify these aspects and determine their interrelation and impact on the preservation of the buildings and sites involved. To this end, based on bibliographical research and on-site examination, it begins with a comprehensive overview of the dreaded built assets, followed by the identification of the players involved in their treatment and their respective attitudes. From there on, a discussion of the interaction of these attitudes is pursued, culminating in original conclusions as to the consequences of this interaction for the safeguarding of the tangible and intangible qualities of the city's "heritage of the dark".

Keywords: Significance, Dark Heritage, Players, Attitudes, Interaction.

1 Introduction

In the whole of Greece, one can identify few cities with an uninterrupted history as long as that of Thessaloniki. Founded in 315 BC, next to the sea and on the intersection

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of major transport routes, it became seat of government in late Roman times, rose to the status of most prominent city after Constantinople in the Byzantine era, ranked among the busiest civic centers of the Ottoman period, and since the early 20th century, evolved into the second largest city of modern Greece.

Each of the major periods of the city's history is nowadays reflected in archaeological remains and architectural works scattered, primarily, in the twenty-four centuries-old historic center, and secondly, in its late 19th century extensions. Among these landmarks, local residents have come to identify over the years a group of buildings and sites whose relation to rare phenomena and curious events has deemed them the city's "dark heritage".

Next to providing a focal point for public imagination, the latter has set into action a remarkable array of separate players, namely journalists, tour operators, and researchers. At the same time, being composed of individual properties with cultural heritage status, it has inevitably attracted initiatives by the respective owners, public bodies, and non-governmental societies. The different approach of each of the above parties reflects the identification of respectively varying values or aspects of significance in the local "heritage of the dark". In the following pages, an original overview of these attitudes will be pursued, in addition to anequally genuine appraisal of their interaction and final impact on the special character of the monuments involved.

2 "Dark Heritage" in the Eyes of the Public

A relative novelty in contemporary conservation matters, "dark cultural heritage" has been skilfully defined as the segment of cultural heritage "that is associated with real and commodified sites of atrocity, death, disaster, human depravity, tragedy, human suffering, and sites of barbarism and genocide" [1]. In the case of Thessaloniki, a poll among merely a dozen of its residents would quickly confirm five buildings and sites as the basic constituents of the city's "dark heritage". Partly believed to be haunted and partly related to curses and supernatural forces by the locals, the five components can be briefly outlined as follows, on the basis of the local narrations presented in the media:

2.1 "Haunted House"

The so-called "Haunted House" is located in the east extension of the city, namely on 263, Vasilissis Olgas Avenue (see Fig. 1). It is undoubtedly the most famous of the five landmarks, having gained a notorious reputation earlier than all the others, not to mention even beyond Thessaloniki. Little is known as to its time of construction and initial owner. Nonetheless, the development of the wider area and its own architectural characteristics point to an early 20th-century mansion [2], which underwent in later times extensive repair, fell more recently into neglect, and is nowadays isolated in the premises of a firm supplying construction materials.

The imposing derelict building is said to be haunted by the souls of two Jewish brothers who owned it before World War II and used it as a hiding place for the valuables of fellow Jews, when the Nazi terror was unleashed upon them. It is also believed to have served as a torture site of Jews during the German occupation, thus becoming a shelter for their innocent souls in present times. Moreover, a curse has been acknowledged in the aftermath of the fate of two contractors who undertook to demolish it in the 1980s - both died the very same day they signed the respective contracts. Even more recently, a photographer who attempted to take pictures of the interior is said to have instantly suffered health problems, in addition to his camera being smashed, while strange lights and sounds at night are frequently reported by neighbors and strollers[3, 4].

Fig. 1. The "Haunted House", main front.

2.2 "Chatzigogos Residence"

The "Chatzigogos Residence" is situated at the outskirts of the east extension of the city, namely on the intersection of Erythraias and Thetidos Streets (see Fig. 2). A fortress-like edifice, it resembles the "Haunted House" in more ways than one. Also built in the early 20th century, to be more precise in 1930[5], it displays a front very much similar in terms of outline and decorative featuresto its more celebrated counterpart. Most importantly though, since its abandonment in the 1980s, rumor has deemed it similarly haunted, with the consequently generated fear leading neighbors to place pictures of the Virgin Mary, flowers, and packs of garlic on the doors and windows, in an attempt to keep away evil spirits. Which is more, people who have taken pictures of the house are said to have identified strange silhouettes in their shots [6].

Fig. 2. The "Chatzigogos Residence", main front.

2.3 “Villa Hirs”

The “Villa Hirs” is located in the east extension of the city, on 144, Vasilissis Olgas Avenue (see Fig. 3). Built in 1911, as the imposing private residence of one of Thessaloniki’s wealthiest Jewish families, it resembles the picturesque early 20th-century rural mansions of central Europe, particularly those of Switzerland, in a clear manifestation of the prominence and international profile of its initial owner [2, 7]. Equally distinctive, though, is the fact that, after the departure of the latter at the outbreak of World War II, it was occupied by an infamous duo, namely the Gestapo and the Nazi Security Police. In the hard years that followed, numerous people were imprisoned and tortured in its lower rooms, mainly members of the local resistance, whose pain and agony are believed to have been entrapped in the interior, thus rendering the presently abandoned mansion a haunted place. In full relevance, strange sounds at night are occasionally reported by neighbors, not to mention identified with the screams of the innocent wartime victims[8].

Fig. 3. The “Villa Hirs”, main front.

2.4 “Pasha Gardens”

The so-called “Pasha Gardens” lie on the sloppy terrain that stretches along the east end of the city’s historic center, just above the Greek-Orthodox Cemetery and the Municipal Hospital. Established in 1904, shortly after the construction of the latter, they were intended to serve as a park for relaxation and enjoyment of the ravishing views opening to the sea and the city. To this end, they were filled with pine trees, while a number of separate structures, among them a fountain, a tunnel, a water tank, and a sitting place, were dispersed in between (see Fig. 4), altogether culminating in a unique manifestation of the “fantastic architecture” promoted primarily by Antoni Gaudí [2, 9, 10]. Yet apart from their functional and architectural distinction, the gardens have also come to stand out in recent years as a presumed meeting place of Ottoman Freemasons and a spot of notorious ceremonies, involving human sacrifice, in the early 20th century. Moreover, the followers of "sacred geography" rank them among the important locations of the region, supposedly as a major junction of geomagnetic fields, while widespread rumor has deemed them the starting point of a dead-end street that appears every three days, at midnight, and then vanishes [11].

Fig. 4. The "Pasha Gardens", view of the upper plateau.

2.5 "Longos Mansion"

The "Longos Mansion", widely known as the "Red House", due to the distinctive brick-like plaster of the exterior, lies on 31, Aghias Sofias Street, in the heart of the historic center (see Fig. 5). Built between 1926 and 1928, by a wealthy industrialist from the nearby town of Naoussa [5, 12], it stands on the intersection of two of the city's most important avenues, just opposite the celebrated byzantine church of Aghia Sofia, a present-day UNESCO World Heritage monument. Next to its consequent urban and architectural pre-eminence, the imposing edifice has lately come to assume a less admirable quality. Various misfortunes that are said to have come upon those who have been engaged in its management have fostered the idea of a cursed building, starting with the events related to its contractor and initial owner. The former, a major construction company of the interwar period, is reported to have gone bankrupt shortly after building works were completed, while the latter witnessed his factory being destroyed by fire just a few years later. In recent times, the subsequent owners repeatedly failed to properly maintain the entire structure, while in 2018, in the course of extensive restoration works, a fatal accident occurred [13].

Fig. 5. The “Longos Mansion”, main front, prior to restoration.

3 The Separate Players in “Dark Heritage” Management

As much as they intrigue and fascinate the general public, to the extent of generating numerous discussion forums on the Internet, the above buildings and sites prove an unmatched field of action for a number of separate players, who can be broadly separated into two groups: professionals with a specialized interest in “the heritage of the dark”, and individuals or bodies with conventional relations to the heritage properties involved.

The first group comprises, primarily, **journalists**, for whom the history and notorious reputation of the five assets stand out as popular subjects, hence a frequent point of focus, through articles published mainly on the Internet and secondly in the few regional printed papers. The writings presented so far in both fields amount to a sizeable bulk of work [indicatively: 3, 4, 6, 8, 11, 13], with a particular tendency to increase every time a curious event or tragic misfortune occurs in the five landmarks. The more recent resurgence of interest in the “Chatzigogos Residence”, after the partial collapse of its main front, with rubble covering a nearby parked car, and the aforementioned fatal accident during the conservation works in the “Longos Mansion” [13] bear fresh testimony to this remark.

Most noteworthy, though, is the fact that, in sharp contrast to their large number, the articles published so far display limited originality; each reporter tends to repeat -often literally- the information already provided by other colleagues, with a mere update in terms of reference to more recent events and inclusion of contemporary photographs [indicatively: 3, 4]. Documentation and critical acknowledgment of the rumors and stories circulated up to that point prove by no means a goal, hence limiting the contribution of the produced writings merely to the arousal and maintenance of public interest in the city's "dark heritage". Moreover, further action for a more constructive engagement with the latter, for instance, judging from the international experience [14, 15], the establishment of digital platforms on the Internet for a proper -and not purely recreational-acquaintance with the special values of the related buildings and sites, including their "dark" side, remains to be undertaken.

Moving in very much the same direction, a number of local **tour operators** have begun over the last years to organize guided walks in various locations of the city, with intermediate stops at certain of its "dark heritage" assets. To be more precise, while aiming to acquaint their populous audiences with considerably broader groups of points of interest, namely celebrated buildings and sites connected with infamous events, particularly crimes, the tour operators in question have come to reserve attention for two of the five landmarks involved; the "Haunted House" has been highlighted in the framework of nocturnal tours in the eastern extension of the city[16], whereas the "Pasha Gardens" have been visited in the course of "mystery walks" along the east border of the historic center [17].

Considering the growing popularity of Thessaloniki's "dark heritage" among both local residents and tourists, the above initiatives, which similarly to the work of journalists contribute exclusively to the arousal and maintenance of public interest, prove unexpectedly limited. Most importantly, amidst the overall infancy of the concept of guided walks in Thessaloniki and of "dark tourism" on the whole in relation to the international context [18, 19], a tour focusing exclusively on the city's "heritage of the dark" is yet to be anticipated. An additional explanation for this delay may lie in the fact that the buildings and sites in question are not located in close proximity to each other (see Fig. 6), hence a visit on foot is easily ruled out. The use of specially adjusted vehicles could provide an alternative solution, which remains though to be implemented.

Next to the work of journalists and tour operators, one would normally expect a certain mobilization of **researchers**, initially in pursuit of the association of the "dark" side of the related buildings and sites with their overall cultural essence. Nonetheless, the hitherto writings prove indifferent to this prospect [indicatively: 2, 5, 7, 9, 10, 12], despite its already acknowledged importance [20]. Secondly, an attempt to counterbalance the evident lack of a rational approach in the initiatives of the journalists and tour operators could be anticipated. Yet in the case of the "dark heritage" of Thessaloniki, such action also remains to be undertaken, with only one exception noted so far.

As previously mentioned, with respect to the "Haunted House", a photographer boldly entered the derelict mansion and attempted to take pictures of the interior. Taking a further step in order to evaluate the rumors circulating about the house, he then recorded on tape the sounds heard in its rooms. Rumor has it that upon playing the tape, he identified a seven-second gap in the noise produced from the nearby street and from a barking dog. Which is more, upon hearing more carefully, he identified sounds that resembled the heavy steps of someone approaching, together with words in whisper, which could not be understood [4].

