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Optimisation of survey procedures and application of integrated digital tools for seismic risk mitigation of cultural heritage: The Emilia-Romagna damaged theatres.
IDAUP XXXIV Cycle

Università degli Studi di Ferrara | DA Dipartimento Architettura Ferrara | Universiteti POLIS

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Candidate: Martina Suppa
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Cycle XXXIV

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UNIVERSITETI POLIS

INTERNATIONAL DOCTORATE
IN ARCHITECTURE AND URBAN PLANNING

Cycle _XXXIV_

IDAUP Coordinator Prof. Roberto Di Giulio

Optimisation of survey procedures and application of integrated digital tools for seismic risk mitigation of cultural heritage:

The Emilia-Romagna damaged theatres.

Curriculum Architecture/ IDAUP Topic 1.5 Cultural heritages. Innovations and ICT processes for cultural heritages use and conservation
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A nonna Ina
e
A Carlo.

Thans to

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[...]Tieni sempre Itaca a mente:
raggiungerla è il tuo ultimo scopo.
Non affrettare però minimamente il viaggio,
meglio lasciarlo durare molti anni;
attraccare alfine all'isola quando sarai vecchio,
ricco di tutto ciò che avrai raccolto per strada,
senza pretendere che Itaca ti offra altri tesori.

Itaca ti ha donato il Viaggio meraviglioso.
Senza di lei tu non saresti mai partito per la tua via.
Essa non ha null'altro da offrirti.

Se la troverai povera, non credere che Itaca t'abbia ingannato.
Saggio come sei diventato, con sì tanta esperienza,
avrai già compreso cos'Itaca realmente rappresenti.

"Itaca" – K. P. Kavafis

[...] "Diceva Ulisse chi m'o ffa fà
La strana idea che c'ho di libertà".

Piccola Orchestra Avion Travel

Abstract

keywords: integrated documentation, digital tools, integrated workflow, seismic damage, historic Emilian theatres, damage mitigation.

The Emilia-Romagna Region's "Three-year High Skills Plan for Research, Technology Transfer and Entrepreneurship" under Legislative and Representative Assembly Resolution No. 38 of 10/20/2015, thematic objective 10 of the ERDF ESF 2014/2020 and the Emilia-Romagna Region's smart specialisation axis funded the research. It was scientifically coordinated by the DIAPReM Center of the University of Ferrara with the collaboration of the Agency for the Reconstruction of Emilia-Romagna-Sisma 2012, and the High Tech Network of the Emilia-Romagna Region, the Research Laboratories of the Technopole of the University of Ferrara and the Cluster Build "Building and Construction" network.

Starting from current procedures, standards and tools for seismic damage survey, the research presents an integrated workflow for seismic damage documentation and survey applied to historic theatres in the Emilia-Romagna region damaged by the 2012 earthquake. The 2012 earthquake highlighted the fragility of the cultural heritage and underscored the lack of proactive conservation and management of historic assets.

The research starts by analysing Agenzia Regionale per la Ricostruzione della Regione Emilia-Romagna- ARRER's requests, which had found criticalities in applying the current Mic (Ministero della Cultura) procedures for the damage survey of complex types: the A-DC form for churches and the B-DP form for buildings. Using the two types of forms highlighted the lack of *ad hoc* tools for complex architectural styles such as castles, cemeteries and theatres, resulting in the loss of quantitative and qualitative information necessary for knowledge, conservation and thus management of the reconstruction process. As a result of these considerations, national and international standards of integrated documentation, existing digital databases for cataloguing and classification of cultural property, and seismic risk management were studied to develop a workflow of integrated procedures for seismic damage survey on the specific assigned case study: Regional Historic Theaters affected by the 2012 earthquake. The research used the holistic and interdisciplinary approach of integrated documentation to develop the integrated procedural workflow to enhance and optimise seismic damage detection operations in the case study. In providing a workflow of integrated procedures for the prevention and mitigation of hazards related to potential states of emergency, both natural and anthropic, the research follows an "extensive" methodological approach to test the survey outside the Emilia crater. The methodological framework led to the critical-comparative analysis, divided into two levels: the first involved studying critical issues in the B-DP form, mainly used in the 2012 theatre survey. The second level covered the techniques - laser scanning, digital photogrammetry - and integrated survey methodologies applied during the in-depth investigations for repair and restoration work. The critical-comparative analysis and morpho-typological study led to the development of an integrated procedural flow to survey damage in historic theatres. It is aimed at systematising and optimising the stages of damage documentation.

The workflow consists of three information levels: L1. Screening level for the visual survey; L2 survey level defines the 3D acquisition steps for the geometric-dimensional study by theatres. The BIM L3 Plus level guides implementing the level of knowledge of parametric HBIM models for documentation, management and monitoring of historic theatres. The three levels were tested and verified on the pilot case of the Social Theater of Novi di Modena. In addition, using the extensive methodology, the L1 level was tested on the Masini Theater in Faenza and the theatre in Split. The integrated workflow is the knowledge tool indispensable for documenting historic theatres on the specific historical-architectural features related to seismic vulnerability. The workflow levels are prerequisites for information database development linked to Inception's HBIM semantic platform. Using the HBIM semantic web and the developed ontology allows to understand the specific characteristics and features of theatres and then to manage within a collaborative environment the monitoring and maintenance operations of the asset. The latter aspect is one of the possible future development of the research suggests for optimising the phases of cultural heritage reconstruction and defining strategies for preserving and managing historical and architectural heritage.

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CHAPTER 1
First Section: Research field and issue
<u>Abstract</u>

The first chapter explains the scientific and methodological approach of the research focused on integrated documentation procedures for a seismic damage survey of historic theatres in the Emilia-Romagna region damaged by the 2012 earthquake. An overview of the leading integrated survey methodologies and techniques that underlie the methodological framework of the research (topographic, photogrammetric, Lidar survey systems) is presented. The objective is to develop a workflow of integrated surveying procedures for the historical theatres of Emilia. An integrated meta-protocol through which the specific meanings of the theatres, cultural heritage can be documented, surveyed, and represented to ensure damage mitigation, planned monitoring, preservation, and proactive management of both the specific field of study and the broader cultural heritage. This objective uses a holistic approach that underlies the methodological framework articulated in four WPs. The main phases of the methodological framework are (WP1) of the Art - preliminary analysis; (WP2) Definition of the extensive integrated methodology for the definition of a workflow of integrated procedures aimed at damage survey; (WP3) Development of the workflow of integrated approaches articulated on three inspection-information levels. (WP4) Identification of the HBIM - INCEPTION platform as a management and monitoring tool on the actions of the theatre reconstruction process. Finally, the research limits are described, considering the regional scale of the investigation field restriction and thus a partial control and verification of the integrated workflow.

Cover image-Chapter 1 - Finale Emilia Social Theater- Image from ARRER archives.

1.1 Scientific framework.

The research focused on integrating the levels of knowledge to document the Emilia Romagna *historic theatres' typology* analysing the aspects which influence their seismic vulnerability. The conservation of cultural heritage supposes the accurate documentation of the specific asset. Therefore, the survey project is an essential step toward the knowledge of architectural heritage. Because of this, the more accurate and precise a survey will be, the more it will be possible to draw metric-geometric historical-stratigraphic and technical-constructive information. This approach is even more relevant in the heritage documentation subjected to risk situations. In the survey's particular case, seismic damage is faced in the specific context of historic theatres. Therefore, the need for a study through 3D acquisition containing the Scan to BIM process to obtain a parametric object model represents a significant step to documenting the CH significance (Fig.1).

Relying only on the visual survey is not sufficient to represent and interpret critically and analytically the specific attributes that make up the architecture and connect them with the deformation and cracking aspects that occurred due to the earthquake. Therefore, the acquisition and processing of digital models allow obtaining a database of morphometric data that can be navigated, inspected, and implemented over time. This consideration does not mean that the visual survey through the elaboration of preliminary drawings is an outdated procedure and useless application; on the contrary, they represent the first tool of knowledge, analysis and documentation as they are helpful to set up the survey project. The application of digital techniques of three-dimensional acquisition, however, allows to collect and record, in a short time, the metric, morphological and radiometric aspects of a building, obtaining reliable surveys of high precision and accuracy. These "digital archives" configure themselves as special research tools in cultural heritage. They document the "geometric memory" consisting of an architectural artefact's metric, morphological and surface characterisation data. [Ferrari, Maietti, 2018].

The research stressed the application of integrated acquisition techniques for the survey of seismic damage to record the singular features of the historic theatres to draw a congruent framework of the geometric variations and misalignments caused by the earthquake. Moreover, this is also due to the requirements of the *2011 Directive* for the assessment of seismic damage, which requires "The aim is to acquire, in a reasonably short time, a knowledge of the safety level of these buildings in the most seismic areas given the significant number of protected assets."

The *digital documentation* to analyse seismic risk involves several phases of study [Bertocci et al., 2018]. Therefore, considering the research objective to prepare an *integrated procedural workflow* for surveying seismic damage of theatres in Emilia, the described aspects are the starting point for developing the *integrated procedural workflow* optimised for conservation programmed management of seismic risk.

This paragraph proposes a synthetic survey of the *tools and methods* that underlie the documentation and study integrated with this premise in mind (Fig.2).

In the specific research context, the integrated investigation project is based on identifying the necessary operations and drafting a *workflow* of the survey activities required to study seismic damage. The first step is the visual survey. During this first phase of the survey, through the elaboration of preliminary drawings made on site [G. Chiarizia et al. 2002] identified and discretised the primary geometries, volumes, and relative damages. These preliminary drawings represent the basic level of knowledge to set up the instrumental survey. The preliminary sketches, as occurred in the instrumental survey of the pilot case of the research (Social Theatre of Novi di Modena), are indispensable to define the position of the Targets and the planning of the topographic survey and the subsequent survey activities. In the specific context of a building damaged by the earthquake, the survey campaign planning must also consider the site's safety conditions and possible obstacles, such as the presence of rubble, which could impede 3D acquisition. Therefore, in these particular conditions, it is

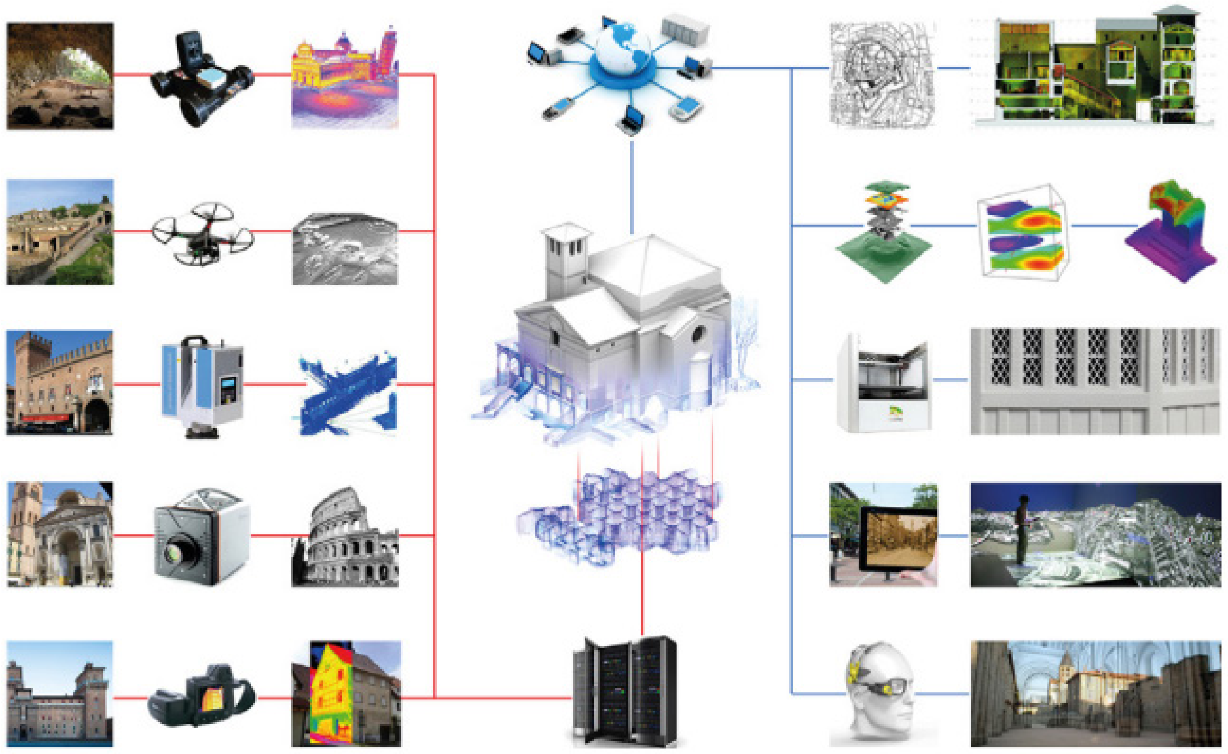


Fig.1 the Outline of the integrated documentation procedure. The operational phases range from acquiring the heritage data to the semantic query of the three-dimensional model. Developed by the INCEPTION team

necessary to opt for the integration of several survey methods and systems to overcome any impediment to collecting the data required for metric-dimensional and geometric knowledge of the building. Moreover, the integrated methodological approach allows obtaining 3D spatial models with a high resolution, accuracy and precision that guarantee the reliability of the morphological model. This aspect is indispensable in the acquisition phase as it processes, represents, and modifies the acquired data.

Since the early stages of the survey campaign, it is, therefore, advisable to select the most suitable and integrated techniques and approaches that allow comprehensive compressive documentation of the cultural property under investigation, considering optimising resources, time and results. The choice of the appropriate and integrated techniques depends on several parameters: a) survey purpose, b) object's morphology, c) the conditions of context in which to operate, d) scale of representation and modelling of the data in the HBIM environment. From the study of the technical reports made available by the RUPs on the theatres damaged by the 2012 earthquake, it was possible to observe integrated survey methodologies to document damages (ch. 4, para 4.2.2). In the specific application case presented in the survey of the theatre of Novi di Modena, the integration of photographic techniques was proposed, with the topographic method (Leica Geosystems TPS 1202), the use of LIDAR technology (Leica C10 and BLK 360) and area photogrammetry (DJI MAVIC MINI). The theatre was surveyed using laser scanner instrumentation because it is more suitable for the architectural space considered, the speed of acquisition times, and the survey's purpose. Moreover, laser scanner technology allows obtaining surveys with a high data quality (precision, accuracy, minimisation of instrumental "noise").

It is essential to the damage survey not only an acquisition aimed at describing the morphological attributes of the historic theatre. But mainly to achieve a survey that must provide detailed information on the metrological and geometrical characteristics of the building as well as make measurable and verifiable the deformation variations and the floor displacements caused by the earthquake.

Before describing the different options of the LiDAR technology, we will focus on the topographic survey, which represents the support for acquiring the 3D data.

High-density data acquisition processing methods can be traced to the Geomatics family, of which this contribution focuses on topographic, laser scanner, and photogrammetric systems. The topographic survey constitutes the starting point of any survey project. “The fundamental principle that oversees the territory’s survey consists of defining the position of a discrete set of points, determined with a high precision, to which support the measurements that will serve to define the geometry of the survey objects” [A. Spanò, 2013], then performed with other techniques. Several methods have been used and completed over time for angular measurements up to today’s satellite methods. The process of triangulation that involved measurement of angles and distances has been replaced by the polygonal, open or closed, which consists in taking measures by a succession of points. By proceeding with overabundant measurements for the geometric resolution of the control network, it is possible to identify minimised deviations with the least-squares method. For the vertices’ measurement, the framing network, the GNSS - Global Navigation Satellite System, is used to measure the coordinates of a point on the earth’s surface using trilateration distance between at least four satellites and a receiver on the ground. The geocentric reference system is the WGS84 - World Global System 1984: “the z-axis is parallel to the direction of the Earth’s pole, the x-axis is given by the intersection of the equatorial plane orthogonal to the z-axis with the plane of the Greenwich meridian, the y-axis is orthogonal to the x- and z-axes” [E. Fillia, 2020]. GNSS receivers can hook up to several satellite systems. For example, we have the NAVSTAR GPS of the US Department of Defense, GLONASS operated by Russia, Galileo of the European Community, and BeiDou of the People’s Republic of China. The topographic survey is carried out using the total station whose data are integrated with the laser scanner and photogrammetric surveys to measure the anchor points of the 3d data acquisition.

The laser scanner systems, applied to LIDAR technology (Light Detection and Ranging), have revolutionised the metric and geometric survey by optimising the time and processes of data acquisition, providing morphometric models of high precision, accuracy, and information density. The use of this kind of tool reached its full maturity several years ago, and the process of modelling from range-based data is now well structured and defined (Cignoni, Scopigno 2008). However, some “bottlenecks” are still related, particularly to managing large amounts of data acquired [M. Russo, F. Remondino, G. Guidi, 2011]. Therefore, it is essential to plan the scanning plan to optimise resources and acquisition time and meet the survey’s objectives for acquisition purposes. The 3D acquisition through laser instrumentation produces a 3D model (point cloud) built from the set of scans of individual stations, which record single point clouds. Each point in the cloud is characterised by the spatial coordinates x, y, z and the reflectance value. The scanning plan must consider various aspects, such as the possibility of covering the entire object to be surveyed in the detailed survey of the thing. In recent years, significant progress has been made for this technology concerning the speed of data collection, improvements in data quality, reducing the noise element, and development of portable and backpack systems that enable the rapid surveying of more challenging survey areas[1]. Laser scanners fall into two main categories: triangulation, pulse (time-of-flight; ToF) or phase-comparison systems (Fig. 3). They are used to obtain reliable, accurate and detailed morphometric models.

Laser scanners based on the survey principle of triangulation are available in several different forms:

- Static, sometimes laboratory-based, scanners scan objects placed on the turntable to cover all sides.
- Scanners attached to articulating arms which provide the positional referencing. They can be either static or taken to the object
- Tripod-mounted scanners are used in the field to scan larger objects and volumes

1 *Historic England 2018 3D Laser Scanning for Heritage: Advice and Guidance on the Use of Laser Scanning in Archaeology and Architecture. Swindon. Historic England.*

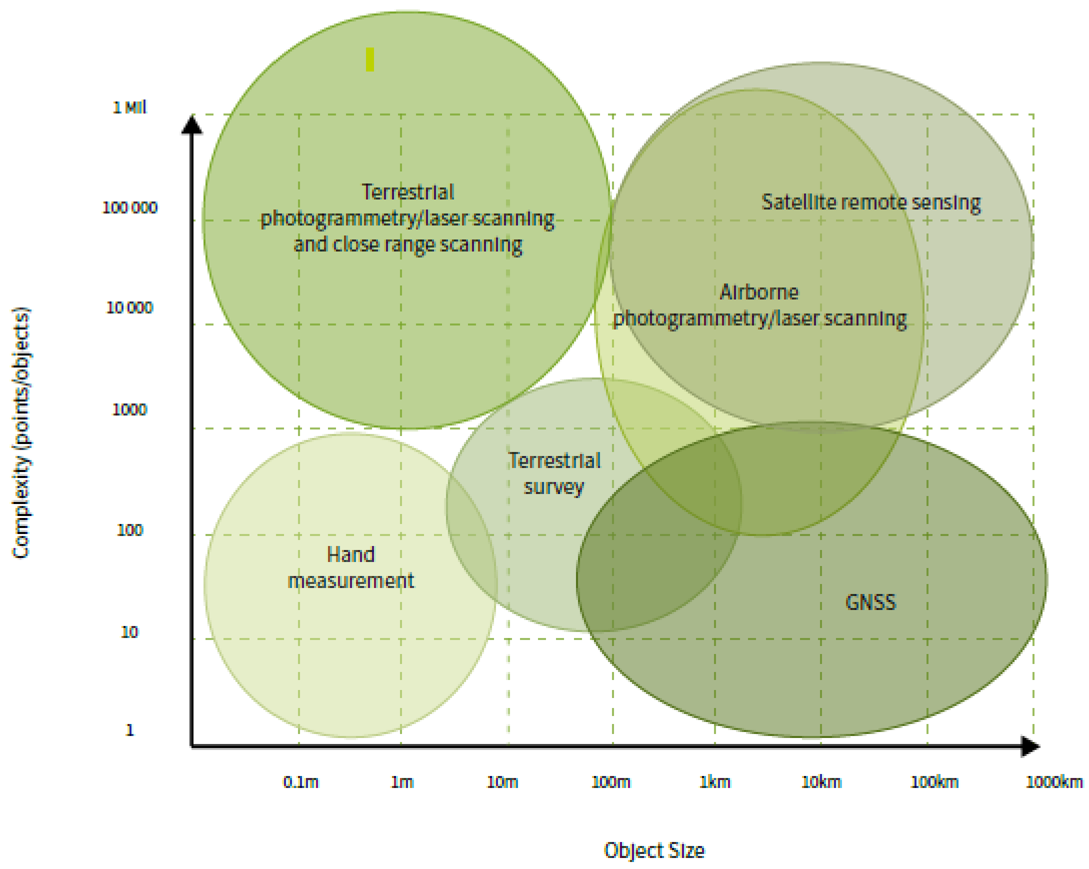


Fig.2 Survey techniques defined by object complexity (points captured) and size, derived from Boehler et al. (2001). Developed by Historic England 2018.

- Handheld scanners for close-range work
- Handheld and backpack-mounted scanners for mobile field use over extensive areas [Historic England 2018].

These scanners are mainly used to survey objects in the cultural heritage, such as statues and bas-reliefs, but they find more application in the industrial field. They can be installed on mechanical arms that allow the orientation of the scan of the object.

These scanners are so easy to handle that they can be used in the laboratory and on-site. In addition, they have high accuracy and

they can detect objects up to a maximum distance of 2-3 with an accuracy of up to 0.05 mm.

Pulse scanners use what can be considered the most straightforward technology: a pulse of laser light is emitted, and the time required for the return flight is measured. The range is calculated by a simple formula involving the speed of light. This aspect is allowed by the mirror’s timing mechanism and rotation system around a vertical axis between 270° and 300° around a horizontal axis of 360°. These factors enable acquiring an entire room. They are, in fact, the most used instruments for the architectural survey reaching high standards of accuracy between 2-6 mm on large distances.

In recent years, TOF scanner systems have been developed that integrate improved cameras to obtain textured scans characterised by high resolution and image quality. With the P40, Leica proposes a technology that allows shooting 260 photograms of 96 MP. Some of the significant innovations in TOF scanners are represented by the BLK 360 Leica, which, compared to the FAcro focus, is lighter and easier to handle. This instrument can acquire 360,000 points per second and includes a 150MP panoramic camera system.

Phase comparison systems, also called continuous wave scanners, are similar in accuracy

Scanning System		Usage	Typical Accuracies (mm)	Typical Range (m)
Triangulation	Rotation stage	Small objects taken to scanner. Replica production	0.05	0.1 – 1
	Arm mounted	Small objects. Lab or field. Replica production	0.05	0.1 – 3
	Tripod mounted	Small objects in the field. Replica production	0.1 – 1	0.1 – 2.5
	Close range handheld	Small objects. Lab. Replica production	0.03 – 1	0.2 – 0.3
	Mobile (handheld, backpack)	Awkward locations eg building interiors, caves	0.03 – 30	0.3 – 20
Pulse (TOF)	Terrestrial	Building exteriors/interiors. Drawings, analysis, 3D models	1 – 6	0.5 – 1000
	Mobile (vehicle)	Streetscapes, highways, railways. Drawings, analysis, 3D models	10 – 50	10 – 200
	UAS	Building roofscapes, archaeological sites. Mapping and 3D models	20 – 200	10 - 125
	Aerial	Large site prospecting and mapping	50 – 300	100 – 3500
Phase	Terrestrial	Building exteriors/interiors. Drawing, analysis, 3D models	2 – 10	1 – 300

Fig.3 Table of Laser scanning systems and their uses. Developed by Historic England 2018.

to TOF systems. Still, they differ in the following respects measuring the phase differences between emitted and returned signals rather than directly on the top.

Directly on the TOF. They provide high density and high point clouds. While suitable in the application of the field of cultural heritage survey present. Today the market offers the possibility to have phase comparison instruments, including cameras and HDR, such as the Z+F IMAGER® 5016, which includes an 80MP HDR panorama and the new FARO Focus 350, a 165MP panorama [Historic England 2018].

One developing technology is the ToF camera. Instead of a pulse of light received from a sensor, an array of sensors can act as an active camera that measures range and intensity. Collections are available with resolutions up to 640x480 pixels, but their use has been confined primarily to machine vision and industrial applications. They can run at up to 60 frames per second, so a massive amount of data can be collected in a short time. Because of the instantaneous capture, they are used for moving objects (perhaps on an assembly line). Still, likewise, the camera itself can be moved around a subject similar to a handheld scanner. Google's Tango concept of incorporating depth-sensing tools into cell phone technology (from Lenovo and ASUS to the present) introduces ToF cameras to the consumer for reality capture and augmented reality display [Historic England 2018.

Another recent development is the integration of a capable laser scanner with a total station. This is the Trimble SX10, which includes whole and part dome (the approximate hemisphere of the scan coverage) imaging capabilities. The design has some compromises, as the maximum data collection rate is only 26,600 points per second. However, such a tool allows for coordination of each scan location and the ability to georeference point clouds directly without using control points in the scene. Trimble had introduced scanning in previous models (Trimble S7 and S9), but the speed was only 15 points per second. Controlling scan

data is discussed in more detail [Historic England 2018].

In recent years, these instruments have undergone a technological evolution, represented by MMS systems that base their operation on SLAM (Simultaneous Localisation and Mapping) algorithms. These systems allow short-range mapping for surveys of interior building spaces with poor accessibility and implement surveys made with other systems. These tools are therefore usable in conditions of risk and damaged heritage. Their first application dates back to 2014 from the University of Brescia for the 3D survey of the open-air way in Botticino [G. Vassena, A. Clerici, 2018]. MMS systems can be defined as combining several sensors, a measurement sensor unit -LIDAR- and a time unit. They can be divided into vehicle sensors on land, water, and air or portable sensors on trolleys, backpacks, and handheld. This classification is relative to the mode of acquisition movement. According to what has been experimented with, vehicle platforms integrated with aerial survey systems perform well in covering considerable distances in urban areas. The scanning stations are based on SLAM algorithms that progressively associate profiles detected by the instrument in movement. The gripping system is based on GEOSLAM's ZEB, a moving head "equipped with a profilometer that captures 2D point profiles, without GNSS receiver or RGB data. The system also includes an inertial measurement unit. The ZEB device's sensor head is mounted on a spring that oscillates freely and passively during operator and vehicle movement. The instrument estimates the trajectory, and raw profiles are continuously captured in time windows and progressively aligned in the 3D reconstruction according to the best match with the surface characterisation. The adrift error may be generated, which can be corrected by closing the trajectory and returning to the starting point of the survey. The result is a point cloud associated with a trajectory and a time reference; moreover, it is possible to visualise the time and estimated quality of the SLAM recording" [G. Sammartano, A. Spanò, 2018].

Finally, digital photogrammetry is among the integrated sensing techniques, thanks to which the phases of orientation and restitution have been automated through the algorithmic processing of image matching.

Photogrammetry is the science, and art, of determining the size and shape of objects due to analysing images recorded on film or electronic media.[KB Atkinson, 1996]

The SfM-based model (image-based surveys) is the result of processing several images to be acquired based on four specified control points. A minimum number of sights is sufficient to scale and translate the model into the required coordinate system.

Image matching recognises homologous points - tie points - on multiple digital photographic images.

