

PAPER • OPEN ACCESS

Integrated survey procedures: a methodological approach for documentation and representation applied to Emilia-Romagna theatres

To cite this article: Balzani Marcello and Martina Suppa 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **949** 012011

View the [article online](#) for updates and enhancements.



ECS **240th ECS Meeting**
Oct 10-14, 2021, Orlando, Florida

**Register early and save
up to 20% on registration costs**

Early registration deadline Sep 13

REGISTER NOW

Integrated survey procedures: a methodological approach for documentation and representation applied to Emilia-Romagna theatres

Balzani Marcello, Martina Suppa

DIAPReM Center and TekneHub - Department of Architecture, University of Ferrara,
via Quartieri, 8, Ferrara, Italy

marcello.balzani@unife.it martina.suppa@unife.it

Abstract. After the earthquake that struck the Emilia-Romagna Region in 2012, the need to activate efficient procedures for heritage conservation emerged. This paper presents a procedure for the integrated documentation of cultural heritage, starting from the current evaluation procedures, standards and tools for surveying seismic damage, namely the Form A (churches) and Form B (palaces) forms used by MiBAC (Ministry for Cultural Heritage). By adopting current tools, several information and details related to the historical, geo-morphological, stratified and structural data are lost. Starting from ongoing PhD research coordinated by the DIAPReM Centre of the University of Ferrara in collaboration with the Agenzia per la Ricostruzione dell'Emilia-Romagna-Sisma 2012, this contribution aims to deepen integrated survey procedures and management of digital tools. This contribution presents the overall methodological approach and a possible application on the Teatro Borgatti in Cento, Ferrara. Therefore, analysing the current scenario and State of the Art, a preliminary assessment of multilevel interpretation of damaged heritage will be illustrated as well as a possible management of seismic risk developing an interoperable and integrated BIM platform.

1. Introduction

This contribution aims to illustrate the integrated survey methodology for the documentation, representation, and interpretation of the cultural heritage damaged by the earthquakes of May 2012 in the Emilia-Romagna Region. The scientific report illustrates the initial phase of the Ph.D. research conducted within the XXXIV cycle of the IDAUP International Doctorate Architecture and Urban Planning program of the University of Ferrara, funded by the European Social Funding of the Operational Programme 2014/2020 Emilia-Romagna Region: high skills for research, technology, and commercial transfer and is part of the strategic objective of the Clust-ER.

The research project, following an "extensive" methodological approach, through integrated surveying tools and the data implementation within an interoperable HBIM platform, focuses on the use of integrated digital surveying technologies and methodologies suitable to develop multiscale analysis, monitor degradation processes, risk factors, manage information and data by leading actors - Ministry, regional and local public administrations, professionals, businesses and citizens - allowing the identification of intervention strategies to preserve and enhance the assets. Documentation understood is an act of detecting, identifying, protecting, interpreting, represents an essential tool for knowledge,



awareness, and conservation of cultural heritage, in agreement with international charters and conventions¹.

In the context of the "Reconstruction" of the Emilian "crater's" protected assets, approaches, methods and tools of the digital survey are to be considered as necessary tools to map and monitor the state of the art of the regional heritage.

The integrated critical approach using, it is possible to identify strategies related to the systematization of the extensive range of existing and latest data, to achieve preventive and programmed conservation. In the architectural and cultural context, each asset becomes a representation of stratified data and metadata levels for which it is necessary to codify and interpret the geometrical, morphological, typological, structural, stratigraphic grammar, the cracking and degradation pictures at the architectural micro-scale and at the urban and territorial macro-scale in which they are inserted [1]. Therefore, the research aims to define an operative methodology starting from the applicative study of the sample of 31 damaged theatres in Emilia. Through integrated procedures of level and multi-criteria data acquisition and processing of the preliminary sketch of topographic surveys, GIS systems, LIDAR systems, photogrammetry, thermography, a cross-disciplinary approach is proposed to reach a data and metadata systematization within the HBIM INCEPTION interoperable and implementable platform to provide unitary documentation on a regional scale. This platform is the main outcome from the H2020 project "INCEPTION – Inclusive Cultural Heritage through 3D semantic modelling", funded by the EC in 2015 and completed in May 2019, and Coordinated by the Department of Architecture, University of Ferrara.

