Early Modern Age Fortifications

Knowledge for Management, Conservation and Valorisation

Marco Giorgio Bevilacqua, Roberta Spallone, Andrea Giordano, Michele Russo (Eds.)



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ISBN 9788899586546

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ISBN: 9788899586546



MARCO GIORGIO BEVILACQUA, ROBERTA SPALLONE, ANDREA GIORDANO, MICHELE RUSSO (EDS.)
EARLY MODERN AGE FORTIFICATIONS.
KNOWLEDGE FOR MANAGEMENT, CONSERVATION AND VALORISATION

© PUBLICA, Alghero, 2025
ebook ISBN 9788899586546
Pubblicazione e stampa Maggio 2025

The volume presents the outcomes achieved at the end of the first year in the project 'INFORTREAT. Reconstructing the Early Modern bastioned front. INformation models for the fruition of constructive knowledge in FORtified architecture TREATises (16th-18th Century): a new integrated analysis tool for the interpretation, restoration and maintenance of Early Modern fortified heritage', financed by the European Union - Next-GenerationEU - National Recovery and Resilience Plan (NRRP) – MISSION 4 COMPONENT 2, INVESTMENT N. 1.1, CALL PRIN 2022 D.D. 104 02-02-2022 – CUP N. I53D23005420006.
The volume includes external contributions presented during the INFORTREAT Mid-Term Conference 'Le Fortificazioni di Eta' Moderna: Conoscenza per la Gestione, Conservazione e Valorizzazione', held in Rome on 11/11/2024.

PROGETTO GRAFICO & IMPAGINAZIONE
Martina Casciola

in COPERTINA
Immagine delle mura della Cittadella di Alessandria; in primo piano il baluardo di Santa Cristina.
Foto ed elaborazione di Michele Russo & Martina Casciola.

PUBLICA
Dipartimento di Architettura, Urbanistica e Design
Università degli Studi di Sassari
WWW.PUBLICAPRESS.IT

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Preface

The book we are giving to the press today contains the contributions presented at the Seminar entitled "Le Fortificazioni di Età Moderna: Conoscenza per la Gestione, Conservazione e Valorizzazione" (Modern Age Fortifications: Knowledge for Management, Conservation, and Valorization), held in Rome on 11/11/2024.

The seminar was organized as the mid-term conference in the scope of the PRIN2022 INFORTREAT project, funded by the European Union – Next Generation EU. The overall goal of the project is to make accessible the constructive knowledge related to military architecture (as described by early modern treatises) through 3D digital information models that can be consulted and queried by scholars, professionals, and the community.

The project is conducted by groups of scholars belonging to four Italian university sites: the lead research group, from the Dipartimento di Ingegneria dell'Energia, dei Sistemi, del Territorio e delle Costruzioni at the Università di Pisa is led by the principal investigator Marco Giorgio Bevilacqua, that from the Department of Architecture and Design at the Politecnico di Torino by the associate investigator Roberta Spallone, quello del Department of Civil, Building and Environmental Engineering at the Università di Padova by the associate investigator Andrea Giordano, that from the Department of History, Representation and Restoration of Architecture at Sapienza University in Rome by the associate investigator Michele Russo. The latter and his group organized the seminar, the outcomes of which we present. The study day was organized to combine syntheses of the work conducted, mostly interdisciplinary and interseated, up to the end of the first year of the two-year project. This was complemented by invited multidisciplinary talks by international scholars dedicated to studies and interventions on the fortified heritage.

The structure of the present volume echoes the articulation of the day. The contribution by Giulia Flenghi and Fabrizio Natta presents a Literary Review about Digital Tools for the Documentation of Fortified Architecture. To achieve this goal, they set up a methodological approach capable of capturing the surveying techniques used in the field and their application in semantically rich digital models.

Valentina Burgassi, Rosa Maria Marta Caruso, Iole Branca, Martino Pavignano, and Denise Ulivieri deal with a Proposal for developing a Digital Database of Military Architecture Treatises. They illustrate the digital infrastructure designed to store relevant information for the INFORTREAT project, to systematically analyse the selected treatises, and highlight the aim to advance the understanding of the geometric profiling of fortress defences, a fundamental aspect of early modern military strategy.

The work by Marco Saccucci, Assunta Pelliccio, and Andrea Giordano faces the issue of the Ontology of the Information Classes for the Knowledge and Modeling of Military Architecture in the Restoration and Maintenance Processes. The authors underline the value of Ontology, which facilitates the hierarchical organization of concepts and relationships, for understanding this complexity and its pertinency in parametric digital modeling, such as HBIM, which relies on precise semantic classification.

In the chapter entitled Digital Informative Models of Early Modern Military Architecture Treatises. Methodological Approach and First Results, Piergiuseppe Rechichi, Virginia Miele, Enrico Pupi, Fabrizio Natta, Marco Vitali, Roberta Spallone, and Marco Giorgio Bevilacqua observe that the design logic of military architecture can surprisingly be combined with contemporary parametric design logic, highlighting the potential of using procedural modeling tools and visual programming languages to create digital models of fortification systems. Moreover, the authors affirm that the applicability of a Building Information Modeling approach appears evident to ensure an effective correspondence between the geometric characterization of the fortification system and the complex network of textual information disseminated in the treatise.

Michele Russo, Gabriella Caroti, Andrea Piemonte, Edoardo Piccoli, Paolo Bertoncini Sabatini, and Martina Casciola in the chapter Digital Survey Techniques for the Documentation of Military Architecture. The Case of the Citadel of Alessandria and Santa Croce Bastion of Lucca underline the complexity of surveying fortified walls. Indeed, they observe that these artefacts require careful survey planning and experimental approaches to preserve their original shape.

Within this process, data traceability is essential to controlling the overall accuracy and obtaining reliable metric information for interpretive purposes.

In the chapter Restoration and Maintenance Issues for the Early Modern Fortified Heritage. Michele Asciutti states that a conscious restoration project cannot abstain from knowledge of the issues related to the fortresses of the modern era, often consisting of extremely imposing constructions, calculated in terms of size, shape, and volume of wall masses, and their relationship with the city, in the multiple aspects they have taken on over the centuries.

The research presented by the invited international speakers deals with multidisciplinary content related to military architecture. The Defense Towers of the Coast of the Kingdom of Valencia in the Modern Age by Pablo Rodríguez-Navarro and María Teresa Gil Piqueras from the Department of Expresión Gráfica Arquitectónica at the Universitat Politècnica de València in Spain, analyses the system of defence towers built along the coast of the Kingdom of Valencia between the 16th and 18th centuries, highlighting their design, distribution, and strategic function, based on documentary sources but especially on the towers still preserved, both in their entirety and as archaeological remains. This knowledge has allowed to conduct formal, constructive, and typological studies and analyses of the defence strategies devised by the engineers of the time.

In the chapter Beyond the Walls: The Entrenched Camp of Rome, Studies, Surveys, Drawings, Giovanna Spadafora from the Department of Architecture at the Università Roma Tre, proposes a synthesis of studies carried out by the author in the last 10 years within the entrenched field of Rome. Starting from the first results presented between 2012 and 2014 within the 'Feasibility study for the recovery and valorisation of the Forts of Rome', the research continues within the PRIN project, studying the defensive systems of the city - the walls and the forts - to reconstruct their different histories of function and patrimonialisation according to a new paradigm: to transform these sites from places of defence to areas of knowledge open to the public.

The contribution entitled The Model of Reality and the Project. Interpretative Aspects for the Restoration of Fortified Structures, presented by Bianca Gioia Marino from the Department of Structures for Engineering and Architecture at the Università degli Studi di Napoli Federico II, deals with the extreme complexity of the architectural heritage that characterises the cognitive process of its material evidence. The digital technology of the last twenty years has highlighted the inexhaustible wealth of data that can be recorded, represented, and calculated. The author, starting from this consideration, initiates a critical reflection on the meaning of the model within the reference context, as it is currently conceived in the National Plan for the Digitisation of Cultural Heritage.

Elvira Cajano, President of the Permanent Commission for the Protection of the Historical and Artistic Monuments of the Santa Sede, presents the chapter Protection Activities for Cultural Heritage. The Case of the Military Forts in the Entrenched Camp of Rome. She underlines that among the numerous institutional activities of the Ministry of Cultural Heritage and Activities, as well as those of the territorial Superintendencies, there are those related to the exercise of protection functions over the historical heritage of military origin. The author, beginning with examining the legal framework, illustrates the importance of defining methodological and operational indicators for protection and conservation, using examples to promote quality projects from both architectural and landscape perspectives.

Information Models for the Fruition of Constructive Knowledge in Fortified Architecture Treatises

Marco Giorgio Bevilacqua, Roberta Spallone, Andrea Giordano, Michele Russo

Introduction

Nowadays, digital models are more and more deployed for the study of Cultural Heritage (CH), to enhance documentation, valorisation and dissemination activities and to support appropriate intervention and conservation practices. However, their application to the fortified heritage is a major challenge still requiring innovative solutions.

Building Information Modeling (BIM) techniques, traditionally set up for the case of new buildings (ISO 19650:2019) have been translated to the Heritage -or Historic- domain (H-BIM) (López et al., 2018; Angulo-Fornos & Castellano-Román, 2020), and web-based platforms have been developed to enable the on-line sharing of digital heritage models (Apollonio et al., 2012, 2018). Within such systems, the digital model, besides containing significant geometric information, is enriched with complementary, knowledge-related information, e.g., concerning the results of historical, technological, conservative, structural analyses, at different Levels of detail (LOI Level of Information) or Levels of geometric information (Level of Geometry LOG, UNI-11337-7:2018). The definition of the levels is strictly related to the purpose of the model, e.g., historical-critical analysis, restoration interview or facility management (Tommasi, 2017).

A crucial aspect in the construction of digital information systems for CH is the study of the real, existing object: this can be done through the mediation of digital surveying -laser scanning and photogrammetry- (Croce et al., 2021; Pocobelli et al., 2018) or rather via the interpretation of the conceptual, ideal models, as derived from architectural treatises, that are upstream of the realization of a given construction (De Luca 2014). In this latter sense, e.g., Carpo (2016), De Luca et al. (2007) and Cache (2009), formalized the architectural knowledge of treatises ranging from Vitruvius to Palladio, for the generation of template shape libraries of classical architecture; the works by Baik (2017), Frazer (2016), Quattrini et al. (2015), and Brumana et al. (2013), were devoted to the construction of parametric libraries of elements for chosen groups of buildings sharing similar features.

Referring to the historical military architecture domain, the digital documentation activities have been so far based on the application of surveying techniques and have mainly concerned the analysis of specific and isolated case studies of fortified constructions and walls.

If in the Middle Age the local identity, in terms of building knowledge and availability of raw materials, strongly influenced the fortification projects at the time, with the advent of the bastioned front in the Early Modern Age an impressive phenomenon of dissemination of knowledges at an international level started, thanks to the diffusion of printed treatises dedicated to military architecture. However, the considerable wealth of knowledge embodied in these treatises, although being the source of constructive inspiration and a valuable tool for understanding these systems, still remains hardly accessible, except for a small circle of scholars. The analysis, both textual and graphic, of historical military architecture treatises could be beneficial for the codification of architectural languages and models of historical fortification, and it could indeed provide original tools for Public Administrations, architects, engineers, restorers in support of maintenance and conservation purposes.

INFORTREAT research project responds to the need to make this knowledge accessible by the open source provision of digital information models of Early-modern fortification projects of urban walls, fortresses and citadels as described in a number of the most important Italian and European treatises on military architecture between the 16th and the 18th centuries. The goal is to translate this knowledge within virtual environments, even by relying on 2D and 3D digital representations that can be readily consulted and interpreted in an open-access web-based digital platform primarily for research and conservation purposes (restoration projects, maintenance plans, etc.), as well as for higher education and other activities promoted by public and private bodies in the field of CH. For the creation of the digital information models, Building Information Modeling (BIM) techniques are applied. The effectiveness of BIM, traditionally set up for the optimization of design, building and management of new constructions, is today internationally recognized in the field of Built Heritage (HBIM), thanks to the possibility to integrate and manage in a single model any data useful to perform an in-depth analysis of an existing artefact.

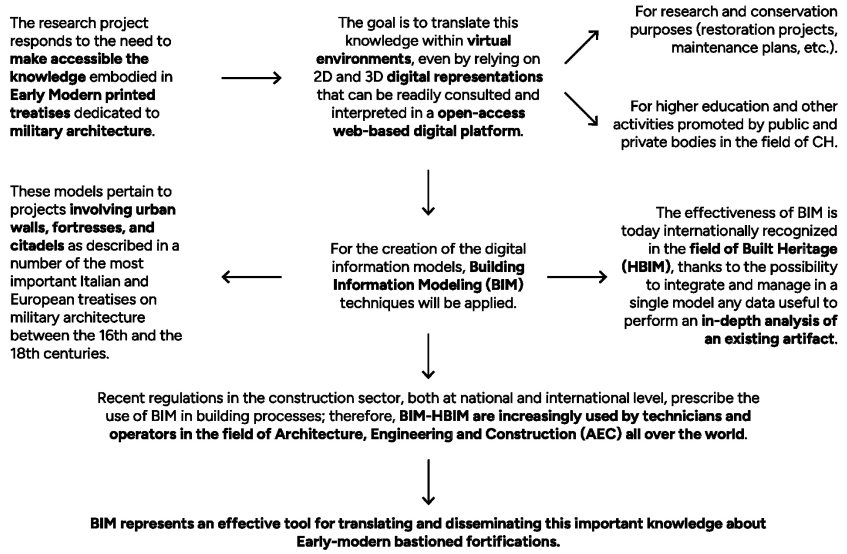


Fig. 1 - INFORTREAT research objectives (M.G. Bevilacqua, R. Spallone, A. Giordano, M. Russo).

It is also worth noting that recent regulations in the construction sector, both at national and international level, prescribe the use of BIM in building processes; therefore, BIM-HBIM are increasingly used by technicians and operators in the field of Architecture, Engineering and Construction (AEC) all over the world. BIM, therefore, represents an effective tool for translating and disseminating this important knowledge about Early-modern bastioned fortifications.

In order to achieve INFORTREAT main objectives, the research methodology is developed based on the following steps:

1. Enrichment of the state of the art on current approaches to the digitization of cultural heritage, with reference to the several domains of the research: 3D surveying techniques application for the virtual restitution of military architecture; methods for the generation of semantically rich H-BIM models; platforms for the digital access and sharing of fortified constructions;

2. Extensive selection and analysis of 16th to 18th century Italian and European treatises on military architecture, in order to form a critical anthology on bastioned front construction;

3. Definition of a specific procedure, based on a hierarchical structure, for carrying out the breakdown or semantic classification of the overall architectural characteristics of fortifications, according to HBIM 'Work Breakdown Structure' (WBS), which logically identifies the construction elements as uniquely recognizable, and following the indications of the Unified Classification for the construction sector (UNICLAS) starting from the definition of the functional space to which the environmental and use data are associated;

4. Generation of BIM models of regular bastioned fronts and construction sections of curtain walls from historical treatises, following the ontology of informative classes described before, and applyling Visual Programming algorithmsin order to automate the digital reconstruction of some recurring and relevant elements;

5. Development of HBIM models of some significant bastioned systems of fortifications built between 1500 and the early 1700s selected as case studies, for which all the historical documentation and results of recent restoration works are collected and digital surveys are developed.

6. Validation of both theoretical informative models from treatises and informative models of the selected real case studies of the digital representation, completing the conventional assessment of the Level of Detail (LOD), as specified by the American Institute of Architects (AIA) Protocol G202-2013 Building Information Modeling, and of the Level Of Development (LOD) as defined by UNI 11337-4:2017, adopted in Italy.

7. Development of a web-based digital platform, fully accessible for research and conservation purposes (restoration, maintenance etc.), where all the digital information models will be visualized, publicly available and open-source.

This book presents the first results of the project at the end of the first year of activity, presented at the Mid-term Conference organized in Rome by the research group of La Sapienza University. The conference provided an important opportunity to discuss and verify the methodological validity and effectiveness of the results with leading scholars and professionals active in the field of conservation and enhancement of the fortified heritage.

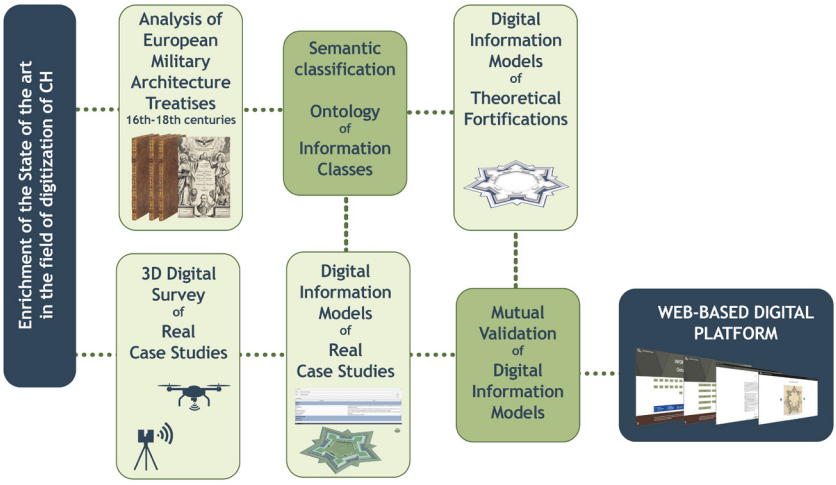


Fig. 2 - Methodological workflow (M.G. Bevilacqua, R. Spallone, A. Giordano, M. Russo).

References

Angulo-Fornos, R., & Castellano-Román, M. (2020). HBIM as support of preventive conservation actions in heritage architecture. *Applied Sciences*, *10*(7), 2428.

Apollonio, F. I., Gaiani, M., & Sun, Z. (2012). BIM-based modeling and data enrichment of classical architectural buildings. *SCIRES-IT*, *2*(2).

Apollonio, F. I., Gaiani, M., & Sun, Z. (2018). A 3D-centered information system for the documentation of a complex restoration intervention. *Journal of Cultural Heritage*, *29*, 89–99.

Baik, A. (2017). From point cloud to Jeddah Heritage BIM: Nasif Historical House – case study. *Digital Applications in Archaeology and Cultural Heritage*, *4*, 1–18.

Brumana, R., Oreni, D., & Raimondi, A. (2013). HBIM for documentation, dissemination and management of built heritage. *International Journal of Heritage in the Digital Era*, *2*(3), 433–451.

Cache, B. (2009). *Fortuito supra acanthi radicem: Essai de lecture contemporaine du De Architectura de Vitruve*. University of Paris I.

Carpo, M. (2016). Parametric notations. *Architectural Design*, *2*(2), 24–29.

Croce, V., Cuca, B., & D'Andrea, A. (2021). From the semantic point cloud to heritage-building information modeling: A semiautomatic approach exploiting machine learning. *Remote Sensing*, *13*(3), 461.

De Luca, L. (2014). Methods, formalisms and tools for the semantic-based surveying and representation of architectural heritage. *Applied Geomatics*, *6*, 115–139.

De Luca, L., Véron, P., & Florenzano, M. (2007). A generic formalism for the semantic modeling and representation of architectural elements. *The Visual Computer*, *23*(3), 181–205.

Frazer, J. (2016). Parametric computation: History and future. *Architectural Design*, *2*, 128–133.

López, F., Lerones, P. M., Llamas, J., Gómez-García-Bermejo, J., & Zalama, E. (2018). A review of heritage building information modeling. *Multimodal Technologies and Interaction*, *2*(2), 21.

Pocobelli, D. P., Boehm, J., Bryan, P., Still, J., & Grau-Bové, J. (2018). BIM for heritage science. *Heritage Science*, *6*(1), 30.

Quattrini, R., Pierdicca, R., & Morbidoni, C. (2015). From TLS to HBIM. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XL-5/W4*, 367–374.

Tommasi, C., & Achille, C. (2017). Interoperability matter: Levels of data sharing, starting from a 3D information modeling. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-2/W3*, 623–630.Brumana, R., Oreni, D., & Raimondi, A. (2013). HBIM for documentation, dissemination and management of built heritage. *International Journal of Heritage in the Digital Era*, *2*(3), 433–451.

Digital Tools for the Documentation of Fortified Architecture. A Literary Review

Giulia Flenghi, Fabrizio Natta

Introduction

The study of fortified architecture has increasingly relied on digital tools to document, analyse, and interpret historical structures. In this context, ensuring a comprehensive understanding of the state of the art requires a methodological approach capable of capturing both the surveying techniques used in the field and their application in semantically rich digital models (The London Charter, 2009; Seville Principles, 2017; VIGIE 2020/654, 2020). To achieve this, two complementary research methodologies have been adopted, each addressing a different yet interconnected aspect of digital documentation.

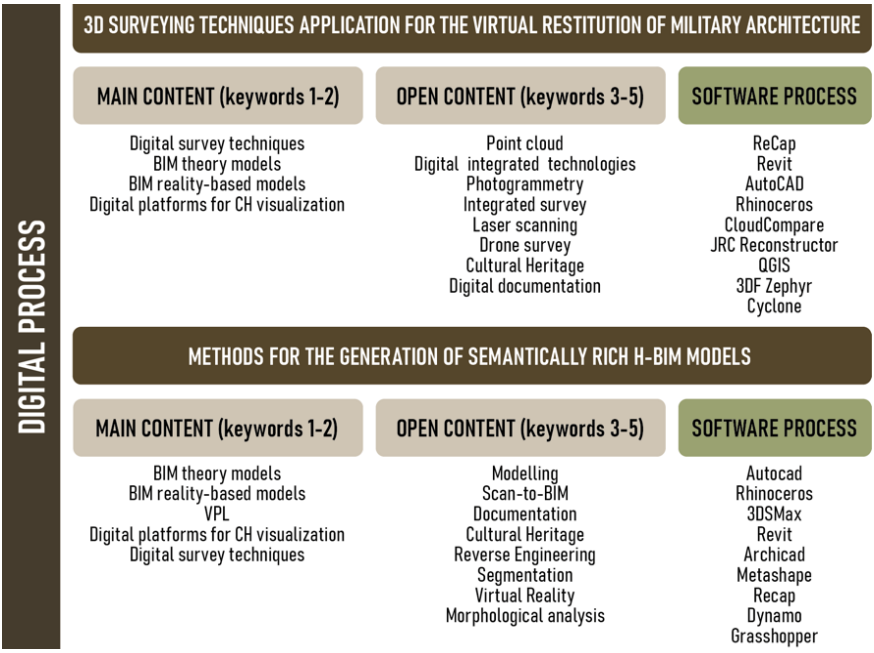


Fig. 1 - Overview of the reference cataloguing phase, highlighting relevant categories (Processing: G. Flenghi, F. Natta).

The first approach structures an interactive bibliographic database, enabling the analysis of trends in surveying methods, historical periods, and fortification typologies.

This systematic framework helps identify research gaps and emerging directions in the field. The second approach delves into HBIM modelling, examining the transition from survey data to structured digital reconstructions, with a focus on point cloud segmentation, parametric modelling, and semantic integration.

By combining these two complementary methodologies, this study ensures a more complete and structured review of digital tools for fortified architecture documentation. The first approach allows for a broad, quantitative overview of existing research, while the second delves into qualitative and methodological advancements in digital modelling.

Together, these strategies provide a more nuanced and integrated understanding of how surveying techniques and HBIM models contribute to the documentation and preservation of military heritage (Fig. 1).

3D Surveying Techniques Application for the Virtual Restitution of Military Architecture

To enhance the state of the art and facilitate a structured analysis of the collected contributions, a methodology based on a Google Sheets spreadsheet has been implemented. This allows filtering and cross-referencing of various parameters from the gathered scientific contributions.

The filtering criteria include the author's name, the title of the contribution, the year of publication, the adopted survey technique, the research objective, and other key factors. This approach enables a targeted exploration of the data, making it easier to identify trends, gaps, and future research directions (Fig. 2). The integration of interactive filtering tools allows for the generation of graphical visualizations that illustrate the percentage distribution of contributions based on the selected parameters.

For instance, it is possible to analyse the distribution of papers according to survey techniques, highlighting areas with a higher concentration of studies and those where further investigation opportunities emerge (Fig. 2).

	A	B	C	D	E	F	G	H	I	J	K
1	Authors	Titol	Year	Survey tecnique	Aim	Communication output	Fortifications	Periodization	Digital model	HBIM-oriented	Note
2	Altadonna, A., Martello, G., Nastasi, A., Todesco, F.	The Fort of the Holy Savior in Messina: historical cartography and digital surveys.	2023	Integrated survey	restor...		Coastal fo...	XVI			
3	Barlozzini, P.; Camagni, F.; Fascio, M.; Lanfranchi, F.; Martelli, L.	From a survey the current state to a hypothesis of the former state. A digital trip in augmented reality into the 'deleted history' of the Capo d'Uomo Tower on Mount Argentario.	2024	Integrated survey	comm...	AR	Tower	XV	X		
4	Basso, A., Meschini, A., Russo, M.	Drawing and interactive architectural walkthrough to communicate complex spaces.	2023	Integrated survey	comm...	VR	Defensive...	III B.C.	X		
5	Benavides, J., Martín Civantos, J. M., Rouco Collazo, J.	Levantamiento arquitectónico y análisis arqueológico del castillo de Piñar como punto de partida para su conservación.	2020	Aerial photogra...	restor...		Fortress c...	XIV	H-BIM		
6	Brizzi, S., Ricciarini, M., Bertocci, S., Riminesi, C.	Studio preliminare sul complesso fortificato di Trogir (Croazia) basato su un approccio multi-disciplinare.	2023	Integrated survey	comm...	Digital Database	Fortress c...	XV			no open-access
7	De Marco, R., Galasso, F., Malusardi, C.	Digital documentation of fortified urban routes in Pavia (Italy): territorial databases and structural models for the preservation of military ruins.	2020	Laser scanner	comm...	Digital Database	Defensive...	XVI			no open-access

Fig. 2 - Excerpt from the bibliographic database on 3D surveying techniques for military architecture, enabling structured data filtering and analysis. (Processing: G. Flenghi).

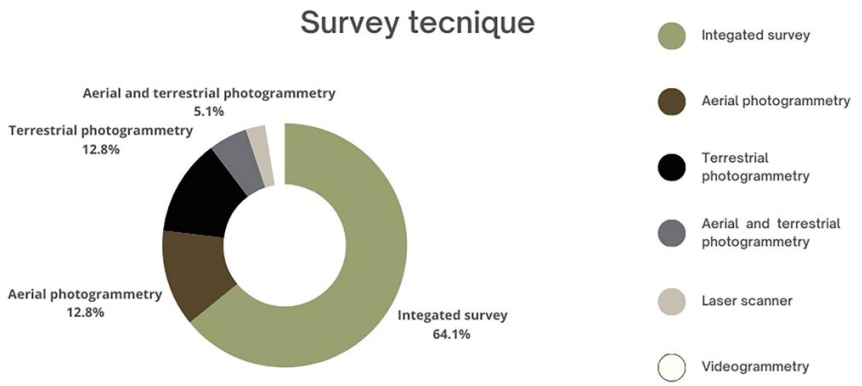


Fig. 3 - Graphical representation of the distribution of surveying techniques in the analysed studies, highlighting trends and research gaps. (Processing: G. Flenghi).

The combined use of filters provides a more granular view of the scientific landscape, supporting a more detailed understanding of the interconnections between techniques, objectives, and methodologies.

An additional value of this methodology is its ability to offer a structured and comparative perspective on the collected data. Through cross-analysis of parameters, it becomes possible to highlight correlations between techniques and objectives, as well as to identify emerging trends within the analysed scientific context. This approach enables a clearer understanding of the distribution of contributions and potential future research directions.

Some parameters, such as the reference model, require further investigation to ensure a more detailed and rigorous analysis. However, the proposed methodology provides a structured and visually effective framework for scientific contributions (Frosini et al., 2023; Russo et al., 2023; Valenti et al., 2021; Vitali et al., 2024). This system not only facilitates access to information but also supports a more efficient review process, allowing for more precise identification of gaps and opportunities (Fig. 3). The adopted approach offers a systematic and replicable strategy for analysing the state of the art. The use of dynamic filters and graphical visualizations makes the process more intuitive and effective, enabling the identification of correlations and unexplored research areas with greater ease (Fig. 4).

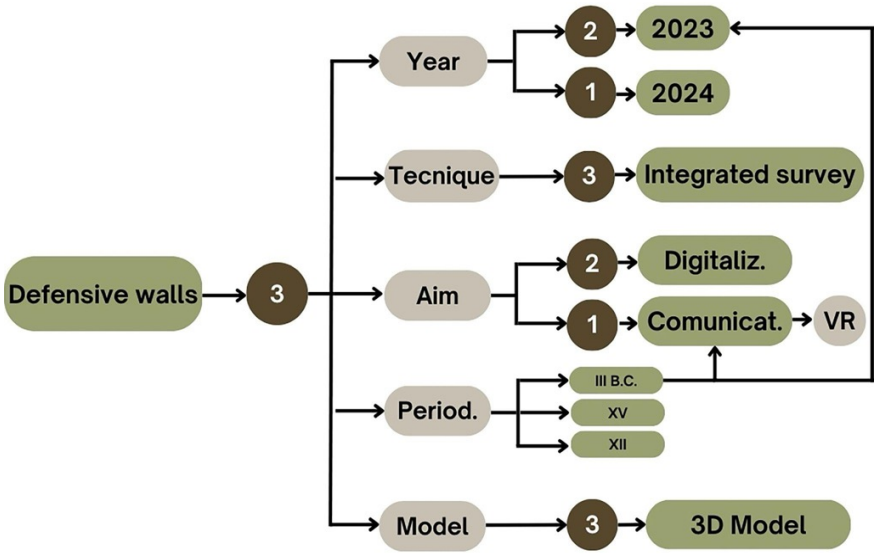


Fig. 4 - Diagram illustrating the functionality of the interactive Google Sheets database, showing how filters and parameters interconnect for a structured analysis. (Processing: G. Flenghi).

Methods for the Generation of Semantically Rich HBIM Models of Military Architecture

The digitisation of fortified architecture represents a significant advancement in the preservation and study of cultural heritage. Recent developments in digital survey techniques and modelling tools have fostered methodologies that capture both the geometric complexity and semantic richness of these historical structures. This review synthesises methodological insights from key studies, focusing on the transition from raw survey data to semantically enriched HBIM models.

The documentation of historical fortifications begins with an exhaustive digital survey. Advanced survey techniques capture the geometrical and spatial characteristics of the structures. Researchers conduct metric surveys of scale models or the structures themselves using a range of data acquisition tools, including laser scanners, photogrammetry, and drone imagery. These tools contribute to high-resolution point cloud datasets. Accuracy and precision are paramount at this stage, as the quality of input data directly influences the subsequent modelling process.

Following data acquisition, the next phase is the segmentation of point clouds. This process involves categorising 3D scans into distinct geometric and semantic components, enabling a more organised reconstruction. Some methodologies process scanned data to identify and classify architectural elements such as bastions, walls, and ancillary structures. This categorisation informs subsequent modelling steps, ensuring each element is represented with an appropriate level of detail.

The next step is 3D reconstruction, where segmented data is converted into a digital model. Automated and semi-automated processes enhance both precision and efficiency. Algorithms generate parametric objects corresponding to the fortification's architectural features (Jacquot, 2014).

This transition from raw survey data to a coherent 3D model involves iterative refinement, as the model is calibrated against known geometrical constraints and architectural typologies. The reconstruction process is particularly complex in fortified architecture, where irregular geometries and historical modifications require adaptable modelling strategies.

A key innovation in recent methodologies is the integration of semantic parsing within the HBIM framework. Semantic modelling attributes meaning to reconstructed geometrical elements, enabling a more nuanced analysis of the structure's historical and functional aspects (Verdiani et al., 2018). Embedding metadata and semantic information into the digital model facilitates data-driven decision-making for conservation and adaptive reuse projects (Spadafora et al., 2020).