From the 2015 Historic England report, some essential aspects of the photogrammetric survey are reported:

- 4.2.1 Accuracy

Image control points are to be provided to a 3-D accuracy of either:

(a) ±3mm; or

(b) other (specify).

A listing of the 3-D coordinates is to be included in the survey report.

- 4.2.1 #Accuracy

Choose an option. Option (a) ±3mm is sufficient for the standard architectural scales.

- 4.2.2 Control of subject

For photogrammetric and orthophotography surveys, a minimum of four coordinated control points, directly observed in the field, are to be provided for each model. Wherepracticable, targets are to be placed on the fabric (see sections 1.6.2 and 2.2.9) and must: be no larger than 60mm × 40mm; no thicker than 0.5mm; and have a matt, non-reflective surface finish.

- 4.2.3 Use of detail points

Where targets cannot be placed on the fabric, it is acceptable to use unambiguous points of detail. A sketch diagram or annotated image showing the location of each point is to be included in the survey report. Detail points must be easily identifiable and must not be taken from the extreme edges of the subject. It will:

(a) not be acceptable; or

(b) only be acceptable where essential; or

(c) be necessary

solely to use detail points in an image or model. [Historic England, 2015]

Based on the purpose of the survey, it should be remembered what is defined by Historic England [2015] in section 4.4.3 about Ground sample distance, the acquisition of data with the photogrammetric method for typical architectural scales of representation the following values are recommended: for the output scale 1:50, 3mm maximum GSD* (*GSD = (H/f) × p. Where H = distance between camera and subject or flight height; f = focal length; p = pixel size (sensor size in one axis divided by the number of pixels in the same axis)

For the output scale of 1:20, 2mm maximum GSD

For output scale 1:10, 1mm maximum GSD

For topographical surveys or orthophotos from SUA aerial photographs, the following are recommended

values are recommended

for the output scale of 1:500, 4cm maximum GSD

for the output scale 1:200, 2cm maximum GSD

for the output scale 1:100, 1cm maximum GSD.

Photogrammetric acquisition techniques are divided into:

- Terrestrial photogrammetry: the captures are made with digital cameras from the ground.
- Aerial photogrammetry: the shots are taken from the above-using aircraft.

Aerial photogrammetry has become more feasible. The drones used can be classified into two categories: fixed-wing drones, that is, wings give reduced manoeuvrability, but more autonomy and are used to cover large areas, and rotor drones, where more rotors offer excellent manoeuvrability that allows operating in small spaces, despite lower independence. Applying this survey technique, digital images - are obtained starting from an analogue electromagnetic pulse that, through an analogue-digital converter, is processed and transformed into pixels [M. A. Gomarasca, 2004]. Each pixel is associated with an RGB value, and the number of pixels contained in length provides the image resolution(dpi). This technique is possible using medium-low-cost digital cameras; it expands cultural heritage surveys through textured surface models (mesh). Also, these technologies are recommended to process surveys of damaged heritage or in situations of risk, such for example surveys of areas affected by seismic events.

1.2 Research field and issues

Modifications designed to lessen the risk or consequences of a disaster in a significant location require a balance between the possibility of substantial damage to property values without them and the certainty of the minor, but often material, damage from the modifications themselves. The need for physical precautions should be considered part of disaster response and recovery planning for the place, based on risk assessment and management requirements and any statutory duties. All options should be evaluated, including improved

management as an alternative to, or in conjunction with, lower levels of physical intervention [147 Historic England,2015].

The historic environment is constantly changing, but each significant part of it represents a finite resource. If it is not sustained, not only are its heritage values eroded or lost but so is its potential to give distinctiveness, meaning and quality to the places in which people live and provide people with a sense of continuity and a source of identity. In addition, the historic environment is a social and economic asset and a cultural resource for learning and enjoyment [Historic England,2015]. [2]

The two principles taken from the document drafted by the Historic England group can be considered the essential foundation of this research work. First, the importance of the management and preservation of historical places about the historic fabric of our cities is the nodal point on which the political-administrative world, the scientific community, and the civic community have been called to respond promptly following the earthquake that struck the Emilia-Romagna region in 2012.

The research path developed within the XXXIV cycle of the International PhD. IDAP of the Department of Architecture of the University of Ferrara has provided a scientific contribution to defining newly *integrated* and optimised procedures for surveying the damage. The specific research contribution was developed following the request of the Agency for Reconstruction of the Emilia-Romagna Region. The ARRER, after the private-residential and economic sector reconstruction was completed, decided to involve the university scientific community, funding three PhD scholarships, to study in-depth the rebuilding of the cultural heritage in the crater area Emilia-Romagna. This approach led to the funding of three regional grants, two assigned to the Department of Architecture of the University of Ferrara for the disciplinary sectors ICAR 17 and ICAR 19, and one to the Department of Engineering and Architecture of the University of Parma for the disciplinary sector ICAR19. have been identified. In addition, ARRER would like to carry out an in-depth study in the field of damage survey, given some criticalities found in the reconstruction process of cultural heritage. Therefore, the regional authority identified three architectural typologies damaged by the 2012 earthquake - castles, cemeteries and historic theatres. Furthermore, their typical morphological and geometrical complexity had highlighted weaknesses in applying the damage scheduling models (model A-DC churches; model B-DP palaces). These aspects will be analysed in chapter 4 of this research.

Starting from this schematisation of analysis proposed by ARRER, the assigned research area was the historical theatres damaged during the 2012 earthquake. The regions of choice by ARRER will be explained in Chap. 3

Based on the theme identified, keeping in mind its disciplinary field of belonging - ICAR 17 design - the research has identified the methodological approach to meet the needs posed by the regional body. First of all, to prepare an ad hoc damage survey form for the survey of theatres, secondly to provide a *workflow* of integrated procedures that from the visual survey to the metric-geometric and diagnostic survey, up to the proposal and choice of restoration interventions, aimed at optimising the survey of the damage. This objective implies the optimisation of the management and proactive conservation process by the competent bodies to protect cultural heritage.

Detecting, representing, and interpreting the seismic damage suffered by these architectures has presupposed the understanding of related social, economic, and identity meanings. The holistic, *integrated* approach has supported the documentation and knowledge process. It has been possible to proceed according to multi-levels and disciplinary procedures that have led to the structuring of a multi-level integrated methodology and then to the definition of a single *integrated workflow* of operations. The workflow tends to develop a meta-protocol, articulated in three complementary informative and applicative levels, building a 4D database to understand the analysed architectural typology fully.

This applied methodological approach has involved different fields of investigation:

2 Conservation Principles Policies and Guidance for The Sustainable Management of The Historic Environment,2015 historical and archival research, historical seismic research of the region and the theatres studied, analysis and critical reading of both the current damage survey procedures and the methodologies implemented by the professionals in charge of the restoration project, the application of *integrated* systems and techniques for the metric-geometric survey, the interpretative analysis of reflectance data for the study of the state of conservation.

The research aimed to develop and validate a methodology for identifying *integrated* procedures for the damage survey of theatres using standardised documentation criteria and application procedures (DAP INCEPTION). The study has organised a hierarchical workflow on complementary levels to reduce survey uncertainties for better decision making and survey procedures for the diagnosis of heritage buildings and the planning of conservation programmes.

1.3 Research objectives

This research aims to improve and optimise integrated survey procedures to ensure the conservation, protection, restoration and valorisation of Cultural Heritage. These themes have been applied to the specific case study selected by the ARRER Cultural Heritage Coordination Office: the *historical theatres a*ffected by the 2012 earthquake. The specific objectives of the thesis are taken up as follows:

(a) the critical-comparative analysis to highlight the criticalities of the current procedures to be resolved in the proposal of a new damage survey tool for the specific architectural typology under investigation;

b) the proposal of a workflow of integrated procedures for the survey of seismic damage of historical Italian theatres;

b.1) the predisposition of a new documentation and damage survey form based on standardised and standard criteria on the international and national scale:

b.2) The application of the integrated DAP protocol of the Inception Project is suitable for the specific field of damage survey. This approach aims to improve and optimise the phases of metric and geometric data acquisition, integrate the survey through predictive diagnostic analysis by working on the discretion and interpretation of the acquired three-dimensional data, to guide the graphic representation by choosing a given level of detail the appropriate scale of representation.

b.3) the parametric modelling of the data acquired in the HBIM environment integrates the information collected during the visual survey and the metric and geometric survey to optimise the assets analysed through the BIM platform.

c) the proposal of a systematic approach for the documentation, management, and monitoring of regional theatres, to be extended to all types of cultural heritage, using the interoperable HBIM platform developed by the INCEPTION project. The use of the INCEPTION platform aims at streamlining the process of conservation and management of monumental heritage while promoting enhancement and inclusive service.

1. 4 Research methodology and phases

Given these premises, considering the disciplinary field of belonging, ICAR17, approaching the issue of the survey of damage, presupposed the adoption of a holistic and multidisciplinary vision, in line with the *integrated* approach. Documenting, detecting, and representing the aspects of seismic damage that occurred on *historical theatres* following 20 and 29 May 2012, meant classifying and decoding the historical, artistic, architectural, technological-structural, and socio-anthropological meanings of these monumental buildings. Therefore, the holistic approach has represented the methodological framework of the research to develop a *workflow of integrated survey procedures* for the historical theatres of Emilia. The workflow is the starting point for creating an integrated meta-protocol. The specific meanings of theatre heritage can be documented, detected and represented to ensure

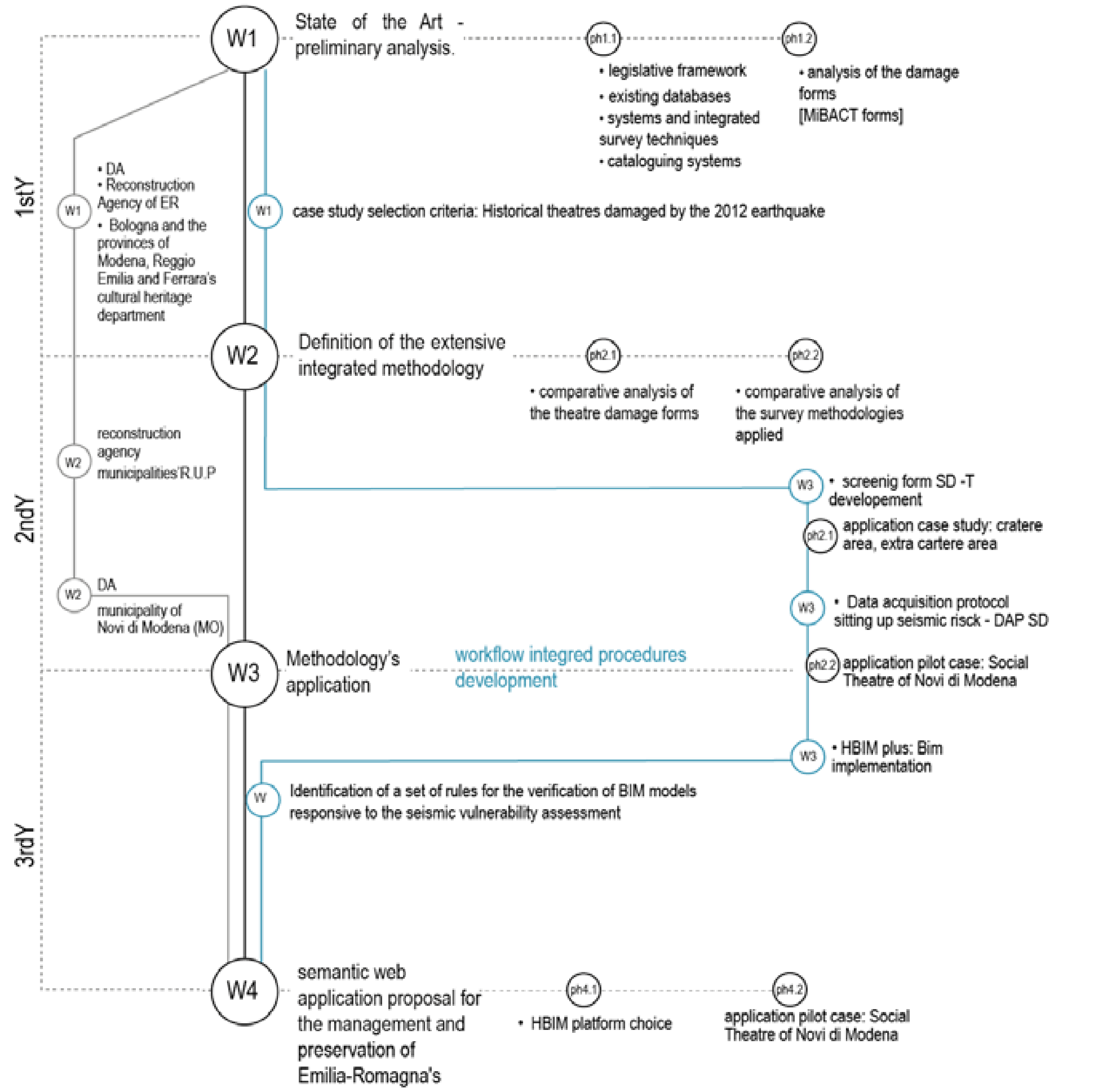


Fig.4 Research development diagram:
▪ (W.P. 1) State of the Art - preliminary analysis.
Assessment of legislative framework, existing integrated survey procedures and current data captured, database managed by Emilia-Romagna's high technological net, present assessment systems of damage and ongoing restoration activities.
▪ (W.P. 2) Extensive integrated methodology.
Setting standards for data capturing through an integrated survey system and stressing a specific method to historic theatres damaged survey.
▪ (W.P. 3) Workflow development of integrated procedures.
Methodology's and judgment's application are connected to cases studied. Development of the integrated protocol of seismic damage survey: Implementation of the damage sheet on theatres; Survey and representation of the pilot case study: The theatre of Novi di Modena (morphometric survey, diagnostic survey); BIM implementation.
▪ (W.P. 4) Identification of the HBIM platform – INCEPTION.
Planning of an INTEGRATED AND INTEROPERABLE PLATFORM realised tanks to BIM and HBIM software. It is recognised to permit inclusive and open data and metadata.
Developed by M.Suppa

damage mitigation, planned monitoring, conservation and proactive management of the particular field of study and the broader cultural heritage. Multi-level, multi-criteria mapping must be applied to protect historic theatres from the regional macroscale to the architectural microscale. This survey methodology documents the specific values of the cultural heritage:

- geographic-spatial, typological, historical, morphological, geometric, techno-constructive, and stratigraphic, including changes over time in response to functional, engineering and restoration interventions.

Therefore, using *integrated* methods and technologies of the survey, it was possible to document, classify and decode [Maietti, 2019] the complexity of the specific values of theatrical buildings to provide appropriate procedures for the management and conservation of the assets under study.

The research to calibrate the integrated method on direct experience of damage survey for region historic theatre, the study proposed a cognitive, analytical, and applicative sampling in stages, which can be summarised in 4 WPs (Fig.4):

(WP 1) State of the Art - preliminary analysis:

1. of the legislative framework on an international, national and regional scale;
2. existing risk management databases at the international, national, and regional level
3. the survey procedures applied during the emergency phase for the expeditious assessment of the damage to historical theatres (Sheet A-DC and Sheet B-DP of MIC);
4. the reasons and needs that moved ARRER to select the theatres as a case study
5. the existing integrated survey procedures applied to the documentation of cultural heritage
6. the typological characteristics of historical theatres
7. the standards and protocols of integrated documentation exist on an international and national scale to elaborate a meta-form. Although set on the specific case study, it had a matrix of categories and standardised information levels applicable to other types of cultural heritage.

(WP 2) Extensive integrated methodology.

Definition of the extensive integrated methodology for defining a workflow of integrated procedures to survey the damage is proposed. Starting from the critical comparative analysis of the MIC damage cards archived by ARRER, the criticalities of a filing model suitable for the theatre's typology are analysed. This is followed by a comparative analysis of an applicative sample of damaged theatres to define categories of functionality, accuracy, and representation related to the level of damage suffered. Based on the sampling analysis and the typological knowledge of the asset, the methodological path foresees extending the research on a regional and international scale. The examined theatres belong to areas with high seismic risk: Croatia on a regional scale - the Romagna area on a global scale.

(WP3) Workflow development of integrated procedures.

The workflow is articulated on several levels; the first is quick and aims to develop a digitally informed ad hoc damage survey sheet, whose hierarchically categorised data can create thematic GIS maps. The second applies the Inception DAP for data acquisition through an integrated survey system (Data Acquisition: 3D Laser Scanner, Digital Photogrammetry) set to the specificities of the damage survey. The last level concerns data processing and implementation in BIM and the HBIM environment. Application of the workflow on the pilot case of Novi di Modena;

(WP4) Identification of the HBIM platform – INCEPTION.

INCEPTION can be considered helpful management and monitoring tool for the actions and interventions of the reconstruction process of theatres. The HBIM environment is

configured as a valuable database for the documentation, classification, and storage of essential information for the knowledge of theatres, updated metric and geometric surveys, predictive analysis on damage, and state of preservation. In addition, it represents a support to the action of conservation planning for professionals and control of management and maintenance of the property throughout its life cycle by the institutional bodies operating in the field of protection and conservation. Finally, the Inception platform is a tool for inclusive use and enhancement accessible to the general public.

1.5 Research limits

One of the limits related to the knowledge of the specific sector of cultural heritage analysed was the access to the complexity of the data related to the 25 damaged theatres. The historical-typological and critical analyses were carried out on an inspection sample restricted to 11 theatres. Only for these theatres were the documents and elaborations made available by the RUPs. Nevertheless, it was possible to identify the lowest common denominators and draw a mental picture of the individual theatres and the theatre system on a regional scale.

Another limitation was found in developing the meta-form of the first level of the workflow, described in Chapter 5. The *first level* of the integrated workflow (screening form) has the objective of developing an ad hoc form to detect damage to theatres producing a seismic identity card of the asset. In this sense, the standards of integrated documentation and the survey of damage defined on a national and international scale were adopted and followed. The main problem was checking the subjective-qualitative compilation of the categories related to the survey of the state of preservation, the collapse mechanisms possibly activated during the earthquake and the related estimate of the damage index. These last aspects in the 2012 survey had left room for several criticalities impossible to manage in case of emergency. It has been adopted the subdivision of the theatre unit in 7 to control the subjective interpretation of the visual survey. It proceeds to the survey of collapse mechanisms and degradation morphologies closely related to the action of the earthquake. Despite records and control indices, the meta form for the visual survey did not prevent the problem of subjective interpretation that could occur in the assessment of the state of conservation and damage. However, being a limitation often found in the definition of expeditious tools, it is a knot that the scientific community is called to solve in synergy with the bodies responsible for the protection and the bodies responsible for the management and monitoring of cultural heritage to structure performative models.

Considering the results derived from the comparative analysis, the modulation of the Theatres meta-format *(DS T)* controls and optimises the survey methodology during visual inspections by guiding the pace of the surveyor and providing graphics. Documentary support is gathered from the archival materials and from what is produced downstream of the post-earthquake process managed, archived and systematised. However, the elaborated digital card model, set on the theatres, presents the limit of needing immediate reference and connection with form. As a result, the visualisation and recording of damage and conservation status on specific elements of the defined macro-elements are complex, especially in case of emergency. Unfortunately, the complexity of preservation practices and the lack of knowledge of historic buildings cause an inefficient recovery process in emergencies. Therefore, if the first categories can support creating thematic maps in GIS valid on a macro territorial scale, the problem remains identifying punctual damage element by element. However, the operational choice not to opt directly for a semantic database but to proceed by integrated levels has been made regarding the database systems used by the Emilia-Romagna region. The region uses various Gis databases, such as "The Minerva portal, which "represents the point of reference and sharing of the information held by the Directorate General for Land and Environmental Care of the Emilia-Romagna Region."[3] It has as one of its objectives to provide databases useful to integrate the information necessary

3 *https://ambiente.regione.emilia-romagna.it/it/servizi-online-home/la-piattaforma-informativa-minerva*

to prepare the cognitive frameworks referred to in Article 22 of Regional Law No. 24 of 2017 - Regional regulations on the protection and use of the territory.

Furthermore, again, the Geoportal[4] of the Region in which the data and information are organised in datasets and can be accessed via “Web Map Service” (WMS), “Web Feature Service” (WFS), and SHAPEFILE vectors. Finally, the WeB of the Cultural Heritage of Emilia-Romagna was designed by the former regional secretariat during the emergency phase for a first survey of the damaged heritage (described in Chap. 2).

To overcome this problem, the research proceeding step by step identifies the used methodology of Building Information Modeling (BIM) wants to implement the framework of relevant, helpful information to estimate a correct assessment of seismic vulnerability. To overcome this problem, the research proceeding step by step identifies the used methodology of Building Information Modeling (BIM) wants to implement the framework of relevant, helpful information to estimate a correct assessment of seismic vulnerability. Furthermore, the parametric HBIM modelling represents an opportunity to directly relate the digital model of the historical building, aimed at managing architectural and system components, with the tools of visualisation and information of the deformation and cracking framework resulting from the seismic action. To conclude, adopting this procedural strategy represents a practical approach to preserving, verifying, managing, and managing the quantitative and qualitative information useful to describe and know the asset. Therefore, the adoption of semantic platforms shortly by the bodies responsible for the protection and preservation of cultural heritage could strengthen their action in preventive conservation and mitigation of damage and represent the research’s expected result.

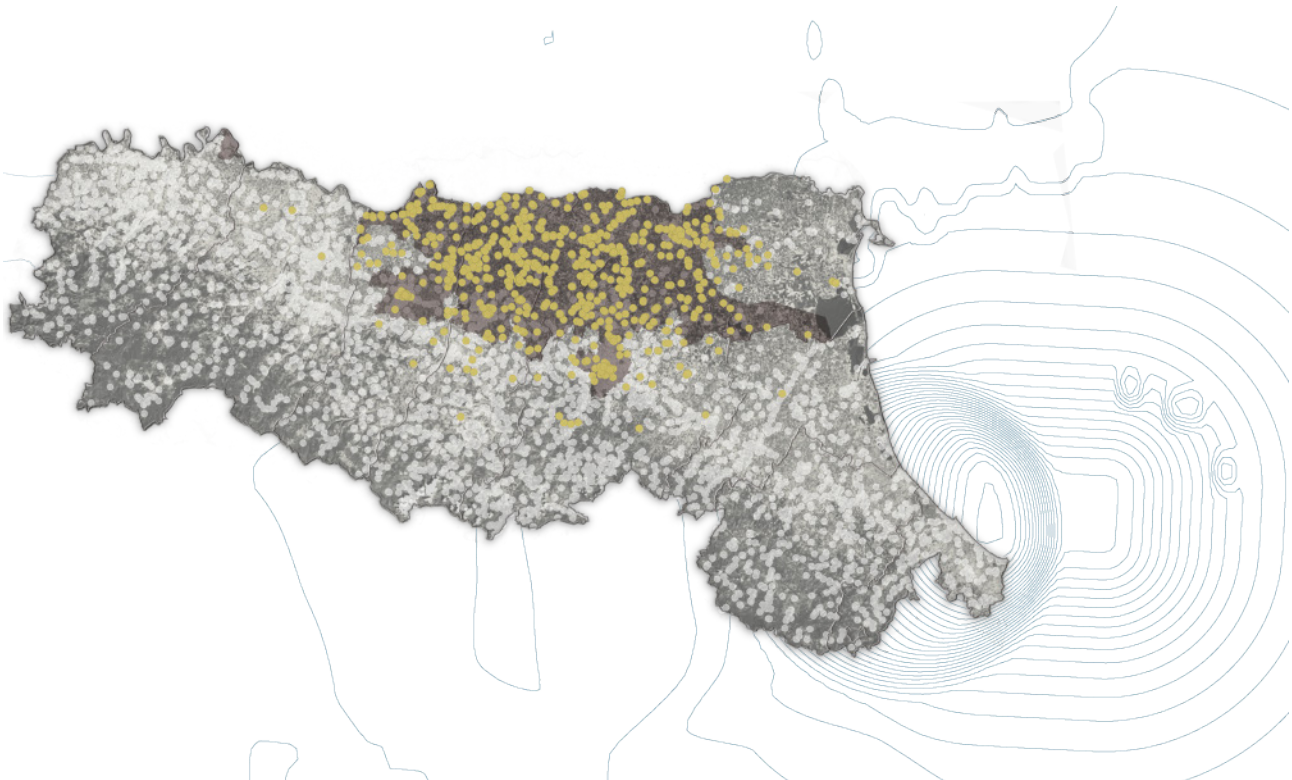
As a final aspect, it must be emphasised that the restriction of the research field focused on historical theatres did not allow to take into account the variables that exist for other architectural types. Even if *the integrated workflow* has been developed on standardised procedures, the restriction of the application field has not allowed to modulate and test the proposal on other typologies. At the same time, the validation for proactive monitoring purposes has been verified outside the 2012 crater area. The Masini Theatre of Faenza, located in the Romagna area between the 2 and 3 seismic macro-zoning, has been selected.

4 *https://geoportale.regione.emilia-romagna.it/*

CHAPTER 2 Second Part: State of the Art

Abstract

The second chapter presents state of the art in damage management, both in terms of the regulatory framework and the databases developed and related to earthquake damage management at the international, national, and regional levels. In particular, the chapter references the regulations and laws enacted following the 2012 earthquake and the strategy of emergency governance by the Emilia-Romagna Region’s Agency for Reconstruction. In addition, an overview of damage management during the post-earthquake emergency and visual relief procedures used by the 2006 DPCM is offered. Also presented is the cultural heritage web gis tool developed by the regional secretariat to take a census of cultural heritage damaged by the earthquake and the restricted databases through which the reconstruction process was managed. Finally, the European project TACE database, through which it was possible to census the heritage of historic theatres on a European scale, is presented.



Cover image - Chapter 2 - The cultural assets damaged by the 2012 earthquake. Editing by M. Suppa

2. Legislative Framework

2.1 National and Regional scale

In May 2012, two strong earthquakes struck the Emilia-Romagna Region, particularly Reggio Emilia, Modena, Bologna, and Ferrara provinces. The first shock of ML 5.9 on the Richter scale, on May 20 2012, affects the Po Valley strip of the areas of Modena between the towns of Mirandola and Finale Emilia. The second, which occurred only nine days after the first event, recorded an ML quake of 5.8 a few kilometres west of the previous epicentre (fig.5).

Overall, the Emilian crater of 2012 includes 33 municipalities and 57 localities (fig.6). The emergency state is declared the day after the first shake by the Presidency of the Council of Ministers Ordinance n.1 (22/05/2012). It entrusts the Head of Civil Protection with the coordination of emergency operations according to Decree-Law 59/2012 of May 17. The first emergency phase ended on August 1 2012. The management of the activities coordinated at first by Di Coma C[1] passes to the territorial administrations, followed on August 9 by the ordinance n.15. After that, the emergency management gave the Presidents of the Emilia-Romagna, Veneto, Lombardy Regions and the delegated Commissioners. They were entrusted with defining the intervention strategies for the reconstruction. Finally, the governance choices of the emergency phase and post-earthquake reconstruction are determined and communicated by the Delegated Commissioner through 12 ordinances concerning issuing authorisations to provide financial resources.[2]

The main strategic axes of the governance of the Reconstruction process of the Emilia-Romagna Region can be summarised in the following four priority lines:

1. The reconstruction of schools: it was considered of primary urgency law

 to take all necessary measures to guarantee the education service from the beginning of the school year. The schools' program has provided restoration interventions in schools with minor damage and temporary schools for those most damaged.