The goal is to define a protocol of seismic damage for cultural heritage, to classify, document, and represent the specific significances of the theatrical heritage of the Emilia-Romagna Region, a set of guidelines and best practices applied as a damage management digital tool and useable in case of emergency and the ordinary phase.



1. - *Front view of Borgatti Theatre from the point cloud visualization (Database developed by DIAPReM).*

2. The Damage Survey of Cultural Heritage - State of the Art

The research develops in collaboration with the Agency for the Reconstruction of Emilia-Romagna - SISMA 2012, established in the aftermath of the 2012 earthquake to coordinate the reconstruction within the crater of Emilia-Romagna. The first survey on the damaged regional cultural heritage has been achieved through the consultation of the WeBGIS portal [2] developed by the Emilia-Romagna Regional Secretariat of MiBACT. The WeBGIS platform maps and geo-references the cultural heritage of Emilia-Romagna classified and listed by the Regional Secretariat of MiBACT (former Regional Directorate). After the emergency phase, the Agency for Reconstruction - SISMA 2012, has decided to deepen the

¹ The Athens Charter for the Restoration of Historic Monuments – 1931; International Charter for the Conservation and Restoration of Monuments and Sites (Venice Charter 1964); Convention Concerning the Protection of the World Cultural and Natural Heritage – UNESCO 1972 (Paris); ICOMOS Charter – Principles for the analysis, conservation and structural restoration of architectural heritage (2003);

analysis optimizing the current procedures and improving the assessment of seismic vulnerability to three specific typologies - theatres, cemeteries and castles.

Based on WEBgis mapping, it is evident that the damaged protected regional heritage can have attributed to about 80% of the existing building that presented a considerable fragility of the historical-architectural heritage. This aspect having underlined the historical-architectural heritage fragility condition and several problems encountered in the application of current procedures to survey seismic damage. In the specific field of research on a collection of 105 protected regional theatres, 31 have damaged within the area of the Emilia-Romagna Crater. Basing on MiBACT report, historically theatres had regarded as places of social and cultural aggregation, likewise Churches, therefore, they are considered a priority for the Public Administration and the community of citizens within reconstruction strategies. In a first framework to the survey of seismic damage, it should remind that the DPMC 23/02/2006² establishes the survey of seismic damage to cultural heritage, through the compilation of two dedicated schematic tools: form A-DC (churches), and form B-DP (buildings) is the responsibility of the MiBACT institutions. These survey tools have used to indicate the collapse mechanisms and to record the state of "monument" vulnerability. In the emergency phase, these simplified tools represent the main procedures estimating the damaged index, concerning which has expresses economic founding for safety, structural restoration, plant, and seismic upgrading interventions. Considering the current schematic tools and their economic purposes, many quantitative and qualitative information- historical evolution of the buildings, specific technological aspects, quality of the construction and materials, restoration projects realized in the time [3]- has lost. Whereas, these factors influence behaviour in the presence of seismic stress. The use of a critical and holistic approach of integrated digital surveying systems allows optimizing and implementing the current procedures. A first consideration concerns indeed, the issues that the application of these current procedures of seismic damage assessment - related to specific architectural typologies - create during surveys in emergency conditions. In order to ensure and increase knowledge, documentation, monitoring and management of Emilia-Romagna theatres, the research develops an interdisciplinary and integrated approach [4]. Mitigating the seismic risk of damaged Cultural Heritage, the research proposes the application of existing devices (3D laser scanning, digital photogrammetry, GIS system) integrating them with the data semantic modelling in H-BIM environment (Building Information Modelling applied to Cultural Heritage), as a support for different levels of information. The implementation of a new integrated seismic detection protocol to be adopted not only as an integrated tool to be applied during the emergency phase but also and above all, as a preventive tool.