Parametric modelling techniques, often supported by visual programming languages (VPL), manage the complexity of bastioned fortifications. These techniques allow for the dynamic manipulation of model parameters, accommodating the variability of historical structures.

Using standardised software tools such as Rhinoceros, ArchiCAD, and Revit, these methodologies ensure models reflect not only the physical form but also the underlying design logic of the fortification. This approach supports systematic analysis and future interventions, as digital models can be adjusted to incorporate new findings or conservation requirements.

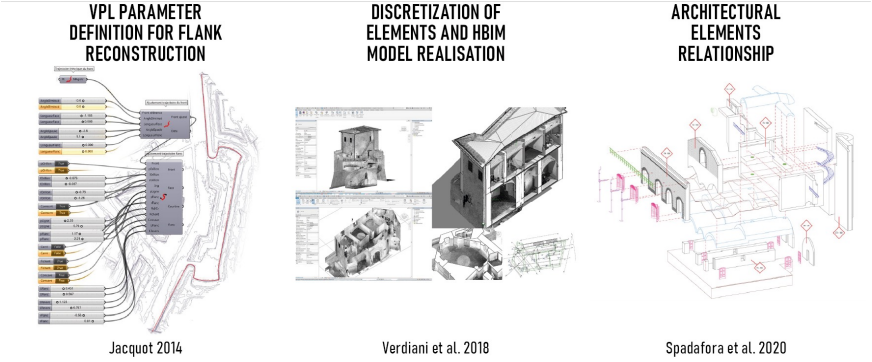


Fig. 5 - Topics and images extracted from selected references (Processing: F. Natta).

Beyond surveying, segmentation, and modelling, some methodologies advocate integrating additional data sources. Incorporating historical iconography, bibliographic research, and environmental assessments enriches the digital documentation process, providing a holistic view of the fortification. This comprehensive approach supports detailed conservation planning and paves the way for adaptive reuse strategies that respect both the structural and cultural significance of these sites. In conclusion, the methodological framework for the digital documentation of fortified architecture continues to evolve, addressing technical challenges and the complexities of historical structures (Fig. 5). While significant progress has been made in automating the transition from survey data to parametric models, further research is needed to refine semantic parsing techniques and standardise workflows across diverse software platforms. Advancements in these areas will enhance the precision, efficiency, and applicability of digital tools in cultural heritage preservation.

Acknowledgments

This paper is the result of a research jointly carried out by the authors. The authors wrote together the introduction; G. Flenghi wrote "3D surveying techniques..."; F. Natta wrote "Methods for the generation...".

References

European Commission. (2020). *VIGIE 2020/654: Study on quality in 3D digitisation of tangible cultural heritage*. Directorate-General for Communications Networks, Content and Technology. Retrieved from https://op.europa.eu

Frosini, G., Parodi, L., Di Paola, A., Vecchio, S., & Garuglieri, S. (2023). Il ruolo del rilievo integrato nell'interpretazione dell'edificio storico: Rocca di Sala a Pietrasanta (Lu). In *Defensive Architecture of the Mediterranean*, Vol. XV (pp. 1047-1054). Pisa University Press. https://dx.doi.org/10.12871/9788833397948132

International Council on Monuments and Sites (ICOMOS). (2017). *The Seville Principles for the international charters for computer-based visualization of cultural heritage*. Retrieved from https://www.icomos.org

Jacquot, K. (2014). *Numérisation et restitution virtuelle des maquettes de la collection de Louis XIV, le cas des fortifications bastionnées* [Doctoral dissertation, Université de Lorraine]. HAL. https://theses.hal.science/tel-01136299

Spadafora, G., Bellingeri, G., Canciani, M., Pallottino, E., Ferretti, S., Antonucci, E., & Dolfini, R. (2020). Rilievo 3D e modellazione avanzata nello studio dei Forti di Roma: il Forte Monte Antenne. In J. Navarro Palazón & L. J. García-Pulido (Eds.), *FORTMED 2020. Defensive Architecture of the Mediterranean*, Vol. X (pp. 463-470). https://dx.doi.org/10.4995/FORTMED2020.2020.11424

Russo, M., Panarotto, F., Flenghi, G., Rossi, E., & Pellegrinelli, A. (2023). A 3D integrated survey of fortified architectures: The medieval Canossa castle. In M. G. Bevilacqua & D. Uliveri (Eds.), *Defensive Architecture of the Mediterranean*, Vol. XV (pp. 1147–1154). Pisa University Press. https://dx.doi.org/10.12871/9788833397948144

The London Charter. (2009). *The London Charter for the computer-based visualization of cultural heritage*. Retrieved from http://www.londoncharter.org

Valenti, R., & Paternò, E. (2021). 3D Integrated Survey for the Study of Archaeological Sites: The Case Study of Euryalus Castle in Siracusa. *IOP Conference Series: Earth and Environmental Science, 767*, 012015. https://dx.doi.org/10.1088/1755-1315/767/1/012015

Verdiani, G., Donato, V., Pianigiani, L., & Marsugli, F. (2018). Patrimonio costruito e BIM: il palazzo di Francesco de' Medici nella Fortezza Vecchia di Livorno fa un secondo passo nell'epoca digitale. In A. Marotta & R. Spallone (Eds.), *FORTMED 2018. Defensive Architecture of the Mediterranean*, Vol. IX (pp. 1117-1124).

Vitali, M., Rodríguez-Navarro, P., Spallone, R., Russo, M., Verdiani, G., & Natta, F. (2024). Study and representation of the bastion of San Maurizio in Turin: An educational experience. In G. Islami & D. Veizaj (Eds.), *Defensive Architecture of the Mediterranean*, Vol. XVI (pp. 627-634). Universiteti Politeknik i Tiranës. https://dx.doi.org/10.4995/fortmed2024.2024.18110

A Proposal for the Development of a Digital Database of Military Architecture Treatises

Valentina Burgassi, Rosa Maria Marta Caruso, Iole Branca, Martino Pavignano, Denise Ulivieri

Introduction

The examination of extensive theoretical works on military architecture from the early modern period (16th–18th centuries) has identified several significant contributions that follow a dual approach. On the one hand, there is a body of theoretical literature on fortifications produced by military engineers actively engaged in the field. This literature is predominantly practical and instructional. On the other hand, there exist treatises intended for educational purposes, designed to impart knowledge of modern warfare to engineers in training at military academies through theoretical descriptions and tabulated data. At present, this rich textual and visual heritage remains largely inaccessible to nonspecialist audience. A comprehensive bibliographical survey has underscored this gap in both Italian and international scholarship. The primary objective of the PRIN 2022 INFORTREAT project is to render this valuable body of knowledge more widely accessible (Fig. 1).

A detailed analysis of construction knowledge in military architecture, as presented in key treatises of the early modern period, was essential to achieving this objective. Given the extensive range of available treatises, the research team conducted an initial historical-critical review, selecting approximately thirty works that played a pivotal role in disseminating the knowledge required by military architecture professionals between the 16th and 18th centuries (Fig. 2). The selection criteria for these treatises were primarily based on their recognised significance, the inclusion of geometric delineation principles applicable to defence, structural design, and references to construction techniques. A digital infrastructure was designed to store relevant information for the INFORTREAT project, in order to systematically analyse the selected treatises. To this end, a database was designed to accommodate the collected data, which was standardised through the creation of structured records that facilitated the comparative critical analysis of the treatises. The digital database could be populated through two methods: by uploading information via a predefined online form that generated a summary sheet or by entering structured data into an extended sheet (Fig. 3).

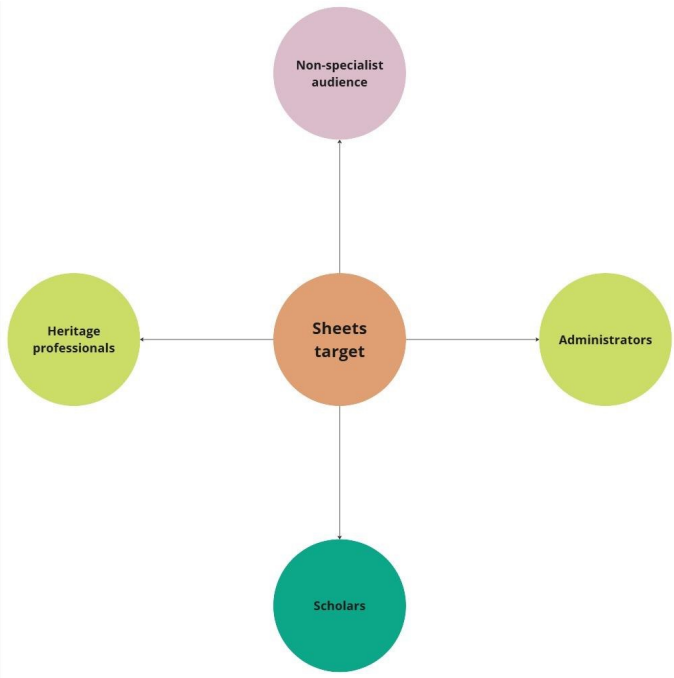


Fig. 1 - Representative outline of the target users of the realised critical sheets constituting the database. By IB

Both databases and index cards were developed as tools for collecting and organising the contents of the analysed treatises.

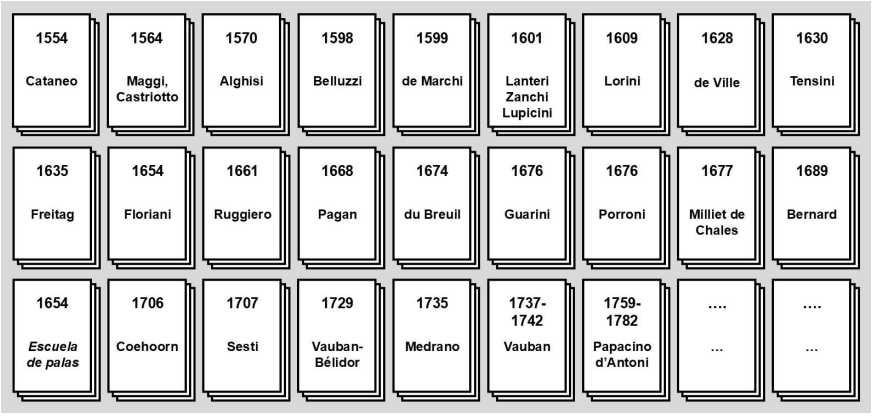


Fig. 2 - Data collection: some of the analyzed treatises (Source: MP).

These tools enabled the extraction of specific information from each work, thereby facilitating comparative analyses and improving accessibility for nonspecialist audience.

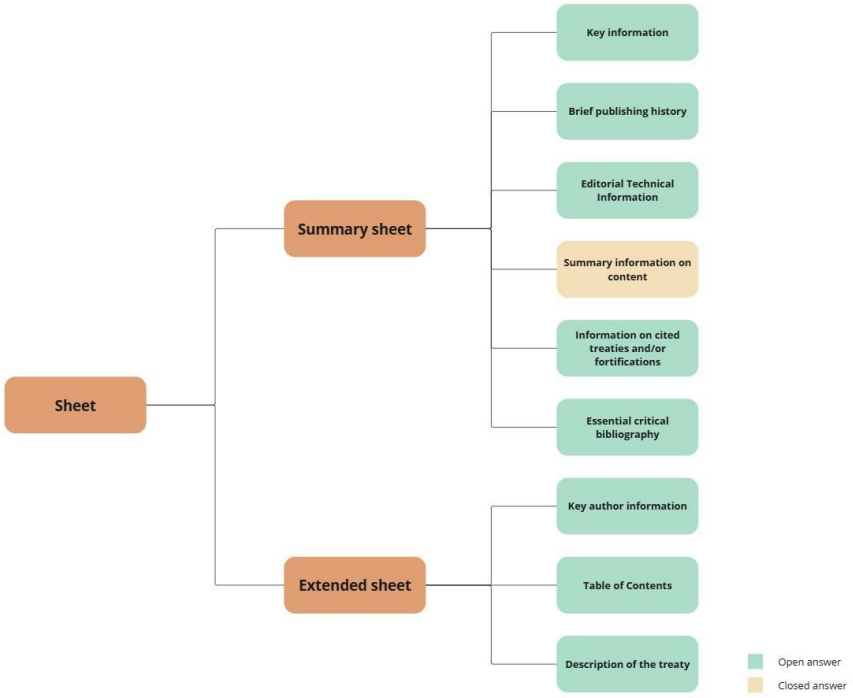


Fig. 3 - Structure of the internal subdivision of the sheet and the sections that can be filled in a closed or open form. Source: IB

The Methodological Approach

The first section, the 'summary sheet,' presents key information about the treatise, including the author's name, title of the work, publisher, and place of printing, year of publication, location of the analysed copy, and a link to the consulted resource for fully digitised works (Fig. 4). To ensure consistency and ease of consultation, a standardised reference format has been adopted, structured as 'Author's surname_ Abbreviated title of the work.'

The remaining fields accurately reflect information related to the treatise. A brief publishing history follows, providing context regarding the treatise's original publication and its subsequent circulation, based on the number of editions. This circulation may have been limited to a specific geographical area or extended to multiple contexts. Additionally, the 'summary sheet' offers a concise description of the volume's specifications, including the number of pages, the count of in-text and out-of-text illustrations, as well as details on its format and printing techniques. Subsequent fields allow for the entry of structured responses, including keywords and closed-response (Yes/No) answers. These fields pertain to the units of measurement identified and the content of the work. When compiled systematically, this information facilitates efficient data collection and enables comparative analyses between treatises with similar content. Additionally, the structured entries contribute to the development of a glossary of military architecture.

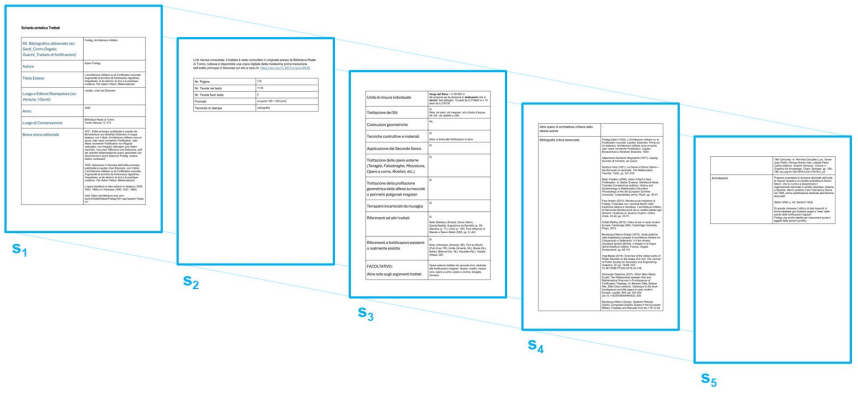


Fig. 4 - Digital database: a summary sheet provides synthetic classification of encoded information. This file collects only textual data, as shown in Freitag 1635 (Source: MP).

For research purposes, it is particularly relevant to determine whether the treatise discusses specific topics such as site treatment, geometric constructions, construction techniques, the application of the second flank, and external defensive works (including tenaglie, falsebraghe, opere a corno, and rivellini), as well as the description of fortifications with embankments encased by walls.

Furthermore, references to other treatises or existing fortifications provide additional context regarding the author's background, influences, and potential intellectual connections.

A critical bibliography related to the respective treatise can be added at the end of each 'summary sheet.' This is essential not only for providing an overview of the studies of Italian and international scholarship on individual works but also for expanding the bibliographic record of military treatises, which constitutes an additional objective of the research project.

The second section of the sheet is dedicated to the 'extended sheet,' which provides a detailed description of the treatise (Fig. 5).

Rather than summarising its contents, this section serves as a descriptive annex to the work. It begins with a bibliographical note and a presentation of the index, offering the reader — or anyone accessing the database — a critical overview of the treatise's contents.

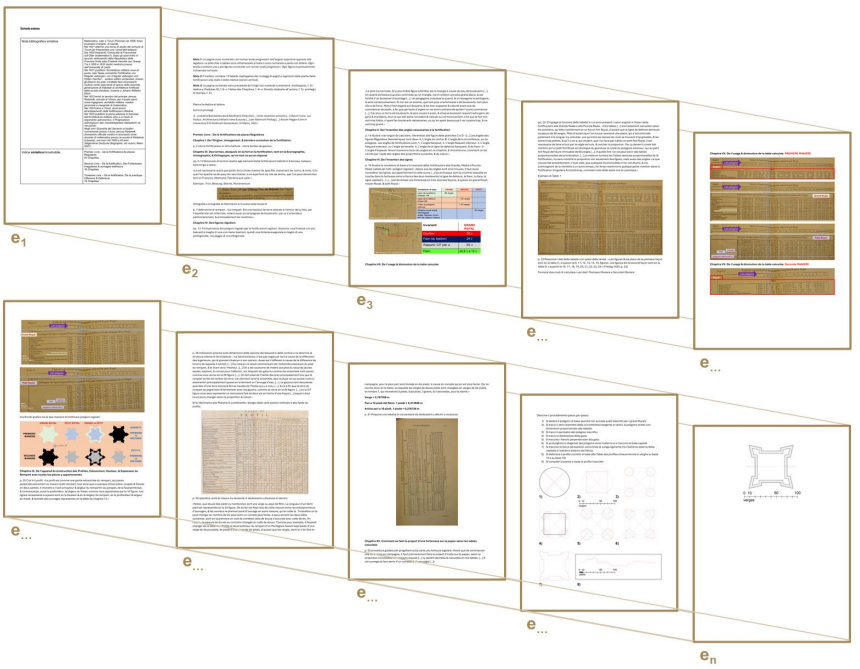


Fig. 5 - Digital database: an extended sheet provides the analytical description and the critical interpretation of the treatise. This file collects both textual and visual data, as shown in the example of Freitag 1635 (Source: MP) images from Freitag 1635 (BRTo, Saluzzo D. 274, details of plate C, tables I, V and du profil, p. 31. MiBACT - Musei Reali).

This section juxtaposes descriptions with tables and highlights the most significant aspects of the work, taking into account the multidisciplinary objectives of the research project. Particular emphasis is placed on the graphic analysis of the illustrations within the treatises, employing critical interpretive methods to explore the languages and conventions of representation. This approach enhances the understanding of visual materials, shedding light on their role in conveying technical knowledge within the context of early modern military architecture.

Results and Discussion

The constructed digital database compiles critical sheets on the analysed treatises, which are accessible in both summary and extended sheets. The summary sheet facilitates the synthesis of information from various treatises by presenting it in the form of keywords. During the initial phase of database development, these keywords were standardised through an iterative process to enable more efficient comparisons between different treatises and to enhance research by subject, date, and author. Additionally, the use of closed-ended responses for specific fields streamlined the completion of forms while ensuring the inclusion of key comparative data, which were designated as mandatory fields. Furthermore, the creation of a more detailed form for each work allows for greater flexibility in critical analysis and accommodates the inclusion of graphic elements, which are integral to the treatises and essential for interpreting the written content.

The database aims to advance the understanding of the geometric profiling of fortress defences, a fundamental aspect of early modern military strategy. This objective is pursued both theoretically and practically through the examination of example sites. Particular attention has been given to identifying graphic scales, geometric constructions applied to both regular and irregular fortification profiles, and references to existing sites within fortification systems, with a specific focus on the application of the second flank.

Where available, relevant graphical representations of these elements have been included, accompanied by appropriate legends or captions. Additional objectives include the systematic description of fortress components to develop a glossary of key architectural elements. External works and related defensive structures have been recorded for each fortification, as they provide essential information for defining and reconstructing fortification systems (Fig. 6).
Moreover, the database places significant emphasis on technical and construction-related details, not only for educational purposes but also through references to both theoretical principles and existing fortifications.

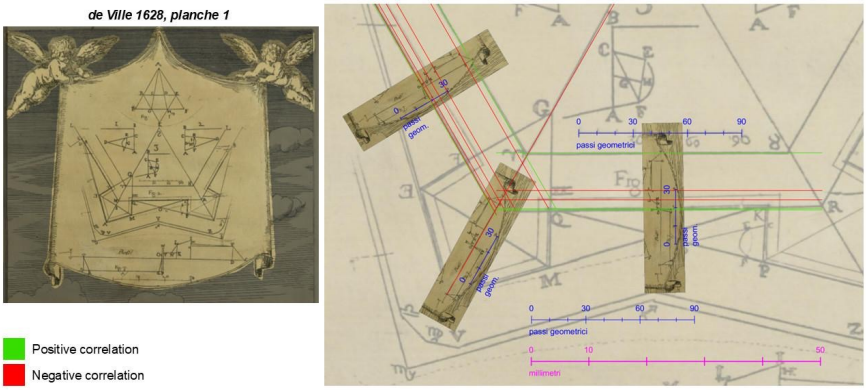


Fig. 6 - Digital database: the extended sheet also collects critical interpretation of each treatise, as shown in the example of the design of the regular hexagon by de Ville 1628 (Source: MP) images from De Ville 1628 (BRTo, Saluzzo F. 171, details of plate 1. MiBACT - Musei Reali).

The primary goal of the database is to create a freely searchable anthology of fortress elements. In addition, it aims to develop a comprehensive knowledge base encompassing geometric constructions, structural components, construction techniques, and references to historical sites. Through the meticulous collection and critical organisation of this information, the project lays the groundwork for the future development of three-dimensional digital models of fortifications. Furthermore, the database serves as an extensive resource for conducting in-depth analyses of treatises, authors, and referenced sites, making it a valuable tool for searching, consulting, cross-referencing, and comparing information efficiently.

References

Bennett, J. & Johnston, S. (1996). *The Geometry of War 1500-1750. Catalogue of Exhibition*. Museum of the History of Science.

Brioist, P. (2017). Dessiner et construire un bastion à la Renaissance. Dans R. Carvais, A. Garçon, A. Grelon (dir). *Penser la technique autrement XVIe-XXIe siècle, en hommage à l'œuvre d'Hélène Vérin, Histoire des techniques*, no. 10, Études, no. 6 (pp. 205 231). Classiques Garnier.

Carpo, M. (1998). *L'architettura dell'età della stampa. Oralità, scrittura, libro stampato e riproduzione meccanica dell'immagine nella storia delle teorie architettoniche*. Jaca Book.

Cámara Muñoz, A. (1981). La arquitectura militar y los ingenieros de la monarquia espanola: aspectos de una profesion (1530-1650). *Revista de la Universidad Complutense*, 3, 1981, pp. 255-269.

Cámara Muñoz, A. & Revuelta Pol, B. (eds.) (2016). *La palabra y la imágen. Tratados de ingeniería entre los siglos XVI y XVIII*. Fundación Juanelo Turriano.

Cámara Muñoz, A. (ed.) (2005). *Los ingenieros militares de la monarquía hispánica en los siglos XVII y XVIII*. Ministerio de Defensa, Asociación Española de Amigos de los Castillos, Centro de Estudios Europa Hispánica.

Cobos Guerra, F. & de Castro Fernandez J. (2005). Los Ingenieros, las experiencias y los escenarios de la arquitectura militar espanola en el siglo XVII. In A. Cámara (ed.), *Los ingenieros militares de la monarquía hispánica en los siglos XVII y XVIII* (pp. 71-96). Ministerio de Defensa, Asociación Española de Amigos de los Castillos, Centro de Estudios Europa Hispánica.

Orgeix, É. d' (2017). *Atlas militaires manuscrits. Villes et territoires des ingénieurs du roi*. BNF/Ministère de la Défense.

Orgeix, É. d' (2013). *Les savoirs de l'ingénieur militaire et l'édition de manuels, cours et cahiers d'exercices (1751-1914), Actes de la 3e journée d'étude du Musée des Plans Reliefs*. Ministère de la culture et de la communication.

Orgeix, É. d' (2007). Fortification and Military Perspective in Seventeenth Century France. In M. Carpo, F. Lamerle (dir.), *Perspective, Projections, Design: Technologies of Architectural Representations* (pp. 127-141). Routledge.

Fara, A. (1989). *Il sistema e la città. Architettura fortificata dell'Europa moderna dai trattati alle realizzazioni 1464-1797*. Sagep Editrice.

Fara, A. (1993). *Le città da guerra nell'Europa moderna*. Einaudi.

Fara, A. (2012), *Napoleone architetto nelle città della guerra in Italia*. Olschki.

Fara, A. (2012), *Geometria dell'architettura militare: Francesco I d'Este e la Cittadella di Modena*. Angelo Pontecorboli Editore.

Fara, A. (2015). *Giuseppe Ignazio Bertola (1676-1755). Il disegno e la lingua dell'architettura militare*. Angelo Pontecorboli Editore.

Fiore, F. P. (2017). *Architettura e arte militare: mura e bastioni nella cultura del Rinascimento*. Campisano editore.

Fontana, V. (1985). Architettura militare. In *Trattati di prospettiva, architettura militare, idraulica e altre discipline*. Neri Pozza.

Galino Diaz, J. A. (1996). *El conocimiento constructivo de los ingenieros militares del siglo XVIII*. Tesi di Dottorato, Barcellona.

Hale, J. R. (1965). The Early Development of the Bastion: an Italian chronology. From 1450 to 1534. In J. Hale, R. Highfield and B. Smalley (eds.), *Europe in the Late Middle Ages* (pp. 466-494), Faber and Faber.

Parker, G. (1988), *Military Revolution, Military innovation and the rise of the west 1500-1800*, Cambridge University Press.

Piccoli, E., Tocci, C., Caterino, R. & Zanet, E. (2019). Building on water and the Modern State. Eighteenth century foundation techniques in the fortifications of Alessandria, in J.W.P. Campbell (Eds), *Proceedings of the sixth conference on the Construction History Society CHS*, *Water, Doors and Buildings. Studies in the History of Construction* (pp. 358-373), Queen's College, Cambridge.

Severini, G. (1994). *Progetto e disegno nei trattati di architettura militare del '500*. Pacini Editore.

Sgrosso, A. (2001). *Rigore scientifico e sensibilità artistica tra Rinascimento e Barocco.* UTET.

Ventrice, P. (1998). Architettura miliare e ingegneria tra XVI e XVII secolo a Venezia. In A. Fiocca (a cura di), *Giambattista Aleotti e gli ingegneri del Rinascimento*. Biblioteca di Nuncius Studi e Testi XXXI.

Vérin, H. (1994). La gloire des ingénieurs. L'intelligence technique du XVIe au XVIIIe siècle. *Annales. Histoire, Sciences Sociales*, 4, 1994, pp. 918-920.

Viganò, M., Flor, M. & Gallia, E (2016). *Bibliografia della fortificazione: parte generale e stati italiani 1470-1945*. Istituto Italiano dei Castelli.

Viglino Davico, M., Chiodi, E., Franchini, C & Perin, A (2007). *Architetti e ingegneri militari in Piemonte tra '500 e '700. Un repertorio biografico.* Omega.

The Ontology of the Information Classes for the Knowledge and Modeling of Military Architecture in the Restoration and Maintenance Processes

Marco Saccucci, Assunta Pelliccio, Andrea Giordano

Introduction

The 'bastioned fortifications' or 'modern fortifications' constitute a sophisticated architectural-defensive system that was introduced by Filarete and refined over 150 years in response to the advancements in artillery (Padovan, 2016).

Numerous specialized treaties from Italy and Europe outline defensive techniques grounded in geometric and mathematical principles, which govern the design of layouts, inclinations, casemates, and trenches (Pisano, 2014).

Analysing these fortification systems necessitates tools illuminating the interrelationships among individual components and their connections to the overall structure.

Ontology, which facilitates the hierarchical organization of concepts and relationships, is invaluable for understanding this complexity. It is especially pertinent in parametric digital modeling, such as HBIM, which relies on precise semantic classification (Varzi, 2019). This study provides a summary of the research activities undertaken to date within the INFORTREAT project (PRIN 2022, CUP N. I53D23005420006), which aims to develop parametric models of modern fortifications for purposes of restoration, reuse, and maintenance.

Ontological Systems

The analysis of modern fortifications necessitates a detailed exploration of ontological systems to determine the most suitable one for the intended purpose.

The use of ontologies has expanded due to advancements in semantic representation languages and improved interoperability between systems. The literature identifies four main macro-areas:

1. Terminological Codification: These ontological structures are based on keywords and concepts that facilitate understanding technical terms.

The primary open-source software used in this area includes Lexique Pro, Lexonomy, and Tiki Wiki CMS (Colucci et al., 2021).

2. Relational and Multi-Scale: These dynamic ontological structures link entities at multiple levels, adapting to changing relationships over time. Notable software in this category includes Protégé and Neo4J (Borin et al., 2020).

3. Semantic Segmentation: These systems intelligently classify data for AI and cultural heritage applications. The software for developing these ontologies includes DeepLab and Segmentation Models (Quattrini et al., 2017).

4. Documentary refers to a semantic structure designed for organizing digital archives. This field's most frequently used software includes Protégé and OWL API (Ferretti et al., 2022).

The complexity of architectural systems often necessitates an ontological system that results from a dynamic combination of two or more ontological systems.

Standardised Ontologies for Information Classes in BIM

The research focused on studying ontological structures for parametric modeling of HBIM (Heritage Building Information Modeling). The Architecture, Engineering, and Construction (AEC) industry utilizes Building Information Modeling (BIM) for the integrated management of buildings and infrastructure (Domer et al., 2024).

BIM incorporates levels of information (LOI, LOIN) and standardized ontologies (such as UNI EN ISO 19650 and IFC) to ensure interoperability (Lai et al. 2018).

BIM ontology is divided into two main categories: informatics, which deals with the digital relationships between entities, and architecture, which defines classes, attributes, and relationships between objects. The Industry Foundation Classes (IFC) bridge these two categories, cataloguing spatial and functional information.

Other standards, such as UNICLASS, classify construction elements to facilitate project management (Gelder, 2015).
The UNICLASS (Unified Classification for the Construction Industry) standard systematically catalogues and classifies every project element, enhancing information management and promoting professional collaboration (Gelder, 2015).

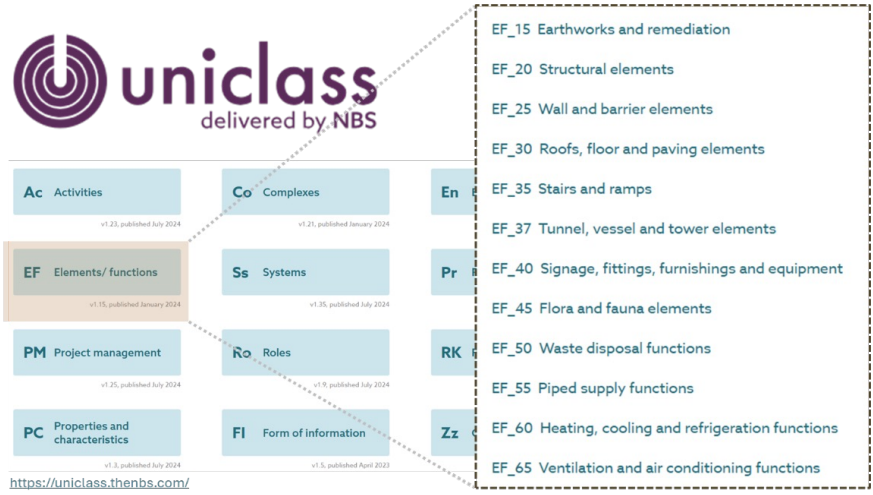


Fig. 1 - Uniclass classification system highlighting 'Elements/functions' categories for construction and infrastructure projects. Source: created by the authors.

This system was designed to support BIM across all project phases, from design to construction and maintenance.

The ontological structure of UNICLASS is organized into various tables or classes, each focusing on specific categories of elements. Each table employs its coding system to accurately identify a project's multiple components. UNICLASS is regularly updated to adapt to industry changes and emerging needs, particularly with the increasing adoption of BIM and digital standards (Molsa et al. 2023).

However, modeling historic buildings using HBIM is complex.

It requires defining new families of unique objects, so the UNICLASS standardization process must be incorporated during creating these families (Fig. 1).