2. The reconstruction of enterprises: In second place on the scale of priorities is the restoration of productive activities, particularly numerous in the areas affected by the earthquake. Funds have been allocated to repair minor damage, where possible, and create temporary structures to move the activity to reduce the economic damage resulting from a prolonged shutdown of production.

3. The reconstruction of homes: The production sector has also restarted; the focus has shifted to private homes. The criteria for allocating funds to repair the seismic damage suffered have been established.

4. The reconstruction of Public Works: Finally, given the more excellent timing required by this type, the Restoration of Public Works have been carried out: starting from recognising the damaged public buildings, the priorities of intervention have been defined through the annual programs.

These strategic and governance choices have guided the operations and timing of the entire reconstruction process of the Emilian crater intending to make and trigger resilience processes in local communities and the production system.

1 Orbody for the coordination of the components and operational structures of the National Service of the Pcivil rotezione.

2 The ordinances are available on the website of the Emilia-Romagna Region https://www.regione.emilia-romagna.it/terremoto/provvedimenti-nazionali?b_start:int=20

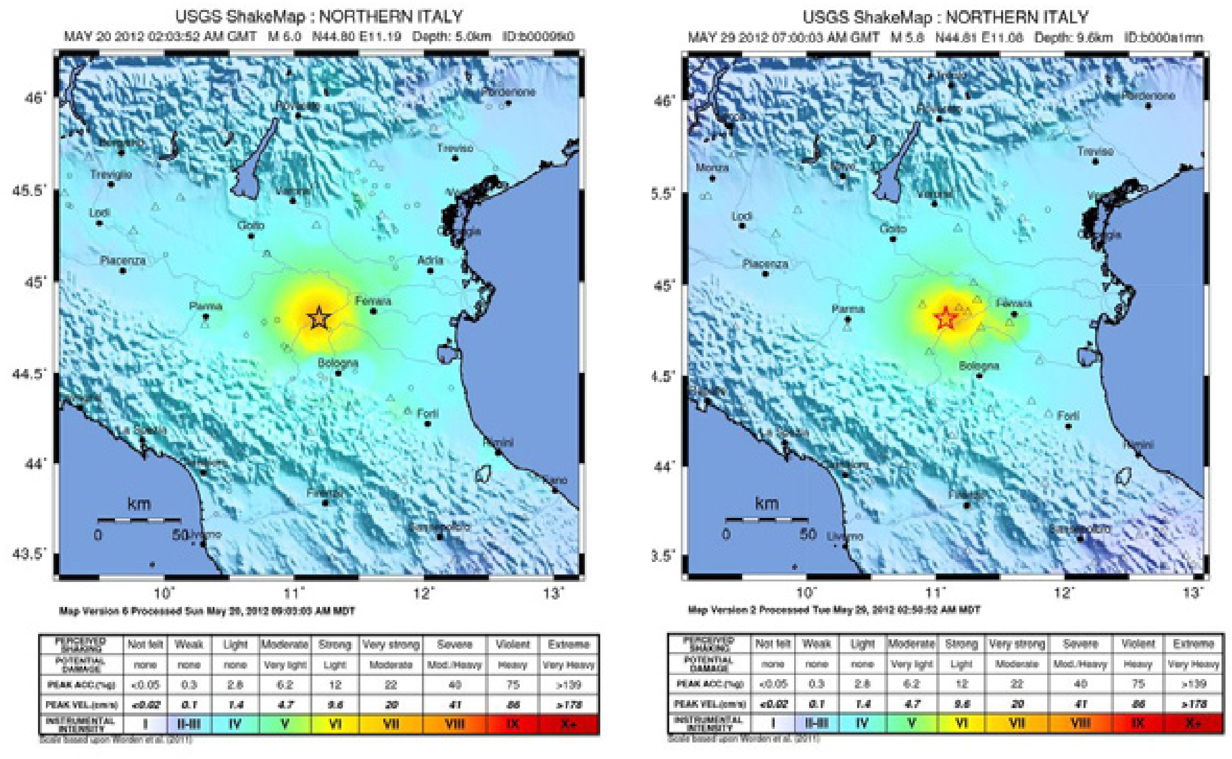


Fig. 5 Shake maps of May 20 and 29, 2012 - Emilia Romagna earthquake.Image from Wikipedia

At the regional level, as prescribed by the priority strategies of intervention outlined in the order of the Delegate Commissioner, the reconstruction of damaged Cultural Heritage represented the last piece of the reconstruction process. Therefore, the emergency operations on cultural heritage were managed by MiBACT (actually MIC) in cooperation with Di Coma C (Directorate of Command and Control).[3]

In the first instance, emergency management of the cultural heritage, which found 80 per cent of buildings damaged, was coordinated by the General Secretariat of the Mibact.

 The circular n. the 24 of Maythe May 20 2012 indicated the Regional Directorate the connection point between the institutes of the responsibility for rescue operations of cultural assets.[4] Thus, the UCN – Mibact (National Crisis Unit) is established, which in concert with the General Secretariat, has the task of applying the survey procedures, ensuring safety interventions, recovery and displacement of rubble, monitoring and verifying conservative interventions, consolidation, and seismic improvement. The UCN is divided into regional UCR sub-units to support and verify emergency operations to protect damaged assets and allow the first safety operations. The UCRs are formed by teams of MIBAC officials, who, in coordination with the Civil Protection, Prefectures, and Fire Brigades, carry out the first survey on the entire area of the crater of damaged heritage. Three specific units form them: the first specialises in the study of damage to cultural heritage, with the task of training and managing the Mibact staff of the emergency teams, checking the management and storage of the data collected; the second has the function of technical coordination of security measures. The third is responsible for temporary storage and emergency laboratories for movable property. This organisational structure is regulated by circular no. 3216 that Article 1 defines the UCN-Mibact as the Cultural Heritage Protection Command body.

In contrast, Article 2 provides for the collaboration of the peripheral UCR- articulations of the

3 MIBACT (Ministry of Cultural Heritage and Activities and Tourism today MIC (Ministry of Culture)

4 The General Secretariat was established by Legislative Decree no. 165/2001 with the task of coordinating the various offices and administration of the Ministry, of which is directly dependent.

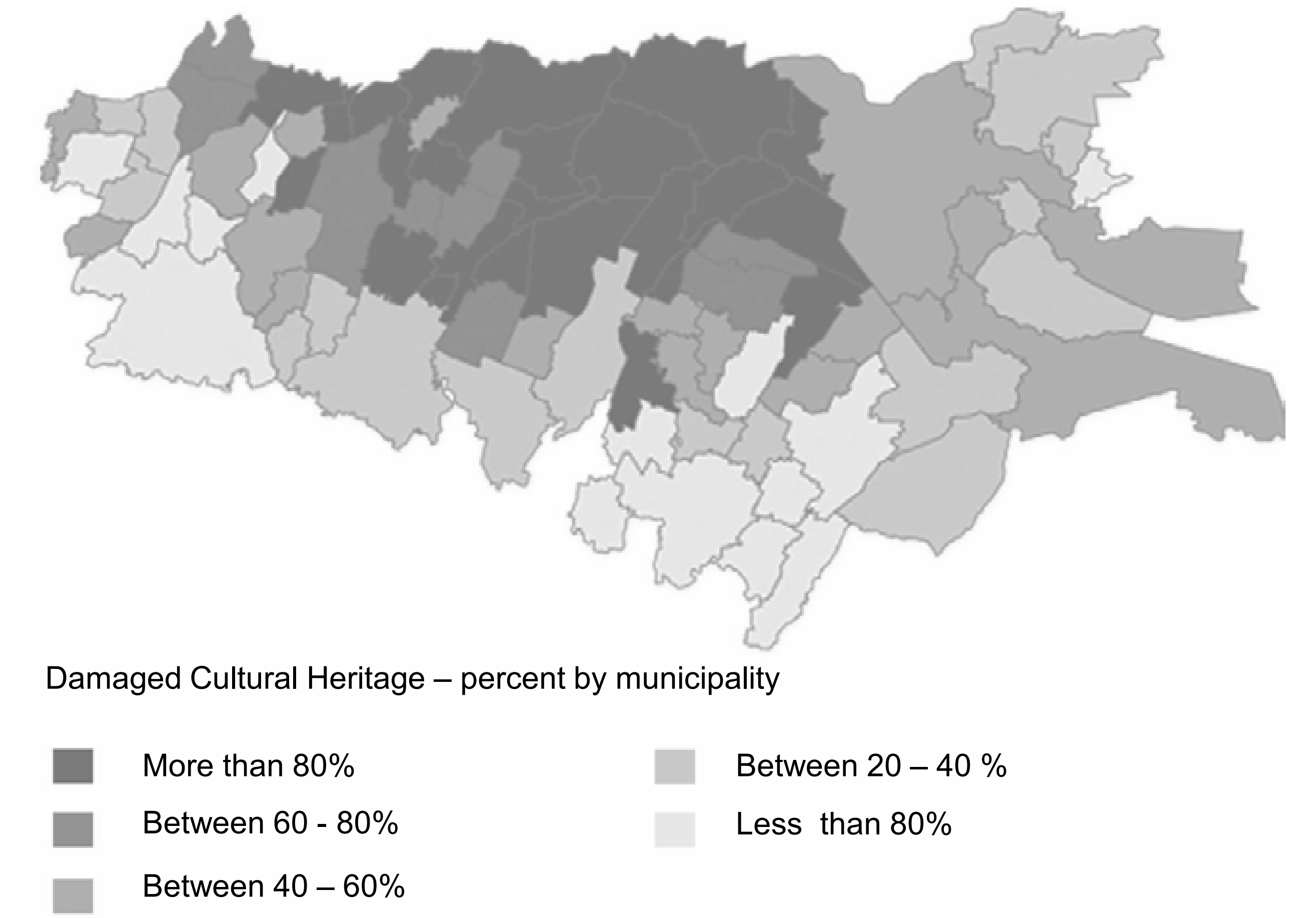


Fig.6 The Emilia crater mapping concerning the distribution of damage to cultural heritage at the municipal scale. Developed by M.Suppa

Cultural Heritage Protection Command. The circular defines the tasks of the UCN, UCR and the Superintendencies and their relations with the Civil Defense and the Fire Department to constitute a hierarchical operational structure. According to this structure, from the General Secretariat to local coordination structures, they are guarantors of preserving and protecting damaged property in delicate emergency operations. The National Law, according to the Cultural Heritage Code and Landscape - 42/2004 [5] - Article 27, provides the protection measures and the specific interventions that can be carried out on cultural heritage in emergencies: "In the case of absolute urgency, the necessary temporary interventions can be performed to avoid damage to the protected property, provided that it is immediately communicated to the Superintendence, to which the projects of the definitive interventions for authorisation are promptly sent."

Article 29, on the other hand, regulates the Ministry's and its bodies' protection and conservation activities in the event of risk, providing:

- Paragraph 1: "the conservation of cultural heritage is ensured through a coherent, coordinated and planned study, prevention, maintenance and restoration activities."
- Paragraph 2: "Prevention means the set of activities suitable for limiting risk situations related to the cultural asset in its context"
- Paragraph 3: "maintenance means all the activities and interventions intended to control the cultural asset's conditions and maintain the integrity, functional efficiency and identity of the asset and its parts."
- Paragraph 4: "restoration means the direct intervention on the asset through a

5 *The Code was amended by Decree-Law No 76 of 16 July 2020, as amended by Law No 120 of 11 September 2020.*

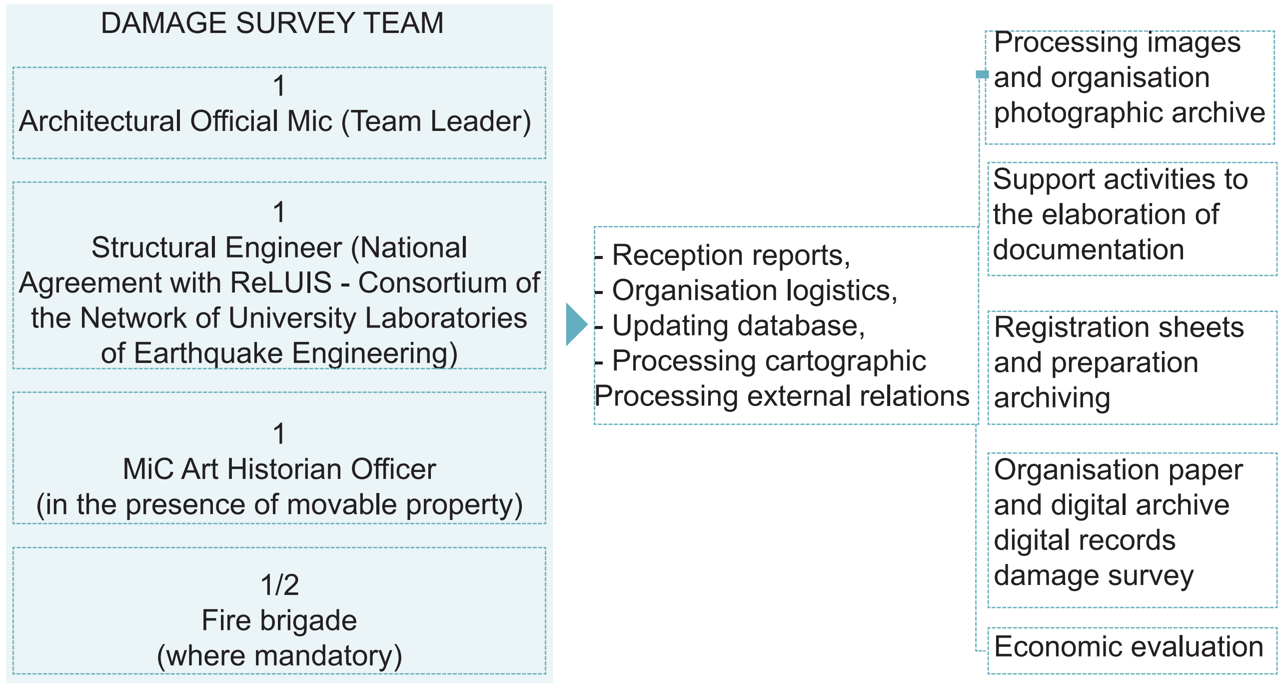


Fig.7 Diagram shows the MiC teams' composition that carried out the post-earthquake visual survey. Developed by M.Suppa

complex of operations aimed at the material integrity and recovery of the cultural asset itself, the protection and transmission of its cultural values. According to current legislation, the restoration includes the intervention of structural improvement". While Article 30 clarifies that the state, regions, other territorial public bodies and any other public bodies and institutions, private owners, possessors or holders, must ensure the safety and preservation of the cultural heritage to which they belong. Among the conservation measures are study activities, prevention, maintenance, and restoration, thus providing constant supervision of the cultural heritage and its conditions.

At the earthquake, the Emilia-Romagna region in seismic micro-zoning was classified as a medium-low risk; therefore, preventive and proactive conservation interventions had not previously been envisaged. Thus, in the aftermath of the emergency declaration, some legislative devices were issued to provide specific legislation to intervene in the damaged regional cultural heritage. The first is the D. L. 74 / 2012, converted into Law n.122/2012: "Urgent interventions in favour of the populations affected by the earthquakes that have affected the territory of the provinces of Bologna, Modena, Ferrara, Mantova, Reggio Emilia and Rovigo, 20 and 29 May 2012" - defines the Fund for the reconstruction of earthquake-struck areas. It should be divided between the Regions Emilia-Romagna, Lombardy and Veneto based on the damage suffered.

In particular, Article 4, paragraph 1 provides an intervention plan for buildings of historical-artistic interest as defined by the Cultural Heritage Code, restricted ecclesiastical or state-owned properties. Moreover, it gives interventions in public spaces such as schools, barracks, municipal buildings, universities, soil protection, water protection, drainage and irrigation. Article 4-bis instead defines the "spending authorisations in favour of the Ministry for Cultural Heritage and Activities". Paragraph 1, in letter a,) it is "authorised for the Ministry the expenditure of 5 million euros for the year 2012", while in letter b) "the expenditure of 500,000.00 euros per year, for each of the years 2012, 2013 and 2014, to meet the costs related to the necessary human use and instrumental resources available. Including fees arising from compensation for overtime performed and reimbursement of mission expenses, including those associated with the help of their vehicles.

Another essential act of the 2012 earthquake framework legislation is the Regional Law n°. 16/2012 containing the "Rules for reconstruction in the territories affected by the earthquake

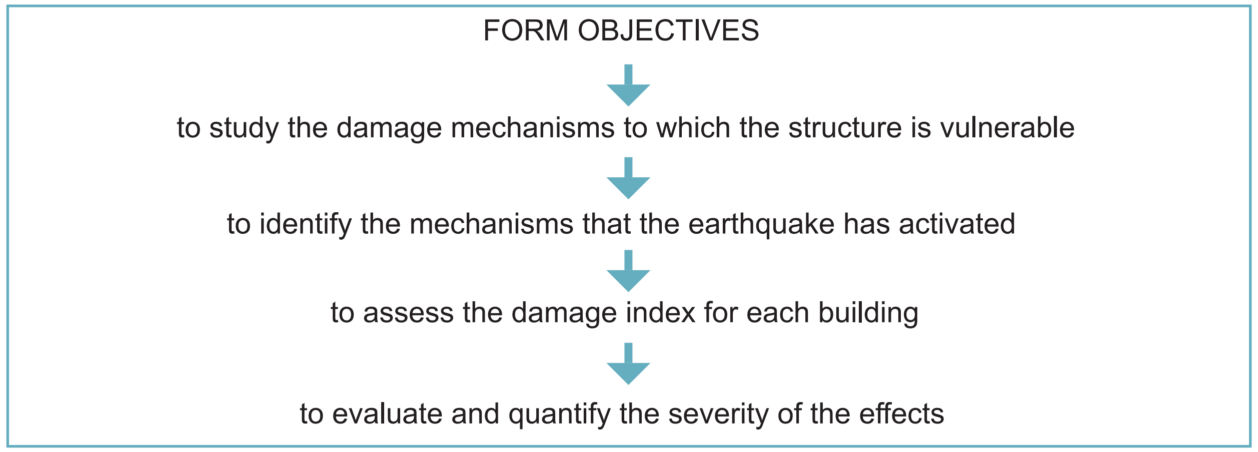


Fig.8 The Chart shows M.I.C. module targets. Developed by M.Suppa

of 20 and 29 May 2012. This Law, taking up article 42/2004 in Article 11, provides for the Public Works and Recovery Interventions program. Therefore, the Regional Council agrees with the delegated Commissioner, whose figure is provided by the same Law in art.11. Thus, the President of the Emilia-Romagna Region holds him to approve the plan of reconstruction activities based on the survey of material damage carried out within forty-five days of the entry into force of the regional Law itself. [6] The program consists of two sections relating to repair and restoration operations with seismic improvement. The other relates to the recovery, restoration, and conservative rehabilitation with seismic adaptation for the assets damaged by the earthquake.[7]

Art. 4 Paragraph 8 specifies: that regarding buildings classified as being of historical and artistic interest, the safety levels to be followed and the seismic retrofitting to be carried out are those defined for cultural heritage by the "Guidelines for seismic risk assessment and reduction of cultural heritage, related to the Technical Standards for Construction referred to in the Decree of the Ministry of Infrastructure and Transport of January 14, 2008".[8]

According to when regulated by art. 11 of 16/2102, the Regional Council, in defining the annual pains and the specific interventions to be carried out, had to take into account the "artistic, architectural, cultural, archaeological and testimonial value of the building and the specific risk of a serious deterioration due to the untimely recovery". Paragraph 7 also provided for the co-financing of interventions by private or public bodies for at least 20% of the entire amount.

Of the 16/2012 are forwarded to remember the Art. 4 containing provisions for the works to be carried out on private properties, reference is made to the Code of Cultural Heritage and Landscape. Art. 5 relates to the reconstruction of historical centres, and art. 6 relates to protected buildings, specifically buildings that collapsed due to the earthquake or the need

6 At the time of the earthquake, the position was held by Vasco Errani.

7 The Commissioner is linked to the creation of the CUR (Unitary Committee for Reconstruction). This is a collegial body made up of representatives of municipalities, provinces and regions, in order to provide opinions on the approval of interventions. In the event that the reconstruction plan concerns cultural or landscape heritage, the presence of a representative of the Regional Directorate of the Ministry for Cultural Heritage and Activities is required

8 The 2011 Directive, in fact, provides information on the procedure for assessing and reducing the seismic risk of the protected cultural heritage, which can be described in seven points: knowing the structure; use one or more mechanical models of the macroelements of construction; set a reference seismic safety level; evaluate the nominal life of the asset in its present state; design the intervention action; consider the nominal life in the project state and finally " adopt appropriate detailed rules in the implementation of the interventions ". The Document can be found both on the Civil Protection website www.protezionecivile.gov.it, and on the website of the Mibact www.beniculturali.it

for demolition to ensure public safety.

Regarding the operations of the survey of damage to Cultural Heritage, as before described, this was coordinated by the Directorate of Directors of MIBACT in collaboration with local administrative bodies, The Episcopal Conference Emilia-Romagna.

From an operational point of view, the coordination of the damage survey on a regional scale was entrusted to the RCOs to organise the damage survey activities, providing the necessary materials - cadastral maps, plans, metric and geometric archive surveys, photographic material, historical documentation. After the first phase ended on June 19, during which the emergency inspections were carried out, we moved on to the field's quick survey operations using the models for the survey of the damage arranged by the MIBACT. In this first damage survey, the data were stored on the GIS web platform designed by the General Secretariat.

The damaged protected regional cultural assets were surveyed through the scheduled procedure developed following the 1997 earthquake that struck Umbria and the Marches. The applied models formalised by the DPCM 23 of 2006 can be classified according to three types: the A-DC model relating to the survey of the damage of the churches; the B-DP model for buildings; the C-BM model for movable property. Responsible for the expeditious survey of seismic damage and the storage of data are the teams of Mibact officials (fig.7). The units are composed of an official architect of the Mibact, a structural engineer and a firefighter; sometimes, the presence of an expert in Cultural Heritage is foreseen for specific evaluations on movable property and an archaeologist for the removal and archiving of rubble.

Both models are divided into two sections, one containing general information on the asset - identification, location, naming, etc. - the other relating to the general state of conservation of the building, the damage suffered by the structure and the movable property present and the decorative apparatus, estimation of the damage index and restoration costs. Inside, therefore, the second forms section has listed the types of collapse mechanisms associated with the macroelements that make up the building. These two simplified compilation models have mainly the objective, in the emergency phase, of estimating the damage index (fig.8). Once the activated collapse mechanisms have been surveyed, the Joint Committee must subsequently express consideration and fair economic value for safety measures, structural restoration, and plant and seismic adaptation. The level of damage is classified according to the Provisions of the Directive as D0 null, D1 mild, moderate D2, severe D3, very severe D4, and D5 collapse.

The model also allows a first assessment of the usability expressed about the acquired data. Each asset surveyed an opinion equal to A usable, I unusable, PA partially accessible, AP accessible with measures, TI temporarily impractical, IE useless for external causes.

In 2014, the DPC produced a manual related to the A-DC model to facilitate damage survey operations. It is divided into two parts: the first provides information concerning the organisation of significant operations; the second explains how to fill in the forms and insert an abacus of the leading emergency measures. However, unfortunately, there is still no manual for B-DP forms.

The intervention procedures have been managed within FENICE, an application that will be analysed in the year's success[9]. The activities related to the reconstruction of Public Works and Cultural Heritage are under the coordination of the Agency for Regional Reconstruction – Earthquake 2012, established on December 14 2015, by resolution of the Regional Council n.2084/2015. This body shall be entrusted with the task of:

9 System for the management of the reconstruction interventions of the Public Works and Cultural Heritage Program prepared by the Technical Structure of the Delegate Commissioner and the Emilia-Romagna Regional Directorate of the Mibact. It is a web application that allows the RUP to request from the Delegate Commissioner the contributions assigned for each intervention included in the Annual Plans.

1. Institutional governance coordinates all the entities involved in the reconstruction process to adopt a common strategy.

2. Technical and administrative assistance for the interventions to be performed. The Joint Technical Table was born, consisting of representatives of the Professional Orders, the Unions of Municipalities, the Regional Agency for Reconstruction, ANCI Emilia-Romagna and the Trade Associations, which aims to share the critical issues encountered by all the actors involved in the reconstruction. In addition, the Joint Commission (Commissione Congiunta) was established with the ordinance n.53/2013. It is formed by a member of the Technical Structure of the Delegated Commissioner, with the functions of secretary; a member of the Emilia-Romagna Region, specifically of the Geological-Seismic and Soil Service, and a member of the Regional Directorate for Cultural heritage and landscape of Emilia-Romagna. The Commission has the role of providing opinions for each project on protection, seismic authorisation and adequacy of expenditure. It represents an indispensable tool in presenting the restoration and seismic improvement project. It means the place where all the architectural and techno-structural aspects of the project are shared and discussed by the various subjects who must authorise the intervention. This has improved the Region's project approval process, which the Commission validates by a single joint opinion.

3. The incentive for long-term development considers the reconstruction process an opportunity to support and relaunch historic centres' social and economic systems.

4. Management and monitoring of the entire process with a view to systematisation and capitalisation of the accumulated experiences. With this in mind, the Agency has started a close collaboration with Universities and research centres to analyse and highlight the best practices introduced following the earthquake.

2.1.2 State of the Art of the legislative framework: international scale.

In October 2016, at the Sixth Committee of the United Nations General Assembly, the International Law Commission presented the work: "The Protection of Persons in the Event of Disasters", in which the term "catastrophe" is defined as a catastrophic event or series of events resulting in widespread loss of life, great human suffering and distress, mass displacement, or large-scale material or environmental damage, thereby seriously disrupting the functioning of society. The United Nations Office has subsequently echoed the definition for Disaster Risk Reduction in 2004, 2015, and 2017, by 69/284 of June 3 2015. So arranged the document Terminology on Disaster Risk Reduction, in which disaster is defined as "a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts." [10]

The document includes the catastrophe, the risk situation "hazard" defined as "a process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation." The risk can be classified with natural events - natural hazard -, anthropogenic phenomena -anthropogenic hazard, or by both factors - socio-natural hazard.

Classifying catastrophes can be geophysical – earthquakes, volcanic eruptions, tsunami-

10 In the 2004 era has been arranged the document "Living with risk: a global review of disaster risk reduction initiatives". www.unisdr.org/we/inform/publications

hydrogeological – floods, landslides linked to particular weather conditions, hurricanes, or climatic variations such as fires and droughts. They can be of interest to the small scale or the large scale.

In the document, earthquakes are referred to as sudden-onset events. The document also defines prevention activities to reduce risk situations and provides for targeted monitoring and proactive management measures for cultural heritage as a reservoir of memory for the international community.

The first of the most important documents on the management of natural disasters concerning the conservation and protection of cultural heritage is the Convention Concerning the Protection of the World Cultural and Natural Heritage of Humanity (Paris 1972), which became effective in March 1973. The Convention still represents a fundamental act signed by all member states. The first two articles define cultural and natural heritage:

Art.1 For this Convention, the following shall be considered as "cultural heritage":

- monuments: architectural works, works of monumental sculpture and painting, elements or structures of an archaeological nature, inscriptions, cave dwellings and combinations of features, which are of outstanding universal value from the point of view of history, Art or science;
- groups of buildings: groups of separate or connected buildings which, because of their architecture, their homogeneity or their place in the landscape, are of outstanding universal value from the point of view of history, Art or science;
- sites: works of man or the combined works of nature and man, and areas including archaeological sites which are of outstanding universal value from the historical, aesthetic, ethnological or anthropological point of view.