2.1 The Borgatti Theatre of Cento: Application of the current procedures for the survey of damages.

The Borgatti theatre of Cento (Ferrara) is an Italian style theatre, built-in 1856 by the engineer Antonio Giordani in collaboration with Fortunato Lodi. The Parmeggiani restoration project included interventions on the Palladian trusses, ceiling, and roof. Metal trusses had placed between the existing wooden trusses, that supporting the tie-rod to which the ceiling has anchored. It is possible surveying no metal trusses there are, and thin metal elements hanging off concrete beams support the ceiling [5]. Used until May 2012, it has a regular layout: an original nucleus (50x22 m and height of 15 m) and at the backside an added reinforced concrete part, (6 to 8 m x 13 and height of 7.5 m). It presents a horseshoe-shaped plan with three tiers of boxes, plus a gallery. Due to strongly compromised structural statics, the Theatre closed (1864). Between 1964 and 1974, the Borgatti was affected by demanding structural and functional restoration works. In the first survey, the current procedure of filling in the MiBACT form for seismic damage was applied, using the B - Palaces. 23 main collapse mechanisms listed were activated: 1. bending breakage of the boundary walls (M3); 2. breakage of the outer shear walls (M6); 3. sliding plane (M8); 4. local collapse of the vault bridge (M11); 5. damage to the roof elements (M15).

The damage index has estimated, basing on activated mechanisms. Except for this indication and a few others related to location, accessibility, metric-geometric data, the generic indication of construction

² DPCM 23 Febbraio 2006, n. 55 "Approvazione dei modelli per il rilevamento dei danni, a seguito di eventi calamitosi, ai beni appartenenti al patrimonio culturale"

materials and brief notes in which are recorded, when reported, previous restoration work, the form returns synthetic information on the Theatre on time. Considering the simplification of MIBACT forms, the only form B-DP compilation appears to be an insufficient tool to documentation, categorization and representation the morpho-metric, stratigraphic, technological-constructive and relational meanings, relevant to understand the behaviour of the factory, because generally they are analysed.



2. - point cloud section (Database developed by DIAPReM)

3. Cross disciplinary method

The survey, according to the conference Verso una “Carta del restauro” (Naples 1999), consists in the “complex of operations, measurements, and analysis aimed at understanding and documenting cultural heritage in its overall configuration, in its historical complexity, in its metric, structural, constructive and formal characteristics[6].”

A necessary premise for the theatre survey project is to identify the main sections that it composed that influence the static scheme. These partitions have classified into three main volumetric macro-blocks: foyer, cavea (which for the static behaviour and plant engineering purposes should be tripartite in the stalls, stage, and backstage) and dressing rooms. Starting this follows the definition of specific macro-elements set on the architectural typology analysed, allowing to identify the distinctive feature of the building both planimetrically and above all in elevation. A first observe is while the static behaviour of the foyers and dressing rooms can assimilate to that of a building, the stall has statically like a church hall. Achieving an overall and adequate picture of collapse mechanisms for this architectural typology, the B form (most used in the emergency phase) should be integrated with the A form. Basing on the first sample of theatres -Teatro Nuovo di Mirandola, Teatro Comunale di Reggiolo [7], Teatro R. Ruggeri di Guastalla, Teatro di Novellara and Borgatti di Cento - showed that the professions performed the described macro-classification for the finalised diagnostic investigations at the restoration intervention. Therefore, as the first degree of reading and relief of stratigraphic units and defining specific macro-elements, it necessary including and standardising macro-blocks. This can be useful to manage the complexity of 3D geometrical models and to set geometric and semantic classifications for HBIM models [8].