Moreover, HBIM utilizes CIDOC CRM (ISO 21127) for heritage applications, an ontology developed initially for museums, archives, and libraries. This facilitates the integration of historical data (Ranjgar et al., 2022) and allows for organizing and linking information related to buildings and their historical contexts, thus supporting conservation and restoration efforts.

The main phases for HBIM parametric modeling of fortification systems are:

1. Definition of the Work Breakdown Structure (WBS) – Organizing the process.
2. Coding and documentation – Standardizing data.
3. Ontological structuring – Establishing multi-scalar relationships.
4. Creation of new families of objects – Performing HBIM modeling.
5. Standardization – Associating with classification codes to ensure interoperability.

Ontology for Early Modern Fortified Heritage

The digital parametric modeling of the various architectural sub-elements that comprise the bastions, walls, and moats of modern fortification systems requires careful consideration of the precise geometric relationships that govern the interactions between these components. To achieve this, it is crucial to adhere to the previously outlined procedure, which currently focuses on the first three phases:

1. Definition of the Workflow: Structuring the system according to a Work Breakdown Structure (WBS) (Fig. 2):
- Level 1– External elements of the fortification.
- Level 2 – Internal structures and functional relationships.
- Level 3 – Materials and construction techniques.

2. Semantic Definition: Examining historical treaties to identify terminologies and architectural properties (Fig. 3).

3. Metric and Functional Relationships: Hierarchizing elements using software such as Protégé creates multi-scalar relational ontologies (Fig. 4).

For this last activity, given the complexity of the software, it was essential to make the data from the ontological structure accessible through the development of a web platform based on OWL, which we named INFORTREAT ONTOLOGY (Fig. 5).

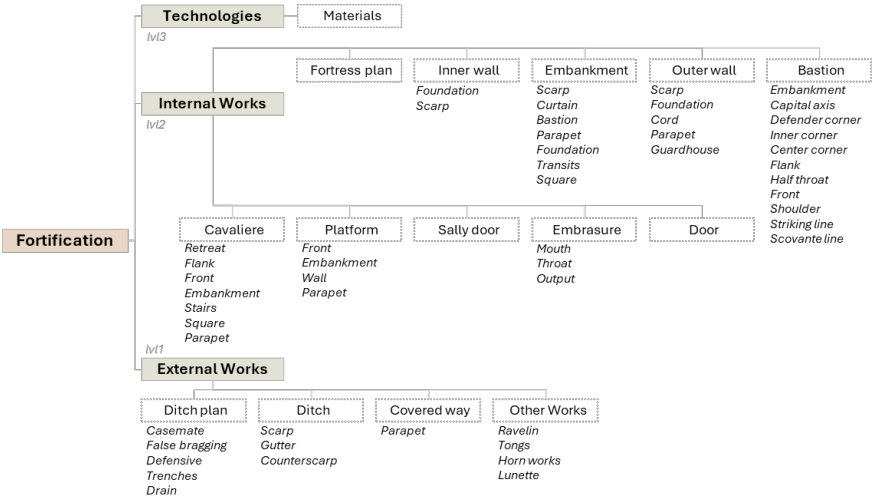


Fig. 2 - Hierarchical classification of fortification components (WBS), organized into External Works, Internal Works, and Technologies. Source: created by the authors.

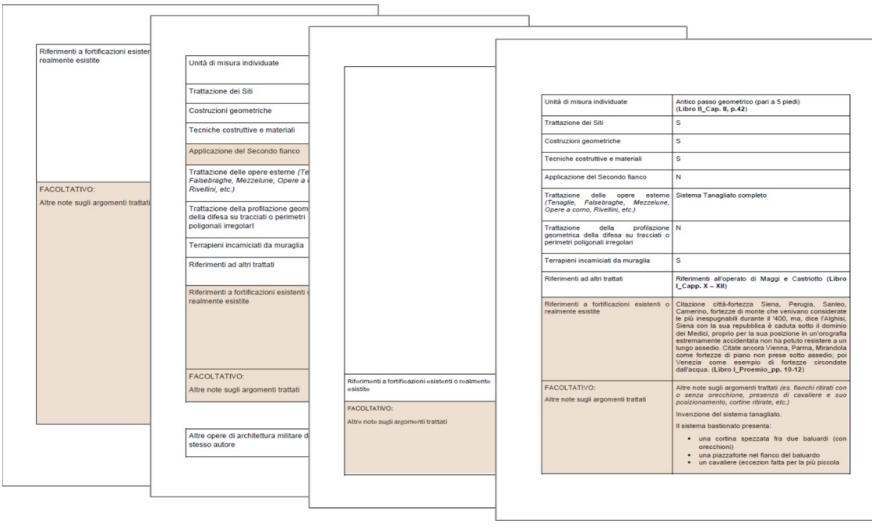


Fig. 3 - Structured analysis sheets for historical fortifications. Source: created by the authors.

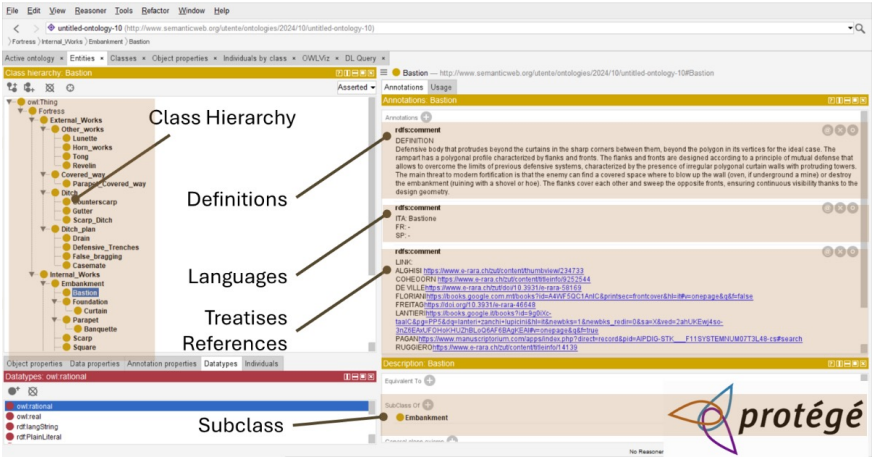


Fig. 4 - Ontology structure in Protégé, showcasing class hierarchy, definitions, multilingual terms, and references for fortifications. Source: created by the authors.

This system organizes the elements alphabetically and provides detailed profiles that include:
- Names and translations in multiple languages.
- Historical definitions.
- Hierarchical relationships with links to sub-elements.
- Reference treaties, complete with links to sources.
- Multimedia content, including images, 3D models, and videos.

Conclusions

The study examined ontologies related to cultural heritage and identified four primary areas of focus: terminology, multi-scalar relationships, semantic segmentation, and documentation. As part of the INFORTREAT project, a procedure for Historical Building Information Modeling (HBIM) was developed based on international standards such as IFC, UNICLASS, WBS, and CIDOC CRM to ensure interoperability. A key objective of this research is to make HBIM ontological models accessible to a broad audience, especially professionals in the field.

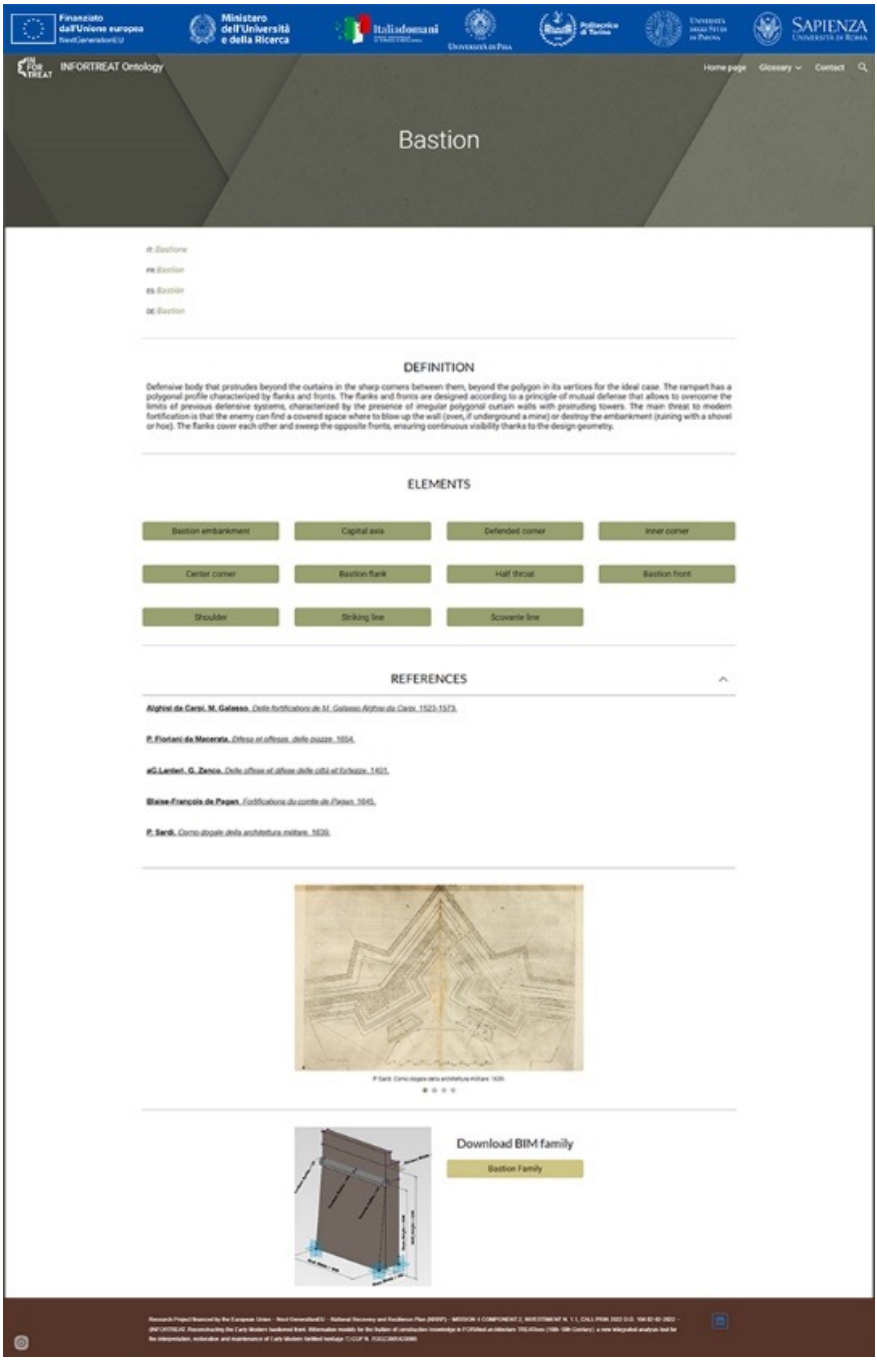


Fig. 5 - "INFORTREAT Ontology webpage for 'Bastion,' featuring definition, elements, references, and BIM family download. Source: created by the authors.

To achieve this, the INFORTREAT ONTOLOGY platform was created, facilitating the management of diverse historical, documentary, and geometric information. It also allows users to download parametric object families for modeling actual fortifications. Future research will focus on developing adaptive parametric families to be included in the platform, ensuring they are easily downloadable. It is important to note that these HBIM objects will not constitute a digital twin model, particularly in terms of historical architectural systems like modern fortifications. However, they will provide new perspectives for restoring and maintaining cultural heritage.

References

Borin, P., Bernardello, R. A., & Grigoletto, A. (2020). Connecting historical information with BIM ontologies. HBIM methods for the visualization of Harris matrix for the Torrione in Carpi. In *Graphical Heritage: Volume 1-History and Heritage* (pp. 757-770). Springer International Publishing.

Colucci, E., Xing, X., Kokla, M., Mostafavi, M. A., Noardo, F., & Spanò, A. (2021). Ontology-based semantic conceptualisation of historical built heritage to generate parametric structured models from point clouds. *Applied Sciences*, 11(6), 2813

Domer, B., & Bernardello, R. A. (2024). *Interoperability: An Introduction to IFC and BuildingSMART Standards, Integrating Infrastructure Modeling*. Switzerland: EPFL Press.

Ferretti, U., Quattrini, R., & D'Alessio, M. (2022). A comprehensive HBIM to XR framework for museum management and user experience in Ducal palace at Urbino. *Heritage*, *5*(3), 1551-1571.

Gelder, J. E. (2015). The design and development of a classification system for BIM. *Building Information Modeling (BIM) in Design, Construction and Operations, WIT Transactions on The Built Environment*, *149*, 477-489.

Molsa, M., Demian, P., & Gerges, M. (2023). BIM search engine: effects of object relationships and information standards. *Buildings*, *13*(7), 1591.

Padovan, G. (2016). *Forse non tutti sanno che a Milano...* Newton Compton Editori Padovan 2016

Pisano, R., & Bussotti, P. (2014). Galileo a Padova: un itinerario tra architettura, fortificazioni, Matematica e scienza "pratica". *Lettera Matematica Pristem*,91(1), 48-58. Varzi 2019

Quattrini, R., Pierdicca, R., & Morbidoni, C. (2017). Knowledge-based data enrichment for HBIM: Exploring high-quality models using the semantic-web. *Journal of Cultural Heritage*, *28*, 129-139.

Ranjgar, B., Sadeghi-Niaraki, A., Shakeri, M., & Choi, S. M. (2022). An ontological data model for points of interest (POI) in a cultural heritage site. *Heritage Science*, *10*(1), 13.

Digital Informative Models of Early Modern Military Architecture Treatises. Methodological Approach and First Results

Piergiuseppe Rechichi, Virginia Miele, Enrico Pupi, Fabrizio Natta, Marco Vitali, Roberta Spallone, Marco Giorgio Bevilacqua

Introduction

The physical modern age fortifications realized over the centuries were influenced by preexisting fortified structures from the middle-age, topology, water availability, existing infrastructures, and resource limitations, but were still related to theoretical models defined in the circulating treatises. The ideal fortification model proposed in military architecture treatises can hardly be identified as an object but should be considered and studied as a complex architectural system characterized by a multitude of interrelated defensive components. The morphology of the fortification is the result of a convergence of defensive design criteria, and geometry is the key to ensure the effectiveness of the defense. The fortification model, precisely due to the attributes just described, is not expressed in the treatises in an accessible and linear fashion. In fact, the body of knowledge that contributes to the completeness and coherence of a fortification model, of both textual and iconographic nature, is disseminated within the treatises according to thematic subdivisions and in accordance with recurring content structures. This composition makes the process of acquiring knowledge of the military architectural model from the treatises extremely challenging, requiring analysis and interpretation that can only be carried out by those who have already acquired a sufficient level of expertise in the subject. To enable greater accessibility to this knowledge, it is necessary to process all the data present within the treatises to extrapolate geometrically complete and coherent fortification models. In a modern fortification system, defense is ensured if specific geometric conditions determined by the knowledge and expertise of the treatise writer are met. These conditions correlate variable quantities (e.g. proportion of the flanks), to parameters (e.g. number of base polygon sides), and allow the shaping of the fortification model's characterization to maintain optimal defense guarantee in different design conditions. The design logic of military architecture can surprisingly be combined with contemporary parametric design logic, highlighting the potential of using procedural modeling tools and visual programming languages to create digital models of fortification systems.

To ensure an effective correspondence between the geometric characterization of the fortification system and the complex network of textual information disseminated in the treatise, the applicability of a Building Information Modeling approach appears evident.

This research question is the central focus of WP5 in the INFORTREAT project. The first tests were conducted on treatises by Sardi, Guarini, Lorini, and Tensini, highlighting criticalities and potentialities for the next steps of the research project.

Digital Informative Models

Recent advancements in digital technologies for architectural heritage documentation have improved large datasets processing capabilities (Chiabrando et al., 2017; Croce et al., 2019). However, critical aspects of architectural analysis emphasize the need for more informational depth and intelligibility in digital representations (Lo Buglio & De Luca, 2012). Research has focused on methodologies for interpreting models from architectural treatises (De Luca, 2014), formalizing architectural knowledge into structured model libraries (Carpo, 2016; De Luca et al., 2007; Cache, 2009), and developing information systems for semantic interpretations of theoretical frameworks (Apollonio et al., 2013).

Various methods have sought to digitally transcribe architectural proportional theories. Giovannini (2023) applied Visual Programming Language (VPL) within the HBIM framework to analyze Palladio's The Four Books of Architecture. Digital 3D reconstructions based on treatise descriptions enhance the understanding of narrated and idealized architecture through graphic analysis, adding depth to historical sources (Palestini, 2017). Further studies explore models from treatises, formalizing architectural knowledge into structured libraries (De Luca, 2014; Carpo, 2016; Cache, 2009), and developing information systems for semantic interpretations (Apollonio et al., 2013). Ontologies refine BIM methodologies and enable tailored queries for built heritage representation through Semantic Web technologies.

Simeone et al. (2019) addressed formalizing cultural heritage information models to support nuanced interpretative frameworks. BIM and VPL integration enables innovative architectural analysis, emphasizing HBIM's potential in heritage conservation. Lo Turco et al. (2022) showed how BIM's structured data management and VPL's flexibility allows dynamic heritage applications. This highlights the importance of disseminating such knowledge via web platforms (De Luca et al., 2011; Stefanini et al., 2013). Web-based BIM visualisation has evolved, prioritizing user-friendly interfaces and advanced metadata queries. Furuta et al. (2023), integrates geometric visualisation with semantic data updates. Interoperability efforts include El-Yamany et al. (2012), who developed a web application for replicating IFC objects, followed by research improving processing speeds for large models (Liu et al., 2015; Li et al., 2022). Despite progress, challenges remain in enhancing IFC model semantic accessibility for non-specialists, as Furuta et al. (2022) noted. Future studies ought to explore the integration of these technologies to improve interpretation, accessibility, and critical interaction with historical architectural data.

Methodology

The methodology adopted for the development of digital fortification models, derived from treatises, is structured into five main phases (Fig. 1):

1. Critical interpretation of the treatise and graphical analysis.
2. Redrawing of the geometric models of fortification.
3. Identification of relationships between parts and VPL modelling of the fortification system.
4. Integration into a BIM environment and model information.
5. Sharing of the model in a web-BIM environment.

From the analysis of the treatise, ontological, dimensional, and functional information related to the geometric construction and characterization of the parts is extracted. Preliminary redrawing guarantees a verification of the coherence between different

prescriptions inside the treatise text and different graphical representations in the treatises' figures.

By utilizing parametric modelling tools, it is possible to reconstruct the treatises' design logics, facilitating the creation and dynamic management of the models. These models can subsequently be transferred to the BIM environment for enhanced information management and consultation.

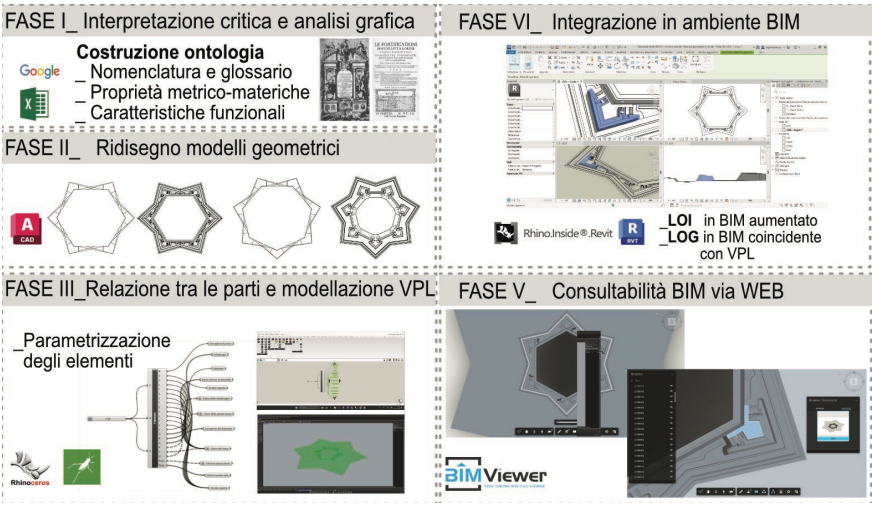


Fig.1 - Methodological diagram for the realization of digital informative models of modern-age fortified systems from the treatises (Souce: Rechichi, 2025; Elaborated by Miele, V.)

Case Studies

Le Fortificationi by Bonaiuto Lorini

Lorini's treatise "*Le Fortificationi*" represents a crucial bridge between early mechanical science and the science of weights, encompassing graphic scales and machines. This seminal work on military fortification highlights the intrinsic connection between theoretical principles and practical application. Lorini (1596) is recognized as the first Italian author to explicitly demonstrate the construction of axonometry (Scolari, 2005, p. 28). His treatise provides a thorough analysis of fortification advancements driven by innovations in artillery and weaponry.

Grounded in the mechanical principles of Archimedes—particularly the law of leverage—and the work of Guidobaldo del Monte (1545–1607), author of Le Mecaniche (1577–1581), Lorini integrates advanced mechanical theories into his discussion. The first edition of this five-book treatise on fortifications was published by Rampazzetto in Venice, following a limited print run of fifteen copies in 1596 (noted by Jordan; Writing on Architecture), which were dedicated to rulers and influential noble families. The treatise circulated widely, with a German translation printed in Frankfurt by Theodor de Bry in 1607. A second, expanded edition, with an additional sixth book dedicated to Grand Duke Cosimo II, was published in 1609 by Francesco Rampazzetto published a second, expanded edition in Venice, which included.

Il *Corno Dogale* by Pietro Sardi

Pietro Sardi, a Roman military engineer, authored two treatises on military architecture (*Corona Imperiale dell'Architettura militare*, 1618, and *Corno Dogale dell'Architettura militare*, 1639) and two treatises on artillery. The *Corno Dogale* represents an evolution of the fortification model previously proposed by Sardi in the *Corona Imperiale*. In addition to revising construction techniques, admitting the opportunity to build fortifications solely of earth under certain circumstances, Sardi reconfigures the external works of the fortification and the layout methods, acquiring and integrating knowledge and expertise related to the latest developments in Dutch-influenced military architecture.

In the seven books of the treatise, Sardi describes methods for regular and irregular fortification, defining two different fortification models: in the second book, he proposes his method of fortification, characterized by a defensive layout of Italian tradition; in the third book, he proposes the Dutch method of fortification, substantially coinciding with that already described by Marolois. The *Corno Dogale* is a treatise of great relevance in terms of geometric design of the defence system; the defensive systems are characterized by a low maintenance with a limited number of artillery pieces. Construction techniques and structural features of the fortification are only partially described.

La Fortificatione by Francesco Tensini

Francesco Tensini da Crema began his military career at a young age, amassing extensive hands-on experience and theoretical knowledge from treatises circulating in Italy and across Europe. His field experiences in Flanders and Friesland during the late 16th and early 17th centuries were particularly influential. His work "*La Fortificatione*," comprising three books and ninety chapters in total, encapsulates the full spectrum of his military expertise, from fortification design to defense and offense, enriched by his own inventions and machines.

The first edition was printed in Venice by Evangelista Deuchino in 1624, followed by a second in 1630 in Venice by the Bariletti brothers, and a third in 1655 at Brogiollo.

Tensini's genius is evident in his ability to synthesize the best of traditional Italian fortification models, integrating them with his own innovations, strongly influenced by his Dutch military experiences. This synthesis allowed him to refine state-of-the-art fortification models that are exceptionally effective and efficient in terms of construction and maintenance costs.

Trattato di Fortificatione by Guarino Guarini

Guarino Guarini's Trattato di Fortificatione (1676) represents a significant contribution to early modern military architecture. Written during his tenure in Turin, the treatise reflects Guarini's multidisciplinary expertise, blending mathematics, architecture, and military engineering. Book III of the work focuses on the "second delineations" of fortresses and their orthography, offering a systematic approach to fortress design through geometric principles and proportional relationships.

Guarini's treatise follows the tradition of contemporary military theorists such as Marolois (1615) and Sardi (1639), presenting a manualistic approach to educate readers on fortification principles. A key characteristic of the work is its tabular system, which defines maximum, average, and minimum dimensions for fortification elements such as bastions, curtains, and ravelins. This method provides a comparative framework, allowing for variations in design while maintaining defensive effectiveness.

The fortification model outlined in Guarini's treatise emphasises the integration of geometric rigour with practical considerations of military defence.

His approach considers factors such as soil type, ballistic trajectories, and structural stability, ensuring adaptability to different terrains and warfare strategies. These principles highlight Guarini's role in codifying fortification theory within a broader architectural and scientific discourse.

Results

The components of fortifications are widely described within military architecture treatises in a non-systematized manner. For instance, the description of an element might be located in a different chapter compared to its dimensioning, or its material and constructive characterization. For this reason, it is fundamental to develop a systematized knowledge structure of the text's contents, which allows for defining the ontology of the fortification presented by the treatise and for systematizing the information related to individual entities. To this end, a specific Excel spreadsheet containing all the necessary information has been constructed (Fig. 2). The quality and consistency of the iconographic apparatus presented within individual treatises can vary drastically. However, the figures are fundamental for an accurate interpretation of the text, for the integration of geometric characteristics not explicitly stated in textual form, and for verifying the overall coherence between textual prescriptions and the dimensions represented in the figures. For this reason, the critical redrawing of the ichnographies and orthographies of the fortifications allows for resolving the geometric characterization of the fortifications themselves with coherence and completeness, before proceeding with the actual creation of digital models (Figs. 6-8). Particular attention must be paid to the critical interpretation of the geometric construction methods of the defensive profiles, a fundamental element in defining the overall form of the fortification system (Figs. 3-5).

Titolo	Corno Dogale dell'Architettura Militare	
Autore	Pietro	Sardi
Anno	1638	

Voce	Tipo	Libro	Capitolo	Pag.	Nota	Unità	Misura
Angolo del centro	Nomenclatura	Terzo	Primo	118	Vedere figura Prima Olandese, segnato Cxu	x	x
Angolo del fianco	Nomenclatura	Secondo	Quarto Principale	49	Vedere figura prima, segnato E	x	x
Angolo della spalla	Nomenclatura	Secondo	Quarto Principale	49	Vedere figura prima, segnato D	x	x
Angolo di congiunzione del fianco del baluardo	Nomenclatura	Terzo	Primo	118	Vedere figura Prima Olandese, segnato DFG	x	x
Angolo di congiunzione della spalla del baluardo	Nomenclatura	Terzo	Primo	118	Vedere figura Prima Olandese, segnato CGF	x	x
Angolo di difensione	Nomenclatura	Terzo	Primo	118	Vedere figura Prima Olandese, segnato 9	x	x
Angolo difeso del baluardo	Nomenclatura	Terzo	Primo	118	Vedere figura Prima Olandese, segnato OCG	x	x
Angolo esteriore del baluardo	Nomenclatura	Secondo	Quarto Principale	49	Vedere figura prima, segnato C	x	x
Angolo esteriore del baluardo	Descrizione	Secondo	Quarto Principale	71	Sottocapo Discorso sopra l'angolo esteriore del baluardo/Opinione c	x	x
Angolo interiore del baluardo	Nomenclatura	Secondo	Quarto Principale	49	Vedere figura prima, segnato A	x	x
Angolo interiore del poligono	Nomenclatura	Terzo	Primo	118	Vedere figura Prima Olandese, segnato Ncu	x	x
Baloardo o sua piazza	Nomenclatura	Secondo	Quarto Principale	49	Vedere figura prima, segnato B	x	x
Base del cavaliere	Nomenclatura	Secondo	Quarto Principale	51	Vedere figura seconda, segnato VX	piede geometrico	lunghezza 200
Bocca (Cannoniera)	Nomenclatura	Secondo	Quarto Principale	73	Vedere figura nona, segnato G	piede geometrico	larga 4
Cannoniera (parapetto)	Nomenclatura	Secondo	Quarto Principale	73	Vedere figura nona, segnato AA. In pianta segnata HH, cannoniera se	x	x
Cannoniera (parapetto)	Descrizione	Secondo	Quarto Principale	72	E questa cannoniera va armata dalle sue bande di graticci fatti di vim	x	x
Cannoniere (fianchi)	Descrizione	Secondo	Quarto Principale	65	Sottocapo De' Parapetti/Le cannoniere dei fianchi saranno 3 e non pi	x	x
Cavaliere	Nomenclatura	Secondo	Quarto Principale	51,55	Vedere figura seconda, segnato P. In figura terza H	piede geometrico	altezza sul piano del terrap
Cavaliere	Descrizione	Secondo	Quarto Principale	57	Rigo 22/in mezzo alle cortine per vedere e battere il nemico da lontan	x	x
Cavaliere	Descrizione	Secondo	Quarto Principale	58	Rigo 24/importanza del cavaliere	x	x
Circolo morto	Nomenclatura	Terzo	Primo	126	Vedere figura decima olandese, segnato punteggiato BCDEF	x	x
Controscarpa	Nomenclatura	Secondo	Quarto Principale	54	Vedere figura terza, primo profilo, segnato E	piede geometrico	altezza 15
Controscarpa	Nomenclatura	Terzo	Primo	129	Vedere figura Duodecima Olandese segnato M	Scala del Reno	larga 6 piedi
Corbelli pieni di terra (feritoie)	Nomenclatura	Secondo	Quarto Principale	54	Vedere figura terza, segnato V	x	x
Cordone	Nomenclatura	Secondo	Quarto Principale	54	Vedere figura terza, secondo profilo, segnato P	piede geometrico	Ad un quarto dell'altezza de
Cortina	Nomenclatura	Terzo	Primo	118	Vedere figura Prima Olandese, segnato F4	Scala del Reno	lunghezza libera 360
Cortina libera	Nomenclatura	Secondo	Quarto Principale	50	Vedere figura prima, segnato GH	piede geometrico	lunghezza 500

Fig. 2 - Table containing information extracted from the textual analysis of the Corno Dogale dell'Architettura Militare by Pietro Sardi. (Souce: Rechichi, 2024; Elaborated by Rechichi, P.)

Different authors propose geometric constructions based on methods of varying complexity and sophistication. In many cases, within the same treatise, multiple methods for tracing the defense are proposed, referencing the traditions of different authors or geographical areas.

Once all components of the fortification are ontologically defined and characterized by definitions of an informative, geometric, and dimensional nature, it is possible to proceed with the digital modeling of the fortifications.

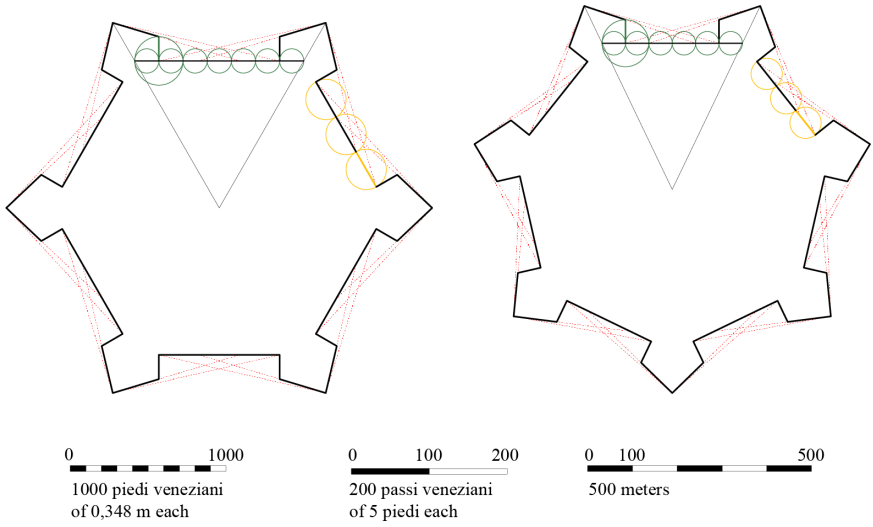


Fig. 3 - Geometric construction of the defended polygon from the treatises by Tensini (hexagon) and Lorini (heptagon). (Souce: Rechichi, 2025; Elaborated by Rechichi, P.)