Art. 2

For this Convention, the following shall be considered "natural heritage":

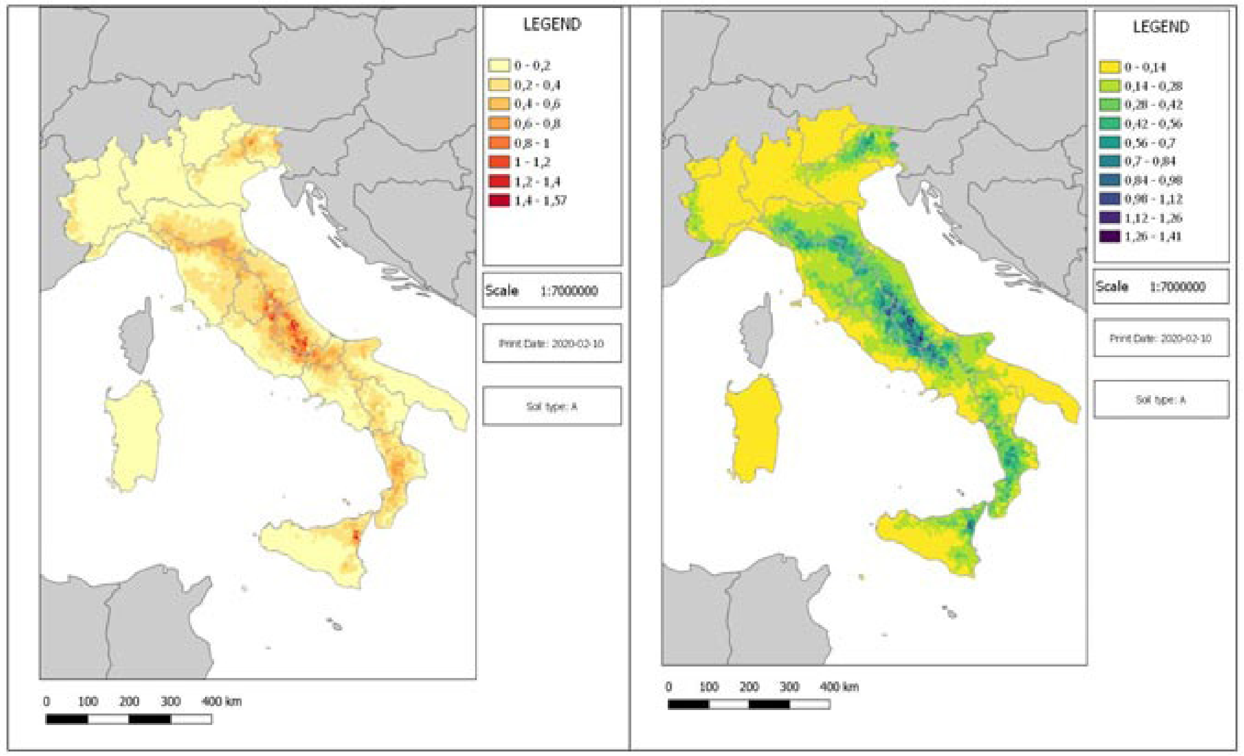


Fig. 9 Seismic risk map relative to the one-year time window. The percentage is of uninhabitable buildings close to entire residential buildings (left) and the rate of homeless relative to the total number of residents (right).

-natural features consisting of physical and biological formations or groups of such formations, which are of outstanding universal value from the aesthetic or scientific point of view;

-geological and physiographical formations and precisely delineated areas which constitute the habitat of threatened species of animals and plants of outstanding universal value from the point of view of science or conservation; -

atural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty.

Preceded by the 1954 Hague Convention that protects cultural heritage in armed conflict, it aims to safeguard the cultural and natural heritage understood at the international level. It is conceived as a heritage of the whole of humanity. The focus of the Convention is on cultural heritage recognised as of exceptional interest for which specific measures are laid down in case of risk situations, which aim to protect their tangible and intangible values. The Convention prescribes that the international community is responsible for protecting heritage through collective and collaborative action with the States affected by the state of emergency. Although the CH taken into account by the Convention is limited to the assets of the UNESCO lists, it represents one of the European framework devices for the protection of cultural heritage, a sort of methodological approach that aims at protecting and safeguarding the world heritage. In fact, In article 11 - in fact, two lists are prepared of it: the first, the World Heritage List" (art. 11), and the second, the list of heritage in danger for sudden and unexpected risk factors (such as earthquakes, floods, etc.). According to Art, in the event of natural disasters, each member state can present.

Moreover, 20 of the Convention may apply for assistance for sites belonging to the UNESCO list affected by catastrophe or threatened by dangers. The Committee, following the provisions of art. 21 paragraph 1, has the task of intervening urgently and evaluating the immediate disbursement of economic resources to cope with the emergency and guarantee the protection of the asset. Paragraph 2 of the same article provides that a reserve fund is established for such eventualities. The Convention has been accompanied by operational guidelines addressed to the Committee for the Protection of Cultural and Natural Heritage. Since then, the Convention and the guidelines have been updated, up to the 2017 version introducing strategic and preventive planning for risk mitigation and management regarding cultural and natural heritage.

Based on this international document, in May 2012, in the aftermath of the earthquake in Emilia, UNESCO Director-General Irina Bokova ordered an inspection of the UNESCO sites in Emilia, in the area of the earthquake crater, to ascertain the damage suffered by the protected sites[11]. Therefore, UNESCO experts came to inspect between 7 and 8 June 2012, particularly in the Modena area. After verifying the state of the damage, UNESCO experts have drawn up an evaluation analysis of the management of the reconstruction of UNESCO assets.

Concerning international provisions, the UNESCO Recommendation (Paris 1978) on the protection of movable property is worth mentioning.

Of considerable interest is the Unesco study 116 EX/21 of 1983 - Etude préliminaire sur les aspects techniques et juridiques de la préservation du patrimoine culturel contre les catastrophes et autres grandes calamités[12]-,which provides for effective measures to be taken for the protection of cultural heritage threatened by situations of risk. Within the document, a distinction is made between long-term actions impacting the mitigation of the earthquake vulnerability of the heritage, and temporary activities, which aim to introduce measures to cope with the contingent emergency phase. The formulation and adoption of "risk maps" are also indicated to map and locate cultural heritage in the areas most subject

11 the city of Ferrara and the territory of the Po Delta, the cathedral, the civic tower and Piazza Grande in Modena

12 https://unesdoc.unesco.org

to natural disasters and risk situations. Furthermore, the study provides classifies the assets with their importance and relevance. For each cultural asset, it is necessary to prepare a complete dossier of the specific characteristics, an instrument of historical knowledge of the protected building that must direct the conservation and restoration project in case of damage to the heritage. Finally, the document sets out regular maintenance and monitoring measures to facilitate the proactive protection of cultural heritage. The study also involves steps for the safeguarding of movable assets, which must be moved safely to a location outside the risk zone if risk factors are present, the study says.

Specifically for emergency actions, the document, dealing with the distinction between "alert phase" and "post-disaster", recommends for the alert phase:

a) the organisation of a team in charge of security;

b) the control of emergency devices;

c) temporary Shelter of protected monuments and buildings;

d) the transfer of movable property to safe places if the risk conditions are high to require its movement.

For the post-disaster phase, on the other hand, management pains are recognised as necessary, which include some actions:

f) the closure of any monument, historic building or museum to prevent the entry of unauthorised persons;

g) the expeditious assessment of the damage; h) the adoption of numerical and chromatic codes to indicate the severity of the damage;

h) the removal of debris and its simultaneous classification (relevant decorative elements, reusable building materials, debris no longer usable and to be disposed of);

i) the provision of first safety measures for damaged buildings or parts of buildings;

l) the protection of damaged buildings from meteorological phenomena, the action of which could adversely affect the stability of the building;

m) the transfer of property in severely damaged buildings to safe places. The document provides that restoration and consolidation plans for the damaged heritage will be drawn up once the emergency phase is over.

The last decade of the last century has seen the commitment of the United Nations to face the risk related to climate change, of which the Kyoto Protocol represents the actual act adopted on December 11 1997.

In the specific field of protection of cultural goods, two EC treaties produced in the nineties of the last century should be remembered: the TEU (Treaty on European Union) and the TFEU (Treaty on the Functioning of the European Union). Art. Article 167 TFEU, in particular, makes explicit the interest in the conservation and safeguarding of cultural heritage of European importance", based on which the Union "shall foster cooperation between the Member States and, if necessary, support their action."

Within the framework of the European provisions on the protection of cultural heritage from risks, the manuals for the management of disaster risk in cultural heritage developed at the request of the World Heritage Committee by the UNESCO World Heritage Centre and organisations - ICCROM, ICOMOS, IUCN - appear to have a significant role. The UNESCO manual published in 2010, "Managing Disaster Risks for World Heritage", represents a supplement to the document drawn up by the World Heritage Centre, collaborating with ICCROM and ICOMOS: HERB STOVEL Risk Preparedness: A Management Manual for World Cultural Heritage, 1998. In the face of the increase in disasters and natural disasters that put cultural and natural heritage at risk, the handbook highlights that the risk management plans for cultural heritage are still low and that the vulnerability of the assets is recognised in most cases, always following the catastrophic event. Therefore, a common strategy for the proactive management and conservation of cultural heritage is still lacking. In this regard thus, three fundamental phases for risk management are defined. The first call – Before disaster – is focused on identifying and assessing the risks that may affect an asset. At this stage, measures are implemented to prevent and mitigate the classified and identified hazards, based on which a work plan is developed. Arrangements are made, for example, to provide an emergency response team, install early warning systems, and identify temporary storage locations for debris that must be moved because it is subject to a hazardous situation. The next phase -During disaster- starts 72 hours after the catastrophic event. The first safety actions are introduced. After a disaster, the damage is evaluated, and restoration work is carried out in the third phase.[13]

Within the Manual, clarifications are given on how to draw up the Disaster Risk Management Plan – GRC Plan – considering the above phases. According to what is described, the GRC must:

- Identify and assess the disaster risks to which the asset is exposed; indicate the tools, techniques and strategies for preventing and mitigating the risks above;
- Describe the appropriate emergency actions to be implemented during the disaster, including a post-event recovery plan for site recovery.
- Inventory the movable property contained in the protected immovable property, and the fixed figurative and decorative apparatuses represent its specificity.

The plan is drawn up by figures active in the site's management, such as members of local administrations, expert emergency teams and the civil community itself, which is called to assume a role of awareness and active participation in protecting its cultural heritage. About risk assessment, the Manual classifies them according to three types: a) primary (earthquakes, cyclones, fires); b) secondary, which increase the vulnerability of the asset (humidity caused by a rise in the water table); c) underlying, relating to the environment in which the asset is inserted, an environment that can have in itself aspects that contribute to increasing the vulnerability of the asset.

The risk factors are followed by classifying the probability that it will occur. Therefore, three probability scenarios are defined - high, medium, and weak - to which the evaluation of the catastrophic consequences - serious, light, progressive, null is associated.

The risk classification is fundamental to outline the measures taken in the first safety operations and the successful restoration interventions.

Please note that the Manual has a strictly indicative function and does not represent a technical-operational compendium.

In 2015 the "Sendai Framework for Disaster Risk Reduction" is essential, setting the mitigation and risk reduction objectives for 2015-2030. Preceded by the Hyogo Framework for Action (2005-2015), this non-binding document adopts the approach of reducing risks due to natural disasters or disasters caused by human action by setting four priorities: 1) knowing and understanding disaster risks in all their dimensions of exposure, vulnerability and hazard characteristics, 2) strengthening risk management governance, 3) invest in prevention, 4) improve the timing and quality of reaction and reconstruction in the event of a disaster

The framework sets seven objectives to be achieved by 2030:

1. reduce disaster victims.
2. reduce the number of people affected.
3. reduce economic losses.
4. reduce damage to infrastructure.
5. by 2020, increase the number of countries with risk reduction strategies, both locally and nationally).
6. by 2030, support developing countries in their national actions to implement the Sendai Roadmap.
7. by 2030, increase the availability and access of the population to information related to disaster risk and early warning systems.

13 July 2016 -30th session, held in Vilnius -Lithuania

An inclusive and participatory approach involves civil, productive, and scientific society actors. Within the document, the protection of cultural heritage from possible risk factors does not appear to be central. This is easily understood because the objectives of the United Nations are international peace and security.

The protection of cultural heritage returns to have a priority role in the international dimension. The UNESCO publication is recently collaborating with the World Bank on the document Culture in City Reconstruction and Recovery – then called CURE-. It provides guidelines for planning and financing the reconstruction of cities following disasters or armed conflicts. In the face of the climate emergency and the number of ongoing crises, CURE focuses on preserving and managing cultural heritage as a critical aspect of initiating sustainable development and rebuilding entire communities. To emphasise the importance of reconstructing an asset following a catastrophic natural event or linked to human action is the Recommendation on Recovery and Reconstruction of Cultural Heritage in Warsaw in 2018. The recommendation stresses the importance of rebuilding damaged assets, as they represent the symbolic significance of their communities. Rebuilding a site or a cultural asset means healing the wound of communities destroyed by a catastrophic event. It means preserving and enhancing the tangible and intangible values introjected by them and, therefore, the memory and identity of their communities.

2.2 THE EXISTING DATABASES

<u>2.2.1 SICURO+: National scale.</u>

In the national context, thanks to the work of the Civil Protection in synergy with the scientific community, the national document "National Risk Assessment" was presented in 2018 to comply with the commitments of the Sendai Protocol for disaster risk reduction 2015-2030. The work carried out by the Civil Protection with the European Centre for Training and Research in Seismic Engineering – EUCENTRE and the Network of Laboratories for seismic engineering - ReLUIS have produced a work on the assessment of the seismic risk of the residential heritage, which has led to the development of the SICURO+ platform[14]. The seismic risk maps constitute the analytical scientific premise of the platform developed for the National Risk Assessment within the WeB IRMA – Italian Risk Maps – environment created by Eucentre (Borzi et al. 2018). These, elaborated on a national scale, are connected to the ISTAT databases and use a single hazard model adopted as a reference at the national level starting from the Ordinance of the President of the Council of Ministers 3519/2006.

Classes and subclasses of vulnerability catalogue the ISTAT data standardised according to the macroseismic scale EMS 98 defined by Grunthal in 1998. Different fragility curves are associated according to 6 models of vulnerability. Within SICURO+, navigation is managed according to the following three steps:

Step 1: Choice of the municipality of interest;

Step2: Information on seismic risk and its related components (hazard, vulnerability and exposure);

Step 3: "What to do", actions recommended to citizens to mitigate their seismic risk.

Impact indicators can be viewed using numbers and descriptive graphs. The municipalities' colour map reads and identifies the indicator's value for the selected and neighbouring cities. In addition, it can provide each standard information on the three components of risk assessment: hazard,[15] vulnerability and exposure.

14 https://www.sicuropiu.it/index.xhtml

15 For the danger, SICURO+ uses the map produced for the national territory by the INGV (National Institute of Geophysics and Volcanology, MPS04).

2.2.2 The Emilia-Romagna databases for the management of the reconstruction process: DURER, MiRC; OPEN RECONSTRUCTION; Patrimonioculturalewebgis

As part of the management of the reconstruction process, the Emilia-Romagna Region, based on the priorities outlined by the Delegated Commissioner, has adopted operational actions for the recognition and survey of the damage from the compilation of the Aedes forms to the MiBACT forms and usability for ordinary buildings. Furthermore, the information collected in the post-earthquake emergency phase was digitised to share the heritage - construction, production, and cultural- damaged during the earthquake and optimise the implementation phases of the interventions to mitigate and reduce seismic vulnerability. It is with this in mind that regional digital databases have been developed with the function of monitoring the reconstructive process. Tools such as the DURER (Single Database of Reconstruction of the Emilia-Rome Region) and the MIRic (Monitoring reconstruction interventions) and OPEN RECONSTRUCTION have been made available by the regional administrative body to local administrations, citizens, and other institutional actors involved in the reconstruction of for active management and monitoring (fig. 10). Data from three different information systems converge within the databases mentioned above: "Mude Emergenza Terremoto," FENICE respectively used to manage Financing the Bodies for private and public building reconstruction interventions and SPHINX for Contributions and subsidised loans to companies.

The information in these three databases is supplemented by the data in other regional databases such as SITAR, SICO, Register of executors and national databases CUP - Single Project Code and MIP - Monitoring System of Public Investments. All the data flow into the DURER, developed with Data Warehousing and Business Intelligence systems, which function to systematise and correlate data from the different strategies to optimise funding disbursement. It, therefore, provides a summary framework of reconstruction-related activities accessible to all users profiled to share information. Within the DURE R. are available periodic reports, historicised and in progress, on the improvement of the practices, economic contributions assigned, and the progress of the work. Otherwise, M.I.Ric is a

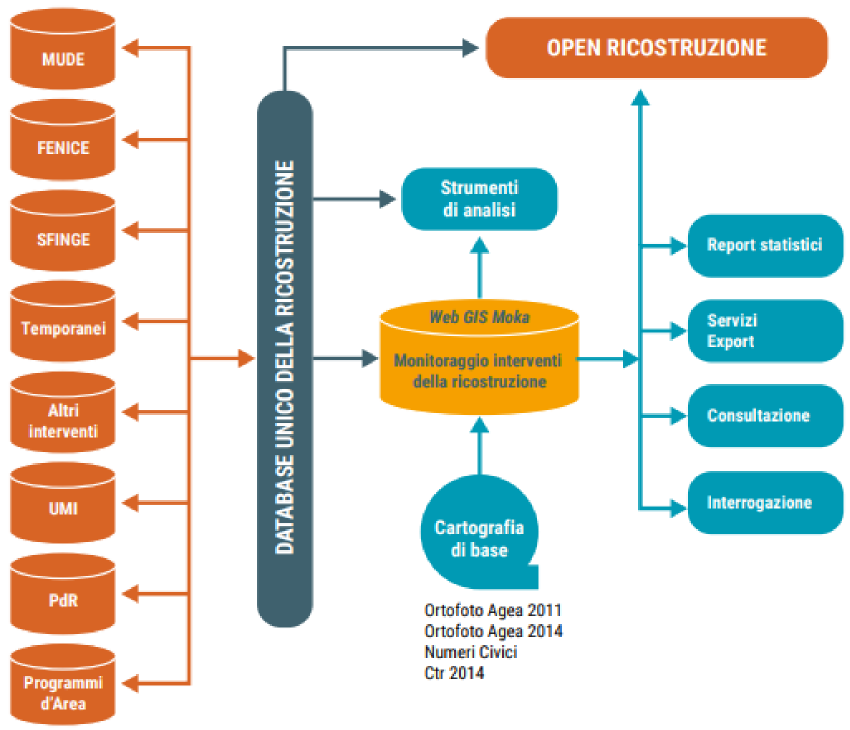


Fig.10 Schematic structure of data archiving related to the reconstruction process of the instruments DURER (Unique Database of Reconstruction of Emilia-Romagna Region) monitoring tools, MIRic (Monitoraggio Interventi della Ricostruzione), OPEN reconstruction. Image from ARRER report 2017

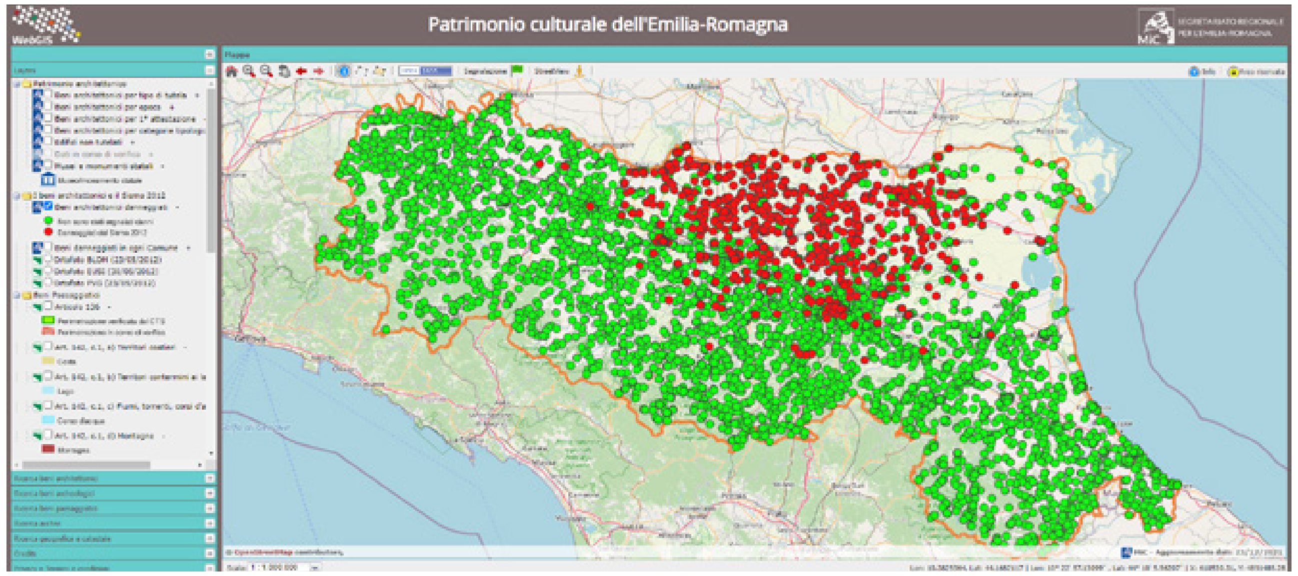


Fig. 11 Representation of damaged cultural asset at the regional scale. Image from www.patrimonioculturare-er-it/webgis/

geodatabase developed on the ETRS-UTM32 cartographic coordinate system. This is a WeBGis contained in the geo-server of the Region and can be consulted through the MOKA system. It is related to DURER and provides an analytical and georeferenced mapping on a territorial scale of the archived interventions and analyses the post-earthquake planning tools. The M.I.Ric contains cadastral data and the territorial location of each building to which a relational code is associated. The information is hierarchised and connected with the regional Database of Integrated Cadastral and Geographical Services for the Administrative Monitoring of the Territory: SigmaTer. In addition, within the geodatabase is included the perimeter of the UMI - Minimum Units of interventions, to orient and monitor the planning of urban centres through the Reconstruction Plans -PdR) in hands was capillary and on the entire territorial scale. Into WEBGis application, spatial queries, interactive consultations on dynamic maps and orthophotos before and after the earthquake are possible. [16] It also consulted the tables and rules of the municipal plans – PSC, hydrographic network, and cadastral maps.

The two macro databases flow into the Open Ricostruzione online platform[17] designed in cooperation with Civil Protection, Open Polis, Wikitalia and Actionaid. Through the platform, the information collected and catalogued in the DURER represents the dialogue database with the platform a.

Together with the applications developed by the Emilia-Romagna Region, in the specific field of cultural heritage, it is necessary to deepen the WebGIS of the cultural heritage of Emilia-Romagna developed by the former Regional Secretariat of the Ministry of Cultural Heritage and Cultural Activities and Tourism for Emilia-Romagna with the help of the Superintendents of the territory. The WeBGIS is developed within the emergency management phase to provide a georeferenced and precise mapping of the damaged architectural heritage of public, private and ecclesiastical property falling within the Emilian crater. Using the WeBGIS platform, delicate emergency operations were managed. This has made it possible to collect reports, archive and digitally systematise the data collected with the MIBACT expeditious survey forms and subsequently monitor the interventions of rubble removal, safety and restoration projects (fig.11).

The assets damaged collected are 1426, which through the application of filters, were divided with

16 *Ortofoto before the earthquake are available on AGEA 2011, orthophoto posteriori his AGEA 2014.*

17 *www.openricostruzione.it*

their provincial and municipal territory and catalogued by architectural typologies. Therefore, selecting several layers makes it possible to navigate and consult geographical maps that give the picture of the State of the Art in the aftermath of the earthquake

The WebGIS was developed in an Open-Source environment and implemented on the Debian Linux operating system and PostgreSQL software with Postgis extension to manage geographical data. Vector maps and maps and vector data web services were gestures collected through Mapserver. [18]The desktop client for consulting, entering and modifying data consists of the geographical software QGis. In contrast, alphanumeric data mask interfaces developed in the MS Access environment during the emergency period have been adapted. Furthermore, the Web interface has been created in HTML and Javascript environments.

The WebGIS platform of the cultural heritage of Emilia-Romagna is configured as a tool of knowledge as each asset has been surveyed by reporting synthetic information relating to the address book, cadastral data, protection measures, and property. In addition, it is an interoperable tool related to other digital information databases of the Ministry, such as ViR, SICaR, and Churches Census, through which it is possible to access detailed documentary, binding and photographic information.

Due to the sensitive data being contained in the geodatabase, access and use of the platform have been provided by credentialed profiling, using which the right and need to consult specific information is released.

In fact, in the act of its development, having been prepared to manage the regional cultural heritage affected by the earthquake, its use was mainly offline in desktop mode. This use employing MS Access and QGIS masks are still in place for regional, local, and ministerial office operators.

Administrative users are reserved for:[19]

- the visualisation of the architectural heritage perimeter area (instead, the archaeological heritage area, according to the agreement with the Superintendence and the Region, is available to everyone).
- consultation of measures for the protection of architectural and archaeological heritage and letters of updated cadastral information.

It should be emphasised that after the 2012 emergency, the platform was implemented and today includes wide-ranging information relating to the cultural heritage of the entire regional territory, turning into a tool for managing and monitoring the conservation of cultural heritage and enhancing the CH itself. Suffice it to mention the connection to data and information related to FAI days or Wiki Loves Monuments.

Therefore, to date, the internal use by the offices is mainly linked to the updating of the data relating to the protection measures and the connection of other information with those contained in other digital databases.

While browsing and consulting, non-sensitive information has free and public access.

As an interoperable tool, moreover, WebGIS is equipped with Open Data for GIS software users through the standard WEB services defined by the Open Geospatial Consortium (OGC) and also in the most common open formats (CSV, Gpx, Json, GeoJson). The data is contained in the geodatabase and can be downloaded directly in WMS and WFS format.

To date, the WebGiS can be consulted on mobile devices, thanks to the WebApp configuration, to facilitate users' public consultation.

From this quick overview, it is possible to see the actions put in place by the Emilia-Romagna Region in collaboration with the superordinate institutions and local administrations to implement a continuous control on the reconstruction path following the earthquake. A holistic

18 software Open Source dell'università del Minnesota

19 They can request credentials for privileged access in addition to users MiBACT also the officials and technicians who work in the Bodies and Public Administrations, Dioceses and other owner Bodies.

approach to dissemination and sharing of the information necessary to support decisions, optimise administrative times and processes and activate operational and political strategies to coordinate the activities and actions of the Emilian reconstruction.

2.2.3 European databases monitoring cultural heritage

Thanks to different Commissions, several tools aim to prevent and manage emergencies on cultural heritage at the European level. The EUCPM guarantees a fundamental role - Civil Protection of the European Union, established by the European Commission in October 2000. The heart of the organisation is represented by the ERCC Coordination Center, whose main task is to coordinate the actions of assistance to communities[20] affected by disasters by defining intervention strategies to protect people, the environment and cultural heritage. The ERCC collaborates with national institutions to limit and share common standards for developing strategic practices and targeted action.

Among the risk prevention and management tools that operate in particular on protecting architectural, cultural and landscape heritage, the main ones are described below:

a) Copernicus; b) Hyperion; d) ProCulther..