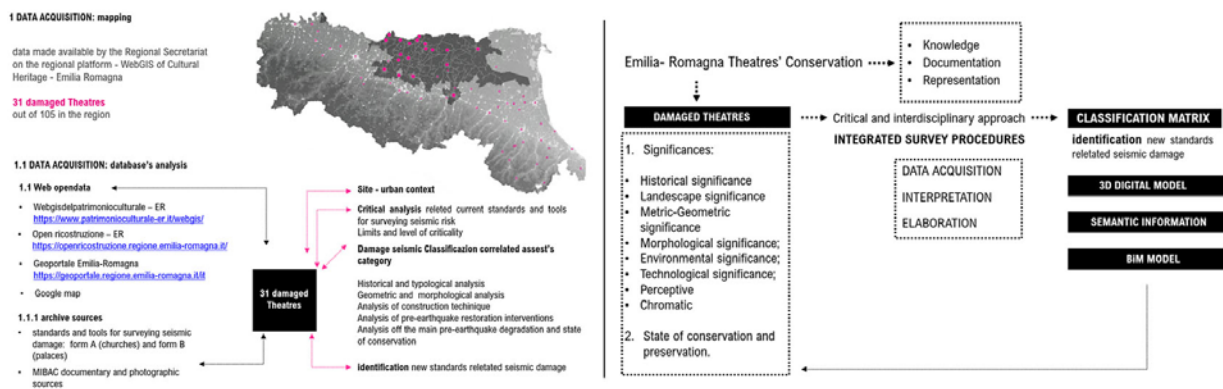
Therefore, the point cloud hierarchy according to the geometric-morphological macro-classification of the main sections has proposed, to represent the articulated spatiality of the theatres, defining comparable standard macro-elements for each one connected specific semantic information. These categories must then be declined in their specific architectural and technological LODs overcoming quantitative and qualitative estimation's difficulties of seismic vulnerability.

Concluding the current schematic forms must be integrated and optimized according to homogeneous criteria and standard definitions set on the Theatre's typology, which must guide professionals from data acquisition, restitution, interpretation to project. [9]

3.1 Digital integrated approach: lands survey and LiDAR technology

Starting from the filling out of the MiBACT form, integrating the topographic survey - performed by Technogeo - and the LIDAR survey - realised by Politecnica with the cooperation of the DIAPReM research centre of the University of Ferrara, the Borgatti survey has achieved in successive phases selecting, segmenting and sampling in order to obtain a three-dimensional digital model on which to make a critical "reading" and interpretation. This operation allowed metric-geometric characteristics representation and consequently, diagnostic analyses. The realisation of the HBIM model supported this first phase.

Currently is being tested the insertion of the HBIM model of Borgatti within the INCEPTION platform: by uploading an IFC model, it is possible to implement additional data and information, annotations, further segmentation of the model according to the semantic, material, structural components.



3. – left: Data acquisition: database's analysis; 4.- right: Methodological approach for documentation and representation applied to Emilia-Romagna theatres.

Three-dimensional scanning techniques integrated with topographic measurements have applied to the survey of the Borgatti Theatre, allowing to obtain a correct georeferencing of the acquired data.

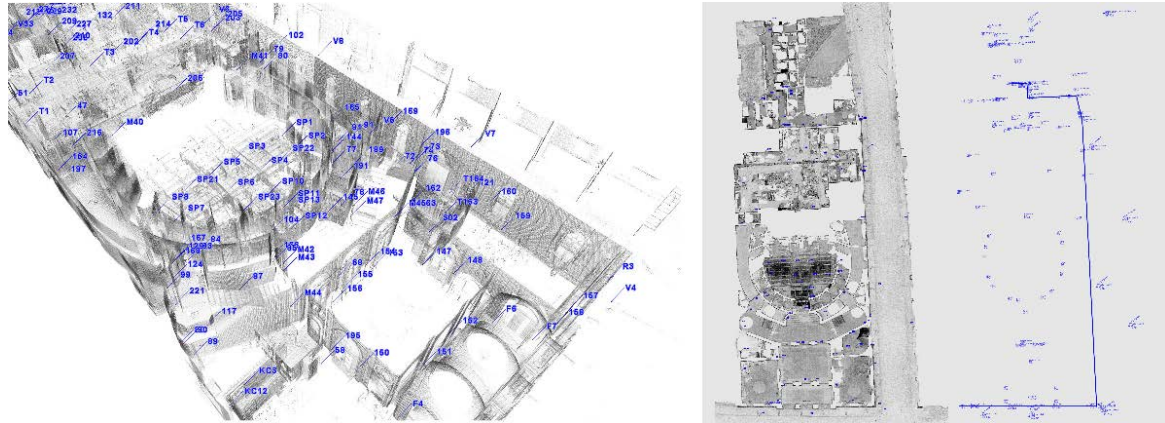
Therefore, the LIDAR system survey is leaning on a hyper-determined closed traverse whose geometry follows the development articulated in elevation of the Theatre. The LIDAR technology survey of the Borgatti Theatre has aimed at analysing the form and static-structural behaviour in the aftermath of the 2012 earthquake.