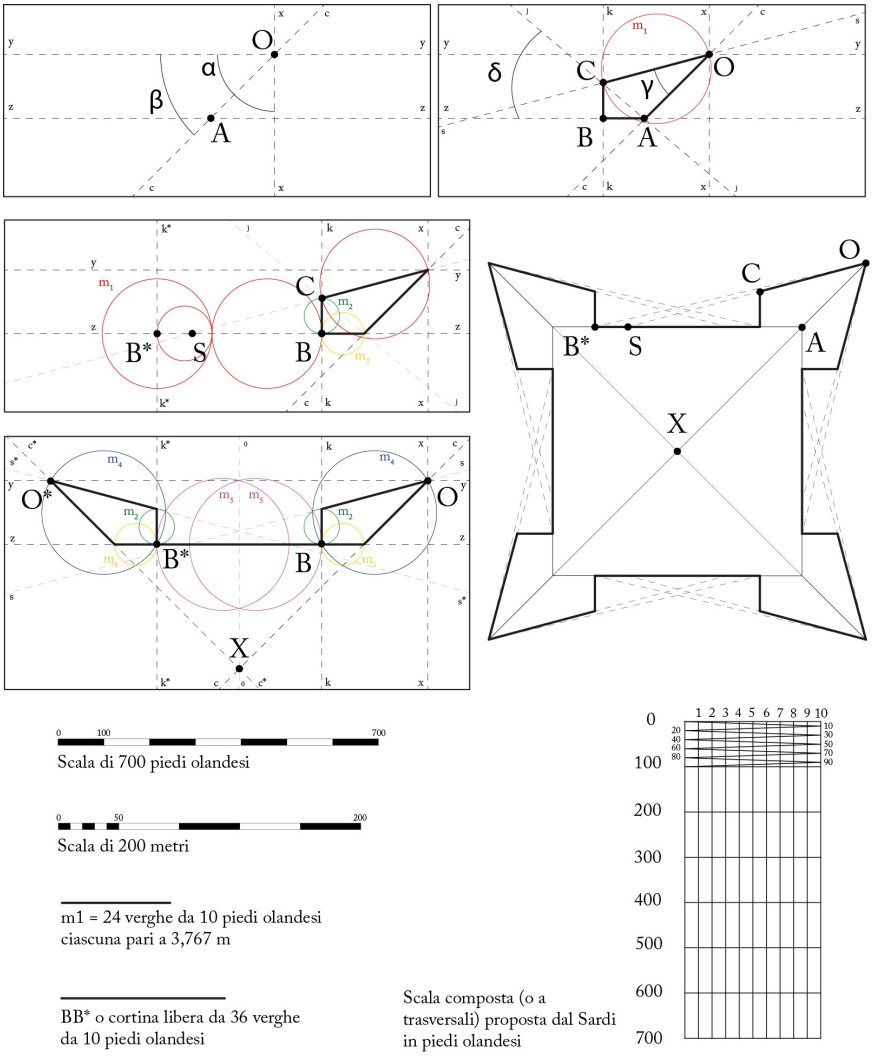


Fig. 4 - Geometric construction of the defended polygon from the third book of the Corno Dogale by Pietro Sardi (Souce: Rechichi, 2024; Elaborated by Rechichi, P.)

The analysis of geometric tracing methods for the defended polygons allows for defining a script in Grasshopper that precisely replicates the tracing operations of the defense following the prescriptions of the treatises. The shape of the defended polygon dynamically adapts to the variation in the number of sides of the reference regular polygon.

The knowledge framework developed through the analysis of the text and the critical redesign operations makes it possible to geometrically relate every part of the fortification to its original defended profile.

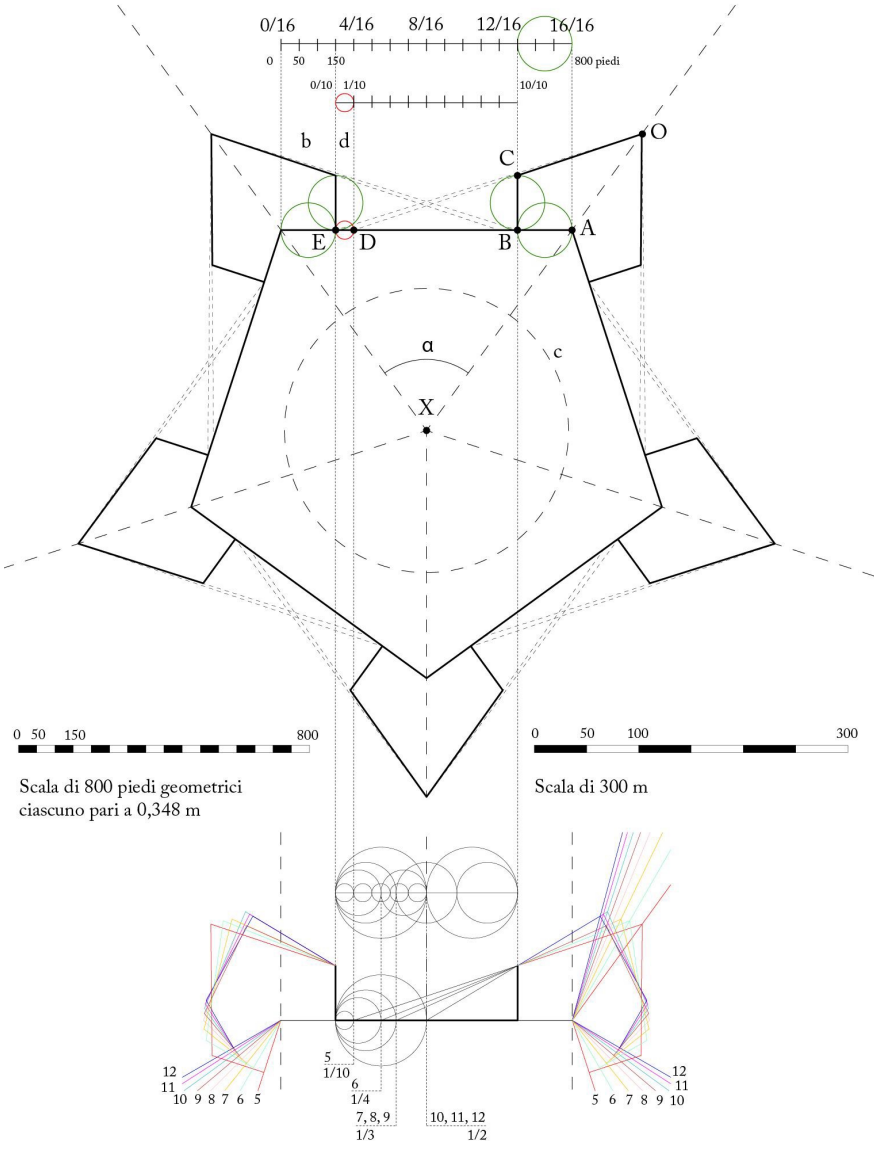


Fig. 5 - Geometric construction of the defended polygon from the second book of the Corno Dogale by Pietro Sardi (Source: Rechichi, 2024; Elaborated by Rechichi, P.)

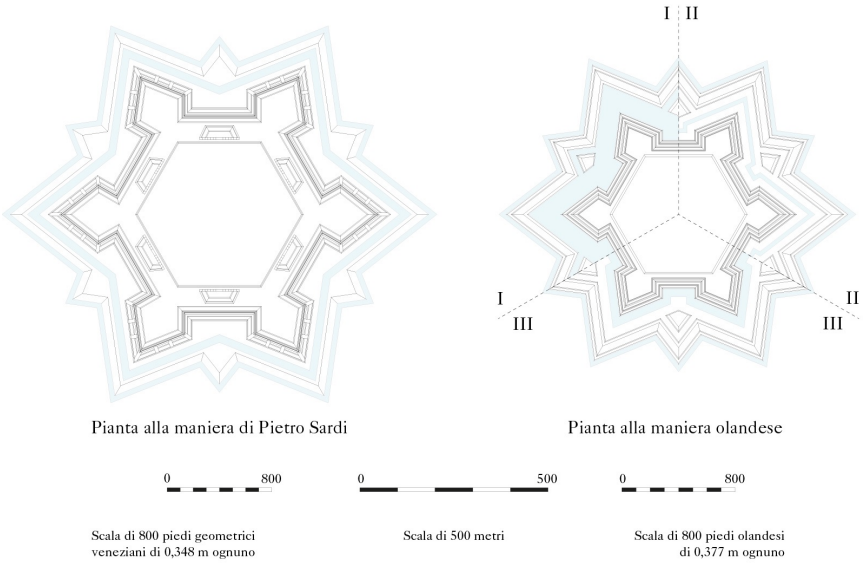


Fig. 6 - Critical redrawing of icnographic projections of fortifications from the second and third book of the Corno Dogale by Pietro Sardi. (Rechichi, 2024; Elaborated by Rechichi, P.)

The computational model of the fortification system is developed by replicating these relationships in VPL within Grasshopper (Fig. 9). Concerning the treatises of Sardi, Tensini and Lorini, the three-dimensional forms of the components of the fortification system are obtained from a composition system of surfaces, generated by two or more closed polyline curves.

These closed polyline curves are obtained as translations, offsets, and intersections starting from only the initial defended profile. With this technique, it is possible to create a script capable of containing all the geometric characterizations of the fortification system, which dynamically adapts to the variation of the parameter representing the number of sides of the regular polygon.

The result of this process consists of a system of closed three-dimensional forms, each corresponding to one of the entities of the fortification system.

It's relevant to note that for the Trattato di Fortificatione by Guarini, a different approach to parametric modelling was adopted compared to the general workflow outlined for the other treatises.

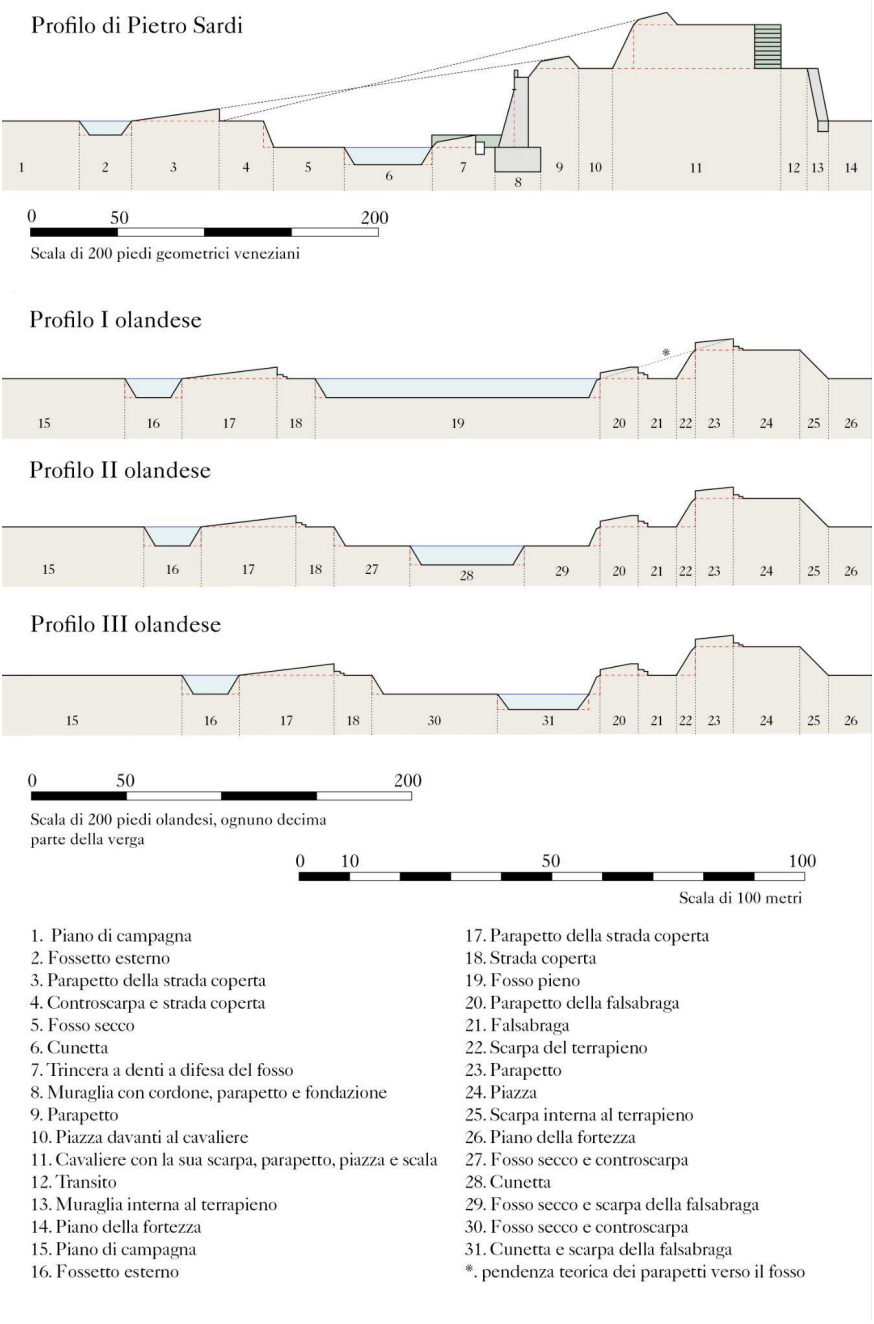


Fig. 7 - Critical redrawing of orthographic projections of fortifications from the second and third book of the Corno Dogale by Pietro Sardi. (Source: Rechichi, 2024; Elaborated by Rechichi, P.)

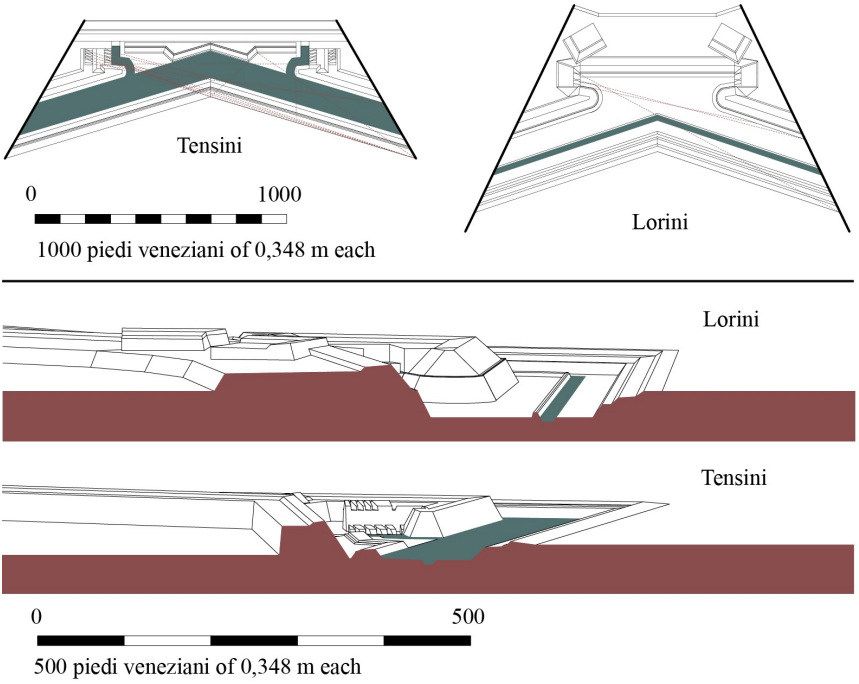
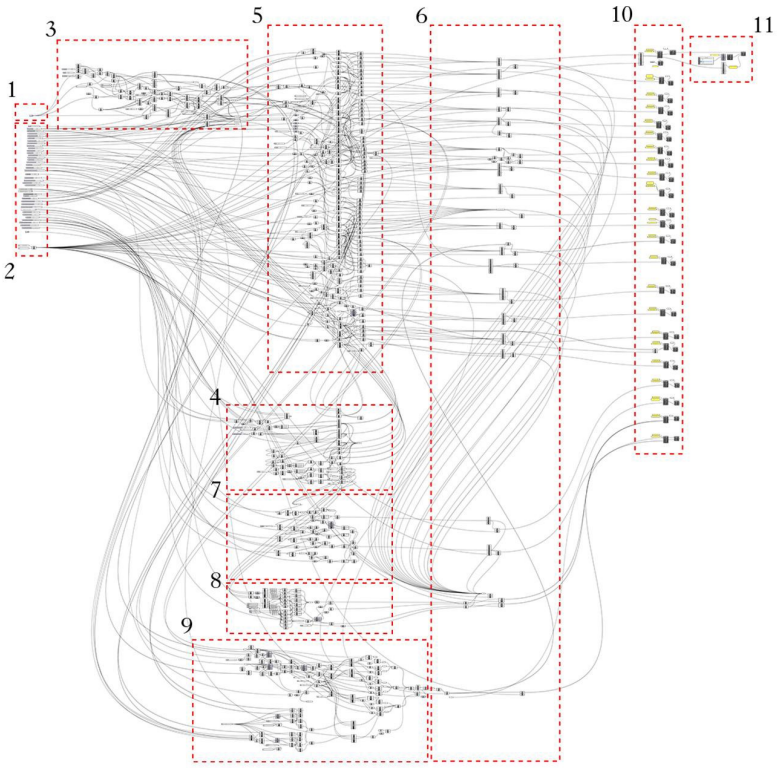


Fig. 8 - Critical redrawing of icnographic projections of fortificatory systems from the treatises by Bonaiuto Lorini and Francesco Tensini. Perspective sections of the same fortificatory sytems (Source: Rechichi, 2025; Elaborated by Rechichi, P.)

The modelling of Guarini's treatise was undertaken focusing on the dimensional prescriptions provided in tabular form within the treatise (maximum, medium, and minimum).

The methodological approach for Guarini involved structuring an algorithm organized into thematic clusters, each dedicated to a specific element of the fortification. This cluster-based organization facilitated the separate management of different modelling phases, from initial delineations to the generation of second delineation elements (Fig. 10).

Dimensional control was implemented using multiline data panels, allowing for simultaneous modification of correlated parameters through a single selector, thus ensuring model coherence across dimensional variations. Geometry generation was achieved through monorail sweeps, with particular attention paid to defining section curves.



1. Numero di lati
2. Parametri dimensionali (espressi in piedi geometrici veneziani) e fattore di scala (modello metrico)
3. Prima delineazione planimetrica
4. Tracciamento in pianta dei cavalieri
5. Polilinee spezzate chiuse per ogni variazione di pendenza
6. Modelli 3D delle singole entità della fortificazione (closed polysurfaces)
7. Corpo e parapetto dei cavalieri
8. Scale dei cavalieri
9. Denti della trincera a difesa del fosso
10. Importazione Rhino.Inside.Revit
11. Aggiunta di un parametro di informazione con il suo valore

Fig. 9 - Grasshopper graph for the BIM integrated procedural model of the fortified system of the second book of the Corno Dogale by Pietro Sardi (Source: Rechichi, 2024; Elaborated by Rechichi, P.)

These curves were constructed as closed polylines based on control points driven by parametric vectors, whose direction and magnitude varied according to selected dimensional values (maximum, medium, or minimum). A key challenge addressed was ensuring geometric continuity between adjacent sections to avoid both penetrations

and discontinuities, achieved through a control point concatenation system where adjacent section curves shared tangent points, ensuring a coherent transition of generated solids.

To digitally inform these entities, the Rhino.Inside.Revit plugin was utilized. This plugin allows for opening a script created in Grasshopper directly from the Revit software.

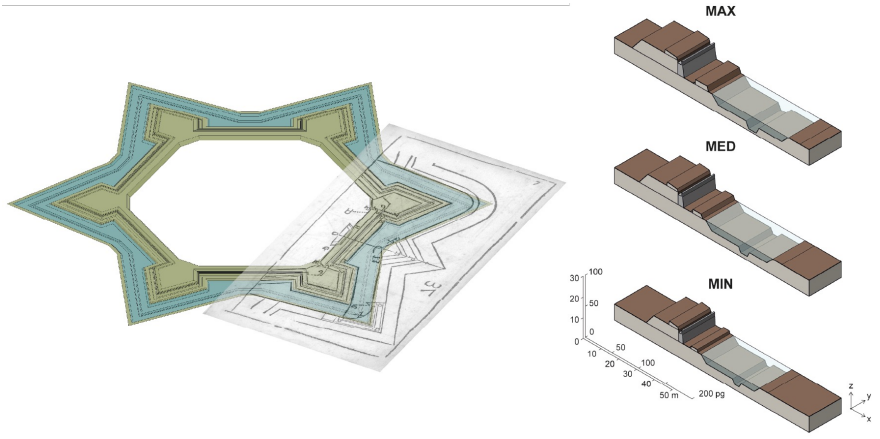


Fig. 10 - Parametric model of Guarini's fortress based on maximum dimensions (L). Axonometric section of Guarini's fortress; variation in size of the consistencies through maximum, average and minimum values taken from Guarini's tables (R). (Source Processing: E. Pupi, F. Natta)

Specific VPL components enable the visualization of the fortification system's geometries as direct shapes in Revit and manage the insertion of custom instance parameters, to which values can be associated that can dynamically vary with the number of sides of the regular polygon.

The model thus created can be used dynamically in Revit or saved as a standalone model constrained to the defined parameter values. Once saved, the standalone model can be freely modified and informed in Revit (Fig. 11).

To facilitate the visualization, querying, and management of fortified models directly within the browser – eliminating the need for dedicated software – this project prioritizes web-based access to BIM models through an intuitive, user-centered interface.

While current solutions allow both visualization and data interrogation online, challenges remain in optimizing performance and enhancing semantic structuring.

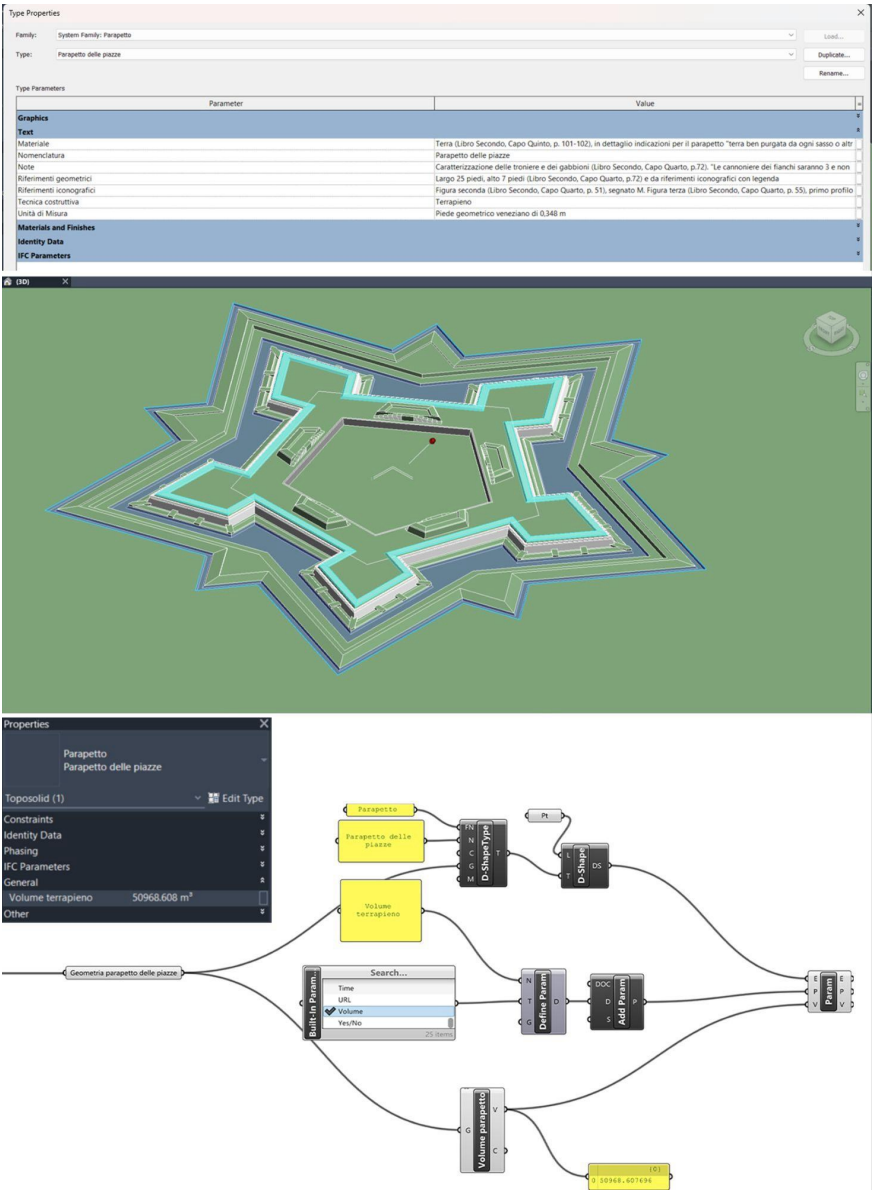


Fig. 11 - Revit visualization and information of the model of the fortified system of the second book of the Corno Dogale by Pietro Sardi (Rechichi, 2024; Elaborated by Rechichi, P.)

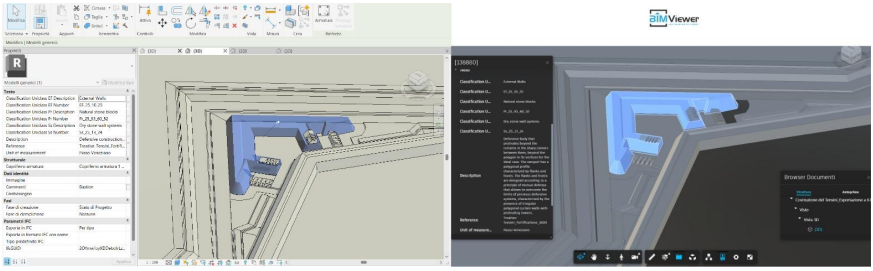


Fig. 12 - BIM Viewer online access to the digital model from the treatise by Tensini (Source: Rechichi, 2025; Elaborated by Miele, V.)

WebGL-powered platforms play a crucial role in this context, enabling browsers to render 3D content without external plugins.
The most widely used tools include Autodesk Forge Viewer, Unity with WebGL, and CesiumJS. Ensuring model conversion to the IFC format preserves essential geometric and metadata attributes, making information accessible to non-expert users. Integrating these visualization tools into a streamlined web environment allows users to explore fortification elements with real-time access to metadata and descriptive content displayed in an adjacent panel. Following a comparative evaluation of available solutions, BIM Viewer was chosen for its flexibility in handling multiple file formats, eliminating the need for IFC conversion and enabling seamless sharing across different platforms (Fig. 12).

Discussion and Conclusion

The creation of digital information models for the fortification systems proposed in the four described treatises has made it possible to verify the capacity of the proposed methodology to adapt or not to the variety of the landscape of early modern military architecture treatises.

The four models present different geometric and functional characterizations, which elevate or reduce the richness and complexity of the elements and their forms.

In this sense, Sardi's *Corno Dogale* is characterized by great descriptive clarity and great simplicity of the fortification model; the experiments conducted on Lorini and Tensini, instead, have demonstrated how increasing the number and geometric complexity of the parts of the fortification can make the development of a script capable of returning a dynamic digital model of the fortification system extremely demanding and complex.

Guarini's *Trattato di Fortificatione* offered a further modelling opportunity due to its tabular format specifying maximum, medium, and minimum dimensions for each element. This distinctive feature shaped a slightly different parametric approach.

Unlike models relying on lofted surfaces, Guarini's model uses sweeps to create forms based on these dimensional sets dynamically, showcasing design variations inherent in the text. This highlights the methodology's adaptability to different dimensional data types and geometric construction techniques, enabling the representation of both singular designs and ranges of design possibilities encoded in historical treatises.

This comparative analysis across the four treatises reveals a spectrum of modelling challenges and opportunities.

The varying levels of geometric and functional complexity encountered in these texts underscore the need for a flexible and adaptable methodological framework. Moving forward, this suggests the potential for tailoring modelling approaches to the specific characteristics of each treatise.

This could involve strategies like developing models with different levels of detail depending on the treatise's complexity, or combining dynamic parametric control for key elements with more traditional modeling for others.

This observation is particularly significant considering the creation of digital information models of treatises that are more focused on the constructive aspects of fortification, which will be the subject of future studies within the INFORTREAT project.

The four treatises studied, in fact, are characterized by a partial and non-exhaustive treatment of these subjects. Furthermore, in the selection of future case studies, the need to broaden the temporal span of publication of the treatises will be taken into account.

References

Apollonio, F. I., Baldissini, S., Clini, P., Gaiani, M., Palestini, C., & Trevisan, C. (2013). The Palladio Library Geo-Models: An open 3D archive to manage and visualize information-communication resources about Palladio. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XL-5/W2*, 49–54.

Cache, B. (2009). *Fortuito supra acanthi radicem: Essai de lecture contemporaine du De Architectura de Vitruve* (Ph.D. dissertation). University of Paris I.

Carpo, M. (2016). Parametric Notations. The Birth of the Non-Standard. *Architectural Design*, *86*(2), 24–29.

Chiabrando, F., Lo Turco, M., & Santagati, C. (2017). Digital invasions: From point clouds to historical building object modeling (H-BOM) of a UNESCO WHL Site. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-2/W3*, 171–178.

Croce, V., Piemonte, A., Caroti, G., & Bevilacqua, M. G. (2019). Geomatics for Cultural Heritage conservation: Integrated survey and 3D modeling. In *Proceedings of 2019 IMEKO TC-4 International Conference on Metrology for Archaeology and Cultural Heritage* (pp. 271-276). IMEKO.

De Luca, L. (2014). Methods, formalisms and tools for the semantic-based surveying and representation of architectural heritage. *Applied Geomatics*, *6*(2), 115–139.

De Luca, L., Busayarat, C., Stefani, C., Véron, P., & Florenzano, M. (2011). A semantic-based platform for the digital analysis of architectural heritage. *Computers & Graphics*, *35*(2), 227–241.

De Luca, L., Véron, P., & Florenzano, M. (2007). A generic formalism for the semantic modeling and representation of architectural elements. *The Visual Computer*, *23*(3), 181–205.

ElYamany, H., Elawady, M., Abdelhay, E., & Khalil, A. (2012). A web service-based framework for an online 3D model viewer. In *Federated Conference on Computer Science and Information Systems* (pp. 1405-1410). IEEE.

Furuta, S., Nakazato, J., & Tsukada, M. (2023). Web-Based BIM Platform for Building Digital Twin. In *IEEE 3rd International Conference on Digital Twins and Parallel Intelligence (DTPI)* (pp. 1-6). IEEE.

Giovannini, E. C. (2023). Making Palladio Digitally Explicit: Geometrical Parameters in Door's Ornaments. *Nexus Network Journal*, *25*, 773–794.

Li, K., Zhao, H., Zhang, Q., & Jia, J. (2022). CEBOW: A Cloud-Edge-Browser online Web3D approach for visualizing large BIM scenes. *Computers & Animation and Virtual Worlds*, *33*(2), e2039.

Liu, X., Xie, N., & Jia, J. (2015). WebVis BIM: Real time web3d visualization of big BIM data. In *Proceedings of the 14th ACM SIGGRAPH International Conference on Virtual Reality Continuum and its Applications in Industry VRCAI '15* (pp. 43-50). ACM.

Lo Buglio, D., & De Luca, L. (2012). Representation of architectural artifacts: Definition of an approach combining the complexity of the 3d digital instance with the intelligibility of the theoretical model. *SCIRES-ITI*, *2*(2), 63–76.

Lo Turco, M., Giovannini, E. C., & Tomalini, A. (2022). Parametric and Visual Programming BIM Applied to Museums, Linking Container and Content. *ISPRS International Journal of Geo-Information*, *11*(7), 371.

Lorini, B. (1609). *Le fortificationi di Bonaiuto Lorini, nobile fiorentino [...]*. Francesco Rampazzetto (Venezia).

Marolois, S. (1627). *Fortification ou Architecture militaire tant offensive que deffensive*. Ian Iansen (Amsterdam).