The COPERNICUS program was founded in 1998 under GMES (Global Monitoring for Environment and Security) to collect and monitor Earth observation data to define strategic actions related to decision-making processes. The management of Copernicus is entrusted to the European Community, while the space infrastructure is managed by ESA - European Space Agency - which, together with EUMETSAT, works the Sentinel satellites.

Six are the services offered by Copernicus: 1) Land monitoring service; 2) Marine environment monitoring service; 3) Atmosphere monitoring service; 4) Emergency management service; 5) Climate change service, and 6) Security service.

Among the objectives of Copernicus is to define a strategic plan to provide answers to future research and innovation needs. With this in mind, strategic recommendations for action are outlined to improve coordination between the different actors, both European entities of expertise and research centres and private industry. This is followed by policy recommendations and the sharing and dissemination of services offered.

The HYPERION project develops an integrated resilience assessment platform to provide an adequate response to the multi-risk factors that may affect cultural heritage; therefore, it uses the services offered by Copernicus, Galileo, and advanced technological systems. Hyperion's holistic platform is intended to be a tool to support decision making. The goal is to combine structural, geotechnical and hygrometric analysis with climatic data, using new sensor systems and high-performance scanning instruments and drones. ICT allows mapping the damage caused by catastrophic events, obtaining a synoptic picture to monitor the asset in the ordinary phase and management during emergency actions. The Hyperion platform represents an open-source risk management planning tool. It is possible to perform a quantified resilience assessment by predicting impact/risk/resilience "what-if" scenarios., In addition, The Hyperion project is attentive to the interaction with local communities that, through the platform connected PLUGGY - Pluggable Social Platform for Heritage Awareness and Participation, support the awareness of citizens and regional actors about the risk factors present on the specific territory to providing technical and scientific support. About this mission of building a holistic platform for monitoring and management of damage to cultural heritage, the project relies on the collaboration of:

1. *ARCH* is entrusted with developing disaster risk management strategies to improve the resilience of historic areas to climate change and natural hazards. The systems are designed in synergy with local authorities and are implemented using different

20 The centre ensures the rapid deployment of emergency support and serves as a coordination hub between all EU Member States, the other six participating states, the affected country, civil protection and humanitarian experts.

methods, tools and datasets.

2. *SHELTER* with the role of drawing a single knowledge framework between data from communities, scientific research sectors and actors involved in heritage management. The objective is to increase the resilience of historical fabrics by reducing seismic vulnerability and proposing coherent reconstruction solutions. The Shelter is structured in 5 workshops corresponding to the challenges of climate and different heritage types. It aims to develop a data-driven and community-based knowledge framework that will bring together the scientific community and heritage managers to increase resilience, reduce vulnerability, and promote better and safer reconstruction in historic areas. The project, starting from the awareness and understanding of individual areas' risk exposure and vulnerability, proposes new and innovative governance and community-based methodologies and tools. The project focuses on implementing natural and cultural risk management strategies based on territorial specificities linked to socio-economic aspects and heritage attributes. A multisource, multiscale platform implements Shelter's cognitive framework by providing a valuable planning and risk management tool, given the complexity of the data.

3. *HERACLES* proposes a holistic methodology for realising an interoperable operational chain that goes from monitoring to forecasting to defining maintenance and recovery strategies. The main objective is always to increase the resilience of the heritage subject to risk situations and optimise the decision-making and reconstruction phases. In this sense, Heracles uses integrated techniques, and standardised procedures for documentation and monitoring of cultural heritage.

4. *STORM* aims to provide improved non-invasive and non-destructive predictive models and methodologies for detection and diagnosis, to perform preventive analysis to mitigate and prevent the threats of changes and risk conditions that affect the damage to built and natural cultural heritage. The project analyses case studies from 5 countries: Italy, Greece, Portugal, the United Kingdom and Turkey. It is a multidisciplinary project based on a methodology to analyse the impacts that climatic factors associated with natural and anthropogenic risk conditions may determine on the heritage and define strategies for managing and conserving cultural heritage assets exposed to risk conditions. It uses technologies and integrated digital survey systems such as LIDAR and UAV systems, advanced acoustic, wireless and inter fluid sensors, and crowdsourcing techniques. The analyses and results of STORM are conveyed in a collaborative platform. The platform is intended to be a tool for sharing methods and practices to optimise heritage management and protection.

The *PROCULTHER* - Protecting Cultural Heritage from the Consequences of Disasters- is a Project developed between 2019 and 2021 by the Italian Civil Protection Department together with Ministère de l'Intérieur - Direction Générale de la Sécurité Civile et de la Gestion des Crises (France), Ministry of Culture and Tourism of the Regional Government of Castilla y León (Spain), the Ministry of Interior-Authority for Disaster and Emergency Management - AFAD (Turkey), the International Center for the Study of Conservation and Restoration of Cultural Heritage (ICCROM) and the Foundation Hallgarten - Franchetti Centro Studi Villa Montesca (VM). The project is co-financed by the Directorate-General for European Civil Protection Operations and Humanitarian Aid. It aims to develop and implement methodologies and actions to protect cultural heritage exposed to disaster risk. The result of the project is to have defined European methods for the protection of cultural heritage in emergencies and the preparation of minimum requirements to support intervention actions for cultural heritage subject to risk situations. The main objectives of the project are to establish the protection of cultural heritage as a national priority of civil protection bodies; to define technical support tools to improve decision-making in disaster management on a national scale, to increase

the competence of the European Civil Protection UCPM in supporting actions in the field in case of emergency.

Within this context, it is essential to mention the European Project RESCULT - Increasing Resilience of Cultural Heritage - which has the main objective to prevent and mitigate the impacts of disasters on Cultural Heritage sites by increasing the action of prevention and intervention of Civil Protection. In this sense are set three basic steps:

1. Enhancement of the capability of Emergency Management Bodies and Operators to understand/prevent/mitigate disasters impacts on Cultural Heritage.

2. Improvement of Disaster Risk Management, policies and behaviours (for prevention and resilience), according to the principles of the Sendai Framework.

3. Increase cooperation and interoperability between EU member states to protect Cultural Heritage (information sharing, interoperable protocols, best practices dissemination, alignment with EU policies/standards) [RESCULT project]

To strengthen the Civil Protection Body, RESCULT has developed an integrated, interoperable database - EID. The design and implementation of this Database aim to provide a single framework for the different actors involved in the project - National Ministries, European Union, Civil Protection and Local Authorities - and support them in the decision making process of risk management and mitigation of damages to cultural heritage, with a view to proactive conservation of protected assets, to predict the impacts of injuries on the use of assets and to increase awareness and sensitisation of communities. EID must meet the following functionality and features:

- a European Heritage Map to provide a representation of European cultural assets using information such as classification, location, ownership, vulnerability, etc.;
- a cadastre to provide historical archives of disasters and their classification (fire, earthquake, flood, induced), magnitude, technical data, damages, etc.; and
- a risk scenario platform to visualise risk indicators (classes, values, weights) for various types of threats and to produce risk maps;
- link to 3D models acquired from a multiscale 3D survey with different levels of detail to preserve people's memory and support post-emergency recovery. In some cases, there will be the possibility to visualise the 3D models by linking to an external viewer to make them available and accessible geometry and additional information. [Oliviero S. et al.].

The focus of RESCULT is, therefore, to emphasise the need to have a DB based on standardised criteria (Europeana, UNESCO, MIBACT and ICCD) and shared for emergency assistance, based on which to have maps of cultural heritage at risk to be compared with maps of natural hazards and risks. The implementation of the Interoperable Database is proposed to support decision-making for the management of the risk of damage to cultural heritage. The Database has the function of collecting all the information helpful to represent through mapping the different cultural heritage cases and connecting them with the risks that may occur. The mapping was carried out in response to international standards: INSPIRE and CityGML. The latter is based on an open data model in XML format to facilitate the exchange and storage of three-dimensional City models. The use of CityGML allows associating the geometries to the semantic values of the city objects to have a temporal multi-representation based on different reconstruction assumptions and different LoD. Different levels of map detail are provided, to which the accuracy of the representation is related:

LoD 0, offering a 2D model for buildings, was included in the latest version of City GML;

LoD 1 with block models (flat roofs);

LoD 2 with the shape of roofs;

LoD 3 with an accurate description of exteriors (including openings: French windows);

LoD 4: interior model.

The methodology underlying the creation of EID interoperability is to combine the representation of cultural heritage with risk and hazard factors. In this sense, the data model with INSPIRE extension is structured to allow the connection between three thematic aspects

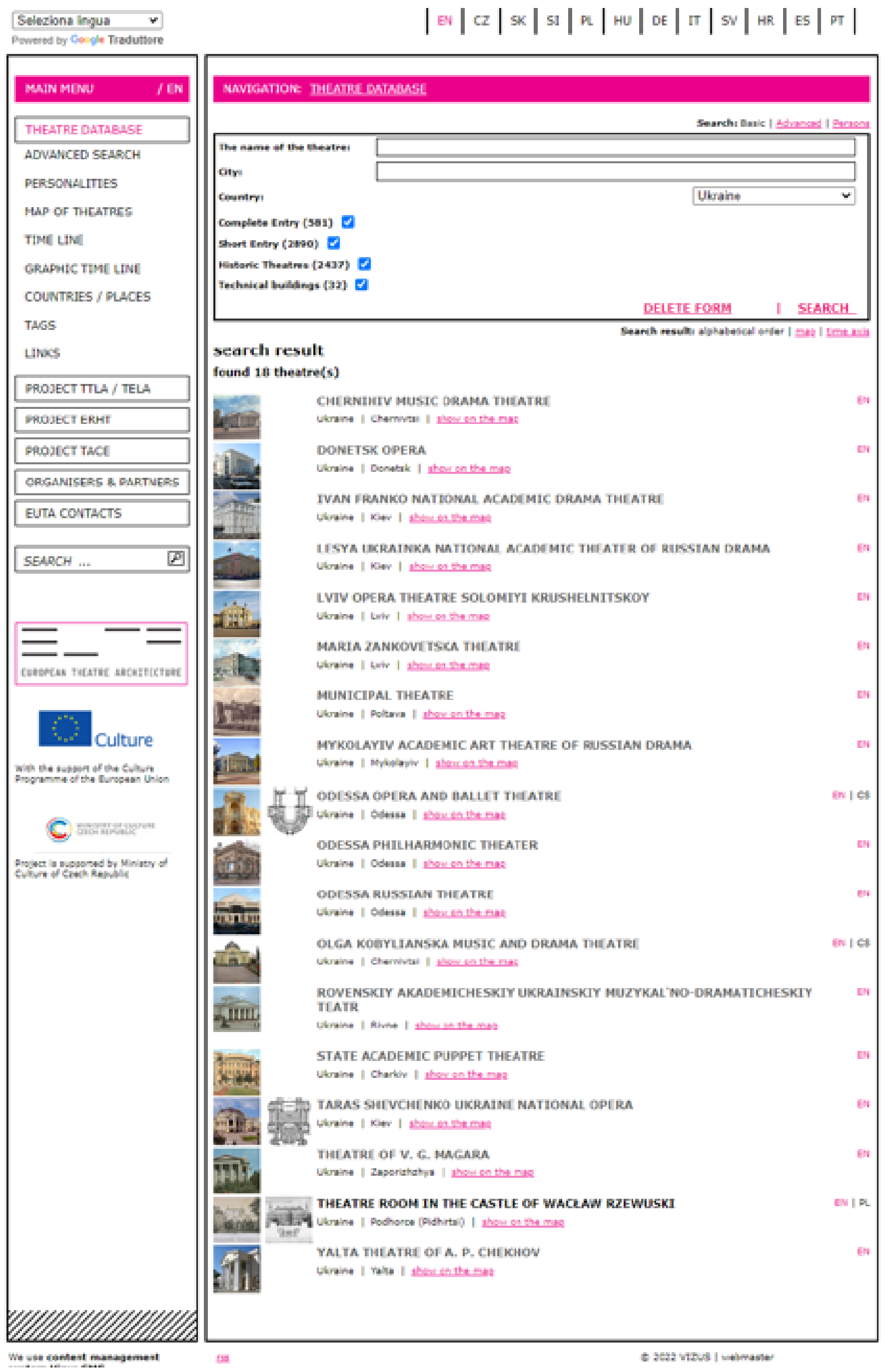


Fig. 12 interface of the TACE database, a project co-funded by the European Union. It consists of compatible interconnected databases - electronic archives of the theatre architecture of all participating institutions and their joint presentation on the Internet. Image from Tace Database

and the semantic and geometric values associated with them: buildings, protected sites and natural risk zone. The significant values define a specific cultural heritage's classification in the Database:

- archaeological significance
- landscape significance
- architectural significance
- cultural significance [21]

21 This value includes other sites with some cultural value that are difficult to place in the previous categories (e.g., mixed built and natural heritage, an area related to intangible heritage)

Four entities define the representation of the objects:

- Cultural Entity according to which assets are classified and represented about their tangible or intangible meaning or characterisation of being movable or immovable assets
- Object Container according to which each object is identified by its architectural or natural

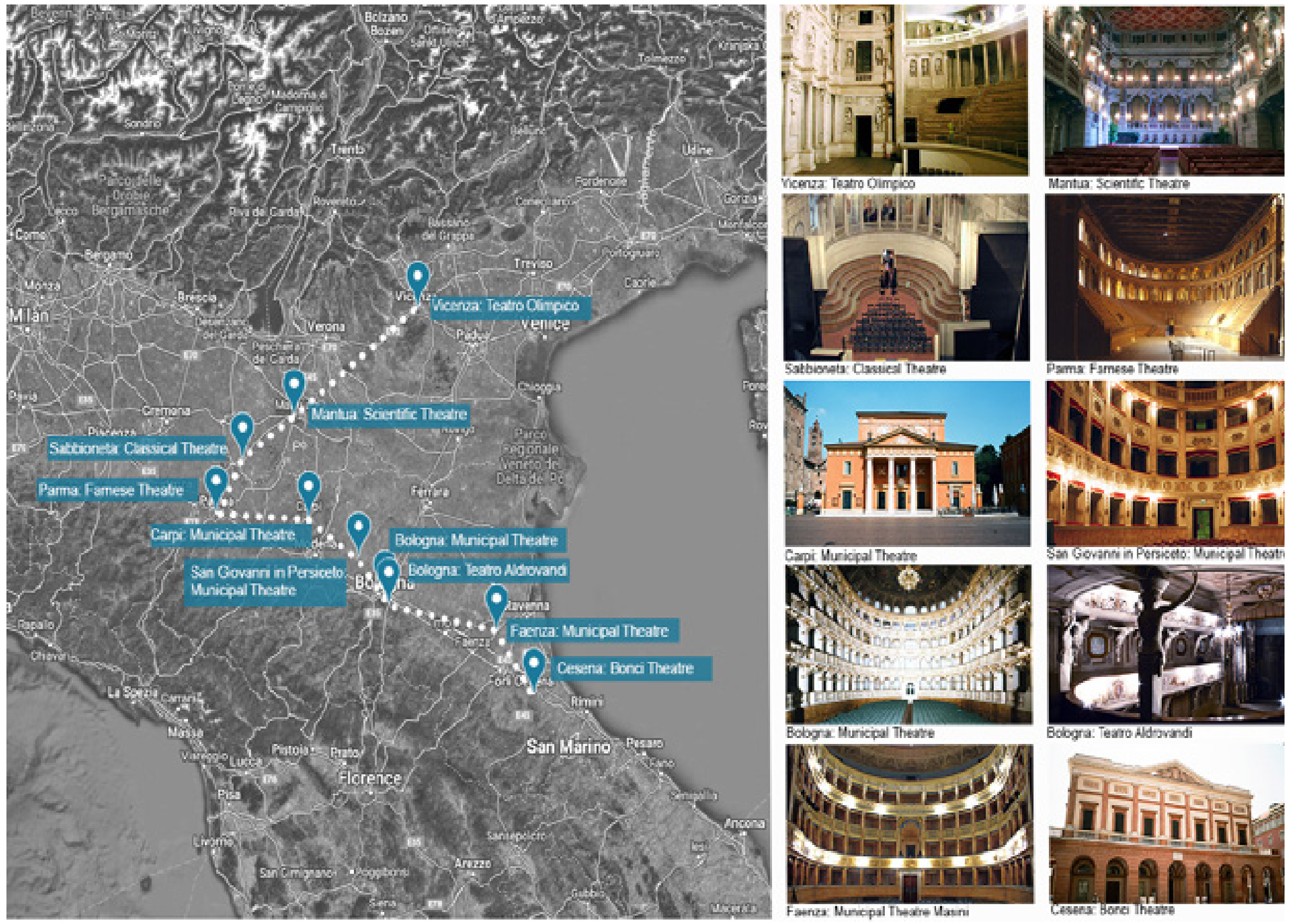


Fig. 13 The Emilia Romagna Historic Theaters' redrawn mapping, the survey made based on descriptive and photographic data from THE EUROPEAN ROUTE OF HISTORIC THEATRES database. Images from https://www.erht.eu/page/en/home.php. Developed by M.Suppa

specificities (e.g. building/park)

- danger
- risk.

The platform provides seven types of services:

1. EID-DI service through which information about disasters that affected the asset is recorded and systematised. Data on the magnitude, rainfall rates, damage, etc., are included. This service makes use of GIS tools allowing risk mapping and information sharing.

2. EID-3D service for developing 3D models to support restoration interventions and develop virtual reality scenarios for enhancing and inclusive use of cultural heritage.

3. EID-RA service was developed to analyse the vulnerability of cultural heritage to disasters and support the implementation of resilience recovery measures. It uses a GIS interface connected to EID through which it is possible to visualise factors and indicators of risk for each cultural property.

4. EIC-CA service lets users upload information such as cultural heritage data, strategies and best practices, and datasets. Three different types of uploads are allowed. First, they are uploading concerning the unique cultural heritage identified by type, name, location, etc. The best action and intervention refer to the disaster and description

of the intervention; cultural heritage database. (name, type, location, etc.); single best practice data (disaster-related, description, URL link, etc.) and cultural heritage database.

5. Sendai Framework support services to monitor disaster risk mitigation.

6. decision-making support for those involved in risk management and prevention. In particular, it provides risk analysis for both movable[22] and immovable[23] assets.

7. Support service to emergency operators in identifying vulnerabilities of Cultural Heritage about significant natural hazards such as earthquakes, fires and floods.

The EID platform and its dataset can be integrated through a library of SQL Script and other existing databases such as Europeana Database, Joconde Database and SIRPAC Database.

In the field of databases present on an international scale about the specific area of research, we examined the Database designed within the *TACE project*, which maps, documents and classifies historical theatres on a European scale. The TACE Project - Theatrical Architecture in Central Europe, was co-financed by the European Union through the Culture 2000 program and lasted three years. TACE is led by the Art Institute - Theatre Institute (IDU), the National Theatre Prague (Národní Divadlo Praha) with partner institutions such as Theatre Institute Bratislava, and Hungarian Theatre Institute and Museum, Theatre Museum of Ljubljana and Theatre Institute of Warsaw. It had the task of collecting and systematising information about the architecture of theatres addressed to both a specialised and non-expert audience. The project started in 2008 and ended in 2011, involving several European institutions and then channelled into the *EUTA - EUROPEAN THEATRE* ARCHITECTURE project. The Database represents the first attempt to build a digital archive that collects the information necessary to document and valorise an architectural typology representing a specific cultural heritage sector. However, there is no systematisation of data on a European scale.

Theatres are an exemplary example of the constructive and formal-spatial technical evolution that, from the late 16th century, has affected theatrical spaces up to the present day regarding the socio-economic characteristics of the communities in which the theatres are located.

The realised Database, whose implementation was completed in 2017, includes compatible databases. It, searchable in 10 languages, is built on a methodology of collecting and systematising historical, architectural, and technical data of well over two hundred historical theatres about temporal parameters or the principal designer.

Through the Database of TACE, it was possible to collect historical, technical, and iconographic information related to Croatian theatres included in this research about the FIRESPILL project. Furthermore, the inclusion of Croatian case studies having the same formal architectural characteristics as the theatres in Emilia damaged by the 2012 earthquake is aimed at strengthening the role of ARRER in the transfer of procedures for the management and mitigation of seismic damage and, therefore, to share and suggest the integrated methodology developed by this work.

In the light of the historical context we are going through of the Ukrainian conflict, the possibility of having digital databases of integrated documentation of cultural heritage represents a resource of great value in terms of reconstruction and preservation of historical, architectural, identity and cultural memory. Especially in the European context, the risk factors of damage and loss of meaning of cultural heritage about armed conflicts, which the events of the last period have brought to light, had been forgotten. Therefore, it is essential to emphasise that this research work focused on seismic risk mitigation, the need for integrated digital documentation, and other factors that damage and loss cultural heritage. TACE database availability represents a vital documentary resource in case European historic theatres and subsequent reconstructions are damaged. Therefore, implementing documentary sources, iconography, and morphometric and parametric models would be desirable to obtain digital

22 Methods of analysis for the safeguard of works of art - MASA

23 Asset Risk Evaluation Cards - AREC

and integrated documentation of European theatres. These pieces of information are applicable, as repeatedly stressed, to the reconstruction and management of monuments.

Therefore, a screening of Ukrainian theatres (fig.12) registered in the Database was conducted due to the current European context. As far as the Ukrainian territory is concerned, the Database includes 18 theatres, among which there is no information on the Mariupol Theatre, which was bombed last March. However, the structure of TACE, including an archive of designers' indirect information for the reconstruction of the Theater, could be the result of work by analogy. In conclusion, the Database of TACE - www. theatre-architecture. eu is hooked on the project ERTH - European Route of Historic Theatres - carried out by PERSPECTIVE[24] from 2012 to 2017. The project aims to introduce historic theatres to the general public through historical-architectural, cultural and geographical routes. The Route comprises 16 partner organisations, each of which is responsible for a specific section of the itinerary. The itineraries activated to date are 12, and each crosses one or more countries, including a dozen theatres per Route. However, on an overall scale, the project encompasses - 120 theatres. Within ERTH, there is also the Teatro A. Masini of Faenza, a case study extra crater detected during the research path, aiming to test the survey phase of visual damage (fig.13).

24 Non-profit Association of Historical Theatres of Europe

CHAPTER 3: Third part: Research field: the Historical Theatres damaged by the 2012 earthquake

Abstract

The third chapter presents the case study of the historic theatres of the Emilia Romagna region damaged by the 2012 earthquake and the historical, identity and architectural-monumental significances of theatres. The 2012 earthquake out of 106 theatre structures affected 25 located between Bologna, Modena, Reggio Emilia and Ferrara provinces. The reconstruction of theatres has represented for local communities one of the points of primary importance as they are civic spaces of aggregation, production and cultural fruition. Starting from this assumption concerning the specific themes of the research focused on integrated digital documentation finalised to the detection and mitigation of seismic damage, the specific attributes and meanings of regional historical theatres have been analysed to reach a morpho-typological analysis. Through the latter, it was possible to draw a picture of the characteristics of the theatres surveyed about the foundation date. The results of the morpho-typological analysis were the starting point for directing the methodological approach underlying the critical comparative analysis and subsequently the development of the integrated workflow of damage survey and documentation procedures.

Cover image - chapter 3 - Regional Theatres damaged by the 2012 earthquake - Images taken from PATER archive. re-editing by M.Suppa

3.1 selecting the case study: The Agency for the Reconstruction of the Emilia-Romagna Region reasons and motivations

In the aftermath of the earthquake, the regional administration needed to define a strategic and organic line to outline policies and practices related to the conservation and management of the Reconstruction of the historical-architectural heritage damaged by seismic action. This task was entrusted for the specificity of the sector to the office for the coordination of post-earthquake reconstruction interventions on buildings subject to the protection of the Emilia-Romagna Reconstruction Agency – Sisma2012, a regional body that arose due to the earthquake and was responsible for the entire post-earthquake reconstruction process. In the order of priorities defined by the Commissioner responsible for the Reconstruction, the regional administrative body focused on rebuilding with an overall view, the rules and comAZmon objectives to be built in collaboration with civil society and democratic representations. This line of vision has woven the mission of post-earthquake Reconstruction concerning the private, productive-economic housing system, public building, and interventions on cultural heritage.

In particular, the fragility of the historical-architectural heritage highlighted by the extensive damage found due to the seismic action underlined the urgency of having sustainable and integrated management of the system of regional protected assets. In fact, at the national level, the lack and fragmentation of common and shared strategies of preventive and programmatic conservation between public administration, research centres and bodies responsible for protection represented and still represents a crucial node for any intervention on cultural heritage, especially in the post-emergency phase. Regarding the seismic vulnerability assessment issue, despite the recent major seismic events that struck the areas of the Italian Apennine ridge - Irpinia 1980; Abbruzzo 1984; Marche and Umbria; 1997; L'Aquila 2009- led to an advancement of the rules and procedures of risk assessment and seismic damage. Nevertheless, they still constitute an uneven apparatus to the tools indicated by the Ministry of Cultural Heritage (MiC) that prevents a systemic vision of documentation, management and preventive mitigation of damage, especially for cultural heritage.

The Agency, based on the direct experience of 2012, thought it necessary to adopt some research grants to reach a strategic and organic practical line on a regional scale to systematise and then manage the interventions on the damaged cultural heritage. Moreover, the Agency thought it would be worthwhile to adopt preventive measures and procedures of documentation and helpful preservation to monitor the state of health of the protected assets of the regional territory, thus limiting the danger of seismic damages due to future earthquake events. This decision is to overcome the limited approach of the current post-emergency procedures, found in the experience of the Emilian earthquake often ineffective, incomplete and expensive.

This premise helps frame the context in which the research develops both in its methodological and applicative structure.

The reasons that led the Agency for Reconstruction to fund three research focuses on deepening the evaluation of three types - cemeteries, castles and Theaters damaged by the earthquake - are linked to the problems encountered in assessing seismic damage for these complex types applying the Mic form (Fig.14). Before analysing why the damaged historical theatres fall for their tangible and intangible value in this selection, it follows a framework on the state of health of the regional heritage damaged in 2012. Finally, the thematic deepening of the research is placed.