Considering the morphological characteristics and its complex articulation in elevation, it has deemed necessary to design preliminary sketches to assess the schematic spatial configuration, the different locations of the scanner, the extent of individual acquisitions, position and targets. It has been necessary to survey several control points measured both topographically and with LIDAR technology, allowing to constrain the different views and reduce the propagation of the residual alignment error. The sectioning levels on the point cloud made it possible to investigate the damage suffered by verifying the alterations of the deformation-structural framework and the conservative state of the masonry.

Using the laser scanning procedure has possible to obtain a three-dimensional digital model that would correctly give information on the correlation between seismic damage and the intrinsic characteristics of the object. It has supported the structural analysis, verification geometry's misalignments thanks to the segmentation of the cloud according to horizontal and vertical profiles. Furthermore, the hierarchy of the cloud has allowed to isolate and verify individually and globally the stratigraphic, technical-constructive and material specificities (wooden ceiling in original body, masonry vaults, brick vaults, stalls, and backstage have concrete brick slabs, wooden beams, and Varese beams) of the macro elements specific to the Theatre to which a certain degree of vulnerability is connected.

Levels of horizontal and vertical section studied ad hoc to return the complex spatial articulation have allowed verifying the degree of vulnerability of the main damaged portions:

- Foyer: A) excessive deformability of the wooden elements in the roof; B). absence of retention at the top of the walls, the C) overturning of the facade caused by kneeling portal, the excessive deformability of the inclined central beam, lack of stiffening of the slabs, absence of interconnection of the intermediate decks and the roof; D) injuries along the walls of the main facade dragging the orthogonal walls and adjacent vaults (consequential to the C); E) displacement of the shutters of the masonry entrance vault.

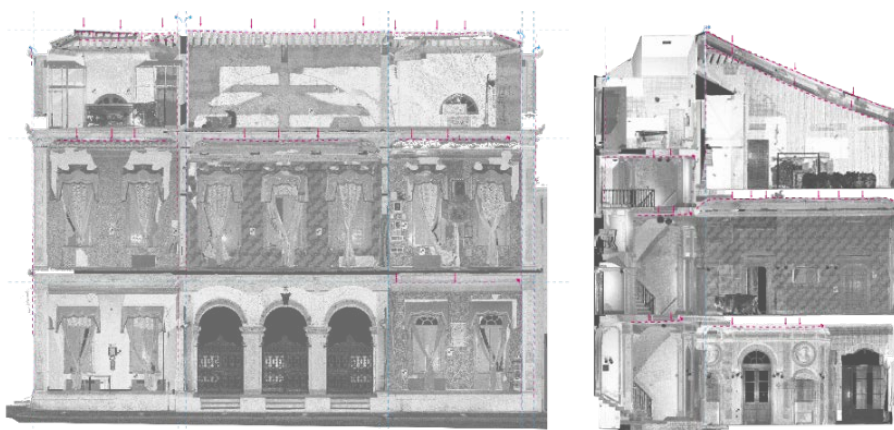


5. - left: in blue the homologous points between the scans necessary to register for the Point Cloud; 6. - right: overlap of the topographic network to the homologous points of the point cloud.