Fig. 6. Map showing the location of the buildings and sites of Thessaloniki's "dark heritage".

The initiatives of professionals with a specialized interest described so far are coupled with the actions of the already mentioned second group of separate players in "dark heritage" management, namely the individuals and bodies with conventional relations with the assets involved. Among these, one distinguishes, first of all, the **owners** of the separate buildings and sites. All four structures constitute private properties, whereas the remaining place belongs to the local municipal authority. Remarkably, both the private parties and the public body have so far shown little or no interest at all in promoting the "dark heritage" status of their distinguished possessions.

With the conservation of historic buildings receiving minimal support from the state, the owners of the "Haunted House", the "Chatzigogos Residence" and the "Villa Hirs" have actually shown total disregard for any kind of maintenance and beneficial use of their properties. For them, the prospect of a change in ownership proves the primary goal in the years to come. Interestingly enough, though, the consequent continuation of the dereliction of their properties ends up strengthening their notorious profile.

By contrast, in the case of the "Pasha Gardens", the municipal authority has initiated plans to conduct repair works and improve lighting conditions, whereas the "Longos Mansion" was recently restored (see Fig. 7) and currently houses its new owner, as already mentioned.[2]These initiatives evidently erase the prolonged neglect that has

[2]In the case of the "Pasha Gardens", the Technical Service of the Municipality of Thessaloniki drafted a preliminary conservation project, which was forwarded for approval to the respective regional services of the Ministry of Culture and Sports on 28 August 2018. As concerns the

marked the recent history of the two assets, thus depriving them of a major contributor to their "dark" reputation, with no follow-up, such as a discreet photo exhibition or information sign, which could add to their historical and architectural importance.

Fig. 7. The "Longos Mansion", main front, under restoration.

After the owners, one needs to note the involvement of **public bodies**. According to the relevant Greek legislation [21-24], as segments of the city's built environment, the buildings and sites in question need to be maintained in sound condition, with no direct or indirect threat being posed to the health and safety of neighbors and strollers. In addition, since four of the five assets are listed monuments ("Chatzigogos Residence", "Villa Hirs", "Pasha Gardens", and "Longos Mansion"), their proper maintenance and use need to be even more attentively secured, with the respective owners being in both cases fully responsible.

With private initiatives for architectural heritage enhancement proving scarce in modern Greece, public bodies, namely the respective local authorities (Municipality of Thessaloniki, Region of Central Macedonia) and the governmental bodies responsible for monument protection (Ministry of Culture and Sports, Ministry of the Interior) are required to perform periodic inspections, advise on necessary measures, oversee repairs and, in case of inadequate action on the part of the owners, carry out urgently required works, with the option of charging their cost to the latter[22-25].

Being obviously obliged to enforce the law, the employees of the bodies in question have no alternative but to assume the prescribed courses of action, in defiance of rumors about ghosts, curses, and supernatural forces. A vivid portrayal of this "compulsory indifference" is observed in the case of the "Villa Hirs" and the "Chatzigogos Residence".Being in a bad state, with no repairs conducted by the respective owners for over three decades, the two listed monuments were examined by specialized

"Longos Mansion", it was restored on the basis of a conservation project approved by the Ministry of Culture and Sports on 26 September 2016.

committees of the Ministry of Culture and Sports.[3]Each committee was required to record existing structural problems and outline immediate measures for their alleviation [26]. To this end, their members surveyed and photographed the two mansions, both from the outside and inside, with no room available for concern over the fear-generating stories circulating about them. On the whole, it is worth noting that such work, along with all the aforementioned courses of action, aims to ensure a state of preservation and use far from the abandonment and dereliction that is most characteristic of haunted places and plays a vital role in their public acknowledgment as “dark heritage” assets.

Lastly, one ought to discuss the involvement of **non-governmental societies**. In this particular field, a comparatively limited amount of action has been so far witnessed, namely the annual festivities of local associations in the “Pasha Gardens”. To be more precise, since 2015, the civic non-profit company “Sfendamos” has been organizing a “Monument Running Race” in the wider area, with runners passing through various places of historic interest, including the gardens. On the other hand, as of 2016, the Branch of the Hellenic Society for the Environment and Culture and the Branch of the Young Men’s Christian Association (YMCA) have been celebrating World Environment Day in the unique context of the latter.[4] The events in question have come to attract strong support from the local authorities and other collective bodies, with the sole purpose of arousing public awareness and enhancing the use of the site as an invaluable green space and ideal place for relaxation and recreation. To this end, rumors about rare phenomena and curious events have been put aside, not to mention fully undervalued, in an attempt to avert the generation of fear and consequent avoidance of the gardens by the public.

4 Interacting “Aspects of Significance” and Final Outcome on “Dark” Identity

The preceding review of the separate players involved in the management of Thessaloniki’s “dark heritage” and their respective attitudes highlights a remarkable conflict of values in the overall perception and treatment of the latter. On one hand, journalists, tour operators, and researchers acknowledge the notorious reputation of the buildings and sites involved, and further on, promote public fascination with them, worth remembering on the grounds, not only of a specialized interest, but also of a necessary income. On the other hand, the respective owners, associated public bodies, and related non-governmental societies show total disregard for the rumors circulating in each case, opting for action on the basis of individual priorities (owners), legal obligations (public

[3]The two committees were established on 6 July 2016 (for the “Villa Hirs”) and 11 October 2018 (for the “Chatzigogos Residence”).

[4]For additional information on the two events, see the announcements posted on the Internet by the respective organizers: https://www.facebook.com/YediKuleConquest (for the “Monuments Running Race”, last accessed 2022/11/07), and https://www.facebook.com/events/441827186260877 (for the celebration of World Environment Day, last accessed: 2022/11/07).

bodies), and fixed aims (non-governmental societies), with a subsequent common contribution almost entirely to the removal of "dark heritage" status.

The final outcome of this conflict is determined primarily by the course of action selected by the owners. If the latter opt for complete neglect of their property, with minimal intervention from there on by public bodies and non-governmental societies, the assets involved are certain to preserve in full their fearful reputation, in a combined effect of their derelict image and notorious past. Such is the case of the "Haunted House", the "Chatzigogos Residence", and the "Villa Hirs". All three will most likely continue to provide a highly attractive subject for journalists, tour operators, and researchers and a hence unrivaled field of fascination for the public in the years to come.

On the other hand, if the owners select to pursue the proper maintenance and beneficial use of their property, possibly in conjunction with initiatives of non-governmental societies aiming to arouse public interest in them, the latter will be evidently deprived of a most significant -if not the most important- segment of their intriguing character. Consequently, their special identity will diminish, but not necessarily evaporate, depending on the pursuit of discreet references to the "dark" aspect and on the extent to which journalists, tour operators, and researchers will continue to address related events and rumors in their works. This is the case of the "Pasha Gardens" and the "Longos Mansion". Their latest enhancement has allowed little, but not necessarily no room at all for maintaining a certain fearful reputation, dependent, exclusively,on the circulation of past stories and future news; news of every strange event or unexpected misfortune that may occurin their interior or to the people related to them henceforth.

5 Conclusions

The "dark heritage" of Thessaloniki constitutes an undeniable segment of the city's cultural heritage, whose perception and treatment as such is nonetheless endorsed by merely half of the parties playing a role in its management. Journalists, tour operators, and researchers acknowledge its intriguing character and provide significant contributions to the arousal and maintenance of related public interest, while the respective owners, associated public bodies, and non-governmental societies opt for actions that reflect disregard, in favor of varied priorities.

This sharp contrast in the aspects of significance currently identified in the city's "heritage of the dark", coupled with the overall precedence of the purely incidental initiatives of the owners, leaves considerable room for a future diminishment of the fearful reputation of the buildings and sites involved. On the whole, though, it does not also foreshadow a complete extinction. A certain notorious profile will definitely persist in each case, with an equally certain prospect of a more solid appreciation of the concept of "dark heritage" by the city's residents and visitors, on one hand, should the professionals with specialized interest assume additional courses of action for its promotion. Such courses could include the establishment of digital platforms on the Internet for the constructive -and not purely recreational- acquaintance of the public with the special values of the related buildings and sites, including their "dark" side, the acknowledgment of the latter in associated historical and architectural research as a significant contributor to the buildings'and sites' cultural essence, and the development of guided tours, with specially adjusted vehicles.

On the other hand, the respective owners and non-governmental societies could opt for a subtle acknowledgment and projection of the intriguing past of the dreaded assets. Next to necessary maintenance and restoration works, which will ensure their preservation and capacity to accommodate original or compatible modern uses, discreet references, in the form of photo exhibitions or information signs, could be reserved for the "dark" aspect, as means of adding value to the buildings'and sites' historical and architectural importance.

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The need to safeguard cultural heritage in Albania against climate change

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Abstract. The biggest challenges of our time are climate change and the preservation of cultural heritage. In the Albanian context, promoting innovative ways and incentives for the traceability of cultural heritage is seen as a solution for regenerating new insights to support and safeguard culture. The aim of the paper is to assess the threats posed by climate change and other risks in order to prevent deterioration, enhance protection and reinforce related policies. The interdisciplinary research presents different aspects of securing sustainable development through culture and cultural heritage. The findings indicate good practices and innovative measures for the protection of Albanian cultural heritage against climate change. Moreover, the discussion is placed within the role of local and policy-making processes in validating and promoting solution for the effective resilience of cultural heritage against climate change through this multidisciplinary research.

Keywords*:* Cultural heritage, Climate change, Innovative measures.

1 Introduction

Climate change with extreme weather and environmental degradation are among the greatest threats to culture and heritage, starting from physical damage to issues on the practice and transmission of cultural traditions [1]. Global cultural heritage is threatened by the increasing severity and frequency of natural disasters caused by climate change [2]. International experts and researchers emphasize the importance of managing cultural heritage sustainably [3], [4]. Culture and heritage are crucial concerns for addressing climate change in a postmodern society as an effect of growing globalization challenges, from management practices to psychological states, for communities during and after climate-related emergencies [5].

Studies show that culture and heritage play a fundamental role in achieving sustainable development and they are also sources of creative solutions to climate issues [6]. The importance of cultural heritage for sustainable development has been widely recognized and supported by creating and sharing a common goal specific to strengthening global efforts to protect the world's cultural and natural heritage [7], [8], [9].

This study aims to explore Albanian challenges for sustainable development through culture in its tangible and intangible dimensions. It discusses the potential challenges climate change presents to cultural heritage and the need to safeguard it as an important aspect affecting the Albanian context to adapt to climate change and to support the creative economy and tourism. Based on climate change models studying the current and past climate systems developed over the past few decades, attempts have been made to identify the main threats from climate change, including the threats to historical and archaeological remains that characterize Albanian cultural heritage. The study also shows how sustainable practices in cultural heritage have been implemented in the face of climate resilience. Special attention is dedicated also to awareness-raising practices and to the steps in inventorying parts of cultural heritage in Albania.

1.1 Cultural heritage in the climate change era

The term cultural heritage has its origins in the roots of humanity and it is preserved as a cherished value in all cultures that have been passed down through the generations [10]. Cultural heritage combines cultural and natural heritage, this is the definition of the UNESCO Convention for the Protection of the World Cultural and Natural Heritage held in 1972. This concept is related to the universal understanding of heritage and the common preservation of the most precious places of cultural and natural importance [5]. Many cultural heritage assets such as the contents and collections of historic buildings, monuments and archaeological sites are a heritage that is linked to the identity and well-being of the local population [11], [12].