Palestini, C. (2017). *Imagination and Images: From the Treatise to the Digital Representation*. Sforzinda and the Bridges in the Inda Valley. *Proceedings*, *1*(9), 893.

Rechichi, P., Miele, V., & Bevilacqua, M. G. (2025). Digital Dialogues between military architecture Treatises. The case of "Le Fortificationi ..." by Bonaiuto Lorini and "La fortificatione guardia difesa et espugnatione delle fortezze ..." by Francesco Tensini. In Zerlenga, O. & Cirillo, V. (eds.) *Defensive Architecture of the Mediterranean, Vol XX (pp.1165-1172)*. University of Campania, Luigi Vanvitelli, edUPV.

Rechichi, P., Miele, V., & Bevilacqua, M. G. (2024). Modelli informativi digitali di architettura militare della prima età moderna. Il caso del Corno Dogale di Pietro Sardi/Digital informative models of early modern military architecture. The case of the Corno Dogale by Pietro Sardi. In F. Bergamo, A. Calandriello, M. Ciammaichella, I. Friso, F. Gay, G. Liva, & C. Monteleone (Eds.), *Misura / Dismisura. Atti del 45° Convegno Internazionale dei Docenti delle Discipline della Rappresentazione/Measure / Out of Measure. Transitions. Proceedings of the 45th International Conference of Representation Disciplines Teachers* (pp. 3603-3626). FrancoAngeli. https://doi.org/10.3280/oa-1180-c502

Sardi, P. (1618). *Corona Imperiale dell'Architettura Militare*. Barezzo Barezzi (Venezia).

Sardi, P. (1639). *Corno Dogale dell'Architettura Militare*. I Giunti (Venezia).

Scolari, M. (2005). *Il disegno obliquo: una storia dell'antiprospettiva*. Marsilio.

Simeone, D., Cursi, S., & Acierno, M. (2019). BIM semantic-enrichment for built heritage representation. *Automation in Construction*, *97*, 122–137.

Spallone, R., & Vitali, M. (2024). "Prima daremo le regole universali, indi le misure particolari". Geometria, balistica e costruzione per il progetto delle fortezze nel Trattato di Fortificatione di Guarini. In F. Bergamo, A. Calandriello, M. Ciammaichella, I. Friso, F. Gay, G. Liva, & C. Monteleone (Eds.), *Misura / Dismisura. Atti del 45° Convegno Internazionale dei Docenti delle Discipline della Rappresentazione/ Measure / Out of Measure. Transitions. Proceedings of the 45th International Conference of Representation Disciplines Teachers* (pp. 621-642). FrancoAngeli. https://doi.org/10.3280/oa-1180-c502

Stefani, C., Busayarat, C., Lombardo, J., De Luca, L., & Véron, P. (2013). A web platform for the consultation of spatialized and semantically enriched iconographic sources on cultural heritage buildings. *Journal on Computing and Cultural Heritage*, *6*(3), Article 13.

Tensini, F. (1630). La Fortificatione guardia difesa et espugnatione delle fortezze [...]. Antonio Bariletti et Fratelli al Segno del Mondo (Venezia).

Digital Survey Techniques for the Documentation of Military Architecture. The Case of the Citadel of Alessandria and Santa Croce Bastion of Lucca

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Introduction

The survey of fortified walls outlines a broad research domain, highlighting different elements of complexity. These artefacts require careful survey planning and experimental approaches to preserve their original shape. Within this process, data traceability is essential to controlling the overall accuracy and obtaining reliable metric information for interpretive purposes. The activity described here is devoted to surveying a portion of the walls of the Citadel of Alessandria and Lucca.

Case Studies

The two case studies (Fig. 1) show significant differences due to the period's historical development and construction techniques. Starting with Lucca's example, the fortifications' construction began in 1544 and was completed in 1650 (Martinelli, 1983). The portion of the wall surveyed is the bastion of Santa Croce, located in the northwestern corner of the defensive circuit. Its shape reflects the articulated and layered internal conformation of the medieval walls due to modifications (Bertoncini Sabatini, 2023) in the project of Muzio Oddi (1569-1639). The founding core is the early 16th-century keep, incorporating a pre-existing corner turret. A series of interventions conducted in 1571 inserted the gunnery and vaulted gallery to access the inner powder magazine. Further interventions in 1597 by Ginese Bresciani absorbed everything into a semi-bastion facing east, creating a double system of manoeuvring squares. This work contributes to the definition of the current layout (Martinelli, 2013). The conservation conditions in terms of materials and vegetation, as well as site accessibility, are acceptable, thanks to systematic control by the inspection and maintenance agencies.

As for the Alexandrian fortress, it was designed in its essential components by Giulio Ignazio Bertola and built from 1728 to the 1760s (Marotta, 1991, 2018). The area of interest is the bastion of Santa Cristina, located to the southwest near the access bridge to the Citadel.

The work has concave sides with entrenchments and is made with extensive use of rammed earth, including buttresses and prominences on the inner side of the masonry (Marotta, 2015). There are no traces of underground rooms in the present bastion.



Fig. 1 – Case studies photos and relative historical map: on the left Lucca, on the right Alessandria. (Source: figure processed by the authors)

The Citadel was built as a plain fortress, so the foundation system mainly used is that on piles (Piccoli et al., 2019). Interventions conducted at the end of the 18th century and in the following century contributed to changes in the vegetation framework of the ramparts, also involving the upper knight area (Marotta et al., 2018). The current condition is framed by pervasive vegetation due to the complicated maintenance and management of the asset, making the accessibility of the site complex.

Survey Methodologies

The methodologies are based on integrating active and passive sensors and adjusting them to individual case studies to meet their specificities (Fig. 2).
The geodetic reference and control network of the bastion of Santa Croce was implemented with 19 points with a dual-frequency differential GNSS (GS18, Leica Geosystem) used in NRTK mode and connected to the Smartnet Italpos network (Leica Geosystem). The latter allowed the data to be geo-referenced in the ETRF2000 (2008.0) reference system. The range-based acquisition was based on the use of a TLS RTC360 (Leica Geosystem), with a distribution of 127 indoor scans at an average distance of 6÷8 m and a resolution of

about 1 cm@10 m and 63 outdoor, with an average baseline of 15÷20 m and a resolution of about 1 cm@5 m.



Fig. 2 – Survey phases: from the left GNSS and TLS acquisition in Lucca and GNSS and TLS acquisition in Alessandria. (Source: created by the authors)

The spatial articulation of the site justifies the large number of stations (Fig. 3). Finally, the photogrammetric survey focused on some details, such as the wall traces of the turret, using a Nikon D750 camera with a 50 mm fixed focal length lens.

The bastion of the Santa Cristina presents significant differences. The presence of a pre-existing survey with LIDAR made it possible to avoid surveying the upper part, focusing only on the outer curtain wall.

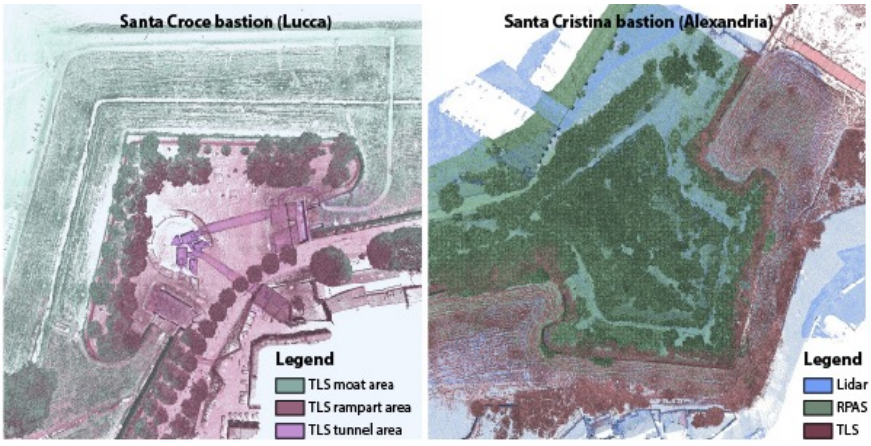


Fig. 3 – Maps with relative survey data distribution. (Source: created by the authors)

The absence of tunnels made it possible to reduce the number of scan stations significantly.

However, the presence of invasive vegetation and the extension of more than 16,000 square meters required the planning of precision controls. The survey, therefore, took on the dual function of supplementing and verifying the existing one.



Fig. 4 – Global range maps of the areas: Santa Croce on top view, Santa Cristina on the bottom. (Source: created by the authors)

A geodetic grid of 8 points was materialized using the GNSS GR5 receiver (Topcon) in NRTK mode connected to Topcon's Netgeo network. This control grid allowed subsequent surveys to be metrically verified and made consistent in the ETRF2000 (2008.0) reference system, the same as the existing survey. The range-based survey used TLS RTC360 (Leica Geosystem), acquiring 24 scans at an average distance of 30-40 meters (resolution of 6 mm@10 meters), corresponding to a 2-3 cm sampling step on the walls (Fig. 4). A photographic survey campaign of a masonry portion was planned using a DSC-HX60 camera (Sony) with a focal length of 4 mm.

Data Process

The internal and external 3D scans of the bastion of Santa Croce were mutually aligned in Cyclone Register 360 software (Leica Geosystem) and oriented in ETRF2000 (2008.0), highlighting centimetre residuals. The enormous amount of data acquired, necessitated by the morphological complexity of the case study, required the definition of an information optimization path for managing the survey model. The approach was based on two levels of individual filtering of the individual scans: the first according to the working distance, the second according to the position inside or outside the bulwark. In the indoor scans, a 10-meter distance filter and a 1-cm subsampling were applied, while in the outdoor scans, we used a 40-meter distance filter and a 2-cm subsampling.

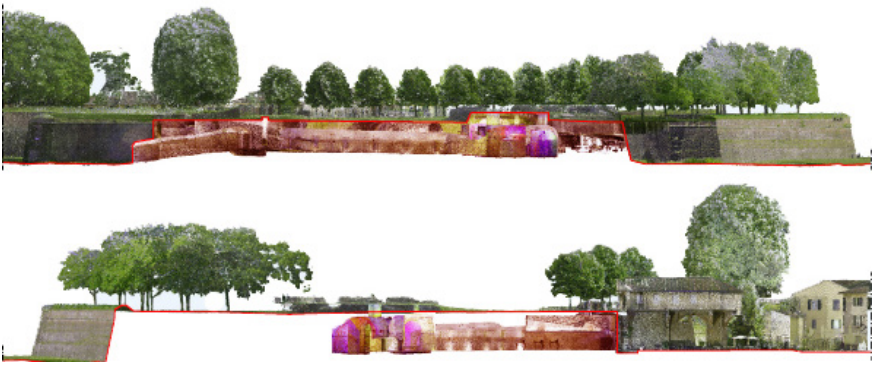


Fig. 5 – Two sections of Santa Croce baluard with tunnel area highlighted in red. (Source: created by the authors)

All clouds were managed within the Recap platform (Autodesk) (Fig. 4) extracting sections (Fig. 5). The photogrammetric blocks were processed separately, orienting the models with GCPs (Ground Control Points) extracted from the range-based data in the global reference system. Regarding the Santa Cristina case study, GNSS coordinates were imported into Cyclone Register 360 software (Leica Geosystem) to constrain the scans' alignment.

This step was essential to orient the range-based data in the absolute reference system (Fig. 4), optimizing the orientation residuals, given the considerable presence of vegetation and flat wall surfaces that reduced the ICP algorithm's efficiency.

This process resulted in residuals of no more than 8 cm. The photogrammetric block was oriented using the 3D laser scanner points oriented as GCPs, resulting in residuals of a few centimetres. Given the complex boundary conditions, comparison sections were extracted between the 3D data.

This analysis showed consistency between the range-based and image-based in terms of geometry while highlighting variations in radiometric quality (Fig. 6).

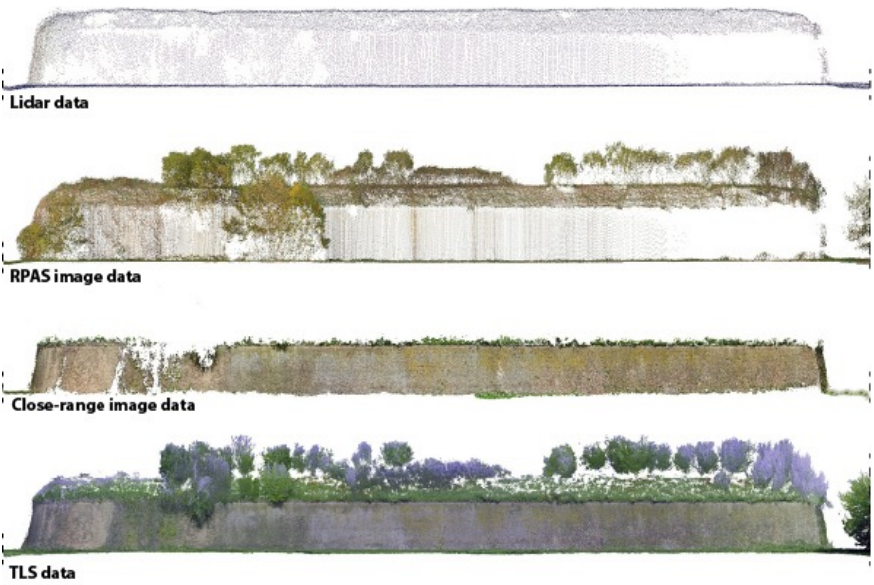


Fig. 6 – Comparison of the same wall of Santa Cristina baluard with different 3D survey techniques. (Source: created by the authors)

Finally, a vertical offset of 10 cm was present between the existing and new surveys, probably due to the different vegetation status and the lower accuracy of the LIDAR survey. The data were then integrated correctly.

Conclusions

The survey activity described compares two different experiences in surveying bastions in Lucca and the Citadel of Alexandria.

The two case studies showed different problems in data acquisition and processing, demonstrating again how established survey methodologies still require readjustment to the working context and characteristics of the individual case study.

Checking accuracy at different stages allowed the process to be tracked, resulting in reliable survey models which allow data extraction and comparison activieties (Fig. 7).

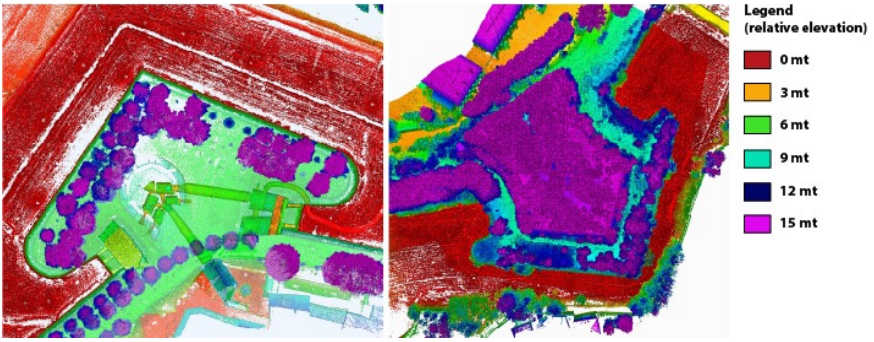


Fig. 7 – Comparison of DSM of Santa Croce (on the left) and Santa Cristina on the right. (Source: created by the authors)

Acknowledgements

The authors would like to thank architect Francesca Lupo, Soprintendenza Archeologia Belle Arti e Paesaggio di Alessandria, Asti e Cuneo, for the permissions granted for the Cittadella survey activities and for sharing the data previously acquired by the TecnoIN Company. In writing the text, M.R. is responsible for the Introduction and Conclusions, E.P. and P. B.S. for the Case Studies, G.C. and A.P. for the chapter on Survey Methodologies, M.C. for the chapter on Data Process.

References

Bertoncini Sabatini, P. (2023). Muzio Oddi architetto di fortificazioni nell'Italia del Seicento. In M. G. Bevilacqua & D. Ulivieri (Eds.), *Defensive architecture of the Mediterranean (Vol. 13): Proceedings of FORTMED – Modern Age Fortification of the Mediterranean Coast, 23–25 March 2023, Pisa* (pp. 29–36). Pisa University Press.

Martinelli, R., & Puccinelli, G. (1983). *Lucca. Le mura del Cinquecento, vicende costruttive dal 1500 al 1650*. Matteoni.

Martinelli, R. (2013). *Lucca e le sue mura*. PubliEd Editore.

Marotta, A. (2015). Fortifications in the territory of Alessandria: An heritage to preserve and enhance. In P. Rodriguez-Navarro (Ed.), *Defensive architecture of the Mediterranean. XV to XVIII centuries (Vol. 2): Proceedings of FORTMED – Modern Age Fortification of the Mediterranean Coast, 15–17 October 2015, València* (pp. 215–221). Editorial Universitat Politècnica de València.

Marotta, A. (2018). La cittadella di Alessandria nel primo impianto bertoliano (1728–1761): La conoscenza come parametro di progetto. In A. Marotta & R. Spallone (Eds.), *Defensive architecture of the Mediterranean (Vol. 7): Proceedings of FORTMED – Modern Age Fortification of the Mediterranean Coast, 18–20 October 2018, Torino* (pp. 135–142). Politecnico di Torino.

Marotta, A., Netti, R., & Pavignano, M. (2018). La cittadella di Alessandria negli sviluppi del periodo napoleonico (1808–1860): La conoscenza come parametro di progetto. In A. Marotta & R. Spallone (Eds.), *Defensive architecture of the Mediterranean (Vol. 7): Proceedings of FORTMED – Modern Age Fortification of the Mediterranean Coast, 18–20 October 2018, Torino* (pp. 143–150). Politecnico di Torino.

Marotta, A. (Ed.). (1991). *La Cittadella di Alessandria. Una fortezza per il territorio dal Settecento all'Unità*. SO.G.ED. Edizioni.

Piccoli, E., Tocci, C., Zanet, E., & Caterino, R. (2019). Building on water and the Modern State: Eighteenth century foundation techniques in the fortifications of Alessandria. In J. W. P. Campbell (Ed.), *Water, doors and buildings: Proceedings of the Sixth Conference on the Construction History Society, CHS, Studies in the History of Construction, 5–7 April 2019, Queen's College, Cambridge* (pp. 1–16). University of Cambridge.

Restoration and Maintenance Issues for the Early Modern Fortified Heritage

Michele Asciutti

Introduction

That of fortified architecture is clearly a very complex and articulated theme, but one of enormous historical-architectural, technological and urban importance.

Castles, towers and fortresses are elements that have characterised the man-made landscapes of villages, historic centres and the agricultural and natural environment in Italy and throughout Europe since ancient times.

Indeed, war requirements have always modelled regions and cities, strongly conditioning the urban and landscape design with defensive and surveillance works in continuous evolution and reinforcement, up to and after the permanence of conditions of real or potential danger.

In the case of fortresses of the modern era, we are often faced with extremely imposing constructions, calculated in terms of size, shape and volume of wall masses, factors necessary to respond to new war requirements due to the technological progress of offensive weapons.



Fig. 1 – The citadel of Alessandria (AL), object of study of the INFORTREAT research project. Commissioned by the Savoy family at the beginning of the 18th century, of great importance is its layout and the relationship with the river and the historic city (Source: image from Google Maps, 2025).

These factories represent, from the 16th century onwards, a settlement phenomenon of enormous impact, with foundation, on existing or new buildings, of extremely clear and articulated layout, indebted to the models and solutions of the walled city of the Renaissance, as a perfect interaction between residential and defensive needs (Figs. 1-2).



Fig. 2 – City walls of Lucca (LU), object of study of the INFORTREAT research project. Built as a deterrent from the mid-fifteenth century, they are the best-preserved modern wall within a city. The historical centre is contained within the walls, while the modern city develops around (Source: image from Google Maps, 2025).

All this in a panorama of military art consolidated by the production of a series of treatises of high scientific value, in which questions on fortified architecture were addressed for the first time in a systematic and accurate manner. Essays on war engineering inspired by geometry and the mathematical relationships between the parts, useful in establishing the best morphology of the fortress in order to defend and offend in the most optimal way, to safeguard life inside them and in the cities.



Fig. 3 – Rocca Paolina, Perugia (PG). The fortress (1540-1543), commissioned by Pope Paul III Farnese and built according to a design by Antonio da Sangallo the Younger, is an example of a stronghold constructed by incorporating the houses, towers and streets of an entire neighbourhood and partly by demolishing the houses of the noble Baglioni family (Source: https://www.bellaumbria.net/it/storia-e-archeologia/la-rocca-paolina).



Fig. 4 – Rocca Paolina, Perugia (PG). Detail of the Porta Marzia from the Etruscan era incorporated into the Sangallesca fortress (photo credits https://www.expedia.it/Rocca-Paolina-Old-Town-Perugia.d6073792.Punti-di-Interesse).

A conscious restoration project cannot abstain from knowledge of these issues if it wants, as it must, to understand the nature, the role of these monuments and their relationship with the city, in the multiple aspects they have taken on over the centuries: when they have remained basically intact, when they have changed their primary function, when they have been reused and transformed according to new needs, when they have been abandoned to their own devices, when they have been dismantled but still exist in the city design as an urban trace.

On each of these occasions, the inhabited area may or may not have 'invaded' the space of the fortification or distanced itself from it, further extending the casuistry (Figs. 3-4).

Knowledge and Design Methodologies for Conscious Restoration

It is therefore fundamental to understand the historical-territorial reasons for the construction of these fortresses, their geometric, formal and material logic, their relationship with the historical and present-day city and the remarkable technological-constructive articulation to which they bore witness, not only in terms of the warlike aspect, which is of course fundamental in this field, but also with regard to the stylistic, constructive and plant-engineering solutions, in order to be able to recognise them as clearly as possible and grasp the characteristics and relative values that must necessarily guide the choices of a restoration project.

The reading, systematization and reproduction of the architectures proposed in the military treaties, according to the norms and provisions indicated by them and with experimental and state-of-the-art computerised tools (HBIM), is a fundamental first step towards understanding the existing structures, for which it is thus possible to highlight schemes and typologies on the wartime functioning and the architectural technologies employed, proper to the material body of the built-up area.



Fig. 5 – The citadel of Alessandria (AL), entrance portal. You can see the architectural features, the different types of walls and the degradation of the structures (Source: https://radiogold.it/news-alessandria/cronaca/233980-cittadella-alessandria-fai-giornate-aperto/).



Fig. 6 – City walls of Lucca (LU). You can notice the architectural-constructive features that constitute the walls and their state of conservation (Source: www.comune.lucca.it/vivere-il-comune/luoghi/le-mura-di-lucca-un-parco-urbano/).

A mapping of the materials and their state of conservation, obtained by the same means, is equally important for the understanding of the state of the sites, a *conditio sine qua non* for the formulation of a restoration project attentive to the conservation of the material and authentic values of the buildings. In this sense is fundamental a representation of the architecture realised by means of high-precision instrumental surveys, capable of handling dimensions of an urban nature and simultaneously defining the form and dimensions of the masses, as well as the construction details and masonry textures of buildings that are also considerably stratified (Figs. 5-6). The aim is to search for those material traces indicative of the characters and transformations the buildings have undergone, which allow the reconstruction of their various construction phases and their history as unique and unrepeatable monuments. The use of the aforementioned technologies is also important for the creation of a database as a space for comparison and interchange for the various disciplines that provide the specialist knowledge that contributes to the formulation of a restoration project, with the possibility of wide dissemination of the scientific results obtained and the best conditions for their transmission to future generations.

Conclusions

In order to achieve this, it is not enough to deal with formal and material aspects, but it is necessary, where this is not explicit, to rethink the role of these monuments by grasping their more properly architectural vocation, in order to return quality architecture to the city, and thus to its population, with the identification of compatible functions that can favour their accessibility and usability. In this way, the buildings do not represent 'only' a memory, but live again through recreational or service use or as an open-air museum, different functions but always cultural issues, favouring care and maintenance extended over time, capable of prolonging life well beyond restoration work.

In short, a modelling of the architectures described in the treatises contributes to the creation and recognition of a model applicable

to real case studies, which in their formal characteristics and their historical-architectural values, recognised thanks to the quality of a detailed survey, restore a state of facts and a relationship with the territory that is extremely peculiar and different from time to time, guiding the choices of a conscious restoration project that is attentive to the authenticity of the monument, its compatible use and its transmission to posterity.

References

Bruschi, A. (1999-2000). Architettura come processo e trasformazione. Problemi metodologici e critici. *Architettura: processualità e trasformazione*, *Proceedings of the International Study Conference* (Rome, Castel S. Angelo, 24th-27th November 1999). *Quaderni dell'Istituto di Storia dell'Architettura*, *n.s.*, *34-39*, 29-32.

Canonaco, B. & Bilotta F. (2018). Analisi e conoscenza del sistema fortificato della costa dell'alto Tirreno Calabrese. In A. Marotta & R. Spallone (eds.), *Defensive Architecture of the Mediterranean*, *Prooceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2018* (Turin, 18th-20th October 2018), vol. VIII (pp. 479-486). Politecnico di Torino.

Carafa, R., Guadagno, V. & Carafa, E. (2018). Restauro del Castello Ducale di Sessa Aurunca. In A. Marotta & R. Spallone (eds.), *Defensive Architecture of the Mediterranean, Prooceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2018* (Turin, 18th-20th October 2018), vol. VIII (pp. 487-494). Politecnico di Torino.

Carbonara, G. (1996). La conservazione integrata e il patrimonio edilizio. In G. Carbonara (eds.), *Trattato di Restauro Architettonico*, vol. 1 (pp. 91-99). UTET.

Carbonara, G. (1997). *Avvicinamento al restauro. Teoria, storia, monumenti*. Liguori Editore.

Dameri, A. (2018). Demolire per difendere. Lo smantellamento di fortezze nel XVII secolo. In A. Marotta & R. Spallone (eds.), *Defensive Architecture of the Mediterranean, Proceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2018* (Turin, 18th-20th October 2018), vol. VII (pp. 87-94). Politecnico di Torino.

D'Avino, S. (2018). La ricostruzione dell'identità. La cinta urbana di Norcia. In A. Marotta & R. Spallone (eds.), *Defensive Architecture of the Mediterranean*, *Proceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2018* (Turin, 18th-20th October 2018), vol. VIII (pp. 543-548). Politecnico di Torino.

De Cadilhac, R. (2020). Quale futuro per il patrimonio fortificato: problemi di conservazione e valorizzazione. In J. Navarro Palazón & L.J. García-Pulido (eds.), *Defensive Architecture of the Mediterranean*, *Proceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2020* (Granada, 26th-28th March 2020), vol. XI (pp. 859-865). Universidad de Granada, Universitat Politècnica de València, Patronato de la Alhambra y Generalife.

Doglioni, F. (2010). Leggibilità della costruzione, percorsi di ricerca stratigrafica e restauro. *Archeologia dell'architettura*, *15*, 65-79.

Gallozzi, A. & Cigola, M. (2018). Rappresentazioni di guerra tra XVIII-XIX secolo. Piani d'attacco e Piani di difesa della fortezza di Gaeta. In A. Marotta & R. Spallone (eds.), *Defensive Architecture of the Mediterranean*, *Proceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2018* (Turin, 18th-20th October 2018), vol. VII (pp. 103-110). Politecnico di Torino.

Gentilini, G. (2024). Resoconto sul primo cantiere di restauro conservativo delle murature dei bastioni settentrionali del castello dei Paleologi a Casale Monferrato (Alessandria). In G. Islami & D. Veizaj (eds.), *Defensive Architecture of the Mediterranean*, *Proceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2024* (Tirana, 18th- 20th April 2024), vol. XVI (pp. 239-246). Universiteti Politeknik i Tiranës.

Magnano di San Lio, E. (2018). L'architettura fortificata nella cultura ingegneristica dei secoli XVIII e XIX. In A. Marotta & R. Spallone (eds.), *Defensive Architecture of the Mediterranean*, *Proceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2018* (Turin, 18th-20th October 2018), vol. VII (pp. 319-326). Politecnico di Torino.

Malagugini, M. (2018). Le fortificazioni genovesi: dall'analisi alla valorizzazione. In A. Marotta & R. Spallone (eds.), *Defensive Architecture of the Mediterranean*, *Proceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2018* (Turin, 18th-20th October 2018), vol. VIII (pp. 705-712). Politecnico di Torino.

Miarelli Mariani, G. (1992), *Centri storici. Note sul tema*. Bonsignori Editore.

Spagnesi, G. (1999-2000). Storicità, autenticità e contemporaneità delle architetture. *Architettura: processualità e trasformazione*, *Proceedings of the International Study Conference* (Rome, Castel S. Angelo, 24th-27th November 1999). *Quaderni dell'Istituto di Storia dell'Architettura*, *n.s.*, *34-39*, 17-28.

Tunzi, P. (2018). Piante di città fortificate raccolte da Giulio Ballino (1569). In A. Marotta & R. Spallone (eds.), *Defensive Architecture of the Mediterranean*, *Proceedings of the International Conference on Modern Age Fortification of the Mediterranean Coast. FORTMED 2018* (Turin, 18th-20th October 2018), vol. VII (pp. 257-264). Politecnico di Torino.

External Research Contributions

Proceedings of the Mid-Term Conference 'Le Fortificazioni di Eta' Moderna: Conoscenza per la Gestione, Conservazione Valorizzazione', Rome, 11/11/2024

The Defense Towers of the Coast of The Kingdom of Valencia in the Modern Age

Pablo Rodríguez-Navarro, María Teresa Gil Piqueras

Introduction

This study analyzes the system of defense towers built along the coast of the Kingdom of Valencia between the 16th and 18th centuries. These structures were fundamental in protecting the coastline against attacks by Berber and Turkish pirates. Previous studies exist, most of which focus individually on one of these constructions or on a specific area within the Kingdom. However, in the present study, they are examined comprehensively, emphasizing their design, distribution, and strategic function, based on documentary sources but especially on the towers that are still preserved, whether in their entirety or as archaeological remains. To this end, site visits were conducted, three-dimensional graphic surveys were carried out, and architectural plans were subsequently obtained.

With these new documents, multiple analyses can be conducted, ranging from formal to constructive or typological studies, as well as analyses of the defense strategies devised by the engineers of the time. Additionally, we have incorporated the use of digital 3D models by non-experts, facilitating their understanding and put in value.

A New Defensive System

This study focuses on the emergence of military architecture along the Levantine coast during the 16th century, primarily driven by the confluence of a particular socio-political context and aspects of technological development.

Since the 15th century, the coasts of the western Mediterranean had suffered constant attacks by Berber pirates, whose main base was in North Africa. These attacks were encouraged by the Ottoman Empire, which used piracy as a tool to weaken Christian powers. In this context, the Crown of Aragon and later the Spanish Monarchy implemented defensive strategies to protect their coasts (Aguiló, 2006).

In 1557, upon ascending the throne, Philip II initiated the ambitious project previously outlined by Bernardino de Cárdenas, Duke of Maqueda, for his father.

This project aimed to establish a network of watchtowers and coastal defense towers tasked with warning neighboring towns of attacks, as well as serving as the first line of defense. This initiative led to the creation of the institution known as the 'Coast Guard.'



Fig. 1 - Xarco Tower, Alicante. Source: created by the authors.

During the 15th century in Italy, a crucial shift in military architecture took place in response to the destructive power of artillery and the new warfare strategies it entailed.

A change was necessary to address the demands of defining borders, not only by directly protecting against enemy attacks but also by alerting the rear lines of their approach. Consequently, it was concluded that isolated tower systems should be adapted and increased to serve as the first line of alert and defense.

The defense problem of the Valencian coast was, without a doubt, similar to that of other Mediterranean coasts in the 15th century.

However, after the Turks settled in Algeria in 1516, the issue exponentially expanded to the Valencian coast, primarily due to two factors:

- the presence of Muslims in Valencia (forced to convert to Christianity), who constituted the majority of the Valencian population and not only did not prevent but even facilitated Turkish attacks;
- the absence of fortifications and even naval defense systems, which were only found in large cities and not in smaller settlements, making them vulnerable entry points for invaders.