Plateau: F) damage to the ceiling whose suspension system does not have horizontal bracing elements; G) intrados and sub-horizontal injuries to the external longitudinal walls and the pitch; H) deformability outside the tunnel corridor floor; I) deformation, due to the absence of elements absorbing horizontal thrusts, of the lowered vaults of the access corridors to the stages. L) lesions in the corridors concerned the removal of the shutter and locally the sliding of the bricks, causing the loss of contrast due to change in shape.

Stage: M) excessive slenderness of the longitudinal perimeter walls; N) injuries to the top of the walls connecting to the roof (overturning out of level) due to the lack of connection between the planking and the perimeter walls of the stage.

Backstage: O) deterioration of the wooden elements of the second warp. P) deformability in its plane of the roof pitch. Q) hammering of the perimeter walls and damage to the roof covering.

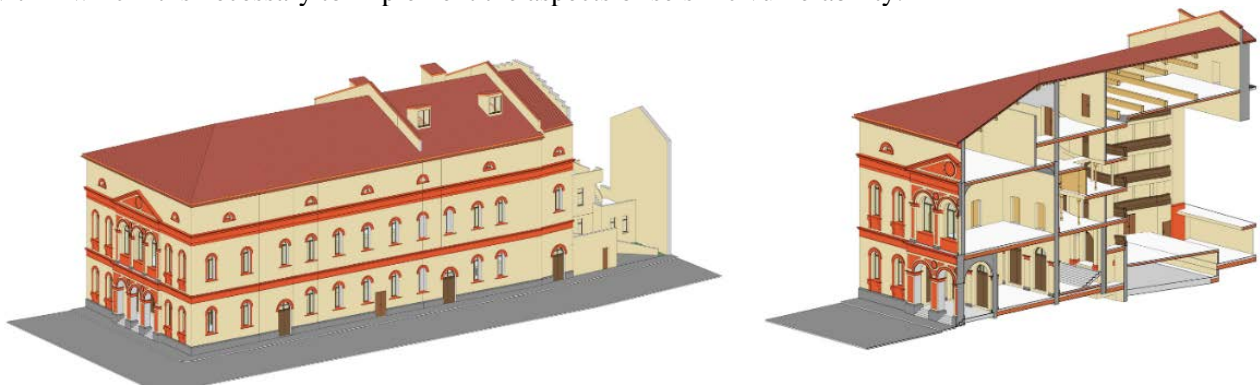


7. - point cloud section: damage analysis in the foyer area (Database developed by DIAPReM - graphic elaboration by M. Suppa)

3.1.1 Borgatti HBIM Model

Borgatti's BIM digital model, one of the case studies developing within the Por Fesr industrial research project "eBIM", coordinated by Prof. Balzani within the TekneHub research activity, has not modelled by point cloud segmentation, but through comparison with it using orthogonal exports, which verified by CAD in elevation and plan were imported on Revit. The modelling was performed with a low LOD and the macro elements, identified according to a generic classification related to the historical building, report a simple stratigraphy.

In the Borgatti modelling, different modelling problems have found for elements such as the roof, the attic and ceiling system, the corridor vaults, due to the lack of integration with the laser data. Therefore, it should be relevant to hierarchize the point cloud and break it down into the volumetric macro-classification, followed by the setting of macro-elements proper to the type by controlling the geometric stratigraphic hierarchies of the model to which then correspond specific semantic hierarchies, within which it is necessary to implement the aspects of seismic vulnerability.



8. - *Modeling and processing of the three-dimensional digital model HBIM (elaboration by A. Zattini)*

4. Conclusions

The evolution of digital technologies at the service of the representation of architecture has allowed the achievement of objectives previously indispensable for the survey, knowledge, and communication of the built heritage. By integrating the possibilities offered by three-dimensional, solid and parametric modelling tools with systems for data management and sharing, BIM systems promise new scenarios for the storage and management of large amounts of information for the knowledge of Cultural Heritage [10].

The systematization of data and metadata collected since 2012 is one of the key issues on which the Emilia-Romagna Region is working in synergy with the Agency for Reconstruction - SISMA 2012, local authorities, professionals and specialized companies. This aspect is a crucial node of the ongoing research because it is the first step for the definition of the integrated seismic damage detection protocol.