Cultural landscapes of Albania, often characterized and enhanced by the presence of exposed and buried archaeological remains, are threatened by environmental processes, anthropogenic pressures and, more specifically, by climate change and natural hazards. The identity and values of heritage buildings are the strongest reasons to preserve and restore them. These heritage assets have always been interacted and will continue to do so with their environment, mainly influenced by constantly changing weather factors [13].

The intangible form of culture appears as the memories, emotions, values, customs, and use of instruments, objects, and cultural spaces that communities, groups, and in some case, individuals recognize as part of heritage culture [14]. Tangible or intangible forms of culture connect us with the past and help in understanding the present we live in and what we will pass on to future generations. Those keep us connected to religions, traditions and beliefs, creating and developing identities as individuals and communities [15].

Cultural heritage plays a strong role in both economic and social life, although most of it remains informal, without public protection and without clear management as they are the main institutions that link history, territory and society, defining the cultural context of social life [16].

Climate change poses a major challenge to cultural heritage, as many of the negative effects we now face are unprecedented. Extreme climate change exacerbates the exposure of cultural heritage to climate stressors causing serious damage [39]. We are facing a new situation that we have not faced before, and we have no previous model. Thus, we need to react in creative ways to climate changes [17], [18]. Currently, climate change represents one of the biggest threats to culture and heritage, as physical damage and periodic damage due to changing weather conditions and recent cases of extreme impacts have increased. The obvious threats to Europe's tangible and intangible cultural heritage come from climate events such as heavy rainfall, prolonged heat waves, droughts, strong winds and rising sea levels, which are likely to rise dramatically in the future with immediate consequences, such as floods, forest fires and erosion [19]. Climate change is also a problem for building interiors, as outdoor climate conditions can directly affect indoor conditions in uncontrolled buildings, such as many historic buildings [20]. Museums house a variety of collections, organic and inorganic, often housed in historic buildings that lack modern climate control measures and equipment, so the potential impacts of climate change on indoor environments must also be assessed [16], [21].

Reducing impacts on the environmental system is part of the circular economy strategy that represents a tool for achieving and implementing sustainable development, with the aim also to minimize negative impacts on cultural heritage. [22], [23].

Culture and heritage are primarily local phenomena due to hundreds and thousands of instances in the history of human settlements and their local conditions. In this context, local, regional and central governments have a responsibility to protect them. The urban population must have access to a new culture that responds to the needs and other goals of sustainable development [24].

Climate change in the world has led to several negative effects, including increased temperature, changes in humidity, increased heavy rainfall that causes flooding; dry summers appear to increase the impact of droughts and unpredictable weather conditions [25].

1.2 Situation of Albanian cultural heritage

Following a needs assessment and UNESCO support, Albania is taking new steps for cultural development strategies by building professional and institutional capacities for the preservation of its living heritage [26]. The situation is very sensitive as a result of the dynamic processes that occurred after the fall of the communist regime in 1990. In the system of the communist dictatorship, the administered cultural values did not have the proper evaluation. Albania's cultural heritage is a rich and diverse mosaic of cultural elements, expressions and crafts. It includes natural, built and archaeological sites, museums and monuments, works of art, music and visual arts.

However, this heritage is facing significant challenges in maintaining its sustainability in the face of episodes of extinction [27]. The transformations after 1990 created new opportunities for economic and social development, but they also brought new dilemmas, such as continuous waves of emigration, the collapse of previous state institutions, economic problems that particularly affected rural communities and their cultural traditions. Migration of people in cities and abroad has left many villages depopulated, affecting with the damage of cultural buildings [26].

Albanian cultural heritage is under the effect of natural damage and human destruction, therefore it must be protected, because it is the main economic source for tourism and economic and social development [28]. The impact of sea level rise on large archaeological sites in Albania, such as Butrint, Durrës Amphitheater and Apollonia, is evident in a mix of seascape, archaeology, ecology, history, mythology and aesthetics that makes these archaeological centers magic from the most historical sites of Mediterranean [26]. In addition to being a World Heritage Site of archaeological value, the region of Butrinti is also home to an active wetland habitat [29]. Forecasts of different temperatures and their impact on sea-level rise present a complex challenge for the present. Extensive excavations and a multi-volume series of accompanying scientific publications have made this a key site for maintaining an ancient and other culture since sea level rise. Butrint land flooding will not be new. Major human-environmental change, accelerated by deforestation, will occur through the next millennium.

By the Greek Archaic period, the ruin was receding. Instead, they were formed in a way that could be traversed while looking at the high points of the landscape. Long-term falling sea level occurred in the early Roman period. The ancient city of Butrint is a place one meter below the current level. Geological and climatic changes caused the lowering of the sea level in Butrint, which was accompanied by submergence of some of its monuments that are permanently or periodically flooded [29]. The climatic effect in Butrint has come from the retreat of glaciers and ice masses, hot weather, droughts, cyclones, fires, rain and climate changes towards the poles [29]. In Butrint, it is important the way of managing and finding a solution to face the risk of climate change [1].

The heritage of over 3000 years of continuous settlement must be preserved with all its values while maintaining the balance between heritage protection, tourism and development [40]. The initiative of the Albanian-American Development Foundation (AADF) and the Ministry of Culture for implementation of the project for the revitalization of the Roman Amphitheater of Durrës together with the Byzantine Forum and the Roman Baths is a contribution to the restoration and reuse of the cultural heritage of the city and the combination of physical and visual connections between historical and cultural assets. This will turn the city's urban heritage into an inexhaustible tourist attraction in Albania and the region that will further promote local economic development [30].

The ancient city of Apollonia is located in southwest Albania, about 13 miles from the city of Fier. The fascinating landscape of the archaeological park, which has been preserved in an extremely intact state, constitutes a successful combination between the beauty of the monuments and nature, attractive throughout its long history, in an atmosphere of relaxation and meditation. Much of it remains undiscovered to this day, representing an interesting and attractive place for various researchers. The cultural development of Apollonia and its status as a major city of the ancient Mediterranean world is evidenced by the outstanding monuments preserved within their original boundaries, such as Doric temples, various public buildings and a series of houses with well-preserved mosaic pavements [27].

The AADF has taken over the management of Butrint National Park, Durrës Amphitheater and Apollonia, providing funding from UNESCO and the Albanian government. These cultural centers therefore have a new management structure and philosophy. This bold and timely initiative represents a combination of the non-profit and public sectors, with the freedom to envision a long-term and sustainable financial future for the site and, most importantly, to plan accordingly for climate change [31].

2 Methodology and materials

The methodology that was used during the survey involved a preliminary gathering of information about the status of Albanian cultural heritage and about the different agencies involved in it on a national and local level. It was followed with preparation of a sample questionnaire that was used in interaction with different stakeholders during frequent visits and conversation and interviews conducted with cultural heritage practitioners and representatives of different public institutions in Albania.

In order to find data related to the state of cultural assets and the impact of climatic conditions and other extreme conditions, data sources of the Ministry of Culture and Tourism, data of projects on cultural heritage and its preservation were used. Scientific articles by Albanian and foreign authors have been a source of data as have been discussions regarding the current state of heritage and the harmful consequences caused by weather disasters and earthquakes.

Methodically, it is intended to select information to answer questions such as: What is the situation in Albania regarding the preservation of the diverse wealth of cultural heritage? Has there been damage caused by extreme climate conditions and natural disasters and is there a strategy for the preservation of cultural heritage? This study is based on a detailed analysis of events, facts found in recent years on the basis of literature sources and data collected from institutions, associations, individuals and direct contacts with representatives of museums, archaeological centers, institutes and cultural institutions.

3 The experience of climate change impact on cultural heritage in Albania

There is much to be learned from the Albanian cultural heritage presented and represented until today mainly by central and local public archaeological sites, which have developed private financing with autonomy and profitability, transforming into centers of global tourism [32]. According to UNFCCC data, in the last three decades in Albania, temperatures recorded above 37-40 degrees Celsius have increased [29]. Higher temperatures lead to longer periods of drought, extreme weather events and higher erosion. Climate change impacts biodiversity, ecosystems, and the forestry sector. Land use is another factor that is affecting cultural heritage in Albania [29], [33]. The heavy rain that hit Albania in 2018 damaged cultural heritage sites, such as churches and mosques in Gjirokastër, which had been added to the world heritage sites in 2008. This city lost two of its old houses in the middle of the city, originating from medieval bazaar. For years, these buildings have lacked maintenance, but there have been other damaged buildings in Gjirokastra as well.

According to conservation experts, heavy rain was not the only cause of damage [34]. The castle of Libohova was also damaged, and it lost its interior due to the rains. Neglect over the years as well as mismanagement have contributed to these damages. Shkodra's Lead Mosque, built in 1773, is a cultural symbol for the country that is constantly under water after heavy rain. The church of John the Baptist in Derveni, near

Kruja, built in the 13th or 14th centuries and considered a monument of the first category, suffered the greatest damage. This church had been flooded even before the recent heavy rains. Being located below the surface of the earth around which it is dug, it often finds itself under the water that comes out every time it rains [35].

The city of Berat is a historical site under the protection of UNESCO, but in the last ten years it has suffered damage, losing some old houses which have been damaged by chemical factors and lack of maintenance [36]. The lifespan of objects and buildings as cultural heritage is significantly affected by geophysical factors; it is enough to mention here the cobblestones damaged by erosion. The amphitheater of Durrës has been damaged under the influence of climatic factors and urban interventions [32].

Fig. 1a. Climate damage of mosaics of the basilica in the amphitheater of Durrës
Fig. **1b**. Flooding of the Archangel Michael and Gabriel Church in Voskopoja

The Foundation for the Management of Butrint has drawn up a plan with a series of activities and challenges for a period of ten years and seeks the support and commitment of the local community for the protection of the heritage of the ancient city of Butrint from the flood. Climate change protection is already the main issue in the foundation's activities [37]. Touristic activities of these archaeological centers will be endangered over time, because within the next decade there will be further sea level rise [38]. Actions to protect against submergence have included: obtaining reliable annual data on the destructive effects of floods through a hydrological survey; consolidating relations with the villages of the area, developing and implementing a program of archaeological works that record and document as much of the archeology as possible, including the use of salvage archeology for materials at risk of extinction [1], [38].

The changes in the ecology of Butrint have also been evaluated by measuring the salinity of the underground water, which has increased and has thus affected the forests around it.

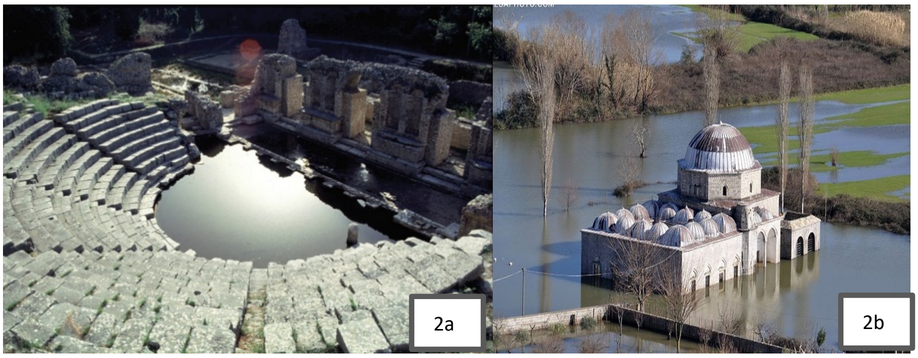

Fig. 2a. Water standing in the Roman theatre of Butrinti
Fig. 2b. Flooding of Lead Mosque in Shkodra

Most ancient sites in the eastern Mediterranean have witnessed natural events very damaging to archaeological sites, such as volcanoes, earthquakes, floods and tsunamis, plagues. But by learning from such events, planning is done on how to respond, especially in terms of ensuring that information is not lost and important artifacts are preserved [39].