Following the earthquakes of 20 and 29 May, of magnitude 5.9 and 5.8 (Fig.15), which struck the Emilian territory, a careful and timely recognition of the state of the damage to the regional cultural heritage was urgent and necessary. From the earliest stages, therefore, the regional administrative authority and the bodies responsible for protection mobilised teams of specialised technicians coordinated by the Civil Protection and the MiC (first MiBAC) to assess the damage suffered to the cultural heritage members to the municipalities falling

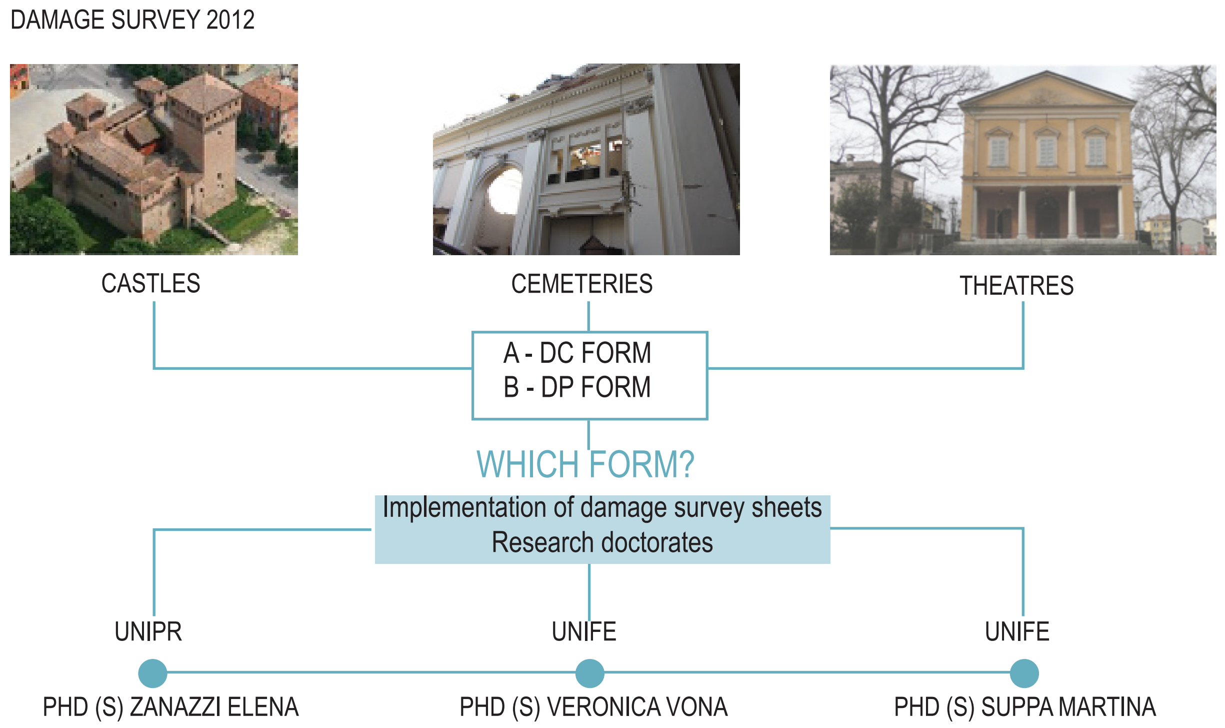


Fig. 14 - Overview of PhD courses funded by the Emilia-Romagna region. Developed by M.Suppa

within the area of the seismic crater by carrying out direct observations in 52 locations belonging to 30 different municipalities. The MiC teams, assisted by the Fire Brigade, carried out the first inspection operations to assess the level of damage. During the first post-earthquake inspection phases, the two seismic damage sheets provided by the MiC were filled in: model A-DC for churches and B-DP for buildings defined by the Prime Ministerial Decree 23/02/2006 "Approval of models for the detection of damage to cultural heritage following calamitous events". During the visual survey, the data collected, which was fed into the Web GIS platform, was used to survey the damage suffered to estimate the damage index based on the activated mechanisms. The damage index aims to provide an initial economic estimate for temporary safety measures and interventions to be financed through the Reconstruction Programme.[1]

The set of information derived from this first expeditious survey has made it possible to ascertain that 79% of the public buildings of the regional heritage subject to protection constraints of the Ministry of Cultural Heritage had suffered damage [Libro, 2019]. From the Web Gis, out of 9614 architectural heritage present on a regional scale, compared to the 2100 reports found in the aftermath of the earthquake, 1433 architectural heritage were damaged[2]. (fig.16)

These were mainly religious buildings and complexes, palaces, castles, fortresses, cemeteries, theatres, towers, villas, factories, all in the vast majority located within the historical centres. They represented artistic and cultural identity. The earthquake in its aftermath offers an alarming overview of the health of the affected heritage, which adds the sense of the communities' disarmament. The suddenly interrupted loss of daily life, human lives, homes, and productive activities added a disoriented feeling of values, identity, and community in observing the loss of buildings symbolic of the cultural heritage within the historical-urban fabric. These buildings' total collapse or severe damage represented the loss of the stratigraphic memory of cities and, therefore, the memory of their communities of belonging. The issue of the CH's preservation is expressing society's cultural principles

1 *In the research paper, they will often use both acronyms to refer to the Ministry of Cultural Heritage, which before the Draghi government was defined as Ministry of Goods and Activities Cultural and Tourism – MiBACT-, today takes the name of Ministry of Culture – Small.*

2 *Data taken from WeBGIS https://www.patrimonioculturale-er.it/webgis/.*

Fig.15 - Damage caused by the 2012 earthquake - ARRER photo archives.

grounded in peoples' relationship to their history [Heathcott, 2006, p. 75]. This care became following the events of 2012 primary, so did the question of process management and maintenance, because it represents an engagement process and a communication act of CH significance. Therefore, for both civil and religious authorities, the Reconstruction of Cultural Heritage and private entities, especially ordinary citizens, was perceived as necessary because it meant reclaiming the historical, community, and cultural meanings that the earthquake had totally or not partially erased. This urgency, therefore, moved the Emilia-Romagna Region to carry out a careful acupuncture survey of the damaged cultural heritage, which ended with the preparation and implementation of the Program of Public Works and Protected Assets. As Carla di Francesco recalls, "The process of rebuilding the damaged Cultural Heritage, however, could not be resolved, as a mere design exercise of the "How it was and where it was". The earthquake had established a new temporal interval of life, therefore "rebuilding, even faithfully, did not mean to return, identical to itself, what was no longer there "(...) although the newly raised building may be very close, even a lot, to the lost one or almost, it will always have something different and "less": perhaps details, finishes, such as parts of painted ceilings, or furnishing elements or decorated plaster, stuccoes and wooden choirs no longer exactly replicable; above all, it will have lost the irreproducible patinas sedimented over the centuries, the signs of the past time and the life of a daily life suddenly interrupted". [Carla di Francesco, 2012]. These words highlight how urgent the Reconstruction of cultural heritage was and how much this process had to have a sense of awareness of documentation, survey and design to guarantee the tangible

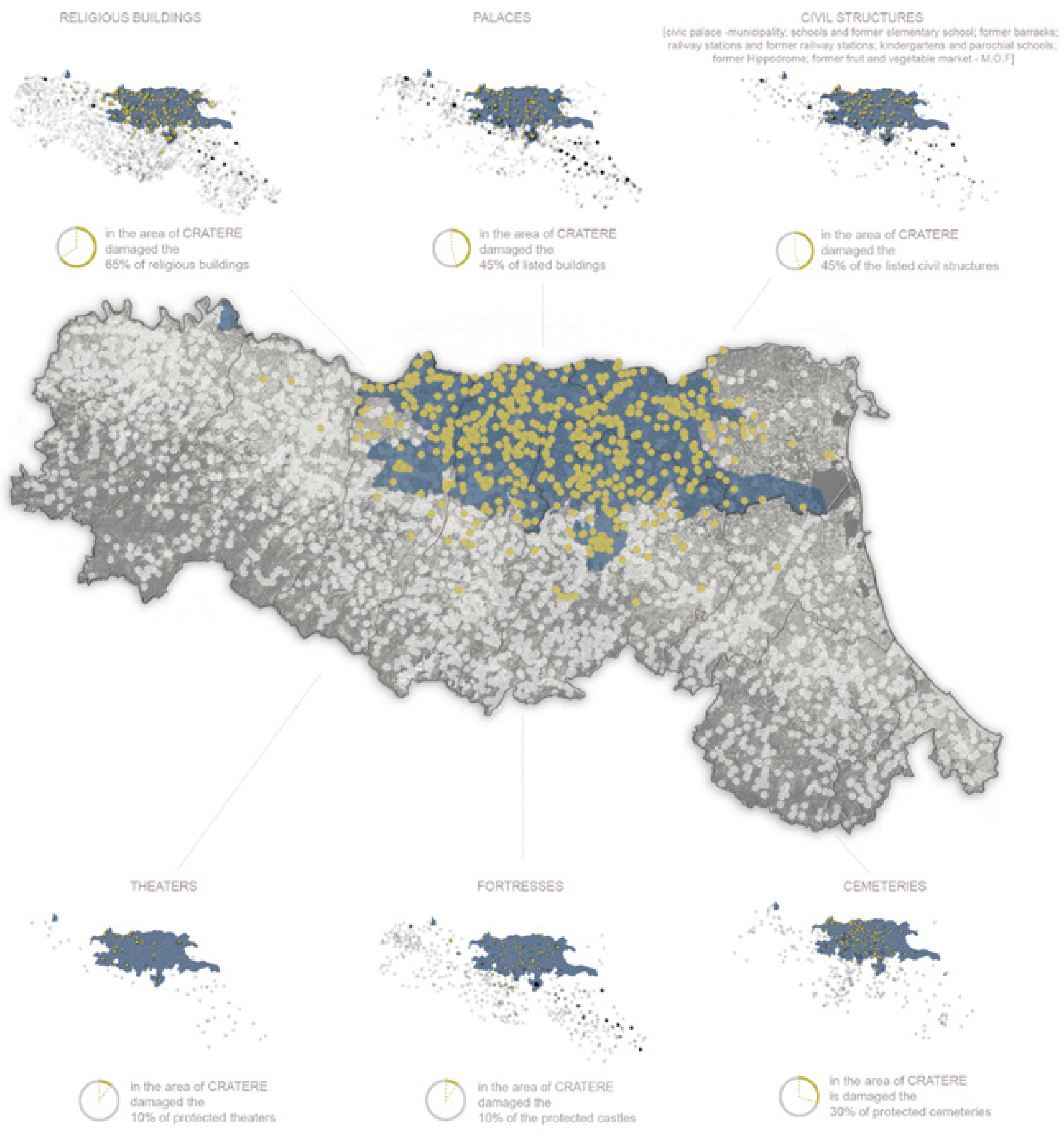


Fig.16 – The Architectural types damaged by the 2012 earthquake. Developed by M.Suppa

and intangible values contained in the damaged goods on which we were preparing to intervene. The Reconstruction of cultural heritage could only be an act of involvement that saw the communities and the stratigraphy of historical-cultural memory inherent in them as protagonists.

Monuments internalise and externalise the identity values shared by communities through their historical-artistic instance. They are, in fact, a physical manifestation of collective memory within urban space. This connotation within society is well understood if we remember the etymological origin of the monument: "The Latin word monumentum must be linked to the Indo-European rootless that expresses one of the fundamental functions of the mind (mens), memory (memini). The verb monere means 'to make us remember', hence 'to warn', 'to enlighten', 'to instruct'. Hence, the monumentum is a sign of the past. The same code of Cultural Heritage in reporting the definition of the monument as "immovable and movable things that, according to the art. 10 and 11, present artistic, historical, archaeological, ethno-anthropological, archival and bibliographic interest and other things identified by law or

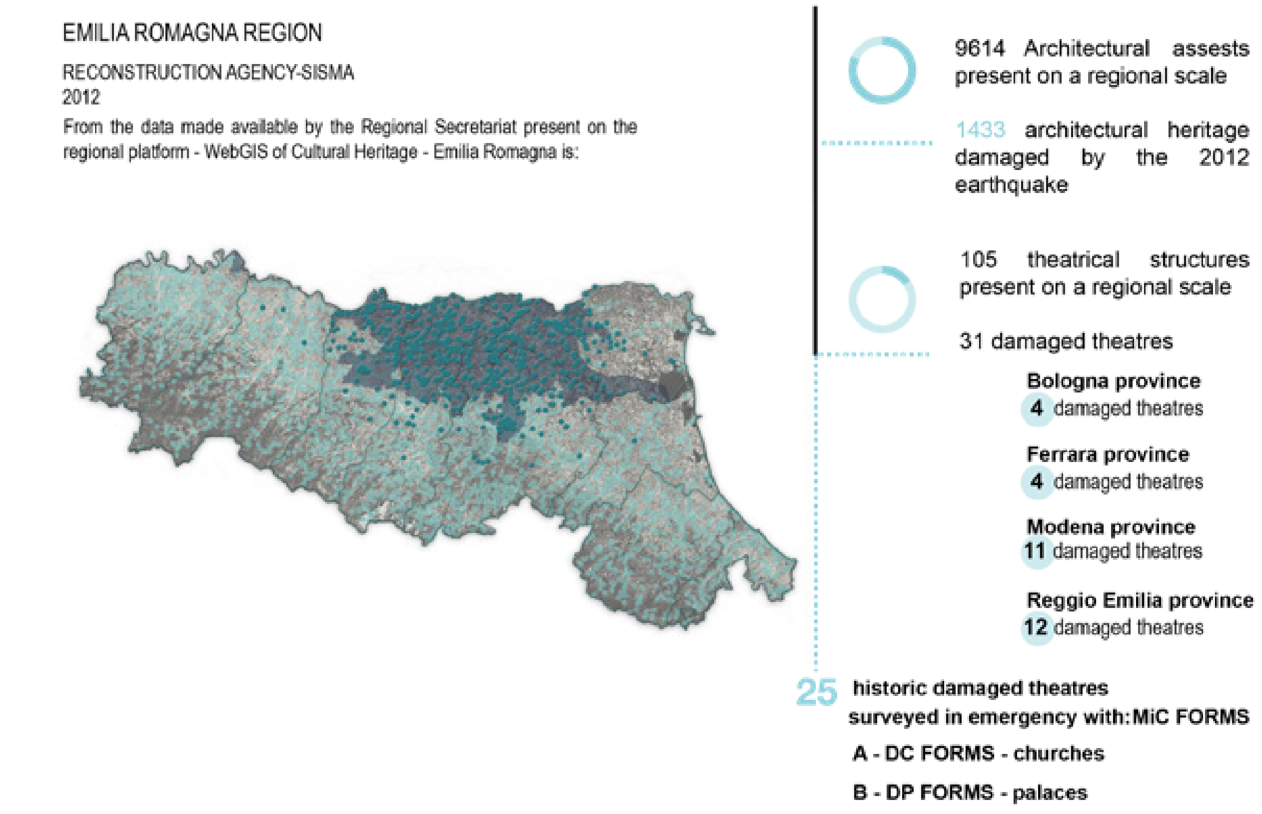


Fig.17 - Representation of damaged cultural asset on the regional scale, Developed by M.Suppa

based on the law as testimonies having the value of civilisation." Therefore, the link between history and memory of cultural heritage in the collective context is evident for its material and immaterial meanings.

The preservation of collective memory requires a great effort and the contribution of various national and international institutions. The definition of intervention strategies for the Reconstruction of cultural heritage does not, in fact, make sense only about the sole specificity of the monument in its architectural characteristics and historical-cultural value, but also to the life and social and economic resilience of the communities The first step for the conservation and management of the cultural heritage damaged by the earthquake was therefore linked to the complete knowledge of the data and information collected, their classification and hierarchisation in a single database. It is precisely the communities themselves, as reported by a Mibact report drawn up in the early post-earthquake phases, to highlight the need to intervene in a short time on the damaged historic theatre halls, as recognised as places of aggregation and cultural production.

From the Web Gis database of the cultural heritage of the Emilia-Romagna Region, it can be deduced that the damaged historical theatres subject to protection are 31 compared to 105 present on a regional scale -12 in Reggio Emilia, 11 in Modena, 4 respectively falling within the territories of Bologna and Ferrara (fig.17).

Historically, in the regional context, especially in Piacenza, Parma, Modena and Reggio, theatres have always been considered places of great social and cultural value. Every urban centre has a small or large theatre. These theatres constituted the city's historical memory identity spaces and an economic resource for their civic and cultural significance. For that reason, the public regional and local administrations and the citizens have recognised the recovery and restoration of the historical theatres as a reconstruction strategies priority of the cultural patrimony once the damage survey on religious edicts has been completed.

The close link between this architectural typology and the communities is understandable by analysing how, in the course of history, starting from the late seventeenth century, the historical Italian theatre is grafted on the regional territory.

The theatrical institution's political, socio-economic, and cultural importance on the regional territory since the late seventeenth century is documented in the first systematic study conducted by the IBC in 1982 on regional historical theatres.

The 1982 report shows 72 Italian-style theatres on regional soil compared to the 130 documented by the first census conducted by the Ministry of the Interior of the Unitary Government of 1868. The significant loss of historical theatres, listed in the IBC census, was mainly caused by the Second World War bombings that destroyed all traces in many cases. It is the case of the Theater of Rimini (Poletti 1840-51), whose destruction resulted in the impossibility to restore any possible reconstruction. Instead of being in a state of complete degradation and abandonment, other halls had been demolished; still others, especially those converted to cinematograph, had been the subject of irreversible transformations, significantly altering their original characters.

The 1982 census protected the historical halls and identified intervention guidelines for the restoration of the same, starting from cataloguing the main historical-formal and dimensional and constructive attributes of the historical theatres. The starting point of the cataloguing was to fix the characteristics that allowed to classify the theatres as historical monuments. Therefore, after a first survey on the regional scale, it was chosen to select the factories that responded to the type of Italian box theatre with the Baroque matrix. This criterion, however, excluded examples of great value and relevance, such as the Teatro Della Pillotta that did not fall within the selected classification standards; therefore, the census considered all theatres to correspond to historical features designed before 1925.

It is also noted that there was complete disinterest in theatres between the eighties and nineties of the last century. During this period, the theatres seem to have lost the socio-cultural role they had previously had: "The crisis of the theatres probably had motivations that went far beyond the more complex phenomenon of cancellation and abandonment to which it had been subjected much of the historical and artistic Heritage: it was perhaps a real crisis of identity. The theatre had been abandoned not because it was no longer functional but probably because it was considered an anachronistic remnant of the past inadequate to the needs of "modern" society" [E. Vasumi Roveri, op. cit., p. 187]. In the mid-90s of the last century, there was a reversal of the cultural trend. The local administrations and the Superintendence promoted the widespread conservative action aimed at a more comprehensive use and enhancing the regional theatrical heritage. Restoring and making some of the theatres usable again was necessary to preserve the documentary and testimonial heritage intrinsic in them. Therefore, a new cultural heritage survey is carried out to update state of the art in the 1982 census. The 1995 study shows a picture of 87 regional halls, of which 30% are closed due to the state of advanced degradation or for modernisation and plant adaptation works or consolidative restoration interventions. In this sense, the first digitisation of the data collected by the IBC since the 1982 census is realised. [3]

Subsequently, in 2002, a new systematic study was drawn up that collects the good practices and results obtained by local authorities in collaboration with protection bodies. This study documents the work carried out since the mid-nineties that allowed the public to reopen numerous restored theatres.

In the early 2000s, few theatres were still closed for plant adaptation interventions, but they were included in programmatic and design planning.

Ten years later, the Emilian earthquake once again marks the state of conservation of the heritage of the recently restored regional historical theatres, making a new survey urgent.

The first survey on the state of health after the earthquake for the Italian theatres of the Emilian crater was conducted using the Ministry's filing models. Unfortunately, this procedure application has led, how it is analysed in detail in chapter 4.2 regarding the comparative analysis, that quantitative and qualitative information has been lost for the documentation and especially for the evaluation of the seismic vulnerability of these complex architectures.

These gaps or rather critical issues found in the survey of post-emergency seismic damage

3 The database www.ibc.regione.emilia-romagna is created.i/database.htm

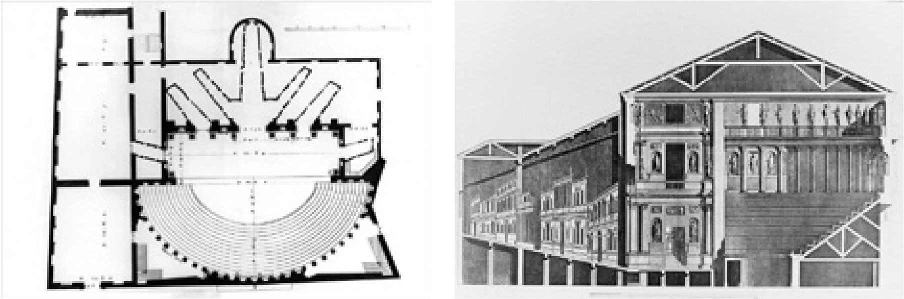


Fig.18,19 - olimppico di vicenza.jpgOn the right the Plan on the left the Longitudinal Section (Ottavio Bertotti Scamozzi, 1776). Images from https://it.wikipedia.org/wiki/Teatro_Olimpico#/media/File:Teatro_Olimpico_pianta_Bertotti_Scamozzi_1776.

are attributable to the lack of an ad hoc form for this specific architectural typology. The theatres are to be considered for their volumetric conformation complex types characterised by significant altimetric variations, which connected with constructive and material factors present a kinematic behaviour by seismic action different from both the behaviour of a building and a church. The use of adaptive ministerial forms, in fact, does not allow documentation and survey responding to the morphological and constructive-structural grammatical characteristics of a theatre; therefore, incoherent seismic damage is surveyed because it lacks quantitative and qualitative information. The Agency verified that based on the data from the visual survey, carried out mainly with model B, the estimate of the damage indices sometimes did not correspond to the actual damage. The framework outlined makes visible the motivations that led the Agency for Reconstruction to choose theatres as a case study. Bases find a reason to implement a good conservation process for regional historical theatres safeguarding the tangible and intangible meanings.

Documenting, surveying and classifying are necessary actions for the conservation of cultural heritage. In this sense, research modulates and develops the analysis and development of its proposal based on the principles and approach of integrated documentation. The integrated methodology using multilevel and multi-criteria acquisition, classification, interpretation and representation criteria guarantees an exhaustive knowledge of the historical-architectural heritage.

Therefore, the objective is the development of the workflow of the integrated procedure of surveying seismic damage, structured on specific integrated methods of documentation, survey, classification and cataloguing of cultural heritage using the current and standardised digital tools of the integrated survey. We want to implement and integrate the current national procedures for surveying the damage, considering the recommendations and standards developed at the European level through the proposed integrated workflow. The workflow set aims to structure the correct acquisition, classification, and processing of data and information in order to ensure a more effective and efficient knowledge of cultural heritage, sharing, according to diversified user profiles, of the data and metadata collected, and finally, of the systematic and programmatic monitoring and management of heritage to risk mitigation, in particular of the seismic one.

Concerning the specific field of investigation, the application of the integrated methodology has allowed the definition of the integrated workflow for the survey of seismic damage for regional historical theatres to investigate for this specific architectural typology: the architectural grammar, the morphological, formal-constructive characteristics related to the level of damage suffered for a knowledge of the state of the art through which to apply best practices and preventive measures aimed at mitigating seismic risk; equip themselves with an optimised tool for the survey of seismic damage capable of expressing the actual and real index of damage, applicable to the regional administration to estimate the funding to be disbursed for recovery interventions.

However, it should be added that the workflow of integrated survey procedures for theatres has, in the first instance, the function of providing an integrated survey tool for the mitigation

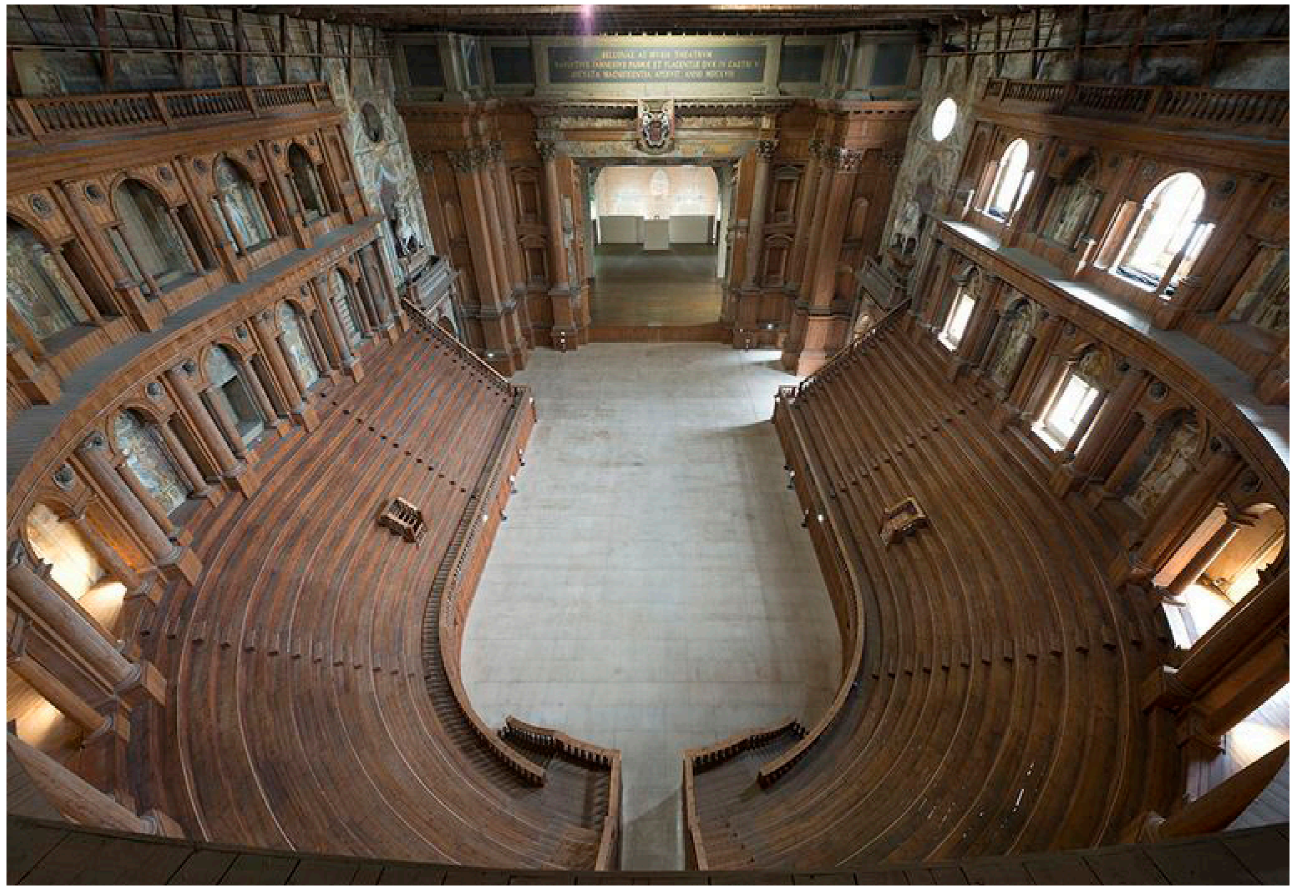


Fig.20 - _SCA7811.jpgParma, Teatro Farnese, an overview of the cavea (photo Andrea Scardova, I.B.C.) 2018. Image from https://bbcc.ibc.regione.emilia-romagna.it/pater/loadcard.do?id_card=26990

of seismic risk in a state of a merger. Still, on the whole, it represents a compendium of guidelines and integrated documentation measures through which it is possible to manage the monitoring and preventive maintenance of the assets. Despite the setting on the specific case study, which limits the detail for other specific historical-architectural types - its structure, being modelled based on existing national and international protocols, is flexible and therefore declinable according to the characteristics of the individual classifications of historical heritage.

Therefore, as an integrated prevention tool, the integrated workflow drawn up has considered, albeit minimally, the aspects related to the enhancement of historical theatres. This consideration is anticipated here explicitly and then structured further because in describing the reasons which led the bodies in charge of protection and the competent office of the Agency to investigate the Italian typology. Furthermore, the focus on enhancing and using them is essential because the theatres are related to the needs and requirements of local communities, which, as described above, understand the theatre space as a place of the identity of their community. Therefore, the typological description of the Italian theatres whose characteristics are present in the study sample before illustrating the damaged theatres studied is presented below.