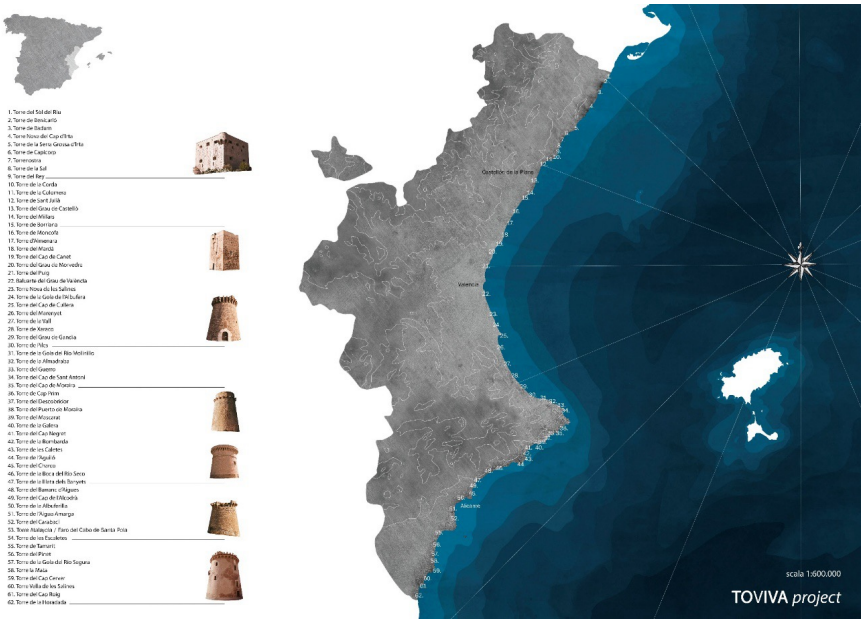


Fig. 2 - Kingdom of Valencia (present-day Valencian Community). Location of the coastal defense towers. Source: created by the authors.

Thus, Philip II decided to entrust the ambitious project of the network of watchtowers and coastal defense to one of these engineers: Giovanni Battista Antonelli 'il Vecchio.' It is difficult to understand Spanish military architecture of the 16th and 17th centuries without the presence of the Antonelli family, a lineage of architects and military engineers who served the Spanish Crown for almost a

century, constructing and designing multiple defensive works on the peninsula and in Spain's African and American territories. The first of this line of engineers was Giovanni Battista Antonelli himself, who accompanied Vespasiano Gonzaga along with his brother Bautista Antonelli, constructing and inspecting all fortifications along the Levantine coast between 1559 and 1580. His nephew Cristóbal Roda Antonelli also joined the two brothers in the watchtower and defense project from 1578. The eldest of the Antonellis had a unique vision of national defense, comparing the coastline to the front of a wall, where cities and towns were the gates, villages corresponded to the bastions, and watchtowers to the battlements (Antonelli, 1563).

Before embarking on such a vast project, an exhaustive survey of the terrain was necessary to acquire sufficient knowledge to adopt appropriate measures and carry out the proper fortification of the coastline. After traveling along it, in 1562 Antonelli submitted a report to the king titled Memoria de lo que Mgd. Mandre proveer para la fortificación del Reyno de Valencia. This report listed forty-six existing towers, fourteen of which needed to be demolished and rebuilt to adapt them to the defensive standards of the time. Within Antonelli's fortification report, it is worth highlighting how he envisioned a fortified coastline with twenty-four significant towns and cities reinforced by castles, bastions, and isolated fortifications that were structurally and architecturally adapted to contemporary military needs. This was the conception of a large-scale project comprising more than sixty constructions covering over four hundred kilometers of the Valencian coast, subject of our study.

Contribution of Historical Cartography

As scientific and technological knowledge advanced in the 15th and 16th centuries, cartographic production experienced significant development, driven by the invention of the printing press and the improvement of navigation instruments such as the astrolabe

and the compass. In this context, Mercator's cylindrical projection revolutionized territorial representation by providing a more accurate approximation of the shapes of continents, though not their dimensions (Aguiló, 2006).

The reign of Philip II marked a turning point in cartographic production in Spain, with a strong impetus to document the territory. It was in this context that engineer Giovanni Battista Antonelli designed his coastal defense plan based on a network of 53 strategically located watchtowers to alert the population and repel pirate attacks (Antonelli, 1554). At the same time, the Flemish cartographer Abraham Ortelius published the first map of the Kingdom of Valencia in 1584 (Fig. 3), in which some of these towers were depicted for the first time (García Edo, 2004).

Throughout the following centuries, various cartographers documented the evolution of the Valencian coast and its defensive system in large-scale maps. Ortelius' map, although pioneering, contained significant inaccuracies in the location and naming of the towers. It mentioned only 26 towers, many under the generic designation of Atalaya, without specific names or exact locations (García Edo, 2004). This lack of precision was partly due to the fact that Ortelius never visited Valencia and likely based his work on previous descriptions, such as that of Jerónimo Muñoz in 1568, who documented a total of 40 towers (Navarro Brotóns, 1997).

By the late 17th century, Francisco Antonio Cassaus produced a much more detailed map, documenting 54 towers with their names and precise locations. His map also introduced a grid that facilitated geographical localization, representing a significant methodological advancement (AA.VV., 2002). Later, in the 18th century, Tomás López, considered the most important Spanish cartographer of his time, created two key maps in 1762 and 1788. In his first version, he included 55 towers, but in the 1788 edition, he made modifications to the nomenclature, removing some towers and incorporating others that were not in previous records, leading to confusion (González Tascón, 1992). On the other hand, José Cavanilles' 1795 map, although considered a reference for the representation of Valencian relief, provided limited documentation of the defensive system, as it included only 28 towers without distinguishing them graphically from other landscape elements (Cavanilles, 1795). Despite these limitations, his map stood out for its precision in the geography and hydrography of the Kingdom of Valencia.



Fig. 3 - Valentiae Regni olim contestanorum si Ptolemaeo, edetanorum si Plinio credimus typus, Abraham Oertel (1585). Source: https://riunet.upv.es/handle/10251/4301. Open source.

In addition to large-scale maps, the production of topographic plans played a crucial role in documenting the towers. By the late 16th century, military and civil engineers began producing detailed plans for infrastructure planning and defense. An early example can be found in the 1585 plans for the Tibi dam in Alicante, where some coastal towers, such as Torre de Agua Amarga and Cabo de Alcodrá, are depicted with notable precision (Cámara Muñoz, 1999, 2000). By the 18th century, topographic plans had become more rigorous, as seen in the Mapa de la Villa de Oropesa (1760–1780), which includes exact representations of the Torre del Rey with specific architectural details.

Property delimitation plans also documented towers, albeit with a more schematic representation. An example is the 1717 map of the coast between Benidorm and Villajoyosa, where Torre del Aguiló is highlighted in comparison to other buildings. However, in many cases, these representations were idealized and did not always accurately reflect the architectural reality of the towers (Rodríguez-Navarro, 2017).

Integrated Methodology for the Documentation of the Towers

Most towers, in the past, did not even have an architectural survey that would allow for the study of their constructive, formal, and typological systems. Instead, they were only represented through sketches and synthetic drawings dating back to the 18th and 19th centuries. In addition to construction projects, we also find basic architectural drawings in some inventories, such as the Aguado Report (Fig. 4).

In this document, we observe the floor plan and elevation survey, conducted by engineer Joaquín Aguado in 1870 as part of his report on the state of the towers in 1870. It is a simple drawing that only provides a general formal appearance of the tower, yet it becomes an essential document for those towers that have since disappeared.

At this point, it is important to clarify that within the different typologies of towers identified (in terms of form, construction, typology, etc.), and their varying states of conservation, the greatest difficulty in their study has been the impact of the different intervention criteria applied during their restoration (or recreation). This has led to one of the main objectives of the research being the documentation and cataloging of all the towers in their current state, providing a reliable record for the necessary analyses to determine the original structure.

The methodology employed for data collection and subsequent office-based processing has been adapted to the specific needs of each tower. In some cases, multiple methodologies have been applied to the same structure, making it appropriate to refer to this approach as an integrated methodology (Fig. 5).

Fundamentally, the process has involved capturing the necessary photographs for photogrammetric restitution of the exterior using SfM+IM (Structure from Motion + Image Matching). In this phase, the use of drones has been essential for obtaining images of the upper sections, such as roofs and wall tops, as well as for capturing photographs from otherwise inaccessible locations, given that many of these structures are situated on slopes and cliffs.

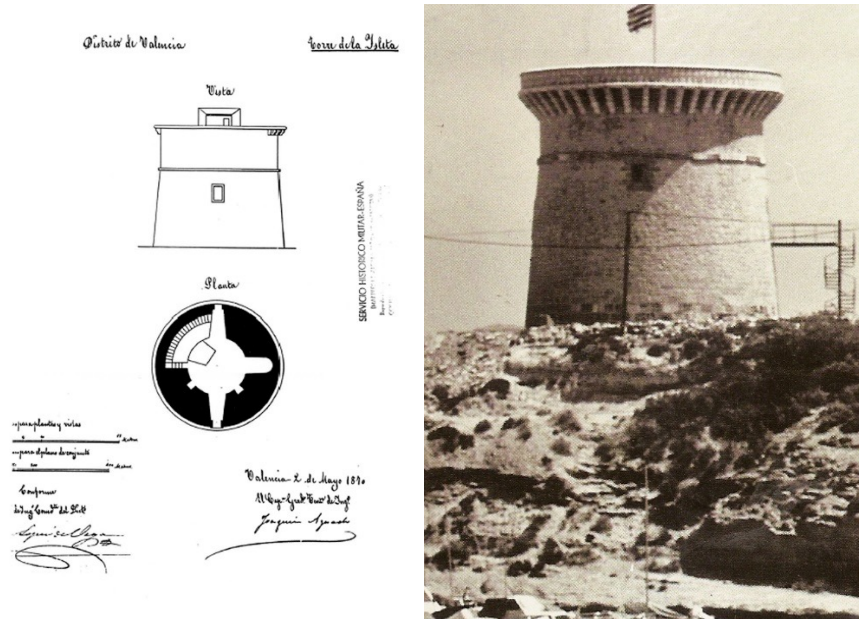


Fig. 4 - Floor plan and elevation of the Isleta Tower. Aguado Report, 1870 (left). Tower after restoration (right). Open source.



Fig. 5 - Piles Tower, Valencia. 3D Model (left) and Architectural Plans (right). Source: created by the authors.

The interiors have primarily been documented using 3D laser scanning, which is particularly suitable for these small spaces with narrow spiral staircases.

Subsequently, both datasets were integrated to generate three-dimensional models of the structures. The results have been highly accurate models, both in terms of measurements and textures, representing the current state of the towers. These models were then processed to generate cross-sections and orthophotos of various architectural views (floor plans, elevations, and sections), allowing for the creation of dihedral projections necessary for their proper interpretation.

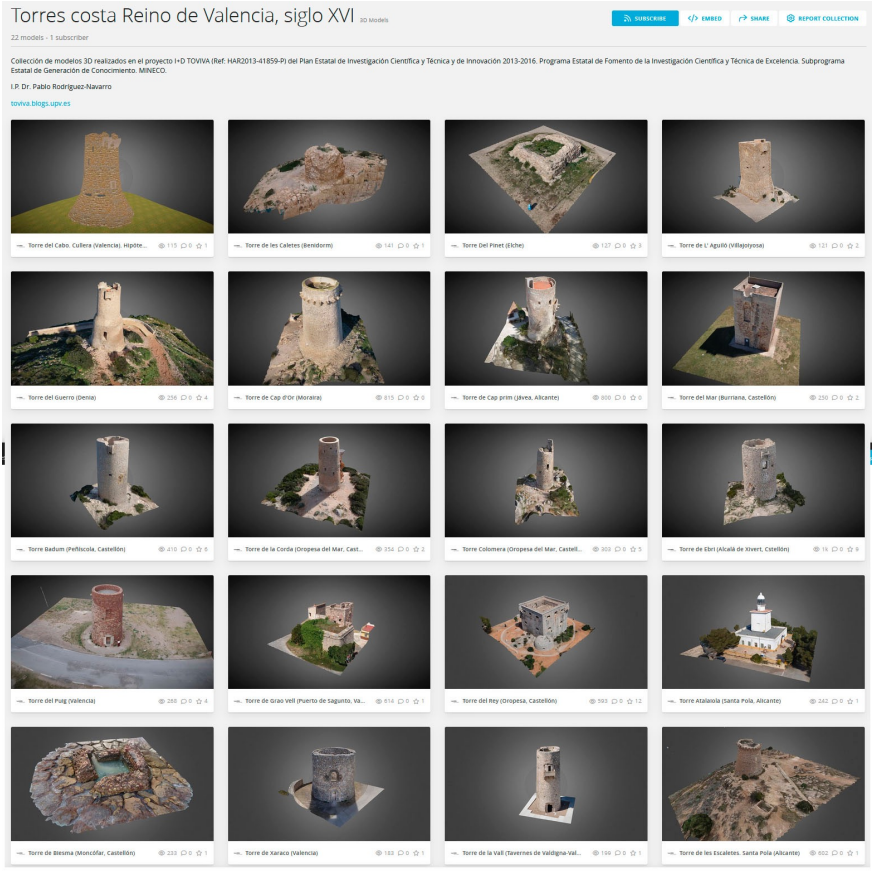


Fig. 6 - Collection of Interactive 3D Models Available in the Sketchfab Repository. Source: created by the authors.

The three-dimensional models have also been used for dissemination through lightweight platforms (smartphones, tablets, etc.), hosting them on the Sketchfab repository (https://skfb.ly/oJYrn) (Fig. 6). From this platform, users—whether specialists or novices—can interactively observe the tower of their choice.
Likewise, they can understand that an individual tower has no meaning on its own; its shape and function are determined by its role within a larger defensive system. In this way, the observer can instantly explore and visualize various towers that together formed the defensive network of the Kingdom of Valencia.

Conclusions

The study of the coastal defense towers of the Kingdom of Valencia between the 16th and 18th centuries provides insight into the significance of these structures within a broader context of territorial defense. The research demonstrates that the conception of these structures was a result of technological and military adaptation in response to threats from Berber and Turkish pirates, reinforcing the need for coordinated territorial defense strategies. The establishment of a system of watchtowers not only allowed for the warning of the population and fortified cities but also represented a model of defensive planning that endured for centuries.

Historical and architectural analysis has highlighted the evolution of these constructions, from their early formulations in the 15th century to their consolidation during the reign of Philip II. The involvement of engineers such as Giovanni Battista Antonelli was crucial in implementing a network of fortifications tailored to the strategic needs of the time. Through historical documentation and three-dimensional surveys, the typological diversity of the towers, their geographical distribution, and the construction techniques employed have been identified, providing a better understanding of their role within the defensive system.

Similarly, historical cartography has played a fundamental role in the identification and analysis of these structures. Over the centuries, maps created by cartographers such as Ortelius, Cassaus, and López

have documented the distribution of the towers and served as valuable references for contemporary studies. However, discrepancies and errors in the toponymy and location of some towers have been identified, underscoring the importance of cross-referencing these sources with archaeological and architectural records.

The methodology applied in this research represents a significant advancement in the documentation and preservation of Valencian architectural heritage. The combination of techniques such as 3D laser scanning, photogrammetry, and digital reconstruction has enabled the creation of highly accurate three-dimensional models that not only facilitate detailed studies of the towers but also contribute to their dissemination and conservation. The ability to visualize these models on interactive platforms expands access to this heritage and reinforces its cultural and academic significance.

In conclusion, this study confirms the historical and territorial importance of the defense towers of the Kingdom of Valencia. Their analysis through documentary, cartographic, and digital surveys has allowed for a more precise reconstruction of their history and architectural characteristics. Additionally, it highlights the necessity of continued documentation and conservation efforts for these structures, many of which have been altered or are at risk of disappearing. The integration of new technologies in the study of defensive heritage opens new perspectives for research and dissemination, ensuring its knowledge and preservation for future generations.

References

AAVV. (2002). *El Atlas del rey planeta. La descripción de España y de las costas y puertos de sus reinos, de Pedro Texeira (1634)*, p. 75 del facsímil, Hondarribia.

Aguado, J. (1870). *Informe de reconocimiento de las torres costeras del reino de valencia del capitán teniente de ingenieros D. Joaquín Aguado para la entrega de dichas defensas al cuerpo de carabineros por encargo de la comisión de reconocimiento de las torres de costa de la subdirección de ingenieros de Valencia.* [Manuscript]. Servicio Historia Nacional (SHN) 4-4-4-1.

Aguilar Civera, I. (2009). *Construir, registrar y representar. Sendas, caminos y carreteras de la Comunitat Valenciana. Mapas y planos 1550-1850.* Valencia: Conselleria d'Infraestructures i Transport.

Aguiló, M. (2006). Los ingenieros en la construcción del Mediterráneo. In: *AAVV (Eds.), España en el Mediterráneo. La construcción del espacio* (pp. 21-22). Madrid: Ministerio de Fomento.

Antonelli, G. B. (1563). *Discurso sobre la fortificación y defensa del Reyno de Valencia del maestre racional de aquel Reyno, y de Juan Bautista Antoneli.* [Manuscript]. Archivo General de Simancas (AGS), E, 329-I. doc.13.

Cámara Muñoz, A. (1999/2000). Proyectar fortificaciones. In: *El vigía de Tierra, Clío y el Geómetra, Primer Simposium sobre Fortificaciones y Patrimonio en la ciudad de Melilla.* (nn. 6-7, pp. 95-110). Melilla.

Cavanilles, A. J. (1795). *Observaciones sobre la historia natural, geografía, agricultura, población y frutos del reino de Valencia*. Madrid: Imprenta Real.

García Edo, V. (2004). *Mapas del Reino de Valencia de los siglos XVI al XIX.* Valencia: Diario Levante.

Oertel, A (1585). *Valentiae Regni olim contestanorum si Ptolemaeo, edetanorum si Plinio credimus typus. [Map].* Amberes: (s.n.) https://riunet.upv.es/handle/10251/4301

Rodríguez-Navarro, P. (2017). TOVIVA Project: una experiencia en torno al proyecto de defensa de la costa valenciana entre los si-glos XVI al XVI. In: J. González Avilés (Ed.), *Defensive Architecture of the Mediterranean XV to XVIII Centuries.* (Vol. 6, pp. 345-352). Alicante: Editorial Publicacions Universitat d'Alacant.

Rodríguez-Navarro, P. & Gil-Piqueras, T. (2019). Interpretation of the Kingdom of Valencia's coastal defence system from the 16th to 18th centuries through historical cartography. *DisegnareCON*, 12(22). https://disegnarecon.unibo.it/article/view/9512

Beyond the Walls. The Entrenched Camp of Rome, Studies, Surveys, Drawings

Giovanna Spadafora

Introduction

The field research on the entrenched camp of Rome, initiated several years ago within the Department of Architecture [1] at Roma Tre University, is conducted in collaboration with the Social Promotion Association Progetto Forti which, during the period 2012-2014, has contributed to the preparation of the 'Feasibility Study for the recovery and enhancement of the Forts of Rome', commissioned by Roma Capitale. Currently, the research continues as part of the PRIN project [2], which involves, in addition to the Department of Architecture at Roma Tre, the CNR (National Research Council) and the Department of History, Design, and Restoration of Architecture at Sapienza University of Rome. The goal of this national research project is to study the city's defensive systems — its walls and forts — to reconstruct their diverse histories of function and patrimonialization. Through the systematization of the acquired body of knowledge, the project aims to update this heritage according to a new paradigm: transforming these sites from places of defense into places of knowledge open to the public.

Structure and Characteristics of the Defensive System

The construction of the entrenched camp of Rome took place between 1877 and 1891, designed to defend the capital [3] of the young Kingdom of Italy. The plan involved a ring of independent fortifications, positioned far enough from the city to prevent enemy artillery from striking inhabited areas. Unlike what happened in other Italian cities, the Aurelian Walls, built in the 3rd century AD, were not demolished (Cajano, 2006). Their gradual defunctioning was accompanied by a parallel process of patrimonialization, now complete. A similar process, though still ongoing and more fragmented, concerns the forts of the entrenched camp, which will be the focus of this discussion.

The forts were positioned beyond the walls, forming the outermost ring of the city's defense, constructed outside the historic linear defensive system, on the edges of the countryside dotted with towers and casali (Fig. 1), which, between the 12th and 13th centuries, had also been configured as a territorial guard system (Carocci & Vendittelli, 2004; De Rossi, 1969).

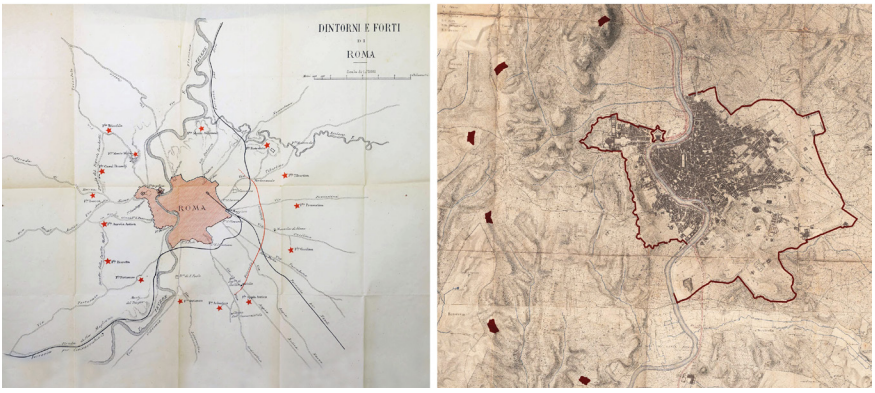


Fig. 1 - On the left, Dintorni from I forti di Roma: notizie storico-topografiche by Michele Carcani, Rome, 1883, in which the forts are represented by a star symbol. On the right, a detail of the Topographic Map of the Roman Suburb, 1870, where the forts have been positioned and the walls and casali highlighted (Source: http://www.archiviocapitolinorisorsedigitali.it/ The original drawing is preserved in the ASCR collection, Fondo Capitolino, 17719, 29).

The entrenched camp consists of 15 forts [4] and three batteries [5], located 4 to 5 km from the Aurelian Walls, near the main access roads.

It includes a fortified perimeter of over three kilometers and various complementary structures, such as roads and powder magazines. However, rapid advancements in military technology soon increased artillery range to about 6 km, rendering the forts ineffective for their intended purpose, as enemy fire could easily bypass their defensive line. Disarmed in 1915, their removal from the list of fortifications was ratified in 1919.

Currently, only Forte Monte Antenne is owned by Roma Capitale, which also manages Forte Bravetta, Forte Ardeatina, and Forte Prenestina, entrusted by the state [6].

Research Methodology and Scales of Analysis

The ongoing research operates at multiple scales: from the urban scale to the architectural scale, to the analysis of construction aspects. The operational methodology includes both the study of manuals and fieldwork, encompassing direct observation, archival research, and 3D data acquisition. The construction of both physical and digital models serves as a moment of verification and control within the research process, helping to understand the architectural articulation of the structures and their systems for rainwater drainage and natural ventilation. At the territorial and urban scale, the research investigates: the settlement principles of the forts, starting with the geological nature of the soil; the geometric analysis of their layouts in relation to their location and coverage area; and the analysis of the monumental protection boundaries established for all forts since 1975. This examination of the protection boundary, which follows the edge of the surrounding moat, raises questions about the opportunity to include currently unprotected areas, such as the one where the ravelin was located (a defensive outwork) [7], crucial for understanding how access to the fort from the city was managed (Fig. 2). This analysis also prompts reflection on the fort-ground relationships established with the city, mediated primarily by the moat, which constitutes a break in the terrain, and than by the surrounding compound. This area is significant not only as a threshold between the urban density and the fort but also for its role in the economic dynamics tied to their repurposing (Spadafora et al., 2023). The work at this scale employs GIS as a tool to produce new visualizations and analyses, some of which are conducted by overlaying late 19th-century maps and the silhouettes of the forts onto the DEM model, in a topographic interpretation from which the study of the original visibility between the defensive structures was initiated. In the absence of direct reference points in what was still a largely uninhabited area at the end of the 19th century, the true scale of these structures becomes apparent only when compared to the urban fabric or historical monuments (Fig. 3), and their size is certainly a critical factor in evaluating interventions for their recovery.

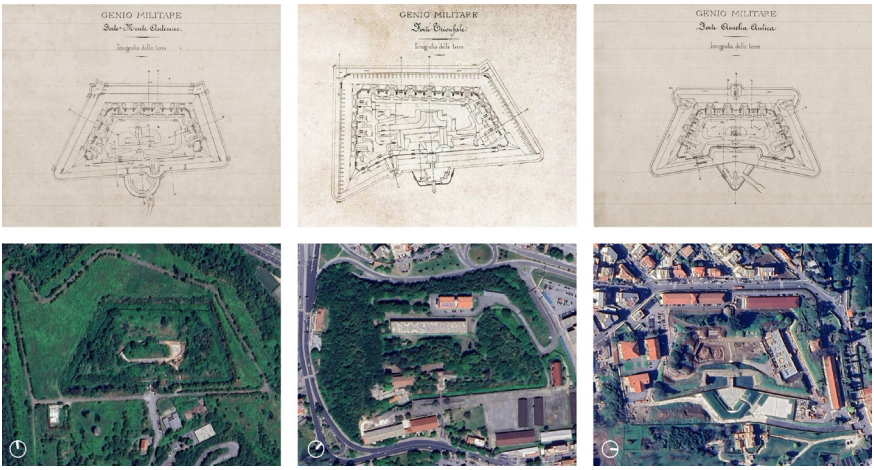


Fig. 2 - The plans of the lands of Forts Monte Antenne, Trionfale, and Aurelia (Source: drawings preserved at ISCAG) alongside satellite images (Source: Map data 2025 Google) showing their current state. On the right, Fort Aurelia with its reconstructed ravelin.

At the architectural scale, the construction and defensive characteristics of the forts, which follow the Prussian model, have been studied through the analysis of archival drawings, continuously compared with manuals, particularly Mariano Borgatti's Manual (Borgatti, 1898). Through direct and 3D surveys, elevations have been produced in both their current and original states [8], thus, documenting a phase of the structures' life that is no longer visible today (Fig. 4).



Fig. 3 - The masonry plan of Fort Prenestina (Source: drawings preserved at ISCAG) compared with the plans of Castel Sant'Angelo, the Colosseum, and the Pantheon, taken from the 1748 map by G.B. Nolli.

This reconstruction was made possible by surveying the wall textures, wooden and iron fixtures, and certain details, such as gutters and the cornices that characterize all the Roman forts, made of brick, travertine, or both. Although many fixtures have been altered due to the various uses of these structures over time, some original elements remain. For example, at Forte Monte Mario, in addition to wooden fixtures, armored fixtures are also found on the internal facade of the main front.

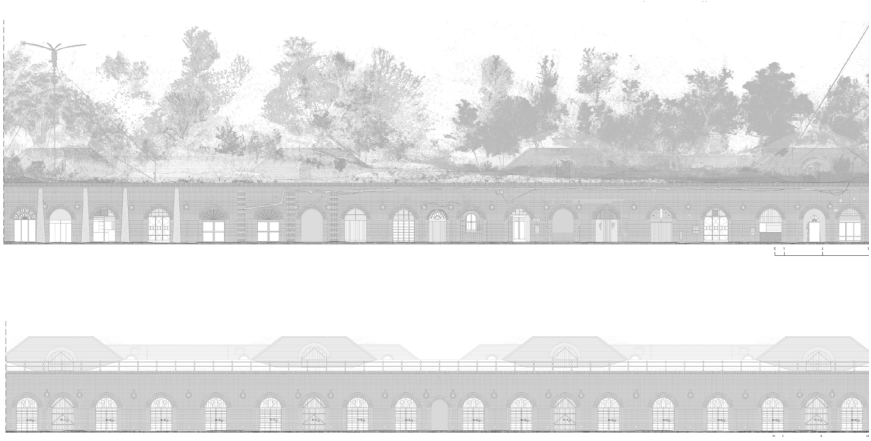


Fig. 4 - Fort Monte Mario. The elevation of the troop quarters, showing the current state and a reconstruction of its original condition. Source: drawings by Lucia Chiarotti, Giulia Lamolinara, and Chiara Middei (graduation laboratory).

The survey of these elements, as well as the doors and access portals to the forts, aims to build a reference catalog that could be useful in restoration interventions for structures in advanced states of decay (e.g., Forte Tiburtina).

In this work, which integrates the study of manuals, direct observation, and 3D surveys, the construction of a three-dimensional model is essential for understanding the architectural articulation of the structures. Through the model, it has been possible to understand, for example, both the natural ventilation system of the forts' interiors and their rainwater drainage systems [9].

At Forte Monte Mario and Forte Appia the natural ventilation system of the vaults covering the soldiers' quarters helps to remove

humidity through a network of channels within the spine walls. At Forte Appia, this system also includes ventilation at the apex of the vaults (Fig. 5).

A comparison with the cross-section of the troop quarters at Forte Monte Antenne shows a similar drainage system for the earth above the rooms, with differences in rainwater collection. The vaulted rooms have two slopes on the extrados, made of bituminous material (Borgatti, 1898, p. 466), to channel water drained from the earth coffers into pipes placed in the valleys.

At Forte Monte Mario and Forte Appia, this water is directed into gutters (cast iron in the former and stone in the latter), while at Forte Monte Antenne, a cast iron collection box also receives water from the cornice above and channels it into an underground system connected to a cistern.

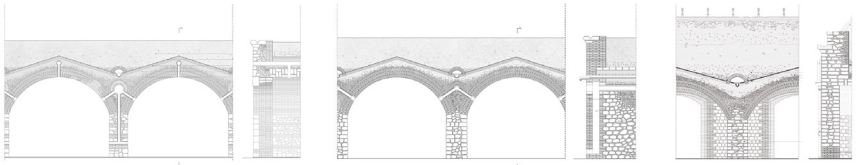


Fig. 5 - Detailed sections highlighting the vault ventilation system and the drainage of rainwater in Forts Appia, Monte Mario, and Monte Antenne. Source: drawings by Lucia Chiarotti, Giulia Lamolinara, Chiara Middei and Eleonora Antonucci (graduation laboratory).

The failure of these systems is one of the causes of the degradation of many structures, exacerbated by invasive vegetation on the ramparts, whose roots infiltrate the walls and vaults.

An example of the damage caused by earth pressure due to inadequate rainwater drainage is visible on the front of the quarters at Forte Monte Antenne, where urgent safety work is needed to prevent the collapse of further sections (Fig. 6).

The analysis related to the identification of mechanisms of degradation of the structures is conducted, within the framework of the PRIN project, using innovative methods and experimental technologies, employing the equipment available in the LARCH [10] laboratories (Laboratory of Acoustics Research Applications

for Cultural Heritage at CNR) and RilTEC (Survey and Digital Technologies Laboratory at the Department of Architecture).

In particular, the range/image-based survey of portions of the affected architectures, besides serving as an important analytical tool for understanding, is used to provide a common geometric basis for the different non-invasive diagnostic techniques.



Fig. 6 - Fort Monte Antenne. The troop quarters front in two comparative photographs (2021–2024). Source: created by the authors.

Also, at Forte Monte Antenne, the analysis of the stability of the masonry of the rifle galleries is underway, which are also burdened by the weight of the soil pressing on the vaults and the perimeter wall. A survey was conducted using laser scanning and dynamic SLAM (Fig. 7), with reference targets placed in each room [11].

The integration of the two data acquisition methods offers the advantage of providing accurate results in relatively short times, and it allowed for the identification of a slight bulging of the front line along the moat. The analysis is ongoing with a detailed study of the vaults that cover the rooms.