Lin's Basilica, an ancient cultural heritage, is located on a peninsula formed by a hilly outcrop near the shore of Lake Ohrid. Its magnificent mosaic is easily exposed to water, which is damaging it [40]. The Europeanization process of Albania with the tendency to create a new modern one is damaging the cultural heritage. By examining different types of tangible culture, including museums, memorials, religious buildings and archaeological sites, as well as investigating heritage from several periods of Albania's past, whether remnants of the Roman or communist period, it is clear how they have lost cultural heritage values [39].

4 Discussion

Ancient cultural sites were designed for a specific local climate. The action of damaging factors can have negative impacts on the preservation of built and natural heritage. Sea level rise threatens many coastal areas. The conditions for the preservation of archaeological evidence can be degraded under the action of earth's temperature. Climate change affects social and cultural aspects; it will change the way of life of communities, leading to migration and abandonment of their built and natural heritage [13], [16].

The issue of climate change impacting natural and cultural World Heritage properties is very real. For this reason, as a long-term measure, the World Heritage Committee in 2006 requested States Parties to implement the strategy to protect the outstanding universal values, integrity and originality of World Heritage properties from the negative impacts of climate change [1]. Updating management plans of archaeological sites and cultural centers threatened by climate change to ensure sustainable conservation requires increased research efforts by competent bodies, local actors and universities and the development of joint and regional projects [41].

We still have time to retrieve or save these national theses from oblivion, and here we refer to costume design, scores, props, visual art, the immaterial universe, etc. Although undocumented previously by the records that administer them, these national documents should be part of the National Heritage Register [42]. Virtual representations of tangible culture are related to the two main aspects of the globalization of all (people's heritage) in the quality and cultural audience [43] on the one hand, and to creating other things and growing feelings towards them, on the other hand.

However, another important trend can be supported, which consists in the report of national masterpieces in the world by means of digital databases and virtual collections, museums or registries often connected within larger, regional or global platforms [43]. Researchers have already begun to investigate the impacts of climate change, but there is still a need to complement the existing findings to ensure that they contribute to their prevention and adaptation policies [16], [22]. Our relationship with culture has evolved profoundly over the past 30 years. We are aware that we must strive to protect cultural heritage from the dangers of climate change. The concept of living and heritage, under the focus of the creative economy, is required to be supported by public and private policies in coordinated actions [36].

Many possibilities have arisen from the search, and many are yet to be discovered. Research should further explore how to make cultural heritage an available resource for climate mitigation and sustainable development. In this context, there are opportunities to promote multidisciplinary research and knowledge exchange in several regions. It is vital that research communities across regions collaborate to address the knowledge gaps identified within the document globally and to protect our cultural heritage for future generations [4].

Government, academia, private stakeholders are investing in the various components of culture, creative economy, cultural tourism, museums and other local cultural organizations focusing on specific components of culture. Assessing the links between culture, heritage and responses to climate change will also serve as a catalyst for new research, projects and publications on culture, heritage and climate action. The ecological and social impacts associated with the losses and opportunities for cultural assets and values from adaptation and mitigation should be investigated more intensively [2,] [24].

The management and programming strategy itself, combined with ever-increasing public-private awareness and effective creative industries policies in the socio-economic ecosystem, contribute to integrated synergy and highlight the best shared values [22]. Regarding structural damage, analysis was carried out on recorded climatic data, and damage and damage patients as a result of climatic and catastrophic loads and causes [33]. Elements, objects and sites of cultural history were ranked into five sensitivity categories within their four climate groups. They weather action, floods, landslides and winds. In addition, a scientific reference base was created on mechanical damage and batteries of historical structures due to the effects of weather and it suggested strategy and adaptive measures.

The impact of wind action on historical structures and art objects happens in two parallel ways [21]. Some typical forms were chosen for roofs and historical structures, the children of the towers of the old town. The three-dimensional model that must be accurate for the investigation of the complex situation and has been validated and calibrated by making test results in the reduced-scale shows in its tunnel. The innovative methodology and the application of hybrid air flow analysis around the complex architectural forms of historical towers achieve a pioneering result in this field [34]. The adopted methodologies also take care of the existing software to change a verified software model of a general cultural building.

The approach was used to model the operation of the effects of climate change on the construction of a building, thus becoming an integral to the internal understanding of the internal structure of the built structure [9]. The simulations present a recent insight into the changes of materials under different conditions [44].

5 Conclusion

The relationship between cultural heritage, in its tangible and intangible dimensions, and climate change has been a topic of significant academic discussion. It reflects the rising challenge of safeguarding cultural heritage and identity in a postmodern society, as well as the challenges from climate changes. Nowadays, more than ever, sites like Durrës and Butrint Amphitheaters, archeological city of Apollonia and other cultural assets facing such problems caused by climate change, need proactive, creative management, bold decision-making and conviction. The recent attention on these cultural artifacts presents attempts in the safeguarding process, due to the transformation of cultural landscapes and the safety of cultural heritage under socio-political, socio-economical, and environmental factors. Cultural heritage is neither prepared for nor adapted to our future climate. Information and related policies are needed on how to make it more resilient to future disasters and how to survive them. Problems and patterns of climate change impacts on cultural heritage in indoor environments should be prioritized.

The changing state of cultural heritage subject to short- and medium-term flooding and long-term flooding should be measured. Good policy, safeguarding strategy, effective training and sustainable practice must all be built on a foundation of scientific research. Cultural heritage is the genetic code of a people that defines who we are as a nation. If we do not document it, protect it from climate damage and transmit it across generations, it is destined for extinction.

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Heritage at Risk
The educational role of Museums in rescuing and promoting tangible and intangible cultural heritage
The Benaki Museum example

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Abstract. The recent directive of the European Union for merging tradition with innovation for the sustainability of European culture and particularly for the resilience of traditional arts has found its perfect example in the past in the seminars of traditional jewellery-making techniques organized for 25 years at the Benaki Museum by the undersigned with the collaboration of several colleagues of the museum. The seminar drew on inspiration from the itinerant goldsmiths of Epirus region and was based on the need for a portable workshop; it was thus traditional in both its concept and implementation. On the other hand, it was also innovative, as it didn't stop with the graduation of the students, but it included a great deal of mentoring, which led to the formation of new businesses (start-ups we would call them today) by the students themselves. Nowadays, when the shops tend to be more and more inundated by computerized designs, this continuing education seminar could become again a highlight for museums which would merge cultural heritage with Creative and Cultural Industries.

Keywords: Heritage, traditional, goldsmiths, continuing education

1 Introduction: The European realization of the value of traditional arts

Since 2018, European Year of Cultural Heritage, the European Commission and other organizations have focused on the need to re-discover and revive traditional arts, albeit with a twist of innovation [1]. The new prerogative is the merging of cultural heritage with creative and cultural industries, in order to maintain a distinct "European" identity in artifacts and works of art, instead of succumbing to globalized aesthetic tendencies, usually imported. A series of programmes have been designed to support this general guideline: Creative Europe and Horizon calls have stressed the need for a rediscovery of long-lost traditional arts and their merging with innovative technologies for a modern, up-to-date and resilient effect. Meanwhile, all over Europe hubs for cultural and artisanal creation make their appearance, enabling artisans to make a living with reduced costs through renting a space and using a basic set of equipment and the mentoring facilitation of the hub organizers. Some examples include the Make Ici organization with 4 hubs all over France (www.makeici.org) and the Craft Hub Project, co-funded by the European Union (www.crafthub.eu). Integrated within the New European Bauhaus philosophy, this prerogative, to which abide also museums and cultural centres, aims at creating a new, citizen- and creative-friendly environment and at rekindling the European creativity which highlighted European civilization in the previous, centuries.

2 Continuing education seminars on traditional gold-and silver-smithing in the Benaki Museum (1989-2014): Materials and Methods

Long before the orchestrated European initiative, however, some museums had already realized that their role, apart from safeguarding heritage artifacts and works of art, was also to preserve intangible tradition and the knowledge of traditional arts that went extinct within the hi-tech frenzy of the '90s and beyond. One of them was the Benaki Museum, which instigated the first adult continuing education seminar on its premises, apart from the educational programmes which were already established towards the end of the 1980s.

This idea for this seminar was first conceived in 1987. and it was designed as a unique seminar in the field of gold-and silver-smithing, even on a professional level, both in Greece and worldwide.[2] Within the international atmosphere advocating the new role that the museums were called to play in the '80s regarding Continuing Education for Adults, mrs. Niki Belesioti, responsible for the childrens' educational programmes in the Benaki Museum, at the instigation of the former director of the museum, Prof. Angelos Delivorrias, and of Aemilia Geroulanou, asked me to inaugurate the first jewellery-making seminar for adults, as she knew that I already had a long experience in the field. [3] In those days I was curator of the Coptic Textiles Collection of the Benaki Museum, which was one of the most important collections of the sort worldwide. Niki Belesioti knew that before I became a member of the Benaki Museum, I had been a consultant for the National Organization of Greek Handcrafts, and that due to my academic specialization in Comparative Ethnology I was an expert in the study both of textiles and of Costumes. I had also been awarded during an exhibition of Greek jewellery in New York.[4]

Inaugurated two years later, in 1989, it was, in those days, a Startup seminar, following present-day terminology, which has been attended by about 1,500 people in total in the course of the 25 years of its implementation. It was obvious that the museum wanted to take its social responsibility and community participation to another level. This had been a long-standing stance of the late Director of the Museum, Prof. Angelos Delivorrias.[5]

Fig. 1. The implementation of the seminar in the Benaki Museum

2.1 "Traditional resourcefulness"

At first, I became enthusiastic with the idea, but I soon realized that the creation of an educational programme (seminar) for hand-made jewellery would be an impossible endeavour due to practical difficulties.

I had to mobilize all my resourcefulness and imagination in order to transform the practical difficulties for organizing a workshop of gold- and silver-smithing in a museum. The reason is that such a workshop requires a permanent space, a workbench, propanium bottles and fuses, oxides and other caustic fluids, heavy steel tools such as clamps, items that are not allowed within a museum. Nevertheless, I managed to find solutions to all that through my study of the gold- and silversmiths' practices from Kalarrytes in the 17th and 18th centuries, who had to commute within Greece and the Balkans carrying their tools within chests from one town to another.[6]

That seminar was welcomed with applause by the broader public and had been taking place annually for 25 years. For a rather long period it constituted the only school for traditional jewellery making, apart from the one of the Vocational Training National Organization destined for young people without income or the State School for gold- and silver-smithing in Ioannina. It is a well-known fact that this art in Greece was a "closed" profession restricted to members of the same family, usually taught from father to son. Apart from the Benaki Museum, this seminar was implemented also in other cultural organizations, such as the Educational Programmes of the Athens' College and the Cultural Club of Palaeo Psychico. Furthermore, the Southeastern College of Greece, acknowledging the importance of the Greek gold-and silver-smithing created a specialised BA and MA. Finally, NTUA also recognized the fundamental value of this seminar by according its accreditation to it.

This educational programme proved a valuable tool of culture, learning, skill building and financial development for a wide public, leading the students to a ludicrous profession. Thus, we attained one of the goals of Antonis Benakis, founder of the Benaki Museum back in 1930, who envisioned a museum which would "contribute to the cultural education of the broader public".

The seminar of "wandering silversmiths" has been internationally acknowledged for its originality and some of the former students have become not only designers, artisans or industrialists but also professors, teaching in municipal or other cultural organisations and transmitting the art of silver-smithing in other cities and islands of Greece.