3.2 The Italian theatre: Typological evolution in Emilia-Romagna context

The research focuses on analysing the typology of historical Italian theatres with boxes of Baroque tradition, which has its theoretical matrix in the humanistic period. In fact, during the sixteenth century, architects were confronted with the need to harmonise the spatial solutions of the tradition of the Greco-Roman theatre with the new instances of “court” life. During the medieval period, the concept of “scenic space” did not yet exist, and theatrical

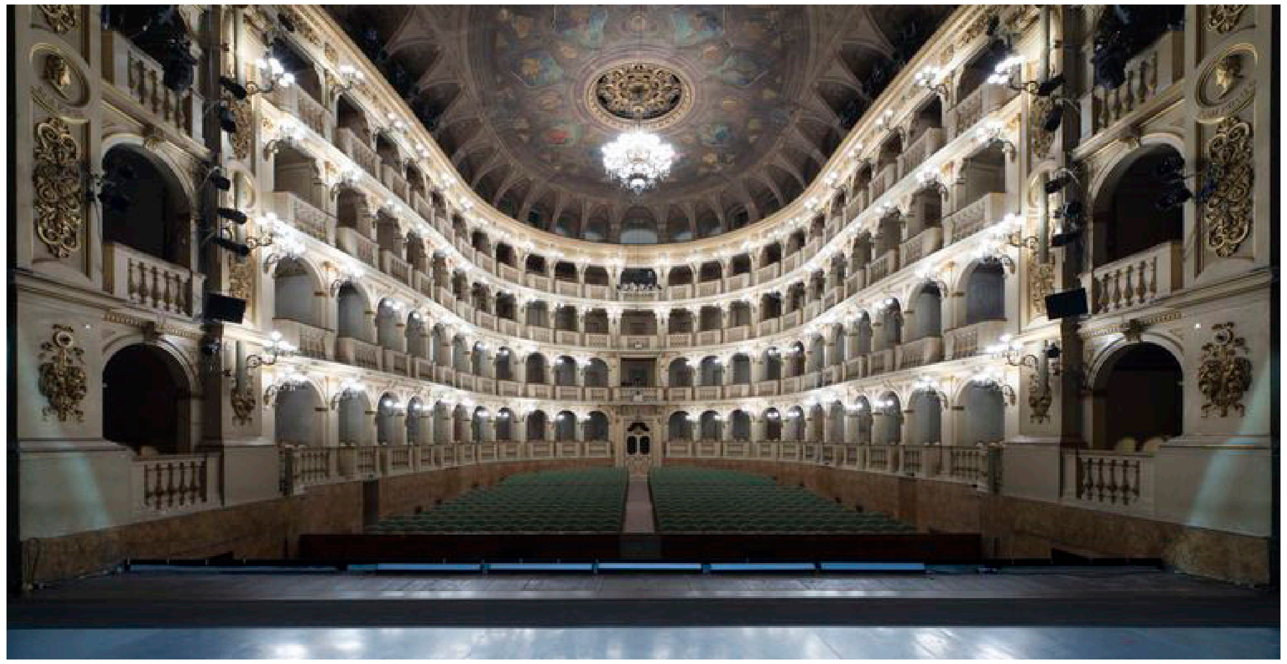


Fig.21 - _SCA3644.jpgBologna, Teatro Comunale, the theatre hall as seen from the stage (photo Andrea Scardova, IBC) 2016. Image from https://bbcc.ibc.regione.emiliaromagna.it/pater/loadcard.do?id_card=26940

performances took place in spaces, mostly open, set up on the occasion of events or parties. This element was also reflected in the early sixteenth century, with installations of outdoor spaces and halls inside the buildings. Although we are not yet dealing with a building with its own architectural-spatial identity, it can be considered that some elements due to medieval and early 16th-century experiments were emerging: tiers of seats, stalls, scenic elevation and raised stage, which would later characterise the 16th-century and the Baroque theatre. The first significant example of Renaissance theatre is the Teatro Olimpico in Vicenza (fig.18,19) designed by Andrea Palladio, representing a first hybridisation of the typology of Italian theatre having a semi-elliptical hall surmounted by a gallery that alternates columns and statues. There is also the orchestra space and an imposing frons scaenae, where the performance is played just like in Roman theatres. [V. Morselli 2018].

The significant contributions to the sixteenth-century theatres' morphological and structural development are attributable to Baldassarre Peruzzi (1481-1536) and the pupil Sebastiano Serlio (1475-1554). The latter in the seven-volume treatise "All the works of Architecture et Perspectiva" in describing the main characteristics of the theatrical spaces of the Italian Renaissance:

A rectangular room with the scene placed at one of the ends and the seats for the spectators made on sloping supports (stepped) on the model of the cavea (hall) of the Greek and Roman theatres.

The fixed scene use, which means with only one view, remained unchanged from the beginning to the end of the performance. The idea was taken from the scaenae frons (stage fronts) of the theatres of ancient Rome. They were composed of a masonry stage element structured as a front of a multi-storey building, on which three doors opened: a larger one in the centre, called porta Regia, and the others on either side of it, named portae minorres.

Introduction of perspective scenes. Unlike the Roman scaenae frons, the Renaissance fixed scene represented a city place and was made in perspective. Initially, it was two-dimensional because it consisted of a simple painted backdrop. Gradually, the scenic space acquired three-dimensionality by using, on the one hand, the scenic backdrops, which depicted architecture and landscapes in perspective, and, on the other hand, by accentuating the inclination of the stage. In this way, the depth of the stages was illusorily increased, which was very small. The buildings closest to the proscenium had two sides: one parallel to the

front of the scene and the other oblique inwards. In avoidance of nullifying the perspective illusion, the actors avoided taking themselves inside the stage structure and acted on the proscenium. Otherwise, they would appear taller than the elements of the scene;

introduction of the typical scenes, referring to the three genres of representation of the Greek theatre reported by Vitruvius (tragedy, comedy and satirical drama). [V. Morselli 2018].

The innovative element of the sixteenth-century theatre hall turns out to be the introduction of the perspective wings with the setting of an exclusively frontal vision, such as to be visible from a single point of the hall, that is, the one intended for the Prince.

The perspective view allowed a scene depth even in small spaces, grecising the architectural space from representation. Therefore, it will be precisely this characterisation of the scene that will give its name to the "Italian theatre/Italian hall. In addition to the Teatro Olimpico in Vicenza, the Teatro Ducale in Sabbioneta in the province of Mantua is the other valid example. Vincenzo Scamozzi, between 1588 and 1590, designed it. It represents the first permanent court theatre built as a building in its own right untied a palace. While Palladio's solution faithfully reproduced the dictates of classical theatre, the Ducal Theater of Sabbioneta experimented for the first time with the characteristics of the Renaissance hall. This has a system on a rectangular base, typical of stately buildings. The stall is a hemicycle formed by wooden steps slightly leaning towards the proscenium, thus being divided from the space dedicated to the representation that recalls the orchestra space of the Greek theatre. The hemicycle is surrounded by a colonnade of twelve Corinthian columns, reminiscent of Roman theatres.

Between the Renaissance models and the Italian Baroque theatre is possible to find the Farnese Theater in Parma designed by the Ferrara architect Giovan Battista Aleotti (1546-1636) and inserted in the Palazzo Della Pilotta (fig.20), like the Medici Theater in Florence. The construction of the theatre took place between 1617 and 1618. It is grafted into the rectangular hall of the building and has an elongated U-shaped Hall to optimise the view towards the stage.

Altimetrically the space of twenty-two meters in height is divided into two orders of galleries punctuated by columns and statues, tracing the Olympic theatre and that of Sabbioneta. The area of the cavea is built by terraces along the long sides of the hall and an ample central space used to set up parties, games and tournaments. Along with one of the short sides, there is the proscenium with a depth of forty meters, a characteristic that the baroque theatre system will then take up to favour the scenic machines' movement. The scenic performance involves both proscenium and stage space for the first time, distinguishing itself from the audience. This autonomy of space between the audience and the stage is emphasised by the proscenium surrounded by the scenic arch having the double function to frame the performance space and hide the machines from the audience.

The Slum layout is perfected, codifying and defining the linguistic-formal and architectural characters during the neoclassical period, after the mid-eighteenth century. Exemplary models of the morphological and structural development of the Italian scheme of Baroque origin is the Teatro Comunale Di Bologna with the bell plan designed by Antonio Galli da Bibbiena, the Masini theatre in Faenza, the municipal theatre of Ferrara with an elliptical plan and the neoclassical theatre of San Giovanni in Persiceto. Mainly, the system of historic theatres of the Emilia-Romagna Region built between the eighteenth and nineteenth centuries presents a planimetric system of the horseshoe, elliptical or U-shaped hall, enclosed by a box system of the typical Baroque tradition. The theatres, on the other hand, built in the early twenties of 1900, has Art Nouveau structures, some of them maintaining the box type. On other occasions, the 900 will see more modern theatres in which continuous galleries replace the stages. Nevertheless, the characteristics of the Italian hall and, therefore, the stable theatre are codified during the neoclassical period and remain almost unchanged for the following two centuries.

From the provided information, the setting of the stage space and audience can be attributed to the theatres' gradual evolution from the Renaissance to neoclassicism. During this period, the Italian Theater becomes a symbolic building in the historical fabric of the cities and at the same time crystallises its identifying characters that can be summarised in two distinctive elements: the articulation in orders of boxes that define the vertical development of the hall. The cavea, for the most part, horseshoe-shaped, follows the semicircular structures of the Greek-Roman theatres. The solution of the horseshoe audience was the synthesis of several experiments. At first, "bell" solutions were adopted for the Bibbiena project for the Teatro Comunale di Bologna and a "U" solution (fig.20). However, both solutions did not solve the visibility of the lateral boxes. The Horseshoe system instead allowed to minimise the problem of view, but at the same time optimised the area of the cavea, leaving more space to the backstage and therefore to the introduction of perspective wings and scenic machines.

On the other hand, the stages rhythmically mark the hall's height. They replace the first sixteenth-century and early seventeenth-century terraces (Teatro di Sabbioneta and Teatro Farnese in Parma) and are divided into different orders. In addition to being an architectural distribution solution, the adoption of the boxes had a precise social meaning. The decorative elements, the height and the spatial location, were closely linked to the political-economic and social power of those who rented it. These two factors characterise morphologically and spatially the Italian theatre halls. These must be added with the ceiling's construction system, which spatially closes the stalls to solve and optimise acoustic problems.[4]

The archetype of the Italian theatre with boxes is the "beehive" structure used for the first time by the Ferrara architect Alfonso Rivarola, known as Ghenda. When he had to adapt a room for gymnastic shows and tournaments in the Palazzo di Podestà in Bologna in 1639, he adopted a solution of this design replaces the cavea of 1500 by dictating a vertical development of the hall.

The box type of the Italian theatre finds its greater connotation in 1941 with Andrea Seghizzi in the Formagliari theatre in Bologna. It represents the first example of Baroque public theatre. The space is exploited to accommodate the widest possible audience: the boxes, equipped with independent accesses at the back and connected by corridors, are arranged on top of each other, degrading towards the hall. These two examples represent the first experiments on which the Italian theatre will develop, which since its birth has the socio-economic and political role of holding together the "social stratification" of the Baroque ideology: on the one hand, the upper social classes, for which the boxes are private spaces aimed at "making the social and economic status legible, the boxes are furnished by the tenants, who compete in pomp and richness of materials; create opportunities for additional profit, through the subletting of the boxes themselves; on the other, the indiscriminate audience of the hall, a place of diversity, which embraces separateness, which unifies rigid stratifications and competitions elected to institutions in the proper sense. [M. Tafuri].

The first experiments of the Italian Baroque typological scheme of the first half of the '600 follow the plant of the Pillotta theatre. They are halls incorporated into pre-existing buildings. These halls have an elongated U-shaped stall, with a steep slope, with benches as seats of the less abject public; the stages instead, sloping towards the scene, are articulated on several orders are divided by radial partitions. It should be noted that the Italian hall, in its vertical development, differently from the medieval tradition with the tribune seats placed

4 *It is the vault that closes the space of the audience. It is a wooden structure made of ribs warped in a direction parallel to the proscenium or radial around the central hole responsible for the descent and ascent of the chandelier and braced by stiffening axes, closed to the intrados by studied reeds to support the plaster layers that host rich decorations and plaster stucco. The morphology of the vaults is closely connected to the planimetric and altimetric layout of the hall: the presence Or the absence of the gallery at the end of the boxes influences the extension of the ceiling. In the first case, the connection between the roof of the hall and vertical structures are made in correspondence with the external masonry of the gallery decreeing the most significant spatial extension of the ceiling, in the absence of the gallery instead; the roof stops near the supports provided by the last order of the boxes. It is with the project of the theatre that the task of the top is completed, destined to assume the most varied physiognomies depending on the type of plan of the hall (bell, U-shaped, elliptical, etc.), the support, wooden or masonry, the type of spatial curvature drawn, and the decision of the designer to make it an integral part of the roofing structures, opting for its "suspension" to the roof trusses, or create a design statically independent of them. [B.Brunetti 2016]*

laterally, brings with it problems of visibility and acoustics, especially for the side boxes. This problem will be solved with the vaulted ceiling system, whose introduction can be traced back to the XVIII, a period that sees the birth of the Teatro Stabile as an urban building independent of the noble palace.

The reasons that push to create autonomous architectural buildings in the urban fabric with a defined social and economic role are rooted in the changing needs of the staging. The stage needs more space and practical needs and protection of the public utility, reducing the fire risk that affects the halls and the buildings in which they are located. In this period, the first autonomous theatrical buildings were born. They are not yet conceived in their formal architectural conformation, despite having specific and recognisable architectural and constructive characteristics, as monuments of the historical city. This feature, however, will be focused on the neoclassical period, during which the hierarchical and decorative façade rules were outlined in the urban context. With the end of the '700, there is a proliferation in the Italian city centres of social, municipal and royal theatres. These autonomous architectural structures acquire their monumental characters within the urban fabrics, such as the realisation of the La Fenice in Venice (1792), the renewal of the S. Carlo of Naples (1816) and the Carlo Felice of Genoa (1828). [5]

Almost all Italian urban centres are dated with theatre halls during the nineteenth century. In Emilia-Romagna, the Piermarini's construction and regio di Parma (N. Bettolli 1829) began spreading the architectural model on which the theatre halls were built during the century.

During the nineteenth century, the typological crystallisation of the Italian theatre took place. A phenomenon closely connected to the affirmation of the socio-economic and political expectations of the liberal bourgeoisie of the nascent unitary kingdom, which finds in the hierarchical structure of the Italian theatre an element of distinction and representativeness. The theatres are getting ready to set a monumental character, exalting the decorum and magniloquence of our cities, as seen in the Reggio Emilia theatre example. With the end of the 800 but especially in the first twenty years of the twentieth century, new spatial conformations relating to the cavea and the stage are introduced. Needs for staging prose performances that spread more and more despite the opera requiring more miniature stages. Even the structure of the boxes changes with the replacement and adoption of unique galleries supported by cast-iron columns. Other changes affect the stalls by improving the system of lifting the stalls to the stage. Other theatres such as the Ariosto of Reggio and the Storchi of Modena transform the underground area, hosting circus games in vogue. At this time, we always find new linguistic research in Art Nouveau style for the interior of the halls and the exterior: an example is the Social Theater of Novi, whose elevations are in DeCò style.

Based on the morpho-typological evolution described above related to the regional scale, are presented some tables on the morpho-typological conformations of some of the theatres studied. As illustrated, the development of historical theatres derives from a series of spatial implications due to specific needs of dramaturgy and stage space. In addition, the meanings of the social, political and economic contexts of the urban contexts in which they are located and the morphological relationship that the theatres themselves have with the urban morphological context must be considered. These aspects of historical theatre represent the specific spatial, dimensional and geometric characterisation of a crystallised typology that responds to the specificity of society in a particular period. This means that the characteristics analysed to detect seismic damage are valid for the stereometric of the historic Italian theatre. However, these attributes cannot be applied to the theatre of the twentieth century, which had to bear the comparison with other media such as cinema, television and the web. During the twentieth century, the character of the theatre as a "cultural institution" lost its meaning. The 1982 IBC census showed that interest in these places had a moment

5 *The first great example of neoclassical theatre is the Teatro Alla Scala in Milan, built by Giuseppe Piermarini in 1778. The Milanese example provides an undisputed model for the proliferating theatrical building. Still, at the same time, there is a typological crystallisation: the element that most characterised the Italian theatre, the hive structure that so well represented the hierarchical stratification of the seventeenth-century aristocratic society, becomes for the new bourgeoisie a guarantee of distinction and representativeness.*

of identity crisis in terms of values.

The typological representations elaborated on the inspection sample of theaters damaged by the 2012 earthquake have been depicted in the following sheets (fig. 21; 22, 23, 24, 25, 26, 27, 28, 29, 18,30, 31, 32,33,34). These charts describe and represent the individual specificities of the development's geometric, spatial and elevational organization, emphasizing how the architectural attributes change and the period of construction and urban and geographical context of belonging. It can be observed that theatres owned by big cities or centres of particular political and economic importance acquire a strongly monumental character in the centre of the urban fabric, compared with the theatres in small towns, which, despite their architectural quality, present more modest dimensions and a schematic spatial organization. The sample theatres of the inspection were subdivided according to the characteristics of the planimetric shape. Based on the criteria of the extensive methodology, the Angelo Masini Theater in Faenza, located outside the 2012 crater area, was included. In addition, Following the criteria of planimetric organization, the sample theatres were divided into seven groups as compared to planimetric similarities. Other historical regional theatres with the same spatial articulation of plan for each group were also listed.

Inspection sample tab legend

- damaged theatres of the inspection sample within the 2012 crater
- theatres in the inspection sample outside the 2012 crater
- theatres with a similar plan

G1 **Pavarotti Municipal Theater - Freni - Modena (MO)**
The Municipal Theater of Carpi - Carpi (MO)
Nuovo Theater - Mirandola (MO)
Giuseppe Borgatti Theater - Cento (FE)
Giovanni Rinaldi Municipal Theater - Reggiolo (RE)
Romolo Valli Municipal Theater -Reggio Emilia (RE)

Angelo Masini Theater - Faenza (RA)

Alice Zeppilli Municipal Theater - Pieve di Cento (BO)
Crevalcore Municipal Theater - Crevalcore (BO)
Bonifazio Asioli Theater - Correggio (RE)
Franco Tagliavini Fortress Theater (Rocca dei Gonzaga) - Novellara (RE)
Regio Theater of Parma - Parma (PR)
Eleonora Duse Theater - Cortemaggiore (PC)
Girolamo Magnani Municipal Theater - Fidenza (PR)
Giuseppe Verdi Municipal Theater - Busseto (PR)
Dante Alighieri Theater - Ravenna (RA)
Carlo Goldoni Theater - Bagnacavallo (RA)
Vittoria Theater - Pennabilli (RA)
Maria Pedrini Municipal Theater - Brisighella (RA)
Municipal Theater of Russi - Russi (RA)
Cervia Municipal Theater - Cervia (RA)
Municipal Theater of Cesenatico - Cesenatico (FC)
Giuseppe Verdi Theater - Fiorenzuola d'Arda (PC)
Alessandro Bonci Theater - Cesena (FC)
Errico Petrella Municipal Theater - Longiano (FC)
Gian Andrea Dragoni Theater - Meldola (FC)

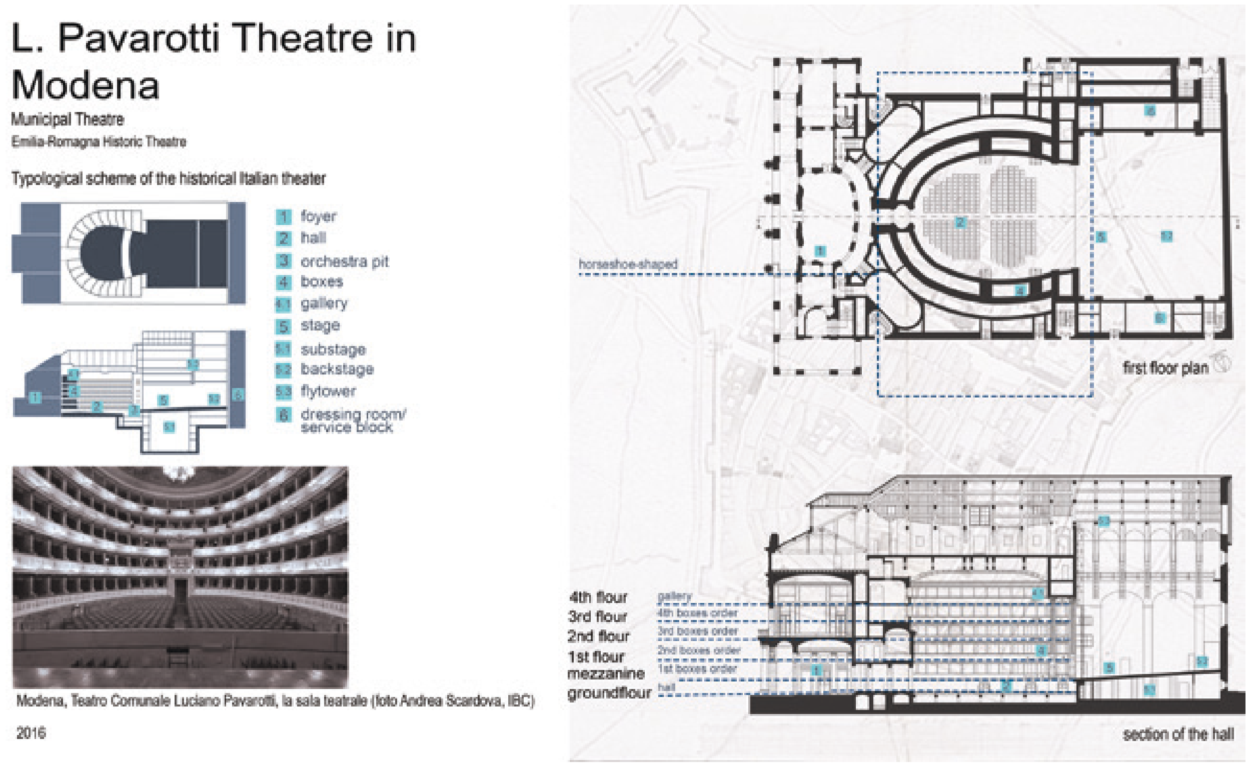


Fig. 22 Pavarotti Municipal Theater - Freni - Modena (MO) characterised by a horseshoe plan with boxes. Developed by M.Suppa

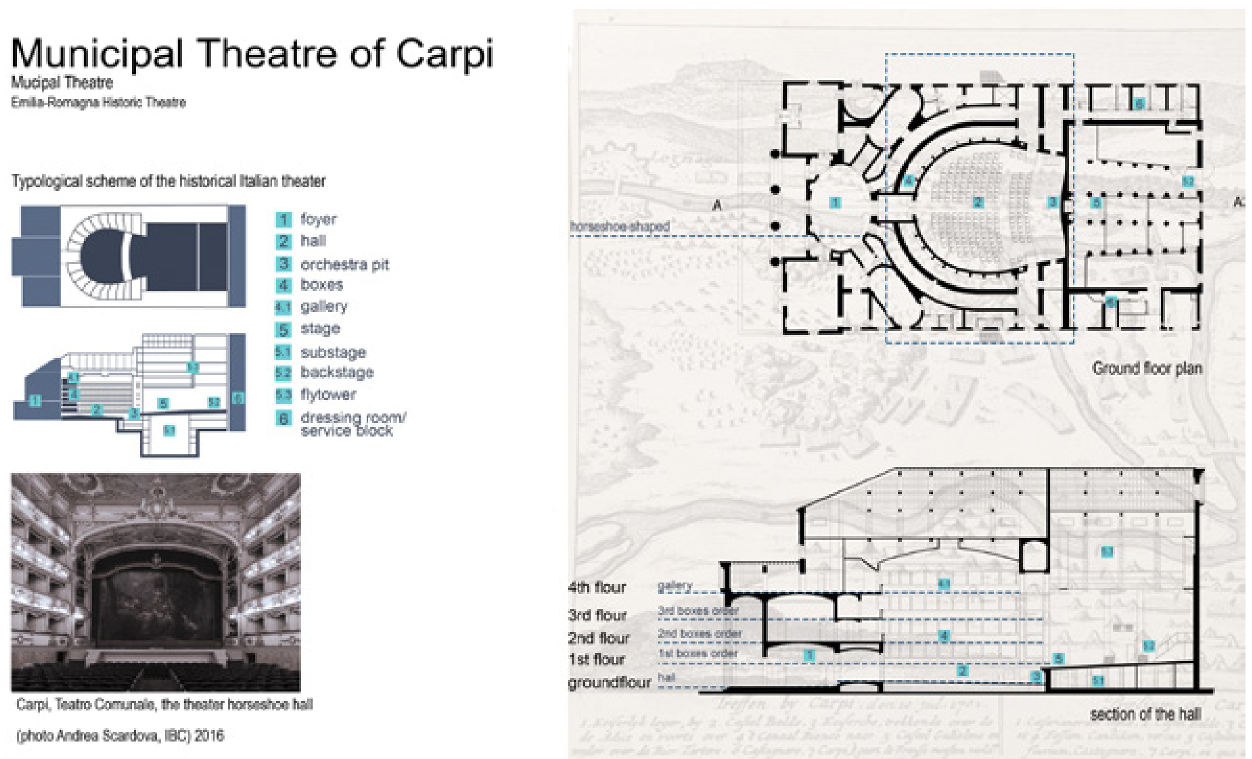


Fig.23 The Municipal Theater of Carpi - Carpi (MO) characterised by a horseshoe plan with boxes Developed by M.Suppa

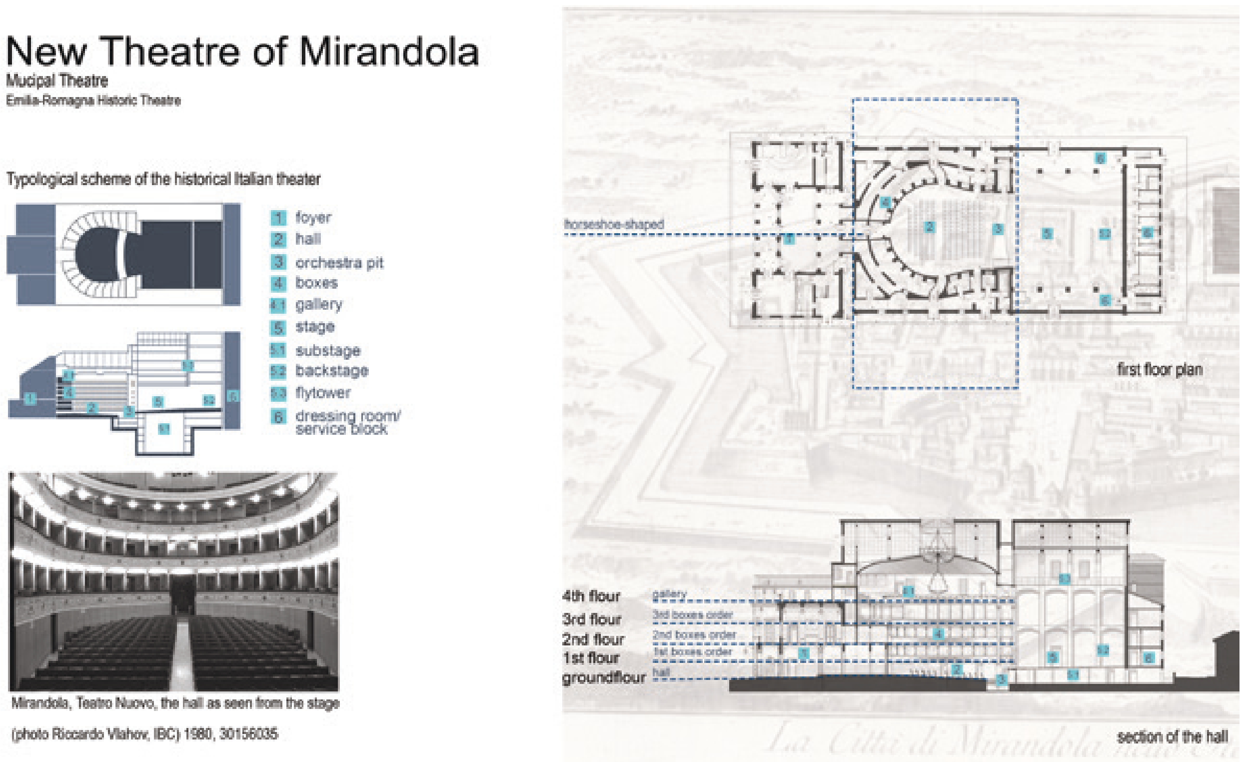


Fig. 24 Nuovo Theater - Mirandola (MO) characterised by a horseshoe plan with boxes. Developed by M.Suppa