To systematize the information collected from MiBACT forms and regional GIS databases, implement geometric-stratigraphic information derived from the processing of critical point clouds and semantic information, the support tool is, therefore, the INCEPTION HBIM platform. This is a web-based online semantic environment, a storage in which to file, modify and implement information on a specific object - model .ifc - of cultural heritage. Optimizing the current survey procedures and implementing the lost qualitative and quantitative information towards an integrated digital protocol able provide to competent authorities with an efficient tool to guarantee the seismic damage management. In order to realize an digital integrated database in which each theatre has linked its ID card, the certify of an integrated protocol is foreseen. Therefore, the research proposes to extend the protocol application and certification to an emblematic set of Romagna's historic theatres. It is necessary to develop a taxonomic classification that responds to homogeneous classification criteria (implementing a synthesis between the ICCD classification and Cultural Heritage Identity Card of eu.chic [11]). This classification will inform both the survey project process and HBIM modelling. Based

on the Statsbygg BIM Manual 2.0 [12], to implement seismic risk information within the model to for knowledge and projects, the development of a rules sets to verify and validate the model is proposed. The rules, finalized to the Clash Detection and Code Checking of the BIM model, will add the seismic damage survey geometrical, technical and semantic information connected the analysed typologies. Therefore, since the theatres are public buildings, the rules must be uniform to UNI 11337.³

References

- [1] Maietti F, Ferrari F, Medici M and Balzani M 2016, *Proceedings of the International Conference “SBE Malta 2016, Europe and the Mediterranean: Towards a Sustainable Built Environment”*, Valletta, Malta, 16th-18th March 2016, R.P Borg, P Gauci, Staines and C.S., Malta (Gutenberg Press), 317–324.
- [2] <https://www.patrimonioculturale-er.it/webgis/>
- [3] Coisson E and Ferrari L, 2019, *Paesaggio Urbano*, **1**, 153-159.
- [4] Maietti F, 2019, n *Between History and Memory, the Blue Jodhpur. Experiences of integrated documentation and survey techniques*, Balzani M, Jain M and M.Jain and Rossato L, Maggioli Editore, 61-64.
- [5] AA. VV., 1994 *Il teatro e la città. 130 anni di attività tra storia nazionale e locale*, Teatro Comunale “Giuseppe Borgatti, Cento.
- [6] G. Tucci G and Bonora V, 2007, *Sistemi a scansione per l'architettura e il territorio Firenze (Alinea Editrice)*, 89-95.
- [7] Balzani M, Raco F and Suppa M, 2019, *Paesaggio Urbano*, **1** 161-169.
- [8] Bonsma P, Bonsma I, Sebastian R, Maietti F, Ziri A.E, Parenti S, Leronés P. Martín, Llamas J, Turillazzi B and Iadanza E, 2016, *Proceedings of the International Conference “SBE Malta 2016, Europe and the Mediterranean: Towards a Sustainable Built Environment”*, Valletta, Malta, 16th-18th March 2016, R.P Borg, P Gauci, Staines and C.S., Malta (Gutenberg Press), 283-292.
- [9] Karachaliou E, Georgiou E, Psaltis D and Stylianidis E, 2019, *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, **XLII-2/W9** , Bergamo 397-402.
- [10] Messaoudi T, P. Véron P, Halin G and De Luca L, 2018. *Cultural Heritage, Elsevier*,
- [11] A. Kioussi A, Karoglou M, Labropoulos K, A. Bakolas A and Moropoulou M, 2012 *Heritage Protection. From Documentation to Interventions. In Proceedings of the EU-CHIC International Conference on Cultural Heritage Preservation*, R Žarnic R, Rajcic V and, Vodopivec B, Ljubljana, Slovenia, 129-131
- [12] <https://sites.google.com/view/statsbyggs-bim-manual-2-0-sbm2/hjem>. BIM manual 2.0

³ DM, 1 dicembre 2017, n.560, “Normativa UNI 11337”.