Furthermore, another positive contribution of these educational programmes of the Museum was the preservation and revival of some ancient techniques of hand-made jewellery, such as *embossing*, an ancient practice that was almost extinct at the end of the 1980s, *filigree* (working with fine threads of metal), *granulation* (an ancient Greek method for chain-making), as well as the rare, for Greek standards, Medieval technique of *incised jewels with nitric acid*. [7]

Let's have a look now into the ways I used for overcoming the practical difficulties regarding the implementation of the seminar in 1989 within the Museum. Its uniqueness and efficiency lay in the fact that it was taught once a week on the basis of a movable workshop: the students were taught one technique every week and they practiced at home. The difficulties they encountered would be resolved in the next lesson, for each one of them, whereas a new technique would be taught as well. This weekly schedule allowed working people to participate at the seminar, who, otherwise would be excluded from daily tuition. The seminar was used as a model for other educational organisations and for fields such as painting, icon-painting, doll-making, hot-wax (encaustic) painting etc.

Beyond the practical aspect of the training in these particular techniques, I was also offering e-mentoring (with modern standards) to my students. By acknowledging their special artistic talents, I provided professional counsels, thus leading them to professional success.

2.2 The "portable" workshop

Fig. 2. The portable workshop

At first, I tried to find tools that would not be permanently settled within a workshop. I therefore looked into the tool market of Athinas street. I realised that there were no metal jigsaws in the market; the ones extant served for sawing wood. Thus I ordered metal jigsaws from abroad. The second step was to order at Dilmas shop a wooden jigsaw-file board with an adjusted screw that allowed it to be fitted on common wooden tables that the Benaki museum used for educational programmes, transforming them into temporary gold-smithing benches for the duration of each seminar module. I then looked for hand-driven drills, given the fact that in this seminar I wanted us to be totally electricity-free, like the old silversmiths and not to be dependent on electric power for cutting or polishing metals like modern artisans.

In 1989 the shops providing jewellers' equipment were only few and far between. I collaborated with one of them, in particular, namely S. Michaelides SA, as they imported tools from Germany, tested by the owner's own son who studied in Germany. In those days the Germans had created light fireproof plaques, made of a new, groundbreaking material, suitable for high-temperature silver melding. This enabled not only my students but also silversmiths in general to avoid "deadly asbestos". As the seminar was taking place on Tuesdays, when the Museum was closed for the public, instead of ventilators we could work in front of open windows when we worked on chemical incisions and oxidation.

Instead of large propane bottles we used little welding torches, which had just arrived from Italy in those days. They proved extremely effective. As for the necessary tools, the guardian angel of the seminar –and guard of the museum, mr. Vassilis Stravoskoufis helped me carry several heavy toolboxes and store them in specific spaces which allowed the museum to keep the hall empty for the public.

The metals I gave to novices were copper and bronze sheets that I bought at Viochalko, measuring 30x40 with a height of 0,5-1.00 mm. After the first lessons, we worked on precious metals and then took the created items to specialised workshops downtown.

3 Design implementation techniques

During the first lesson I presented an introduction to the morphological and structural elements of metals as well as a historic retrospective from the Neolithic period onwards based on archaeological data. I also presented the characteristic techniques compatible to particular metals for creating jewellery based on their use. Aspects such as the ability of metals to be stretched and torn were also presented, thus offering an idea about the metals' structure and features, e.g. their degree of oxidation.

Part of the introductory lesson was also the method of archiving and creating a portfolio, through photographing each creation and placing a date on it, thus making it retrievable for orders of unique, hand-made items.

Fig. 3. Embossed ancient Greek-style by our student Panos Kardasis

Beginners' Techniques:

For eight weeks I taught jigsawing, cutting into metal, filing with files of different sizes, filing through metal, polishing with sandpaper (finishing), metal piercing, incising with nitric acid, hammering (decorative finishing), matière. Also, open chains with wire, rings with open shank, open chains, metal-colouring.

Advanced Techniques:

For another eight weeks I taught hard and soft silver soldering of metals and wires, polishing, annealing, soldering of multi-level compositions with a combination of metals (topography), hand-made clasps for earrings (hooks, nails), construction of compact granules, granulation (from Latin granum=grain), sizing rings, oxidation for silver, reticulation, mokume technique, loop in loop chains (ancient Greek design), gem stone settings. [8]

4 Results: Professional advance and mentoring

There was not an age or other type of barrier for these seminars. Thus, my advice to younger students, was to follow the artistic production, selling their items through art galleries and exhibitions, like other artists, painters, sculptors etc. did.

At this point I have to express my gratitude to the Titanium art gallery and its owner, the late Aristeides Giagiannos, for hosting exhibitions of the best students of the seminars upon their completion of both beginners' and advanced courses. This opened up the perspective of a professional career for them.

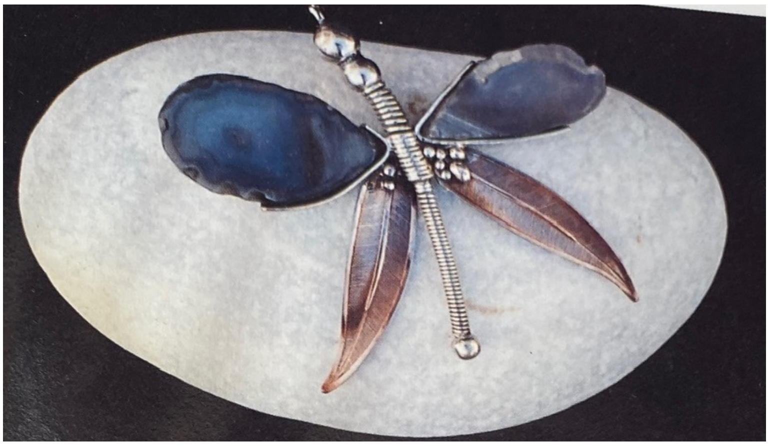

Fig. 4. Artistic by our student Beky Doriza

Fig. 5. Ring by our student Stylia Kapitsimadi

On the contrary, some students with family obligations, particularly women, were advised to appropriate the embossing technique with cold chisels copied from ancient Greek tools from the National Archaeological Museum; I managed to introduce them into the commercial world, so that they could become "modelists". Their original hand-made items were well paid for. For example a hand-made model in those days could be sold for as much as 50.000 drachmas (at a time when an average salary was about 150.000). This professional perspective had created a high reputation for the Benaki Museum seminar.

Through this seminar, people who were already professionals in other fields had managed to find an outlet for their creative talent: architects, artists, biologists counted among our students. Many women, who needed to learn a profession in a short period of time and with little money in order to be able to make a living were also part of our audience; they confessed, later on, that in this way they managed to help their children study or start their life.

All the above is proof that the seminar had become a tutorial with a very low cost and a fast professional development. Some of our graduates were accepted as interns at the workshop of the famous jewellery designer Ilias Lalaounis, in the neoclassical building where now stands the Lalaounis' museum, close to the Acropolis. They produced high-quality hammered jewellery, made through ancient Greek techniques as I had taught them. [9]

In the course of the 25 years of this original and successful seminar, most of our students participated at large professional exhibitions and then created their own shops in Plaka or their own export companies. Some of them have also evolved as artists and they have their own ateliers or exhibit their work in London and New York as well-established designers. Others, became also teachers in similar seminars which started being created in neighborhoods of Athens and other cities all over Greece, such as YMCA, the municipality of Kifissia and other cultural centres. Hence, the interest of the public towards jewellery-making as a creative and lucrative profession offered the incentive to the state authorities to create public Institutes of Vocational Training, whereas the famous gold-and silversmithing school of Stemnitsa, Arcadia, re-opened in 2013.

Important exhibitions also took place at the Athens' College and the Cultural Club of Palaeo Phychico, as well as in the Benaki Museum itself in 1994 and 2000. During the refurbishment of the Benaki Museum, the courses took place at the Goulandris-Horn Foundation in Plaka, a kind offer of the late Dimitris Horn and the Director S. Filinis.

Fig. 6. Silver earrings by our student Tasos Papanastasiou

It is particularly moving that we had students coming to this seminar from all over Greece, from Thessaloniki, Patras, Herakleion, Samos, Lamia, Xanthi. The groups were enthusiastic and exchanged ideas, collaborating in perfect harmony. Friendships and business partnerships were also part of the fruitful side-results of the courses throughout those 25 years.

In the course of my long professional involvement with Greek Gold-and Silversmithing, always from the educational point of view, I also contributed to the enhancement of this art through publications in specialised magazines, such as 24 Carati, Kosmima, The Jeweller etc. My publications were relative to the public's interests as the artisans needed to know the Art Historical aspects of jewellery-making.

5 Discussion: Academic outcomes

In 1993, in the course of the first Presidency of Greece in Europe, I wrote the first book for the global history of the Greek , titled: “The Greek jewellery from antiquity to the present. History-Art-Technique”. It was published through support by the Hellenic Organization of Professional Handcrafts and it demonstrated the ancient Greek origins of jewellery. Later on, another monumental collective work, “5000 years of Greek jewellery” was published by Greek Center for Silversmithing. All this had as a result the enhancement of gold-and silversmithing as an important art and not only as a “guild handcraft” as was the established concept of it within the broader public. I personally became a member of the Board of Trustees of the Greek Center for Silversmithing, which is a state organisation, whereas in 2018, as founder of the not-for-profit organization Heritage and Museums, I have signed a memorandum of collaboration with the Pan-Hellenic Confederation of Artisanal Gold-and Silversmiths and Watch sellers, in order to continue to enhance Greek jewellery beyond the borders of Greece, as an art developed already in the Neolithic and Mycenaean period to the Classical, the Byzantine and the Modern period, in a time-transcending journey. Finally, I would like to stress that my precious assistant during this journey was my student Eirini Sikiaridi, who followed me throughout the Benaki Museum seminars all these years, offering me her support voluntarily. She has become a well-known designer herself.

Fig. 7. Earrings by our student Evelina Papantoniou

6 Conclusion: Future steps

The modern approach to jewellery-making is, of course, striving away from the content of the Benaki Museum seminar. Computerized design and 3D printing are steadily taking their place behind the fashionable window-cases of expensive jewelers. However, there are several techniques that can never be mechanically reproduced. Fine jewellery and artistic jewellery are still pretty much the result of personal inspiration and hand work. The financial crisis in Greece was more or less the reason why the Benaki museum seminar was discontinued. Within a period of instability and with the prices of precious metals skyrocketing, it was a difficult period for the country, let alone design and luxury products. However, the touristic growth in Greece and the request for Greek handcrafts in all e-shops and exhibitions demonstrate that it is high time such seminars take place again. Naturally, the times nowadays request for greater innovation as well as for the digital dimension of every educational activity. Hence, we could propose the organization of hybrid seminars (which would save students from other areas of Greece or even from abroad the cost of commuting) as well as the creation of an e-exhibition space for all specimens of work of the students. Modern networking facilities and selling platforms such as Etsy allow for faster professional development and for participation at joint events. Digitized processes of recording even the minor details in the jewellery design and construction allow for detailed documentation and the creation of digital toolkits to help novices in the jewellery-makers profession to feel more secure. Last but not least, the modern role of museums, which can develop into hubs for merging cultural heritage with Creative and Cultural Industries offers the potential for the merging of modern design with historic patterns, symbols and techniques and produce completely new and appealing results in the jewellery and ornaments field. If museums abide to this role, a fascinating process is about to begin!

For Angelos Delivorrias, former Director of the Benaki Museum,
In memoriam

A little contribution to the man who always believed that a museum ought to have a dynamic presence in the field of culture and education and who managed to rank the Benaki Museum among the greatest museums in the world.