The research activities, which over the years have been developed also within the graduation laboratory on the Forts of Rome, conducted by the author with Simone Ferretti and Elisabetta Pallottino, are currently being carried out under a PhD scholarship[12] funded by DM 118/2023 with PNRR funds, on a project presented by the author, titled 'Entrenched camp of Rome: Study, 3D Survey, and Advanced Modeling for the Knowledge of an Architectural and Landscape Heritage'.

In this project, the construction of an integrated GIS/HBIM system is designed as a tool for managing information at both the urban and architectural scales.

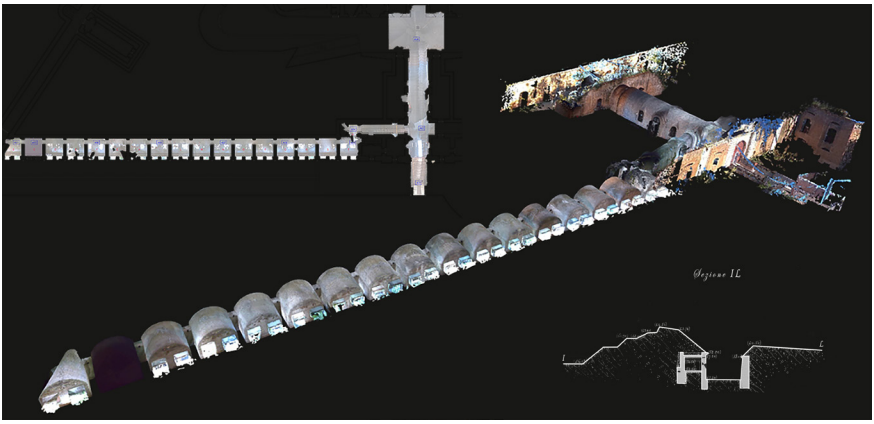


Fig. 7 - Fort Monte Antenne. Top left: plan of the rifle galleries with the location of the targets. Center: point cloud obtained through dynamic SLAM. Bottom right: section of the rifle galleries from the drawing preserved at ISCAG. Source: created by the authors.

In the work dedicated to building an HBIM model, the goal is to define an operational protocol applicable to this type of fortified structure, identifying components with specific nomenclatures and their nesting (Fig. 8). The Roman forts, derived from the Prussian model, share similar characteristics, with variations in form depending on the topographic context. The masonry typology differs only in the external finishes, while rainwater downpipes and cornices vary slightly between forts.

In all forts, the drawbridge is a 'lower lever' type, with cast iron columns, tapered shafts, and Doric capitals, differing in the span of the bridge and the height of the columns, parameters related to the width and depth of the moat. The exception is Forte Appia, where a variable counterweight mechanism of the Poncelet type was adopted. These characteristics make the construction of an HBIM model for the Roman forts particularly interesting, especially for the possibility of creating parametric libraries of objects, given the relatively 'finite' number of their variations.

It is evident how such a model, integrated with an MEP (mechanical, electrical, plumbing) model describing the rainwater drainage and ventilation systems, could be particularly useful in the restoration and maintenance processes of these structures.

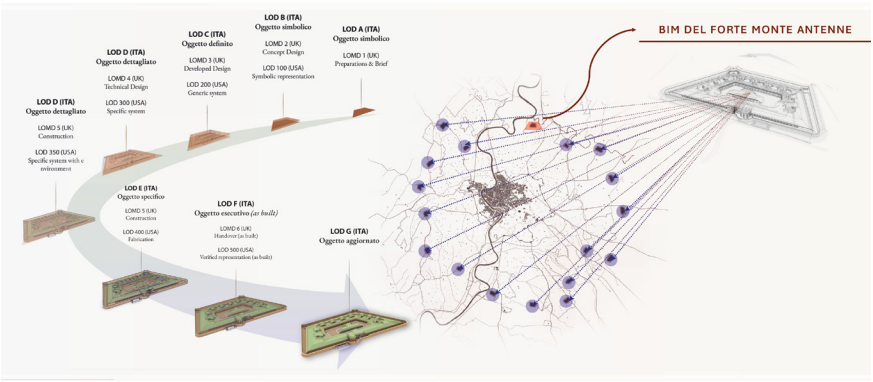


Fig. 8 - Graphical diagram of the process of creating a BIM model: from the development of a 3D model of the individual fort to the definition of parameters for generating BIM models with LOD D (UNI 11337) and medium-high LOIN (EN ISO 19650). Source: graphic elaboration by Barbara De Nitto.

Conclusions

If the goal is to repurpose historic buildings, it is essential to thoroughly understand their characteristics, identifying both critical issues and strengths that can enhance comfort in passive or semi-passive operating conditions.

This approach allows for the design of systems that can operate in synergy with the building, implementing all necessary actions for their reuse. In the ongoing research, the integration of disciplines such as survey, restoration, landscape, urban planning, and technology contributes to shaping an interdisciplinary and multi-scalar methodology for the study the Forts of Rome. This could serve as a valuable tool to support decision-making processes regarding their restoration.

Notes

[1] *The research is coordinated by Giovanna Spadafora and Elisabetta Pallottino the Department of Architecture and by the APS Progetto Forti, under its president, Architect Simone Ferretti.*

[2] *Research Project financed by the European Union – NextGenerationEU – National Recovery and Resilience Plan (NRRP) – M4C2- Investment 1.1, Call PRIN 2022, 2022BSMKX8, The Defensive Systems of the City of Rome in the Past and Present: Processes of Heritage Recognition of the Aurelian Walls and Military Forts (19th-21st Centuries).*

[3] *For works built to defend the capital, see Cimbolli Spagnesi, 2020.*

[4] *In counterclockwise order, on the right bank of the Tiber: Monte Mario, Trionfale, Braschi, Boccea, Aurelia, Bravetta, Portuense, Ostiense; and on the left bank of the Tiber: Ardeatina, Appia Antica, Casilina, Prenestina, Tiburtina, Pietralata, Monte Antenne.*

[5] *Closer to the walls, on the left bank of the Tiber, the batteries of Appia Pignatelli, Porta Furba, and Nomentana were built (see Fig. 2).*

[6] *A recent report, published on February 10, 2025, in the newspaper La Repubblica, states that Forte Bravetta will become a cultural hub as part of the initiatives for enhancing Rome's forts, implemented by Roma Capitale in collaboration with the State Property Office and the Municipalities. The other forts are under the administration of state entities and military corps, some for exclusive use and others with potential for cultural enhancement.*

[7] *Notably, in the restoration works of Fort Aurelia, promoted by the Guardia di Finanza, the ravelin was rebuilt, restoring the original approach to the entrance portal.*

[8] *The archival documentation consists only of plans at a 1:1000 scale and sections at a 1:500 scale.*

[9] *For a detailed description of the rainwater drainage system at Forte Monte Antenne, see Spadafora, Ferretti et al., 2018.*

[10] *The activities of LARCH are coordinated by Paola Calicchia and carried out with Antonio Camassa (CNR-INM).*

[11] *The equipment used (Z+F Laser Scanner and STonex X70 Slam) is provided by the RilTec Laboratory at the Department of Architecture. The*

surveys were conducted by the author with Mara Gallo and Alessandro D'Accolti. To ensure proper alignment of the scans, 7 static stations were set up, and a sufficient number of targets were placed to improve the alignment and registration of the point clouds.

[12] *The PhD scholarship was awarded to Barbara De Nitto.*

References

AA.VV. (2009). *Operare i forti: Per un progetto di riconversione dei forti militari di Roma*. Gangemi Editore.

Araldi, A. (1875). *Studio sulle fortificazioni di Roma*. Mantova.

Borgatti, M. (1898). *La fortificazione permanente contemporanea (teorica ed applicata): Con una premessa sulla storia della fortificazione antica, medioevale e moderna specialmente italiana e con appendici sullo studio di un progetto di opera sul defilamento, sull'attacco e difesa delle piazze, sulle principali artiglierie italiane ed estere*. Tip. G.U. Cassone succ. G. Candeletti.

Cajano, E. (Ed.) (2006). *Il sistema dei forti militari a Roma*. Gangemi Editore.

Carocci, S., & Vendittelli, M. (2004). *L'origine della campagna romana*. Società Romana di Storia Patria.

Cimbolli Spagnesi, P. (Ed.) (2022). *Difendere Roma: Architettura militare della capitale d'Italia 1870–1943*. Ufficio storico SME.

De Rossi, G. M. (1969). *Torri e castelli medievali della Campagna Romana*. New Compton Editori.

Fara, A. (1985). *La metropoli difesa: Architettura militare dell'Ottocento nelle città capitali d'Italia*. SME-Ufficio storico.

Fara, A., & Zannella, C. (1984). *La città dei militari: Roma capitale nell'archivio dell'ISCAG*. Kappa.

Ferretti, S., Pallottino, E., & Spadafora, G. (2017). Strategie di conoscenza per la redazione di un manuale di recupero dei forti di Roma: Il caso del Forte Trionfale. In D. R. Fiorino (Ed.), *Military landscapes. A future for military heritage: Atti del Convegno Internazionale*. Skirà.

Ferretti, S. (2016). Verso un piano strategico del Campo Trincerato di Roma: Pratiche e studi di Progetto Forti. In M. C. Treu & F. Menghelli (Eds.), *Fortezze e vie d'acqua* (pp. 104–113). Maggioli Editore.

Maggiorotti, L. A. (1935). *Gli architetti militari*. La Libreria dello Stato.

Parronchi, A. (1982). *Trattato di architettura militare*. Gonnelli.

Rebora, M., & Storelli, F. (1979). *Le fortificazioni di Roma Capitale: Analisi per un recupero* (Documento n. 5, Unità di ricerca C.N.R.). Tip. Lebeti.

Rocchi, E. (1908). *Le fonti storiche dell'architettura militare*. Officina Poligrafica Editrice.

Rocchi, E. (1912). *Traccia per lo studio della fortificazione permanente: Criteri e norme di carattere pratico*. Tip. Voghera.

Selem, H. (1979). *Il sistema dei forti di Roma nella logica dell'ecosistema urbano per il riuso del costruito*. Bulzoni.

Spadafora, G., Bellingeri, G., Canciani, M., Pallottino, E., Ferretti, S., Antonucci, E., & Dolfini, R. (2020). Rilievo 3D e modellazione avanzata nello studio dei Forti di Roma: Il Forte Monte Antenne. In J. Navarro Palazón & J. A. García-Pulido (Eds.), *Defensive Architecture of the Mediterranean* (Vol. X, pp. 463–470).

Spadafora, G., Ferretti, S., & Pallottino, E. (2023). I Forti di Roma: Una lettura a scala urbana. In G. Bevilacqua & M. Ulivieri (Eds.), *Defensive Architecture of the Mediterranean* (Vol. XIV, pp. 883–890).

Spadafora, G., Ferretti, S., Canciani, M., & Pallottino, E. (2018). Il Forte Monte Antenne nel campo trincerato di Roma: Studi e rilievi in corso. In A. Marotta & R. Spallone (Eds.), *Defensive Architecture of the Mediterranean* (Vol. VIII, pp. 893–900).

Zanotti, B. (1891). *Fortificazione permanente: Testo e atlante*. Tip. G. Candeletti.

The Model of Reality and the Project. Interpretative Aspects for the Restoration of Fortified Structures

Bianca Gioia Marino

The Model of the Real

The extreme complexity of cultural heritage, as a legacy of history in its many forms and, in particular, the architectural ones, also characterizes its cognitive process of its material evidence. With the great possibilities offered by digital technology over the last twenty years, if on the one hand this has standardized processes of acquisition and processing of data useful for the processes of control and management of the building, on the other it has highlighted the inexhaustible wealth of data that can be recorded, represented, calculated.

However, this possibility of 'storing' thousands of information has above all highlighted the difficulty — if not the impossibility — of exhaustively highlighting the range of relationships of which historical architecture is the site in its materiality and even more so in the references to critical cultural issues.

Within the architectural partitions, or with the subtle physical interaction between structure and surface or with the environment in which the building is inserted, with its 'aesthetic structure' and through its spatiality, infinite connections of a perceptive and interpretative nature are established, and this according to a process, then, which is not 'definitive' and univocally determined, but dynamic and changeable by virtue of many variables.

Having said this and going beyond the many meanings that can be associated with the term 'model' in the field of architecture, knowing also that the same meaning can have different meanings depending on the context of reference, today, in the midst of the unstoppable digital transition, it is instrumental to dwell, even if only with a few references, on the term 'model', as it is today conceived in the recent document for theNational Plan for the Digitization of Cultural Heritage.

Herethey define themselvesmodels, in fact, "the structures with which cultural heritage objects are represented and formalised in the digital environment in their reproduction from analogue" [1]. Furthermore, in the case of cultural heritage, it is also necessary to consider "the fruition models that are offered to the user to involve them and capture their attention".

The mere fact of having brought into play these two meanings of the model expresses the complexity of the question: on the one hand the restitution of the polysemic reality of the artefact, on the other its communication.

Let's focus on the model currently in use for buildings, BIM (Building Information Modelling). The computer model of buildings with BIM technology [2] it is, in fact, the model that returns a digital entity of the real building in its metric-dimensional and parametric properties. In the field of heritage, the addition of the H (Heritage) has translated this device to its use for the representation/management of knowledge of the historical artifact.

The HBIM approach does not differ much from the BIM one: there is the disaggregation and specific reading of its constituent components and therefore the association of different types of data and information. Therefore, the data is understood as what describes the properties of the architectural work without specific connotations and which, following an interpretation process, is transformed into information, assuming a meaning referable to the context. In this sense, the model aspires to be a digital twin and a composite database. The digital model can be increased with specific parameters, annotations with the possibility of associating texts, historical documentation (documents, reports, archival data, etc.) and graphics (with photos, images, other drawings).

In the meantime, with regard to the built heritage, there are doubts about the ability of information technologies to restore the complex reality of the pre-existence, precisely because of its specificity as a multidimensional object that requires a close critical hermeneutic approach to a reading that, in most cases, will then have to be transformed into a restoration project with the choice of specific and adequate interventions. To the geometric dimensional and also typological representations, are added, thematically, those regarding the materials present, the construction techniques with the relative chronologies, the conditions of conservation, the aspects of degradation together with the problems of structural failures, static functioning and to these can be added other information, concerning, point by point, not only elements coming from integrated surveys, but also other data deriving from the so-called

indirect investigations, that is graphic documentation or texts, transformations that have taken place, in short all data with a high degree of heterogeneity competing to define a cognitive state that becomes, when the operation is oriented towards design actions and intervention, of a cognitive type. Added to all this is the difficulty of effective interoperability between specific models aimed at analyzing certain aspects of buildings and which collect the relevant data in a differently standardized way.

The issue is currently essential, especially if we consider the obligation to use BIM introduced by the New Public Procurement Code (Legislative Decree no. 36 of 2023) [3] where "digital information management methods and tools for constructions" must be adopted, in addition to new construction works, also for interventions on existing buildings for a basic tender amount exceeding one million Euro [4].

However, recently, a Corrective (published in the Official Journal no. 305 of 31 December 2024 as Legislative Decree 31 December 2024, no. 209) containing "Supplementary and corrective provisions to the public procurement code", of 2023, has modified the application threshold, raising it to two million Euros. The initiative, dependent on economic reasons in order to increase the cost and the building market, is linked precisely to the difficulty of using digital tools in the field of historical buildings [5].

The same new Procurement Code of 2023, in art. 41, regulates the levels of design which, from three reduced to two, are constituted by the technical-economic feasibility project (PFTE) of public works and the executive project. The first is a complex tool and covers all aspects concerning strategies and methods of intervention, also including the relationships with the context (environmental, landscape and archaeological) from an operational, legal and economic point of view, projecting the operations for the building also for those concerning the maintenance of the building [6].

The PFTE Guidelines include numerous contents and aspects also relating to historical-cultural values and to restoration and conservative recovery interventions. Obviously, there is a reference to "any digital information models" [7] and digitalisation for public investments [8] and also includes an Information Specification.

The Domain of Restoration: for a Cognitive Ecosystem of the Architectural Heritage

It has been seen how, beyond all the rules and attempts to normalise the design process, also and above all through the use of increasingly advanced technological tools, especially it ones, the sphere of heritageor often suggests exceptions to its complex connotation precisely in relation to its knowledge of that “truthful entity of the state of affairs” (Fancelli, 1993) to be able to 'govern' also the matter of the meanings that characterise the pre-existence (Della Torre, 2024). Such knowledge requires close comparative readings of the data and the value structure, with a production and organization of information based on the analysis of direct and indirect sources such as bibliographic, iconographic, archival documentary, iconographic, and so on, but through a critical interpretative filter that provides for the recognition of values and priorities for intervention.n addition, through thematic surveys integrated with information from indirect sources, it is possible to identify, in detail, the processes of formation of the building and the subsequent transformations due to use, documenting the material outcomes of the aforementioned process that can become part of a historical critical baggage instrumental to an aware approach with respect to the pre-existence. In fact, a fundamental role in this case is played by the production of chronologies of the historical phases of formation and transformation (of growth or decay) to which to associate as a synthesis the 'relative datings' between the parts that make up the architecture, including among the latter not only what still exists but also any documented parts that no longer exist that may have played an important and fundamental role in its formative process. The historical critical analysis is associated with the observation and documentation of the material characteristics and the state of conservation, or: the material reading produced through contact with the living body of the architecture through the performance of direct and instrumental observations and surveys, at the scales of the building and the construction detail.

It is also a historical-critical knowledge that is practiced with direct observation, with instrumental surveys and the documentation of the material characteristics and the state of conservation; a knowledge that is articulated in an interscalar and interdimensional manner with the physical reading in contact with the living body of the pre-existence. The diagnostic process is also a historical-critical operation with and the in-depth analyses to be carried out need to be planned in the awareness that the buildings - as well as the urban areas - represent the outcome of a stratification generated by specific episodes with phases that progressively define their structures, sometimes with important transformations that can be traced back to different reasons of an order that is also heteronomous with respect to the architecture. Added to this are expansions, tampering with additions or subtractions, the latter of which involve profound transfigurations of the building, but also demolitions of pre-existing structures, giving rise to different static construction structures, sometimes already affected by various external causes or seismic events impact, with collapses and subsequent reconstructions.

Therefore, the unavoidable aspect of in-depth archival investigations and the historical reconstruction of the restorations of the construction sites and the interventions that have taken place over time is understood. in other words, it is appropriate to pay attention to the material connotation of the components in play and to their relationships with accurate observations that produce the necessary and appropriate interpretative syntheses on previous and expected mechanical behaviors.The condition and essence of 'overwriting' of the historical construction are to be taken into great consideration and make the character of the cognitive process specific. The complexity of the material and structural palimpsest therefore requires the accuracy of the same setting and programming of the knowledge process and, at the same time and consequently of the same reliability of the model, of the 'digital twin', and this makes it important to identify the horizon and the objective that we set ourselves. A step towards the awareness of such complexity can be deduced in a recent project aimed at preliminarily suggesting the extent of the intervention on a religious building. In the operation of classifying the pathologies, for each alteration and each degradation the properties and variables necessary to characterize the specific

case in question have been codified, according to the identification of their extent considering not only the technical characteristics. The filter for reading the degree of pathology and alteration is necessary to avoid falling into an automatic mechanism of identification of the pathology and the cause/effect. In this case the gradient of critical historical value relating to the relationship between the pathology and the evolutionary history of the artifact has been taken into account, in consideration of the restoration theories inclined to more conservative orientations, avoiding the deterministic relationship between cause and effect and technical intervention [9].

The Size of the Project and the Fortified Heritage: Guidelines and Lines of Work

The transition from data recording to knowledge is the result of a complex interpretative process. The corpus of cognitive investigations represents an activity that must therefore be carefully planned and finalized. It is necessary to implement a systemic approach to the knowledge project, in a relational and integrated way in order to obtain increasingly in-depth and easily shareable levels; this, addressing specific issues and aspects of the architectural organism and its context of belonging, comparing and relating the heterogeneous classes of data, also considering the landscape and environmental dimension, including legal data, those related to risk and climatic conditions, with attention also to the climatic history of the context. And the more the gradient of digital integration and interaction of the data is increased, the more the quality of the interventions and the culture and restoration project will be enriched (Fig. 1). Interconnection and interoperability is what the National Plan for the Digitalisation of Cultural Heritage 2022/2023 also refers to, and only by sharing some operational levels will it be possible to have an interoperable digital ecosystem for which, at European level, there is a specific measure for the creation of a European collaborative Cloud for cultural heritage by 2025 (Brunet et al., 2022).

The role of digital platforms as new systems for data exchange and control is therefore relevant, to optimize the work of both public administrations and stakeholders. In this sense and on interoperability there have been ICCD projects [10] which is connected to the theme, already mentioned, of the Information Specification (CI). On 'computer dialogue', a research within a PRIN 2022 [11] is verifying the limits and prospects of the interoperability of digital and IT tools. For Torre Guevara in Ischia (Fig. 2), an isolated fifteenth-century structure that presents a strong exposure to atmospheric events and marine action factors, with an interesting internal decorative apparatus, an HBIM modeling is being carried out to be integrated with BEM tools and processes for energy and lighting simulation [12], and where the difficulty of making the IT models interact is emerging, confirming the need, often called for, for a standardization of the platforms [13]. (Gerrish et al., 2017; Guìzar Dena et al., 2024) The dimension of the complexity of the fortified heritage is well clear in the recent Icomos Guidelines on Fortifications and Military Heritage which underlines the importance of an interdisciplinary approach [14] and yet it would be necessary to deepen the articulation of the contents with the definition of the relationship between the contents themselves and information technology, to increase the cogency of the system of values that the document also mentions.



Fig. 1 – An image of the point cloud restitution of the Girifalco Fortress in Cortona. The reflectance highlights the heterogeneity of the masonry structures, highlighting the perceptive behavior and the characteristics of the surface alterations. Source: created by the authors.

In conclusion, the relationship between heritage and information technology should be reviewed with the appopiate awareness to work within a 'digital ecosystem' [15], where hybridization, horizontal dimension and relationships are the foundations of any digital approach and tool for architectural heritage.



Fig. 2 – Ischia, Torre Guevara, restitution of the laser scanner survey of the exterior and contextual data. Source: created by the authors.

Notes

[1] *See Ministry of Culture, National Plan for the Digitization of Cultural Heritage 2022-2023, p. 76. In particular, "the concept of model can be declined not only for what pertains to digital, the IT or information science aspect, but also for what concerns the organization of work, training, the organization of knowledge and the services created for users. In Digital Humanities the concept of modeling represents one of the main activities and can be understood as a creative process and formalization of a reasoning or representation of a domain of interest".*

[2] *The regulatory reference is UNI EN 19650 of 2019, Organization and digitalization of information relating to construction and civil engineering works, including Building Information Modelling (BIM) - Information management through Building Information Modelling. Information*

management basically includes the exchange, recording, updating and organization of building information for all actors, during the entire life cycle of a property, including strategic planning, initial design, engineering, preparation of documentation for assignments and construction, maintenance, renovation, repair and end of life. The BIM standards are the AIR (Asset Information Requirements), the EIR (Exchange Information Requirements).

[3] *I see, The The new public procurement code replaces the 2016 Public Contracts Code which spoke of "specific electronic methods and tools such as modelling for construction and infrastructure".*

[4] *Article 43 of Legislative Decree no. 23, paragraph 1, also establishes that, starting from 1 January 2025, information management does not apply to two types of interventions: ordinary and extraordinary maintenance, unless the works have been carried out with IT procedures. Article 43 establishes methods and tools for digital information management of constructions; Article 41 establishes the levels and contents of planning.*

[5] *The Technical Report of the Corrective explains the reasons and in fact they are traced back not only to the "known increase in the costs of products and raw materials" increasing the amount of the works, but also to the fact that the "complexity of the digitalization of information relating to existing monumental buildings [which] could be costly for small and less equipped contracting stations", suggests a review of the obligation. See. Article 10 (Amendments to Article 43 of Legislative Decree No. 36 of 31 March 2023) of the Corrective Technical Report of the Legislative Decree containing supplementary and corrective provisions to the Public Contracts Code pursuant to Legislative Decree No. 36 of 31 March 2023. [https://www.sentenzeappalti.it/2024/11/12/correttivo-codice-appalti-relazione-illustrativa-relazione-tecnica-e-testo-bollinato-dlgs-36-2023/, consulted on 22 March 2025].*

[6] *For further content, please refer to the Guidelines for the drafting of the technical and economic feasibility project to be used as the basis for the awarding of public works contracts of the PNRR and the PNC, of the Ministry of Infrastructure and Sustainable Mobility, July 2021.*

[7] *Ibid., p. 6.*

[8] *Ibid., p. 7. The Planning Address Document (DIP) "may contain, regarding the digitalisation of processes and information modelling" (p. 12).*

[9] *In particular, the usBIM.bSDD application made available by ACCA software was used to create the "state of conservation" domain with the related classes and properties, according to the BuildingSMART Data Dictionary*

(bSDD), an online service that hosts classifications, standards, dictionaries and related properties, allowed values, units and translations. The workflow was subsequently applied to the documentation of the state of conservation of the Church of San Pietro in Vinculis in Naples, as an artifact representative of the assets of historical interest to be known and safeguarded. The project, entitled State of Preservation Domain to Document Existing and Historic Buildings, was a finalist at the buildingSMART openBIM Awards in the Research Excellence category – Department of Architecture, University Federico II of Naples with the project "State of conservation of the domain to document existing and historic buildings" (seehttps://biblus.acca.it/buildingsmart-openbim-awards-2022). The following were identified: the general characteristics that contextualize the pathology (date of documentation, presence of previous interventions, nearby polluting sources, exposure to water sources, climate, etc.); the most exclusive properties to better circumscribe the specific case (size, color, mechanism, typological specificity, morphology, etc.), and finally a first suggestion for intervention.

[10] *UA relevant factor is the uniqueness of data storage: CDE (ACdat - Data Sharing Environment) interoperability for data exchange between (parametric) models and the central archive aligned with the CIDOC- CRM (seehttps://dati.beniculturali.it/arco/index.html). The adoption of formats and ontologies is the condition for interoperability.*

[11] *PRIN 2022 CHIARA (Cultural Heritage Innovation Adopting Risk Assessment), partners the University of Bologna (PI Marco Pretelli), the University of Naples Federico II (Bianca Gioia Marino) and the Politecnico di Milano (Valeria Pracchi) aims to investigate and deepen the issues of scheduled maintenance with the aim of refining vulnerability indicators for cultural heritage and developing scheduled conservation strategies for peripheral historical artifacts. One of the cases of the Federico II University team is the Torre Guevara in Ischia.*

[12] *The case, with the title Architectural heritage and microclimate. The case study of the Guevara Tower in Ischia in the CHIARA project, will be presented at the conference "AID Monuments. Model, Interpretation, Project" (Perugia, 21-23 May 2025). The interdisciplinary group that authored the contribution is composed of the author, Filippo de Rossi, Laura Bellia, Raffaele Amore, Francesca Capano, Margherita Mastellone, Francesca Fragliasso, Corrado Castagnaro, Daniela Pagliarulo, Ilaria Improta.*

[13] *The lack of compatibility between the BIM model and energy simulation applications, together with the repetitive manual operations required for the creation of the BEM and the lack of standardization in the subjective process, have often led to data loss and misinterpretations.*

[14] *See the ICOMOS Guideline on Fortifications and Military Heritage (2022), point 5. In relation to values, in point 4 the document identifies: Art. 4. "The recognition of such intrinsic values of fortifications and defensive heritage determines the extent to which these aspects condition their conservation, rehabilitation, and general value. 4.1. Architectural and Technical value, 4.2. Territorial and geographical value; 4.3. Cultural Landscape Value; 4.4. Strategic Value; 4.5. Human and Anthropological Value; 4.6. Memory, Identity, Educational Value; 4.7. Historic value; 4.8. Social/Economic Value".*

[15] *See Ministry of Culture, National Plan for the Digitization of Cultural Heritage, cit., pp. 72-73.*

References

Brunet, P., De Luca, L., Hyvönen, E., et al. (2022). *Report on a European collaborative cloud for cultural heritage: Ex–ante impact assessment*. European Commission, Directorate-General for Research and Innovation. https://data.europa.eu/doi/10.2777/64014

Della Torre, S. (2024). Digital Methodologies for the Management of Interventions. In *Atti SIRA 2023,* Sezione 7. https://sira-restauroarchitettonico.it/wp-content/uploads/2024/02/Atti-SIRA-2023-Sezione7-LOW.pdf

Fancelli, P. (1993). The truthful entity of the monumental state of fact. *ANAKH*, 1(2), 22–28.

Gerrish, T., Ruikar, K., Cook, M., Johnson, M., Phillip, M., & Lowry, C. (2017). BIM application to building energy performance visualisation and management: Challenges and potential. *Energy and Buildings*, 144, 218–228.

Guìzar Dena, J., et al. (2024). Optimization testing for the modeling and characterization of three-dimensional elements to enhance interoperability from building information modeling (BIM) to building energy modeling (BEM). *Energy and Buildings*, 317. https://www.sciencedirect.com/science/article/pii/S0378778824005103

Protection Activities for Cultural Heritage. The Case of the Military Forts in the Entrenched Camp of Rome

Elvira Cajano

Introduction

Among the many institutional activities attributed to the Ministry of Culture — and on its behalf to the territorial superintendencies — are those relating to the exercise of the functions of protection over assets of cultural interest such as, in our case, the historical heritage of military origin and, in particular, the forts, which we are dealing with here. This task is already implemented in the design phase by providing methodological and operational guidelines on the works to be carried out, but also by accompanying the implementation of the project with on-site verification; all this can be seen within the limits of a merely bureaucratic occupation of a technical-administrative nature, but instead takes on considerable value if exercised actively, that is, by targeting action at protection and conservation without forgetting the needs of the contemporary community and promoting quality projects both in terms of architecture and landscape. The Republic's implementation of Article 9 of the Constitution includes, among other tasks, protecting and enhancing its cultural heritage. This duty is understood as primary and aims to preserve the community's memory, promote the development of culture, and thus guarantee and foster national identity. Protection, prevention and valorisation must, therefore, be the objectives underlying the actions of the Superintendencies today. Protection is mostly evaluated as a set of actions aimed at ensuring the physical existence of the materials that make up the assets themselves, protecting them from possible physical, chemical, biological degradation factors or due to human action through neglect, abandonment, destruction. This has evolved substantially over time, and today, it is also associated with the need for prevention and maintenance, which is considered heritage care.

Lastly, the need has been added to create, around the asset, initiatives that enable the activation of economic flows, not only cultural, for the material maintenance of the asset itself and the creation of wealth and improvement of the community's quality of life; a circular path, therefore, linking protection to enhancement and the latter to the former [1]. It is, as is well known, the Code of Cultural Heritage and Landscape, approved by Legislative Decree No. 42 of 22.1.2004, which emphasises that, if the protection and

enhancement of cultural heritage are to be considered instrumental functions for the development of culture, understood as a means and not as an end, such growth can only be achieved by ensuring the greatest possible public enjoyment of the assets themselves. This fits perfectly with the subject of our military forts, which for decades have been left to collective oblivion, neglect or use that is not always respectful of their testimonial value. This has in many cases led over time to the mortification of the original structures. The fact that they consist of massive masonry, few holes, tons of soil overlying the roofs, and small rooms inside — in other words, their structural characteristics aimed at withstanding enemy attacks and protecting the community — has meant that substantial human tampering, following their disuse, has been limited in number and has mostly been limited to the rationalisation of the interior spaces, the adaptation of installations and the construction of precarious structures to make some use of them. On the other hand, the action induced by abandonment is different, leaving the field to spontaneous vegetation which, in the absence of green maintenance work, has grown on the embankments, often causing disruption and collapse. Added to this is the issue of compatible use, the main issue to be resolved in the case of safeguarding the property.

There are, therefore, different aspects to be addressed in addressing the issue of protection: structural recovery, environmental recovery, reuse.

Challenges of Reuse and Early Protection Efforts in Rome

In our opinion, all this must have as an indispensable tool a project that can enhance the historical heritage, refunctioning the work for contemporary reuse through a critical action of respect and awareness. To do this, one must not only know and study the object in depth but also, above all, understand it. This entails, among other things, being open to different professions and collaborating with

experts from different disciplines so that everyone contributes their specific knowledge. In this sense, even the Code, in Art. 29, para. 5, emphasises the need and importance of collaboration between the Ministry of Culture and the Regions, Universities and relevant research institutes, to establish an effective dialogue and reduce discretion, which cannot and should not be the prerogative of a single institute.

This also means meeting in place different specialised skills and interdisciplinary knowledge (historical, architectural, existing technical and regulatory tools, current and potential dynamics) to foster the preservation of cultural heritage actively through activities of study and maintenance of both the material integrity and identity of the property. As early as 1988, the Superintendency of Rome focused its efforts on the protection of military forts, launching a campaign of restrictions to complete past measures that safeguarded only some of them, not for their historical and architectural value, but as assets included in areas of archaeological or landscape interest [2].

In 2005, the office wanted to draw even more attention to the military forts that surround the city and that, at the time, represented an asset that was almost unknown to most people and, in these days, a treasure to be disseminated and enhanced.

In those years, the Ministry allocated funds for the extraordinary maintenance and protection of Fort Portuense [3] which the Municipality had just taken over. The work involved the thematic survey, carried out after the clearance of explosive devices, the weeding and deforestation of the spontaneous vegetation that had invaded the complex, to the point of not even allowing access.

Using traditional techniques and localised 'sewing and cutting' operations, parts that had collapsed or were in a precarious static condition were then restored, pending a more comprehensive restoration project that is currently unfeasible.

The publication of a volume in 2006 also aimed to awaken the dormant attention of scholars and citizens, highlighting an urban theme and a document of the Capital's history, to act through active protection on a heritage that was then little studied and experienced.

The first steps were taken by deepening knowledge of the historical history of all forts, their consistency and above all their relationship with the territory, a relationship that has always been of decisive importance, especially in military architecture.

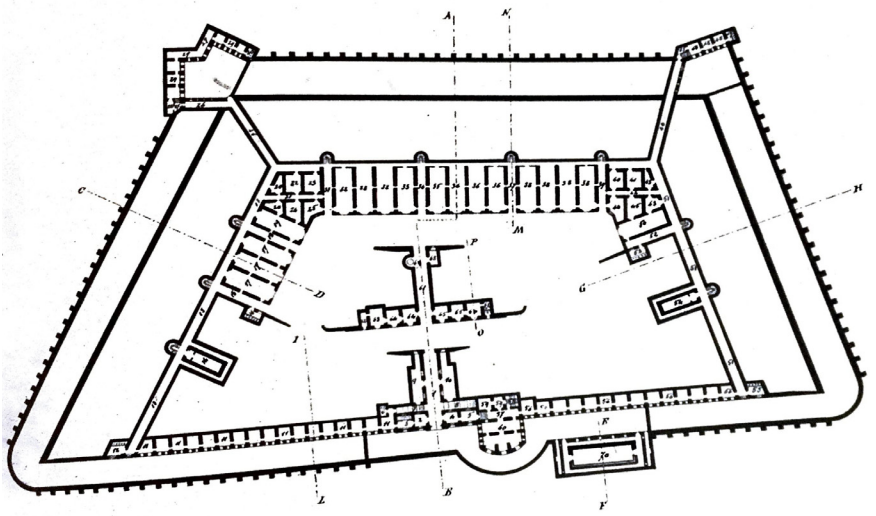


Fig. 1 - Forte Antenne, Pianta delle murature (Source: ISCAG; FT, 79B, 5264, Roma 1889, Tav. III)



Fig. 2 - Roma, Forte Antenne, Dissesti nelle murature perimetrali. (Source: created by the authors)

This is because it was born and exists in a given territory based on reasons and logics that are not only physical, such as views, orientation, routes, the lay of the land, but also about defence and offence functions that must respond to the maximum effectiveness as they are dedicated to the protection of people and cities.

In the volume, however, the intention was not to stop at historical analysis alone, but to address the thorny issue of reuse, providing guidelines on the static recovery of the structures and on possible compatible uses of the forts.

The focus was on Fort Antenne (Fig. 1), disused by the military authority, occupied for a few years and then the victim of collapse, neglect and tampering (Figs 2-3); a design hypothesis for its reuse was studied, to verify the compatibility of the structure to host both permanent and temporary cultural activities, responding to contemporary needs, while respecting its historical and architectural features.



Fig. 3 - Roma, Forte Antenne, Paramento murario in tufo e mattone. (Source: created by the authors)

Strategic Cooperation and National Networking for Forts Enhancement

In the mid-1990s, the Municipality of Rome had already hypothesised allocating the Antenne Fortress to activities of an exhibition and conference nature on an urban scale, but the project had been shelved due to the presence of spaces of limited size, mostly communicating, closed and with little natural light, as had the hypothesis of transforming the structure into a youth hostel.

In the impossibility of carrying out a scientifically complete and correct analysis due to the lack of economic resources and the difficulty of accessing the entire complex, which is still partly occupied by citizens in search of accommodation, the publication was chosen to formulate study hypotheses from a methodological point of view, which would reopen the fort to the city and the Villa Ada complex, a magnificent green lung in which it is immersed and hidden. It was, in its limitations, an opportunity to demonstrate how it was possible to make the fortress perform new functions at the service of the community, offering spaces for leisure and recreation, as well as being a place for meeting and cultural growth.

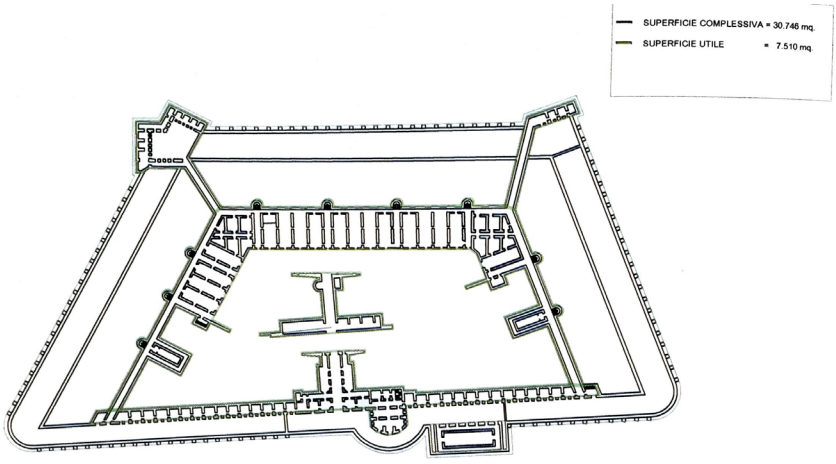


Fig. 4 - Roma, Forte Antenne, Pianta delle murature.

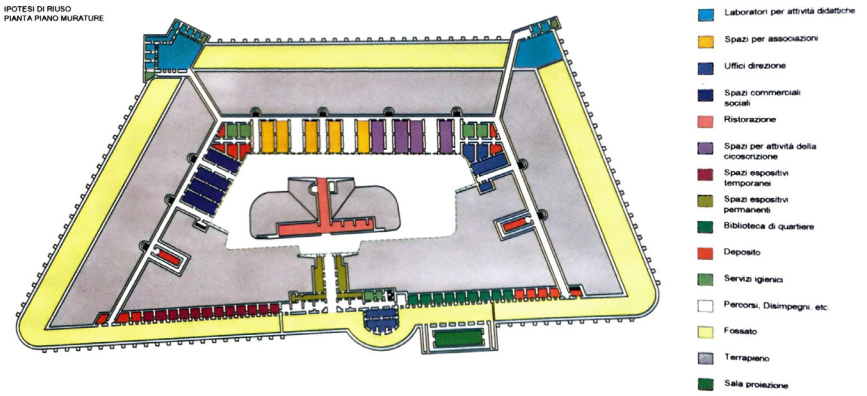


Fig. 5 - Roma, Forte Antenne, arch. G. Ercolani, Ipotesi di riuso, 2006.

Thus, in addressing the issue of reusing the Antenne fort and giving it a direction, we opted for the recovery and strict preservation of the original volumes and materials, dear to the Roman tradition, but adding outside, in the park, contemporary elements both structural and formal.

Cor-ten steel, photochromic and laminated glass, and zinc-titanium were some of the materials that the design wanted to contrast with the traditional brick and travertine in the work, so as not to constitute contrast, but to create a dialogue and balance between the present and the past, each maintaining recognisability and character.

The idea was to 'blow up' the fort, designing a series of bridges that span the moat and allow a dual route, to and from the fort.

They establish a relationship of continuity between the work and the Villa Ada, the town hall and the city, linking it to them and responding to the needs of the population with spaces for permanent as well as temporary activities, in a condition dictated by great permeability.

In the pine forest, a curvilinear path was designed with small pavilions destined to accommodate catering and commercial activities, while in the fort a projection arena was placed in the moat and the reconversion of the interior spaces into small rooms for educational, recreational, cultural and exhibition activities was planned (Figs. 4-13).

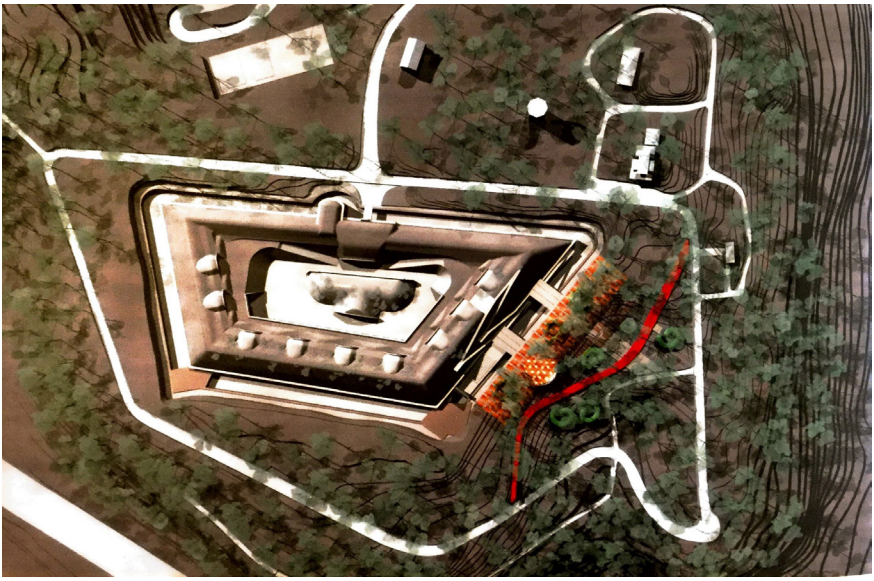


Fig. 6 - Roma, Forte Antenne, arch. G. Ercolani, Progetto di rifunzionalizzazione dei percorsi esistenti, 2006.

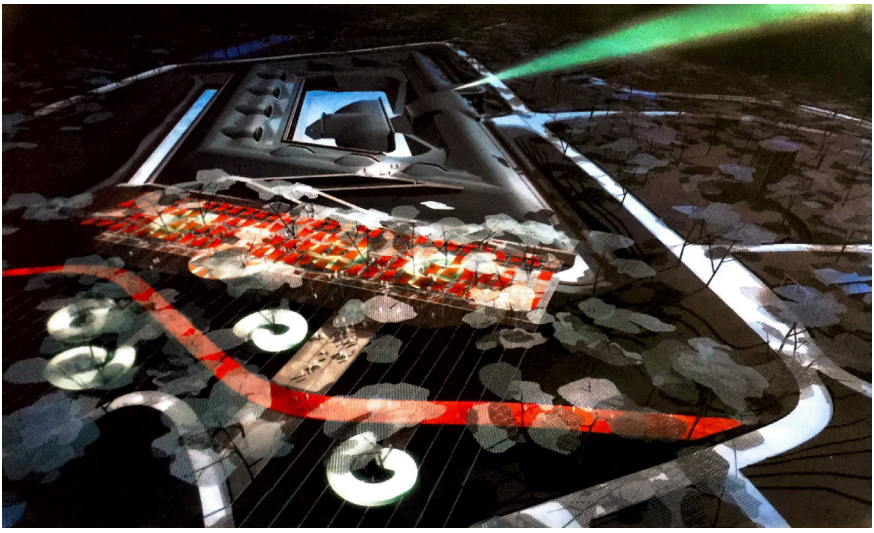


Fig. 7 - Roma, Forte Antenne, arch. G. Ercolani, Immagini del progetto, 2006.

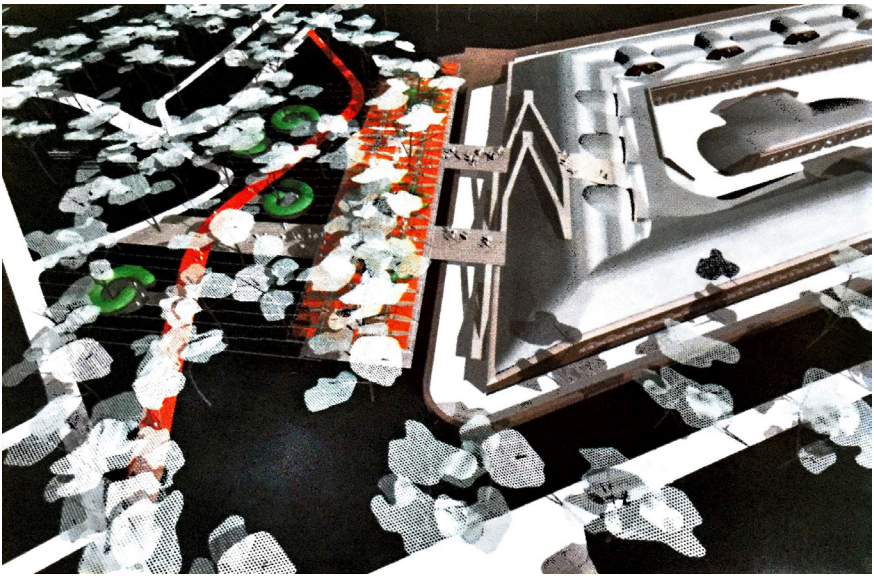


Fig. 8 - Roma, Forte Antenne, arch. G. Ercolani, Immagini del progetto, 2006.

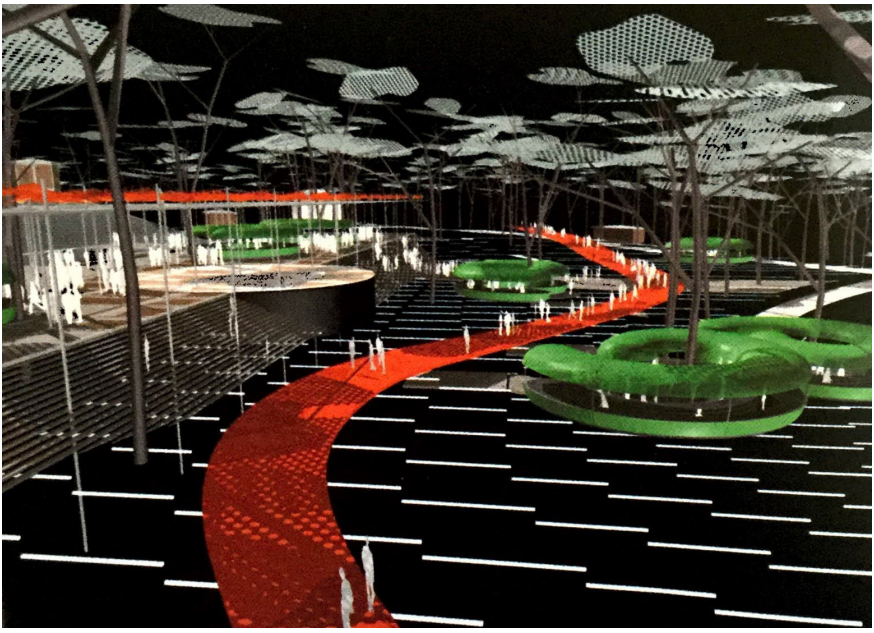


Fig. 9 - Roma, Forte Antenne, arch. G. Ercolani, Immagini del progetto, 2006.

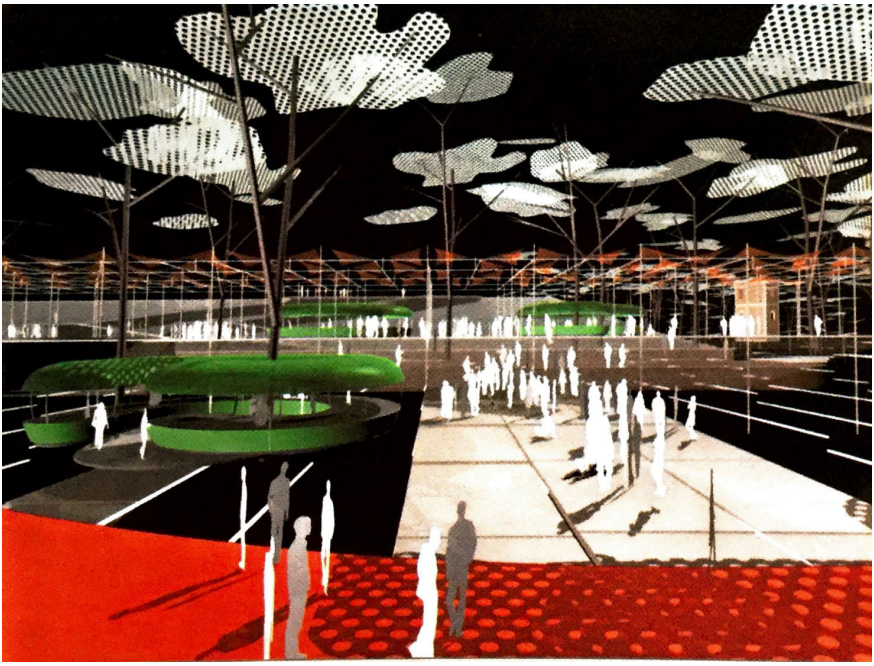


Fig. 10 - Roma, Forte Antenne, arch. G. Ercolani, Immagini del progetto, 2006.

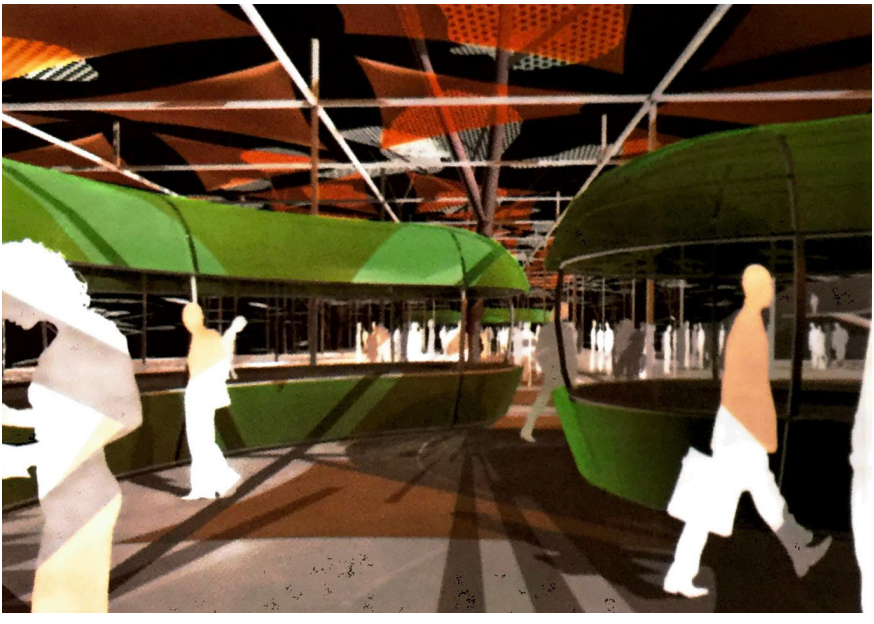


Fig. 11 - Roma, Forte Antenne, arch. G. Ercolani, Immagini del progetto, 2006.

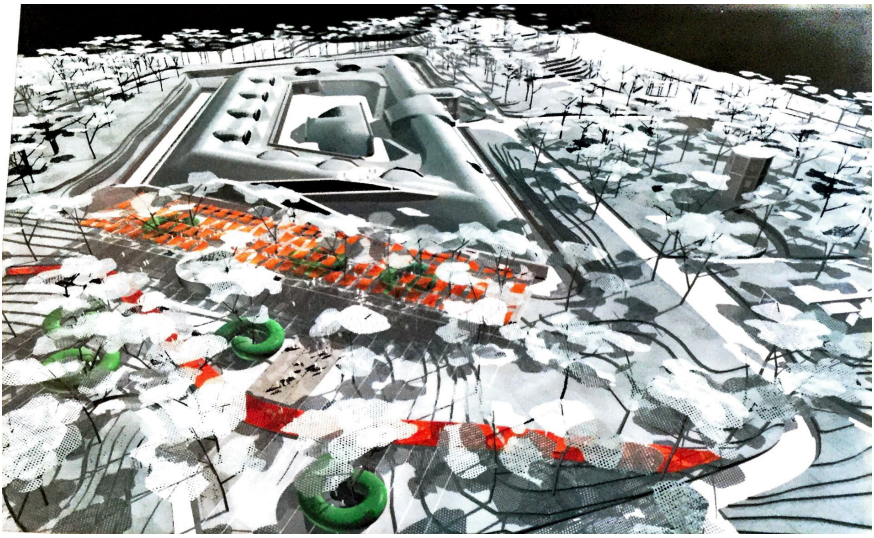


Fig. 12 - Roma, Forte Antenne, arch. G. Ercolani, Immagini del progetto, 2006.

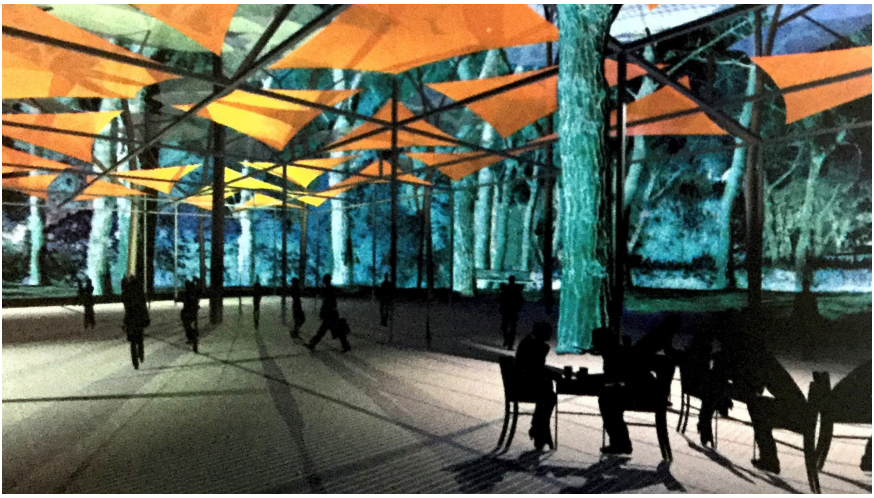


Fig. 13 - Roma, Forte Antenne, arch. G. Ercolani, Immagini del progetto, 2006.

As mentioned, this was a stimulus for reusing the entire defensive structure of the Roman entrenched camp. It was a tangible demonstration that the typological characteristics common to the 15 forts could each find new life in the future, incorporating the needs of the citizens and the municipality, as was now started many years later.

With this in mind, on 28.2.2020, in connection with the celebrations for the 150th anniversary of Roma Capitale, the first meeting of the 'Tavolo Tecnico Forti diRoma' (Rome Forts Technical Table) was held, promoted by the Provveditorato Interregionale per le Opere Pubbliche per il Lazio, l'Abruzzo e la Sardegna del Ministero delle Infrastrutture e dei Trasporti, head office in Rome, in collaboration with the Guardia di Finanza.

The strategic choice was to initiate a confrontation between the various institutional subjects that manage the Forts of the entrenched Fields of Rome, the competent bodies in the field of protection and enhancement, and the city associations [4] involved in order to identify and promote the development and coordination of possible initiatives aimed at undertaking a process of restoration and enhancement of the military forts, to make them available for collective knowledge and enjoyment, through the construction of a common cultural pathway. The common objectives were, therefore, to achieve a shared coordination between the Bodies invited to the Table for the definition of programmes and projects for the redevelopment of the Forts, their understanding and their public availability, using exhibition apparatuses, real and virtual visit routes, cultural events and social aggregation, dedicated publications, conferences and any other possible means of communication.

The positive response of all the military bodies involved, of the municipality's top management, of the Ministry of Culture through the offices in charge of the subject, and of the city associations that have always been active in safeguarding the territory certainly represented a great success, highlighting the awareness that Roman military forts represent an important resource for the community, both from a historical and architectural point of view and in terms of the landscape, as true green lungs incorporated and hidden in the contemporary city [5]. It was recognised that their reuse, besides being a topic of great topicality and interest, constitutes an opportunity to achieve an important collaboration between the institutions involved and an essential condition for strategic planning aimed at recovering the artefacts, according to a joint vision that is aware of and attentive to the needs of each territory.

Unfortunately, the spread of the infectious disease COVID-19 in Italy, in that very year, blocked every initiative of face-to-face meetings, slowed down an ambitious but exciting project that had just begun.

Conclusions

Proposals for a path to enhance the value of military forts continued, however, even during the pandemic period. In fact, at the instigation of the Guardia di Finanza, a structure was set up at a national level, and not only at a local level, made up of the owners or managers of a fortified place built in the 19th or 20th century, to promote common initiatives of a cultural, managerial and environmental nature and to enhance the value of their heritage of military origin [5]. The Network also proposed itself as a national interlocutor with similar European networks of fortifications, for the participation in EU calls for proposals. In this sense, the 'Open Fortresses' event, promoted on 2.10.2022, was the first tangible act of a shared desire to enhance the value of the fortified heritage as a whole.

At the same time, the project for the restoration of Fort Aurelia was discussed with the Special Superintendency of Archaeology, Fine Arts and Landscape of Rome, once again at the impetus and financial burden of the Guardia di Finanza. It is among the first forts built in the entrenched camp of Rome, along the consular road that gives it its. Its name and is located about 3 km from the Porta di San Pancrazio, one of the entrances to the city in the Aurelian Walls of Rome. The task of Fort Aurelia was to help prevent any enemy advance from the Roman coastline and the road of the same name towards the capital, which was strategically linked to Fort Boccea. Its use for military purposes, although not for war, has been uninterrupted from its construction (1887-1881) until today. Headquarters of the 27th Artillery Regiment in 1893, it became the headquarters of the 8th Anti-Aircraft Artillery. Proposals for a path to enhance the value of military forts continued, however, even during the pandemic period.

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The project immediately had as its primary objective the architectural and landscape recomposition of the area, which entailed the 'liberation' of superimposed structures, such as those indicated above, and the patient critical re-stitching of the historical outline, sharing the choices of techniques, materials and above all intentions that the Superintendence provided within the scope of its task of high surveillance [6].

Knowing the artefact for quality design is by now a necessity acquired by all those who work with interventions on antiquity; knowledge of the Brandian principles and criteria of restoration, of the history of the monument, of its transformations and the phenomena that have affected it, but what we wish to emphasise strongly in this paper is that knowledge alone is not sufficient, but must necessarily be accompanied by understanding; this is something more than mere understanding; it means elaborating a critical interpretation. Knowledge, understanding and comprehension must therefore be the three pillars of any restoration work, they must follow each other in that order and always be the basis of our choices. Today we have very advanced means that allow us to read and design the monument more accurately than ever before, but I would like to point out that this can have a negative effect precisely on understanding, contrary to what one might imagine. The survey and design systems we have today, for example the new drawing and modelling software up to the survey software with Artificial Intelligence, if on the one hand they speed up and simplify design, on the other hand they reduce direct, attentive and continuous attendance and observation of the work, thus significantly undermining comprehension, which, I repeat, means providing an individual key to interpretation, but which must be placed at the service of respect for the asset. Surveying and design are one example, but we could also mention other aspects of the restoration process. In our opinion, therefore, frequenting places is absolutely inescapable and necessary for an active conservation of the cultural heritage of every nation. But that is not all. This must be matched by interdisciplinary and not just multidisciplinary coordination of the various professionals in the sectors involved in the restoration process, a close collaboration between architects, engineers, art historians, chemists, physicists, biologists and restorers.

This is a methodological approach that has been developed in various documents over the years and, most recently, in a recent synthesis in the Guideline Document for the quality of architectural restoration projects which touching on various aspects, from planning to knowledge, from method to conservation, prevention and use, from accessibility and valorisation to digital methodologies for the management of interventions, offers an effective guideline to achieve project quality and, with it, effective and respectful restoration interventions.

Acknowledgements

The author would like to thank architect G. Ercolani and the Publisher Gangemi for allowing the use of the images.

Notes

[1] *Those who, like me, entered the Superintendencies at the end of the 1980s, experienced the transition from the task of ensuring only the protection of cultural assets, to the awareness of the need for maintenance, up to the realization of the importance of promoting enhancement.*

[2] *We refer, among others, to Forte Antenne, subject to the protection provisions with Ministerial Decree 27.4.1954, 'Villa Ada and MonteAntenne; to Forte Monte Mario located within the 'Osservatorio di Monte Mario' with Ministerial Decree 3.2.1959; to Forte Aurelia included in the 'Valle dei Casali' with Regional Government Decree 8.3.1988 and to a few others falling within areas of landscape interest based on the current articles 136 and 142 of Legislative Decree 42/2004.*

[3] *Designer and Director of Works: architect Giovanni Belardi, official of the Roman Superintendency. See G. Belardi, The Portuense Fort. An example of restoration,in E. Cajano (edited by), The system of military forts in Rome, Gangemi editore, Roma 2006, pp. 154-169.*

[4] *Present at the table were: the Ministry of Defense and the Army and Air Force General Staffs, the Ministry of the Interior and the State Police, the Guardia di Finanza, the State Property Agency, the Interregional Office for*

Public Works for Lazio, Abruzzo and Sardinia, the Ministry of Culture, with the Special Superintendency for Archaeology, Fine Arts and Landscape of Rome and the General Directorate for Archaeology, Fine Arts and Landscape, the Lazio Region, Rome Capital, the FAI Regional Directorate of Lazio.

[5] *They are part of the network: Forte Aurelia Antica – Historical Museum of the Guardia di Finanza http://www.gdf.gov.it; Forte di Vinadio – Municipality of Vinadio (CN) http://www.fortedivinadio.com; Forte di Bard – Forte di Bard Association http://www.fortedibard.it; Rocca d'Anfo – Val di Sabbia Mountain Community http://www.roccadanfo.eu; Trentini Forts – Forte Cadine – Trentino Historical Museum Foundation http://www.museostorico.it; Forte Ardietti – Municipality of Ponti sul Mincio (MN) http://www.comune.pontisulmincio.mn.it; Forte Monte Tesoro – Municipality of S. Anna d'Alfaedo (VR) http://www.comunesantannadalfaedo.verona.it; MEVE – Municipality of Montebelluna (TV) http://www.memorialegrandeguerra.it; Forte Marghera – Forte Marghera Foundation http://www.fondazionefortemarghera.it; Ridotto Sant'Erasmo – Municipality of Venice. Private property.*

[6] *Regarding the choices and implementation of the restoration, reference is made to the volume currently being published.*

References

AA.VV. (n.d.). *Network of historic military forts in Italy*. Retrieved from the respective websites of the institutions involved.

Belardi, G. (2006). The Portuense Fort. An example of restoration. In E. Cajano (Ed.), *The system of military forts in Rome* (pp. 154–169). Gangemi Editore.

Cajano, E. (Ed.). (2006). *The system of military forts in Rome*. Gangemi Editore.

Ercolani, G. (2006). The project as reuse. In E. Cajano (Ed.), *The system of military forts in Rome* (pp. 136–153). Gangemi Editore.

Meneghelli, F. (2023). General Report on the Executive Project for the Restoration of Forte Aurelia, 2 December 2023.