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Spatial Planning

Redefinition of Rural Spaces: A Methodological Tool

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Abstract. The desolation of rural areas and historic settlements is a particularly intense phenomenon in recent decades. Gradually, the tradition and history of these places are being worn away leading to the alteration of their identity. The economy is monopolized by the service and tourism sectors and quite often, this converts them into a seasonal touristic product.

The "redefinition" of the rural space is a necessary condition in order to formulate a sustainable strategic plan which will respond to contemporary needs and at the same time, respect the uniqueness of the place and preserve its cultural identity.

This paper attempts to highlight a methodological tool for the planning of the rural areas, in terms of protecting and promoting them, on the occasion of the research carried out for the broader region of Fodele village, in northern Heraklion (Crete).

A key element for the research is the utilization of endogenous resources and their correlation with extraneous trends. Using this tool, conceptual networks of different resource types are created. By projecting these networks onto the space, and taking into consideration geospatial criteria (proximity, topography, type of resource), spatial units of particular identity are being formed. Resources- networks of social type - and stakeholders co-act to implement a strategic plan for the revitalization and promotion of the spatial units (anthropogenic and physical environment).

The procedure relates to a system of successive space readings and interpretative mapping at multiple scales. The conclusions derived from each stage lead to the next. Ultimately, this interdisciplinary process forms the essential background and design principles, for the articulation of a comprehensive strategic plan, aiming at the revitalization of the rural space and its sustainable development/enhancement (cultural, heritage, economic, environmental, etc.) in contemporary terms.

Keywords: Rural space, planning, endogenous resources, interdisciplinary, documentation, interpretative mapping, strategic plan, sustainable development.

1 Introduction

Nowadays alteration in the character of the traditional settlements of the greek countryside, which is related to the transition from the primary and secondary to the tertiary sector of the economy is observed. This economic change has led the local, working population to abandon the rural settlements and move into large urban centers for studies and employment. This results in the gradual dereliction or transformation of the rural and pastoral settlements that once formed the core of the Greek economy and culture.

A particular case is that of areas of outstanding natural beauty, where the focus is on the exploitation of the area by the tourism sector. As a rule, in Greece this category includes coastal areas and islands. The major problem lies in the fact that the massive influx of tourists tends to turn settlements and entire areas into a touristic product - a theme park for seasonal use. The ephemeral, consumerist nature of mass tourism, and the obsessive reliance on it as a key pillar of the economy, brings temporary economic relief while causing significant degradation of the natural and man-made environment with negative effects on culture and society. The motive is to prevent the deterioration of the character of the settlements, their degradation and their total or seasonal abandonment. The social and economic regeneration of rural areas with cultural and natural richness requires their redefinition in terms of sustainability and long-term resilience.

The methodological tool for analyzing and planning rural areas described in this paper attempts to provide a solution to the above-mentioned problem and involves the formulation of a strategic plan of action that responds to the contemporary needs of society, respects the uniqueness of the place and unveils its particular culture. This research was carried out in the context of a diploma project for the broader region of Fodele village, in northern Heraklion (Crete) [1].

The identification of the area of study involves primary and secondary research, and interpretative mapping at different scales, focusing on the qualitative characteristics identified at each level that can attract old and new users, capable of utilizing the place as a whole and in the long-term. The conclusions reached after the completion of each phase of the design methodology are the starting point for the next level of site identification.

The systematic detection and classification of these intrinsic spatial and social characteristics throughout the successive focusing stages is one of the most important tools in the identification of a locale. By linking similar qualitative characteristics, called endogenous resources, networks of activities of common interest are created. The spatial footprint of different resources in combination with constraints or facilitations imposed by the existing environment define unique spatial units. The qualitative or quantitative predominance of similar resources in the mix of spatial and social characteristics identified reveals the identity of each spatial unit. Finally, based on this identity, the users' profile and the directions of activities and interventions proposed to be implemented, in order to achieve the regeneration of the area under new conditions, are defined.

2 Broader Study Area

Heraklion, Crete, is chosen as a study area, specifically a part of the northern side of the district of Malevizi, which is defined based on geomorphological and qualitative factors. To the north and east, its boundary is defined by the coastline of the island, to the south by the Gorge of Almyros and the wildlife refuge that interrupts the possibility of human activity, and to the west by the valley of Fodele crossed by the Pantomatris River.[2]

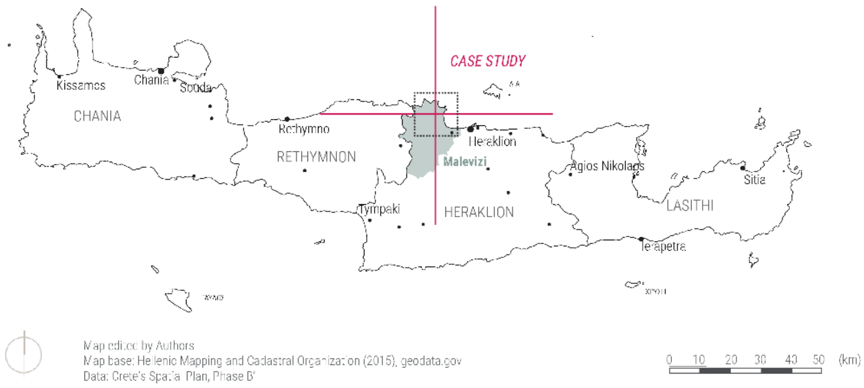

Fig. 1. Case study area [3]

As shown in Fig. 1, the area is located ~30 kilometers away from Heraklion city. Access to the area is provided primarily by the Northern Highway of Crete in the coastal part of the municipality, and secondarily by the regional road network in the highlands. The inland parts of the municipality are inaccessible and rarely visited. The Earth cover map [4] shows large areas of olive groves, vineyards and sclerophyll vegetation, revealing the predominantly agricultural and stockbreeding occupation of the local population until a few decades ago. [5]

Fig. 2. Almiros gorge, Fodele valley, Coastal front respectively

Of particular interest, are the spatial contradictions of the study area as shown in Fig. 2. On the one hand there is the inland with the protected areas of natural beauty and wildlife, such as part of the international geopark of Psiloritis mountain[1], and on the other hand the coastal front with the huge hotel units and the zones of degraded landscape due to mass tourism.

The mapping and statistical analysis (Fig. 3.) of the settlements are in the stage of economic transition from the primary to the tertiary sector. The spatial footprint of this phenomenon is the desertification of the lowland and mountain settlements in the inland areas and the significant distortion of the cultural and natural heritage of the coastal settlements. These observations have led to the selection of the specific study area, which is a suitable ground for the application of the proposed methodological tool.

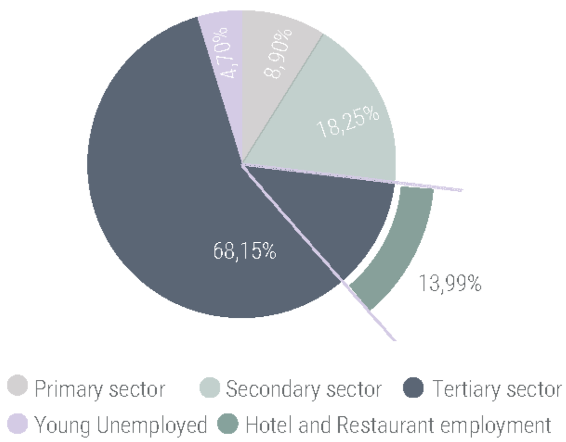

Fig. 3. Statistical data of employment divided by sectors

3 Stage 1: Spatial Unit Formation

The first phase of identification of the broader study area aims to understand its unique characteristics and is carried out by mapping endogenous resources, which are national and international landmarks.

The resources of the study area, which are initially identified over an area of 85.500 km^2, have similarities that allow them to be classified into seven categories: historical, religious, natural, geological, aquatic, residential and social. These categories relate to intrinsic qualitative characteristics of both the natural and man-made environment and

[1]Psiloritis Geopark belongs to the UNESCO International Network of Geoparks, and is characterized as an area of particular geological importance, uniqueness and beauty, in order to preserve its geological heritage. Within and outside the geopark, the territory is also covered by Natura 2000 sites and wildlife refuges for the protection of endemic fauna and flora. As a whole, they constitute endogenous resources of national and international importance, defining the specific identity of the natural landscape of Heraklion County.

the social practices that have developed over the centuries. Religious resources include local monasteries and churches; natural, forests and gorges; geological, rocks and caves; historical, ancient monuments, Venetian, Ottoman, modern history and museums; residential resources relate to accommodation, aquatic resources include beaches, waterfalls, wetlands and rivers and finally social resources include administrative authorities, associations, cooperatives, educational structures and other initiatives for organizing the social life of the area.

The first level of processing involves the creation of cognitive networks, that results from linearly connecting the points of interest that belong to the same category. This process, although still abstract, shows the tendency to unify and strengthen common qualitative characteristics, which could lead to the promotion of these characteristics, and the attraction of the appropriate users to whom each network is relevant to. At the same time, the projection of these coexisting network sin the area, reveals the rich, multi-layered facet of the endogenous characteristics, on which the area's revitalization can be based on. The categories of the identified networks define the general axes of intrinsic activities that can be strengthened, while the density of the endogenous resources of each network reveals the qualitative and quantitative predominance of each characteristic.

In the next stage of this phase, the spatial footprint of endogenous resources is recognised. In particular, the point-endogenous resources identified, are projected on the ground and then a radius of influence is defined for each one. The length of the radius is determined by the area occupied by the resource and the scope of influence. Then, the area of influence created is adjusted according to geospatial constraints and qualitative factors. Thus, the initial circular range of influence of each resource takes on an irregular shape as shown in Fig. 4. Similar resources tend to be attracted, conflicting uses tend to be repelled, while spatial links or barriers affecting communication between resources are considered. The deformation factors are briefly three: proximity, topography and accessibility.

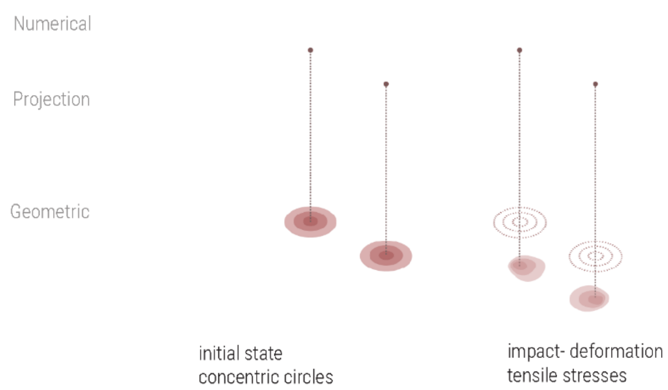

Fig. 4. Diagram presenting the deformation of the initial range of influence

The new, processed spatial footprint of the resources produces discrete densities and dilutions of the mix of endogenous site features recorded earlier. The mix of different resources highlights the multidimensional identity of the place. The identification of the densities indicates the coexistence of separate spatial units within the study area. The appropriate delineation of the resulting units forms the basis for the continuation of the method being developed (Fig. 5).

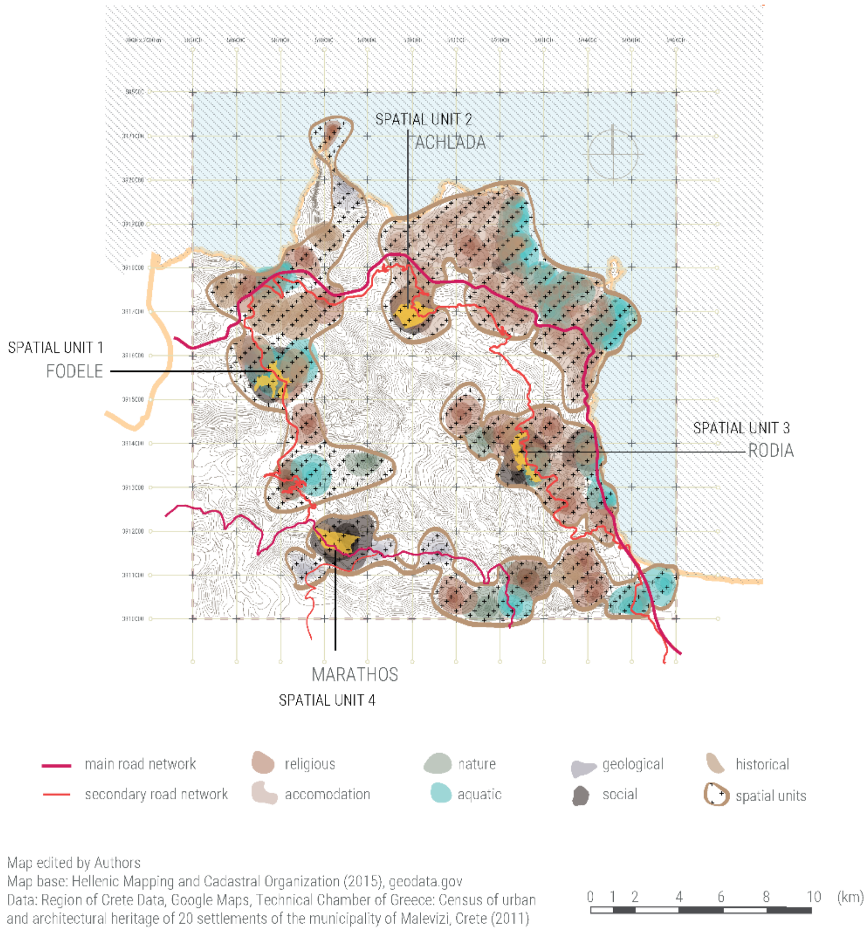

Fig. 5. The spatial units identified in the area

Despite the multitude of different categories of resources found in each unit, some seem to predominate either quantitatively or qualitatively, revealing a unit's identity. The so-called 'identity' of a spatial unit indicates the main axis on which its activation initiatives will be based on. The scope of influence of the resources enclosed within a unit determines their qualitative advantage over other resources. As the scale of identification of the place becomes larger, the mix of endogenous resources is inducted into four levels in order to simplify the process. The classification operates by condensing the original categories that were defined. The levels are: culture, natural environment, economy and administration. The identity of the spatial units is classified on the basis of these new axes.

The ultimate goal of economic and social revitalization of the study area can be divided into the activation of each distinct spatial unit created. An action plan for each spatial unit shall be formed, and it should be based on the identified potential of the endogenous resources. Every predominant level out of the four, either tangible or intangible, constitutes the comparative advantage of each spatial unit. The action plan also incorporates strategic tools to overcome the obstacles observed and utilize the opportunities appearing due to extraneous trends.

The action plan proposed in the study area aims to reverse the trends that have led to the depopulation or the degradation of the rural area. Within the spectrum of these trends, the action plan could incorporate plans coming from institutional bodies and international, national, regional and municipal administration [6], "bottom-up" actions initiated from associations, cooperatives, collectives and the professional expertise. Most importantly, the driving force behind the activation of each spatial unit is its human capital, that uses it and initiates actions that revolve around its resources.

As stated above, the driving force behind each spatial unit is its human capital. It is therefore necessary to define the users' profile in order to identify activities that correspond to the interests of these users. The direction of these activities corresponds with the identity of the spatial unit determined above.

The users of the space belong to diverse groups and can be classified into subcategories based on the time frame of their stay in the spatial unit. Categories of users with a long-term, medium-term or short-term stay are foreseen, i.e., locals, new residents, visitors etc. The activity scenarios to be integrated into the site should focus on attracting permanent and semi-permanent residents or temporal visitors at different times of the year so that the spatial units remain lively throughout the year (365-day approach), in a balanced manner.

Concluding, during the "spatial unit formation" stage that is described above, the endogenous resources of the study area are recorded and classified into categories of qualitative and spatial characteristics, which then form cognitive networks of similar resources. In this way, the multi-layered richness of the area and its potential are highlighted, and the direction to which sustainable activities can be developed is identified. Taking the spatial footprint of the mix of resources as a starting point, spatial units are created and their identity is determined. This identity defines the main axis of activities and the users' profile for the corresponding unit. The next stage focuses on each spatial unit individually, mainly on identifying means of activation based on its special characteristics. The tools of endogenous resources, external trends, networks, spatial units and users, are repeated and adapted to the needs of each scale.

In the study area described, four spatial units were identified and named after the settlements they enclose. These are the spatial units of Fodele, Achlada, Rodia and

Marathos. Each one's identity, based on the comparative advantages it has, falls into one of the four categories. The research continues with the spatial unit of Fodele.

4 Stage 2: Spatial Subunit

The spatial unit of Fodele has been created predominantly by the concentration of natural and cultural resources. It was chosen as a case study as it differs from the other units because the primary sector is still of a major importance (Fig. 6). It is in a transitional phase, as on the one hand roughly one third of its population [7] is still engaged with agricultural activities, on the other hand preoccupation with touristic activities gradually gains popularity amongst locals. Nevertheless, any spatial unit could be approached in a similar way.

Fodele is a settlement located in Crete, with a rich agricultural ecosystem, - especially orange groves - nourished by the Pantomatris River, but also naturalistic points of interest that extend from the mountainous part all the way to the sea. Fodele represents a typical example of a unit, which economy was primarily based on the primary and secondary sectors, but as mentioned today it is transitioning towards the tourism sector. The transition gets mainly represented by hotel units on the coastal part, airbnb within the settlement, retail stores and restaurants (taverna, cafe) addressing tourists and visitors. The settlement’s most important landmarks are El Greco museum and the Monastery of St. Panteleimon (cultural) and Fodele Park (natural).

In winter, as recorded during interviews with locals, the settlement becomes desolated as residents move to urban centres, while the ones who stay have to commute frequently in order to access basic services such as supplies, education and leisure activities.

Access to the settlement is provided by the Northern Highway of Crete and the local road network. Visiting neighboring cities and settlements today requires the exclusive use of private cars. The coastal section, and river’s mouth, has been extensively deployed, as a hotel complex has completely appropriated the beach and the habitat.

4.1 The Procedure

In the Fodele spatial unit, the repetition of the proposed procedure (the generation of the spatial units by mapping resources) creates new spatial sub-units. Each sub-unit is evaluated according to the category it belongs to (culture, natural environment, economy, administration). The numerical superiority of concentrated resources of similar type inherits its identity to the newly formed spatial subunits. In this way, the goal of activating the whole unit of Fodele is distributed over the gradual activation of the individual subunits. When the majority of the subunits is activated, the whole spatial unit also is.

In consecutive successive focuses carried out on the site, the endogenous resources are enriched in accordance with the cartographic scale. With the enlargement of the map scale resources of local range are being added that could not be recorded at smaller scales, highlighting new spatial and social qualities.

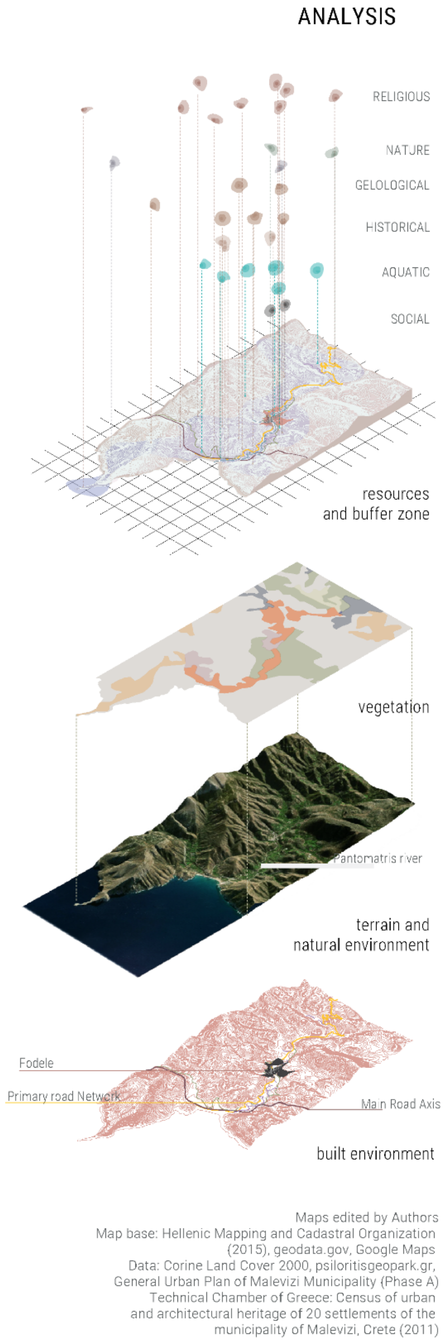

Fig. 6. Attraction of appropriate that defined Fodele's identity

Up until this point, the resources could be mapped and identified by off-situ research. This particular stage requires mapping of endogenous resources in-situ, as the resources may have not been significant enough to be recorded officially. These resources are of local importance and influence. This case study includes archaeological, folklore, naturalistic, religious and geological sites. Many are retrieved by oral history and spatial fragments, such as old paths and routes, abandoned or disdained buildings and abstract landscape formations. Non-existing resources were integrated as well, for they are plans for new buildings or uses of local administration.

What becomes apparent at this point is that endogenous resources differ, not only in terms of type, but also in terms of significance. New criteria arise as some resources prove to be crucial for the survival and daily life of the local population, while others attract residents and visitors for a number of reasons (recreation, interest, promotion), and some are in complete disuse.

It's also important to highlight the complex correlation between the endogenous resources and the attracted users. Specifically, each resource category attracts certain groups of users, and different resources attract users and activities for different durations and with varying intensity. For example, the annual Orange Festival organized by the cultural association (social resource) in the settlement attracts a large number of visitors for one night (short-term use, users: visitors, and residents), while the El Greco Museum attracts short-term visitors mainly in the summer months. Also, the abandoned laundry-building attracts no one, -although it was once the major meeting place for the women of the settlement-and the prospective sports center will attract the local population (residents) for almost daily use.

The aforementioned examples relate the factor of time to the scope of influence and use of each resource. Some resources have been important in the past, but not anymore, while others are expected to become an area of interest in the future. Therefore, assessing the status of the resources, according to their importance to specific user groups, is considered a necessary process for the activation of the spatial unit. Points of interest that attract user groups actively and on a recurring basis are categorized as active resources, (Fig. 7) while resources in a dilapidated state that are unable to attract interest at the present time are classified as inactive. Finally, resources that are valuable to some user groups but inaccessible or underutilized are classified as dormant resources. By reversing or leveraging the current state of endogenous resources, and with the driving force being stakeholders, who are also active, dormant or inactive, a dynamic way of approaching a spatial unit emerges.

As discussed, the activation of the entire spatial unit requires the activation of each spatial subunit and most importantly a strong connection between them. To achieve the first condition, the utilization of active resources is chosen. However, not all spatial subunits have active resources. In this case, it is proposed to strategically utilize dormant or even inactive resources in a way that leverages the endogenous characteristics of the site. In order to achieve the second condition, complementary uses between the spatial sub-units are needed to establish self-sufficient and sustainable spatial units. Architectural interventions are critical for resources' activation, including re-use or repurposing of existing buildings or open-spaces, restoration and place-specific design.

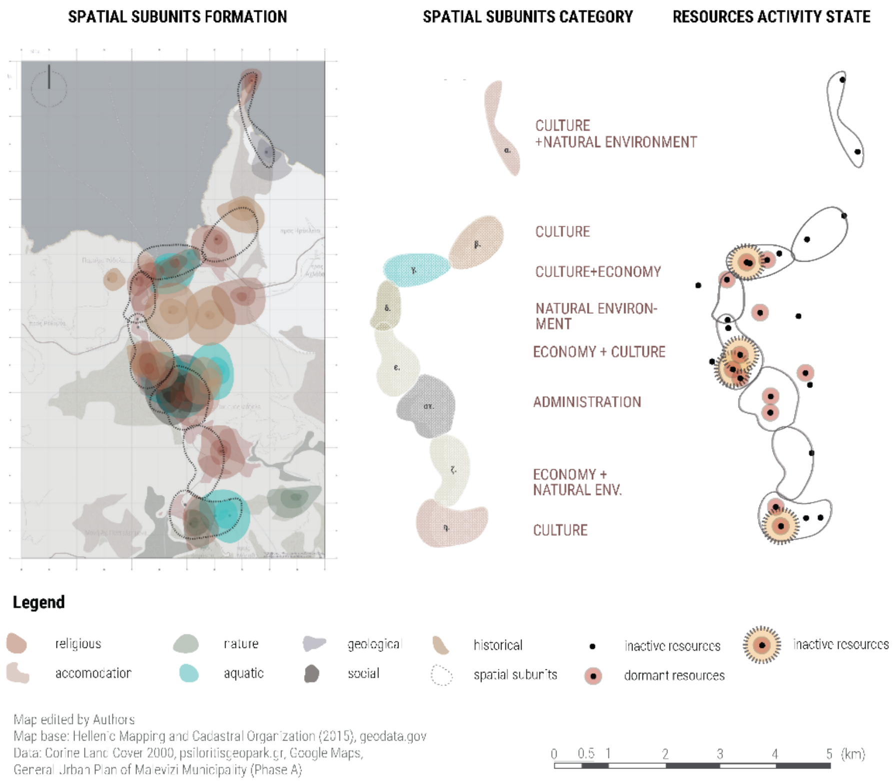

Fig. 7. The sub-units of Fodele spatial unit and resources classification

In addition, the resources should be easily accessible by various means and in close proximity to residential areas in order to be utilized. Thus, accessibility and interconnection between the resources is recognized as being of utmost importance. Subsequently, the creation of primary and secondary connections is prioritized and the key design gesture is to highlight existing active resources and redesign inactive ones.

Summarizing, the methodological stage of "Fodele Spatial Unit" described above, begins with identifying spatial sub-units and their identity, which falls within the four categories specified in the previous stage. More endogenous resources are then detected based on new methods of in situ mapping and qualitative assessment, which are classified as active, dormant or inactive. Ultimately, the aim is to activate all resources in each sub-unit individually and link them together. Architectural design, repurposing of points and accessibility are highlighted as key factors in utilizing the endogenous characteristics of the site and therefore the route is defined as a key tool in the planning method presented.

5 Stage 3: The Route as a Key Tool

5.1 Case study

In the next stage of this methodology, focus turns to achieving the promotion and accessibility of the resources of each subunit both individually and as a whole. As mentioned, the design of the unit is place-specific, thus the existing spatial patterns should be mapped, in order to adapt to the place's unique qualities. What emerges at this stage, are points of interest and routes that can be utilized to spatially activate the subunit's resources. The activation requires accessibility which shall be based on existing paths and road networks or follow the traces of the historic ones. A network of single pathways, running through active resources, picking up new complementary uses (by restoring and repurposing existing resources) and addressing to a diverse group of users may contribute to unify the spatial unit. In this way, the existing trace of the paths is redefined and activated.

In the Fodele spatial unit, the subunits selected to be studied, reveal points that are identified as strategic parts for intervention. These are path intersections, i.e., hubs; path and street intersections, i.e., entrances to the route; and plazas, resources and other spatial forms, i.e., stops.

In the research carried out in the spatial subunit of the Museum, where the endogenous resource of the El Greco Museum (culture) and the church of Virgin Mary (culture) are located, there are dirt roads that were formerly used by the locals, and others that are currently used by farmers. Thus, this subunit whose identity category is culture, acts as a pole for visitors. In the adjoining spatial unit of the riverbed, no active resources are found, only cultivated areas of oranges, olive trees and greenhouses. Due to these endogenous characteristics, in this subunit, the focus of interest is on the primary and secondary sector. Existing abandoned greenhouses (inactive resources) are being restored and taking on agritourism uses (identity category: economy), which can be accessed via the central riverside route of a cultural character (see Museum pole), making use of the existing agricultural paths, and the rest strategic parts of intervention. Thus, an agritourism centre is proposed, which could be a new active resource, utilizing existing inactive assets, consistent with the identity of the sub-unit. The pathway that runs across all subunits, makes the new use accessible by foot, and the proximity to the settlement (proximity to accommodation) increases the potential of activating the resource. Finally, it appeals to people who use the site for different periods of time and purposes. Short-term; visitors and travelers; Mid-term; agricultural specialists, interns, agritourism, Long-term; local farmers, workers specialized in the operation of the centre, professionals etc.

In other districts, plateaus are proposed as recreation and rest areas. Inside the settlement a redesign of the public space and an info kiosk pointing the entrance to the riverside path -and welcoming the visitors- are proposed.

6 Discussion and Conclusions

The research described in this paper proves that systematic analysis and interpretative mapping of the rural space is a necessary tool for its redefinition and revitalization. Implicit characteristics are very important, in order to define a specific area's (spatial unit's) identity in an algorithmic manner. These characteristics involve endogenous resources and geomorphological features of a selected space.

However, the sole recording and analysis of endogenous resources cannot effectively achieve the goal of understanding and defining the identity of a place. It is essential to associate the data with qualitative characteristics. These are the place itself, memory, history, culture, tradition and context (time, external factors). This explains why certain resources tend to be concentrated or diluted, tend to influence more or less than other resources, and ultimately tend to be recognized and protected or destroyed. The identification of interconnections, between resources, outlines distinct spatial units with a unique identity.

Social resources are key for the revitalization of a place. Human resources act as an activating force for the operation of each spatial unit. Without people (local and new residents) and their activities, the place desolates, as well as every precious characteristic attributed to it. Planning for people, especially locals, and in collaboration with them, can prevent the trend of rural abandonment.

Another key component of the methodology described, is mapping resources in successive scales. The analysis that was formed in the smaller scale is used as feedback for the next one. By enlarging the scale, the records are enriched. For larger scales, in-situ research is indispensable. Specifically, experiencing and observing the place, as well as interacting with and interviewing residents of different social groups and stakeholders, helps to recognize and record new resources that are inactive or in dormant state, thus could not have been recorded in previous scales.

Finally, determining the users of the rural space specifies the directions of the strategic planning. Time poses an important factor in this process. As mentioned, an influx of users visiting a place for a limited period of time, tends to over-activate specific resources of this place for the aforementioned period. In contrast, when those seasonal users leave, the resources tend to deactivate. Hence, users living in the area for different lengths of time should be addressed. Simultaneously, a high demand from one group of users and for specific resources, leads to monopolization of uses, thus partial activation just for those particular resources. This leads to gradual degradation of some resources, and failure to address other groups of users. A sustainable planning approach should be inclusive and address to a multitude of users, of diverse background and occupation, and for various durations of using the place.

Choosing Crete, especially a degraded and understudied part of it in Northern Heraklion, provided a prolific ground for this methodology to flourish. Focusing in the Fodele spatial unit as a pilot study, also allowed the methodology to enrich. Researching more places using this methodology could possibly point out more factors, as planning directions are site-specific, not mass and homogenized, respectful of places unique identity and citizen's culture, needs and way of life.

Using the described methodology, a brief diagram of which is presented in Fig, 8, Fodele's case study resulted mainly in the formation of a riverside pathway and the (re)design of activation points along this axis. The path turned out to be the main design tool for the strategic management and planning of the spatial units, in order to create access to existing and new endogenous resources, and their activation, for the specific needs of a diverse range of users.

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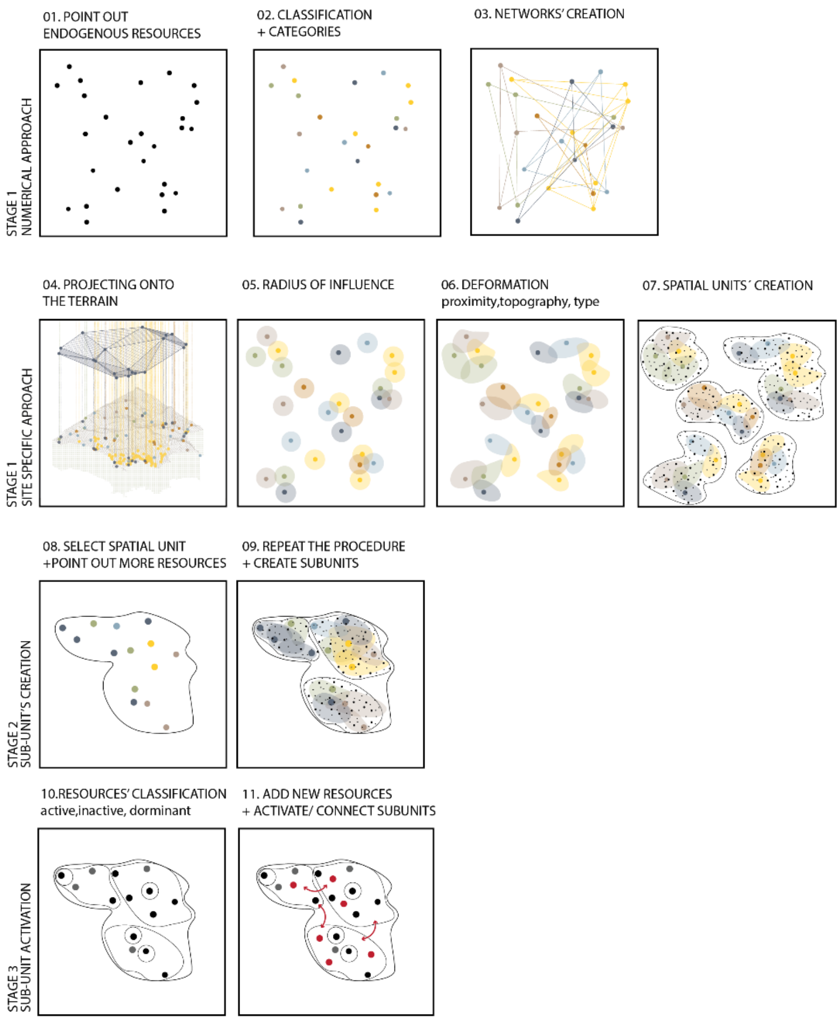

Fig. 8. Explanatory diagram briefly showcasing the consecutive stages of the methodology

The research proves that a comprehensive analysis of rural space and the determination of the appropriate plan to redefine and re-activate it, is a complex, multifaceted procedure that involves dynamic factors. Nevertheless, its importance and necessity are indisputable, especially when it comes to respecting and protecting the culture, the nature, the unique physiognomy of the place, while at the same time addressing contemporary needs. Finally, the adaptation of this strategic planning to the intrinsic characteristics and comparative advantages of a place, can shape a sustainable, culturally rich future of traditional rural settlements that are bound to be degraded irreversibly.

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