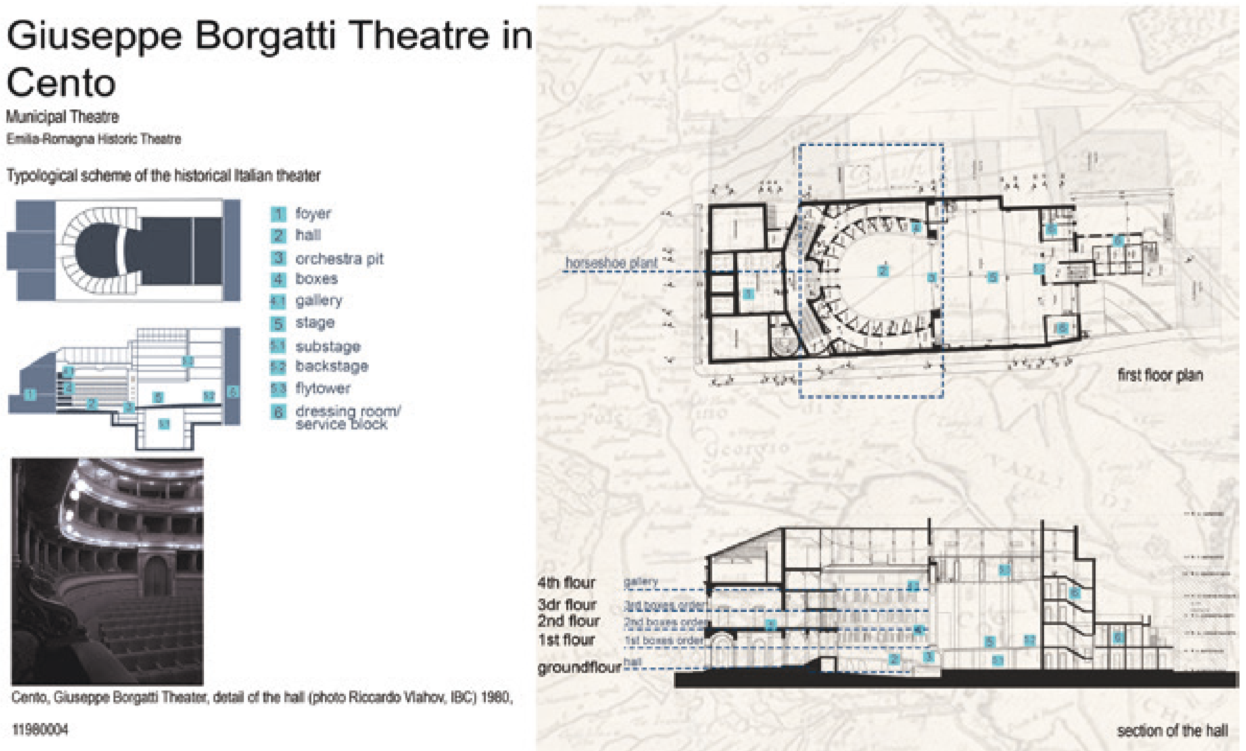


Fig. 25 Giuseppe Borgatti Theater - Cento (F.E.) characterised by a horseshoe plan with boxes. Developed by M.Suppa

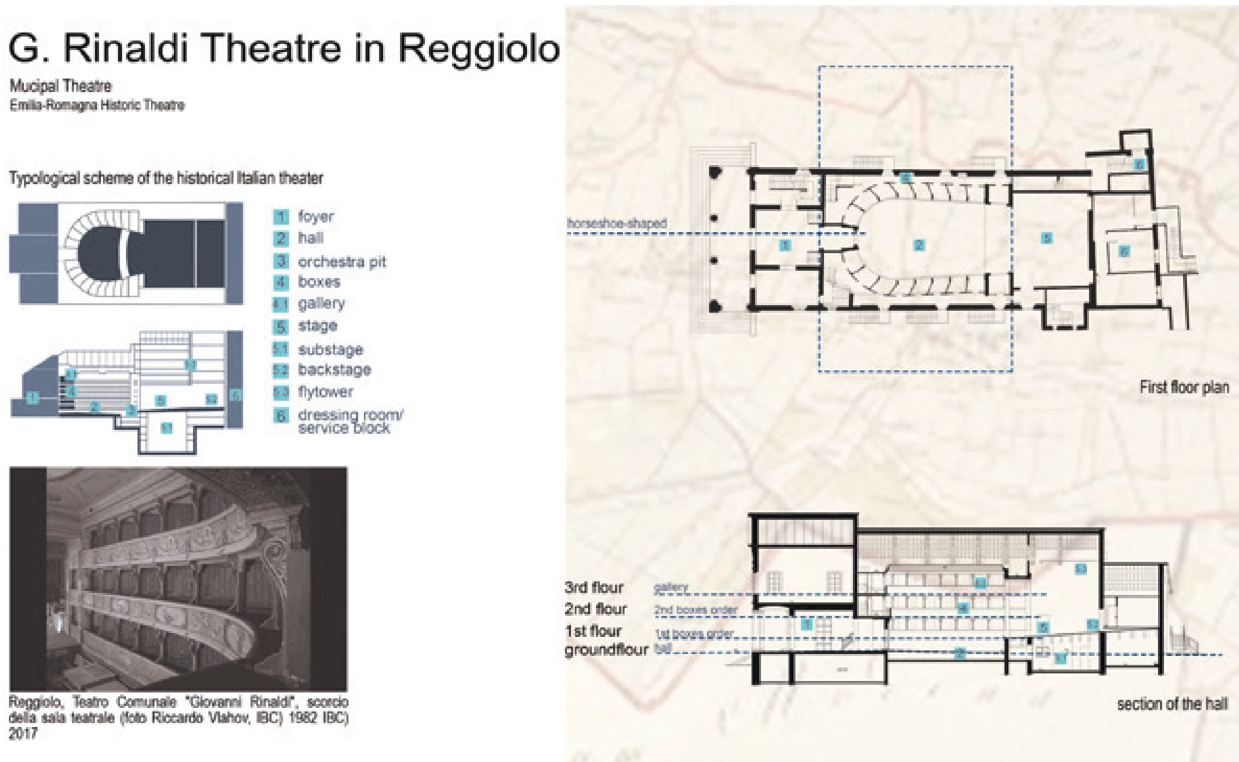


Fig. 26 Giovanni Rinaldi Municipal Theater - Reggiolo (RE) characterised by a horseshoe plan with boxes. Developed by M.Suppa

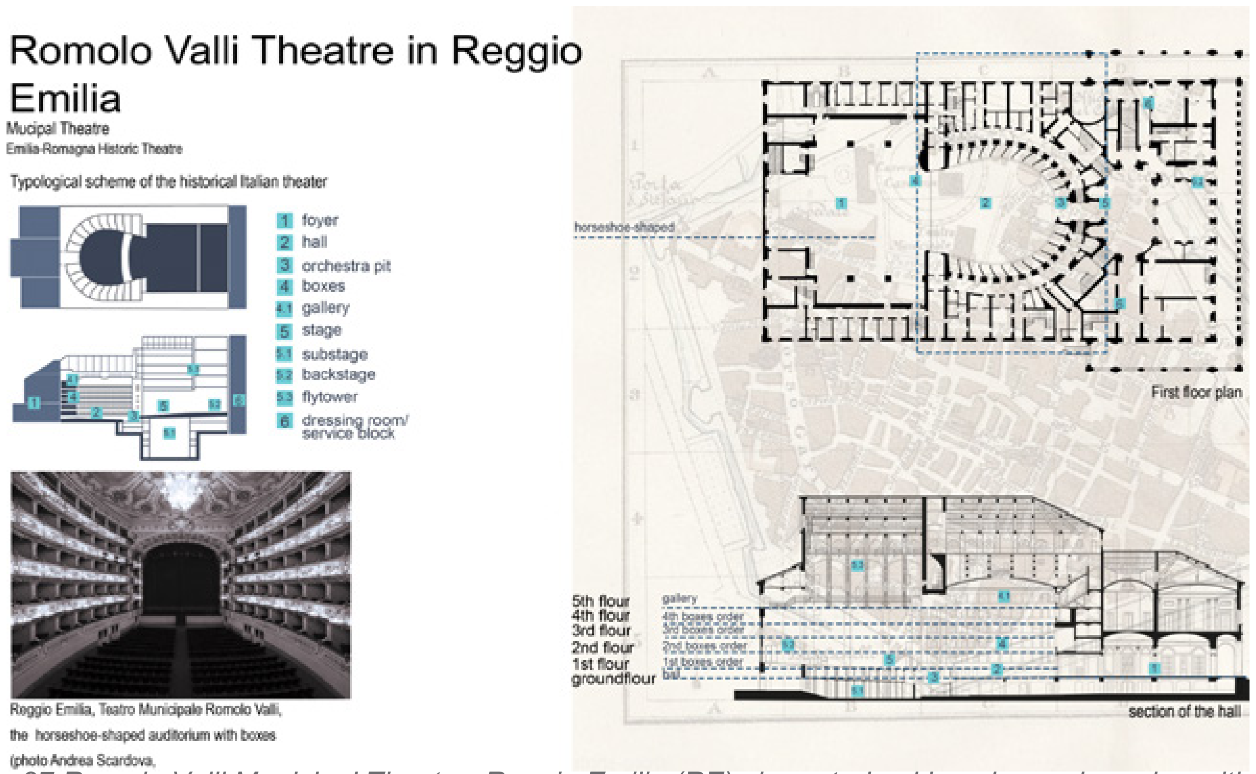


Fig. 27 Romolo Valli Municipal Theater -Reggio Emilia (RE) characterised by a horseshoe plan with boxes. Developed by M.Suppa

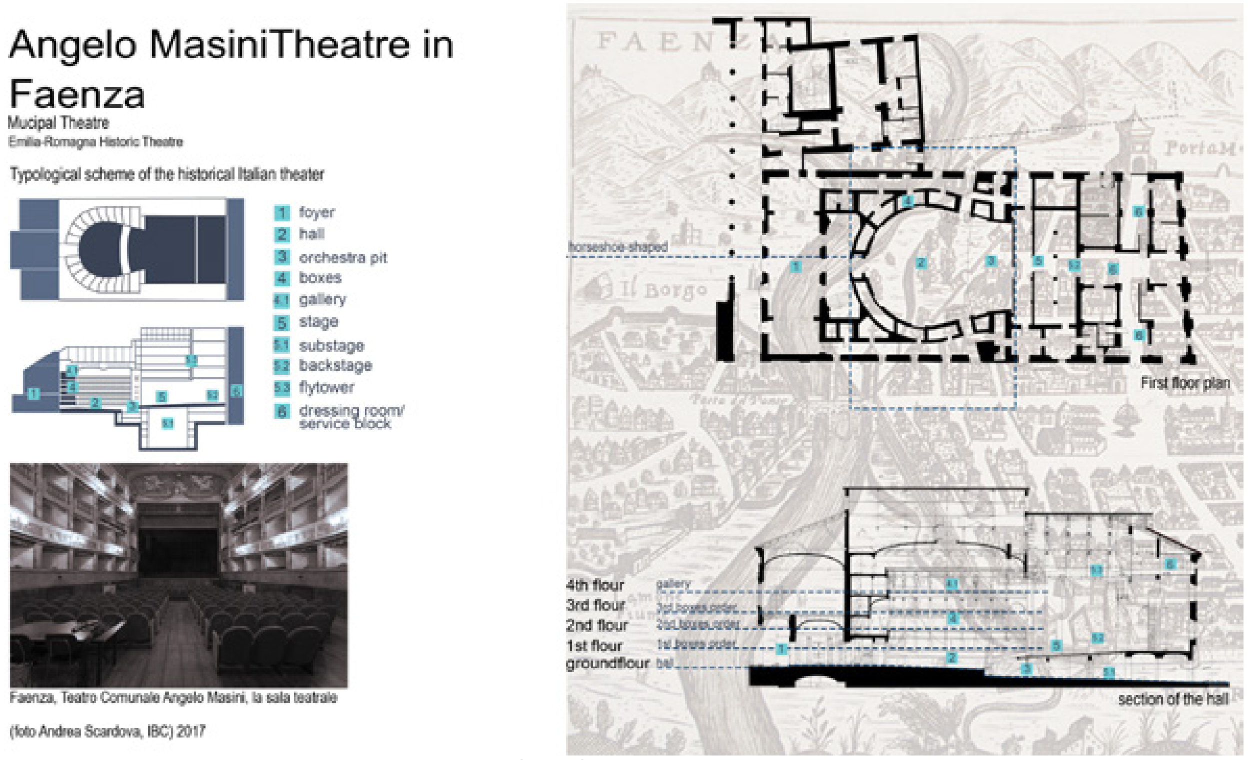


Fig.28 Angelo Masini Theater - Faenza (R.A.) characterised by a horseshoe plan with boxes. Developed by M.Suppa

G2 **Claudio Abbado Municipal Theater- Ferarra (FE)**
Teatro Sociale Luzzara - Danilo Donati - Luzzara (RE)
Teatro Sociale della Concordia - Portomaggiore (FE)
Lorenzo Golfarelli Theater -Civitella di Romagna (FC)
Ebe Stignani Municipal Theater - Imola (BO)
Gioachino Rossini Theater - Lugo (RA)
Municipal Theater - Piacenza (PC)

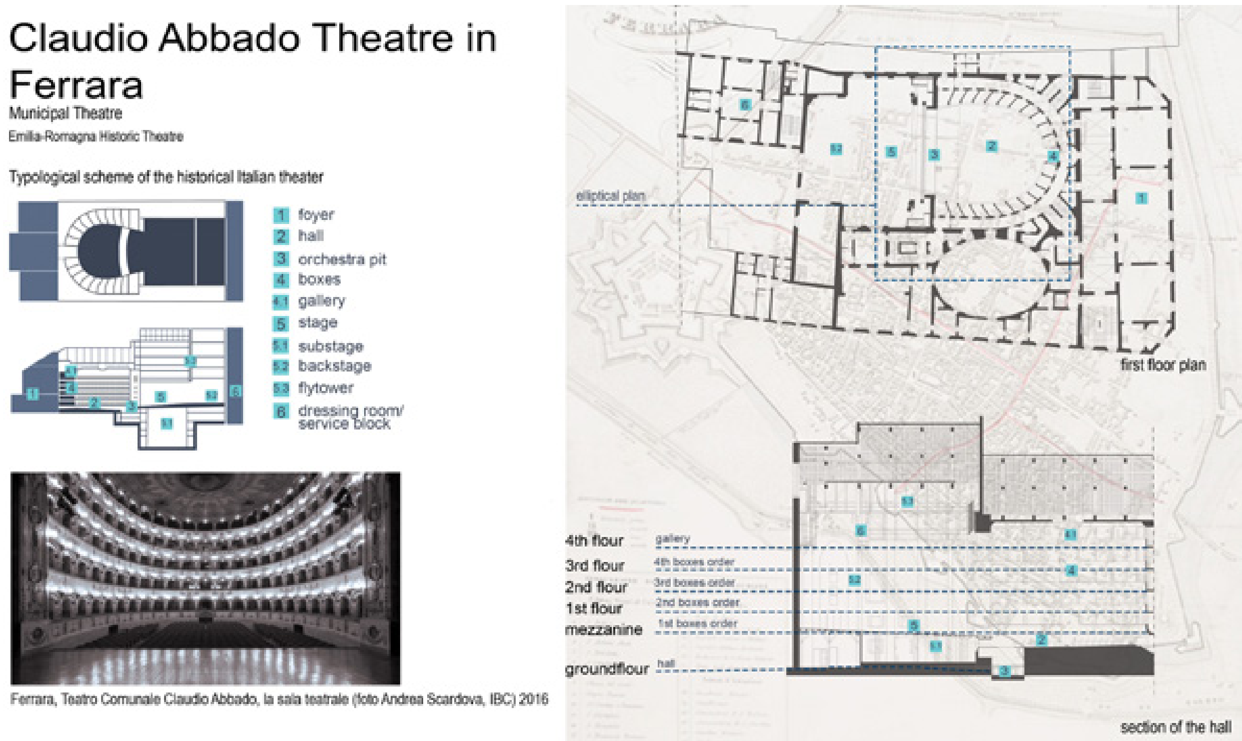


Fig. 29 Claudio Abbado Municipal Theater- Ferarra (F.E.) characterised by an elliptical plan with boxes. Developed by M.Suppa

G3 **Social Theater - Novi di Modena (MO)**
Carani Theater - Sassuolo (MO)
Filodrammatici Theater - Piacenza (PC)
Social Theater -Novafeltria (RN)

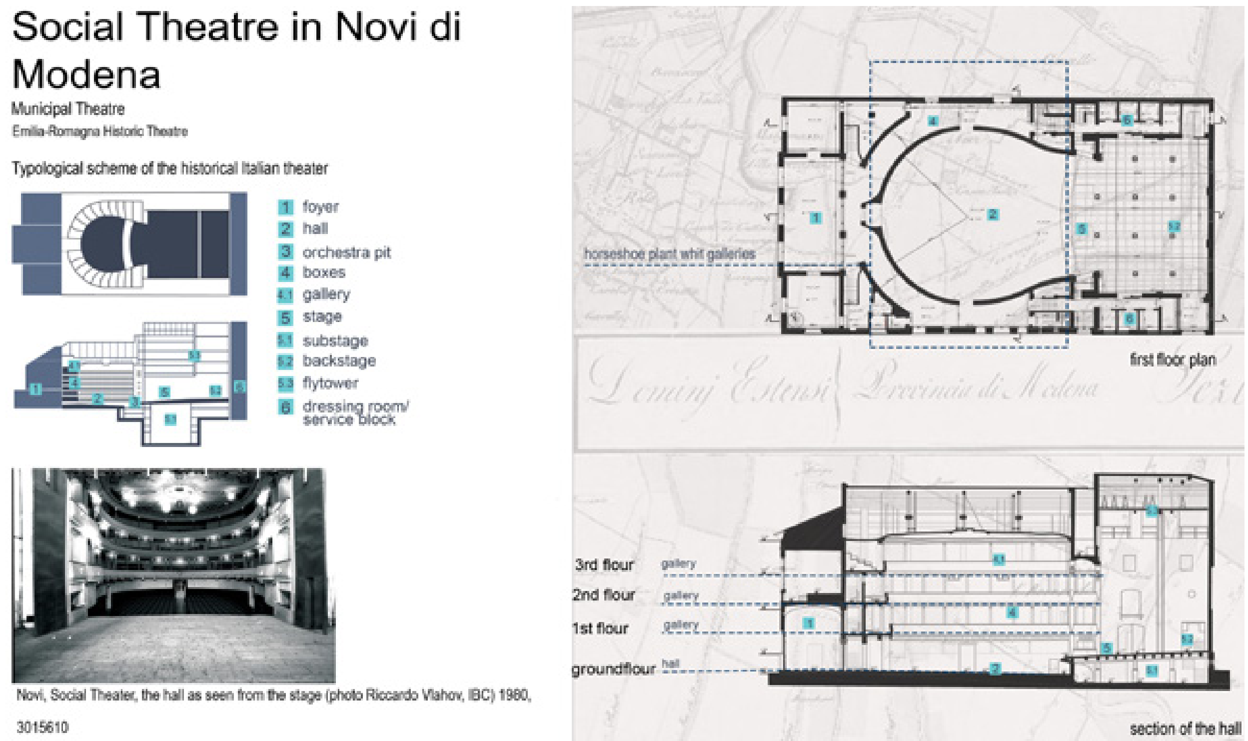


Fig.30 Social Theater - Novi di Modena (MO) characterised by a horseshoe plan with galleries. Developed by M.Suppa

G4 **Storchi Theater - Modena (MO)**
Ludovico Ariosto Theater - Reggio Emilia (RE)
Politeama Sociale - Sassuolo (MO)

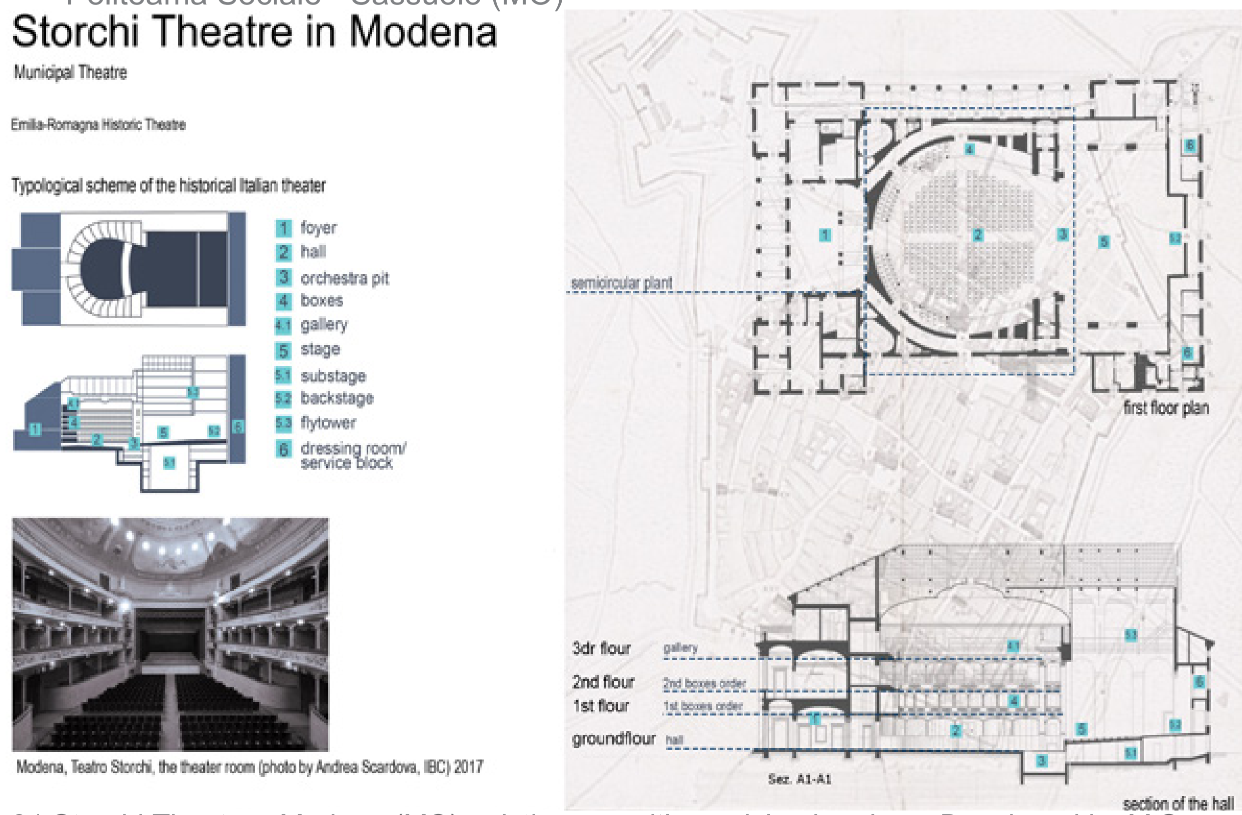


Fig.31 Storchi Theater - Modena (MO) polytheama with semicircular plans. Developed by M.Suppa

G5 **People' Theater - Concordia sulla Secchia (MO)**
Herberia Theater - Rubiera (RE), Estense Hall - Ferrara (FE)
Municipal Theater - Conselice (RA)
Luigi Rasi Theater - Ravenna (RA)]

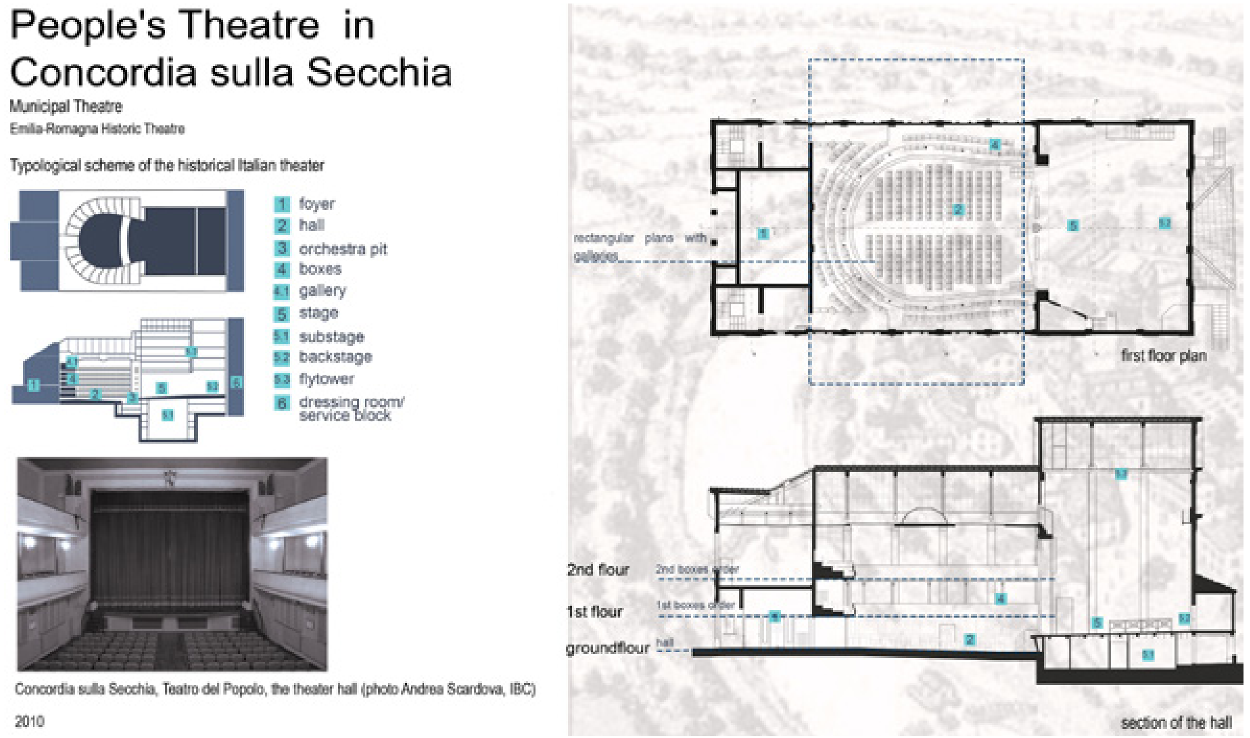


Fig.32 People's Theater - Concordia sulla Secchia (MO) characterised by composite typology. Developed by M.Suppa

G6 **The Municipal Theater of San Felice sul Panaro - San Felice sul Panaro (MO)**
Arena del Sole - Bologna (BO)

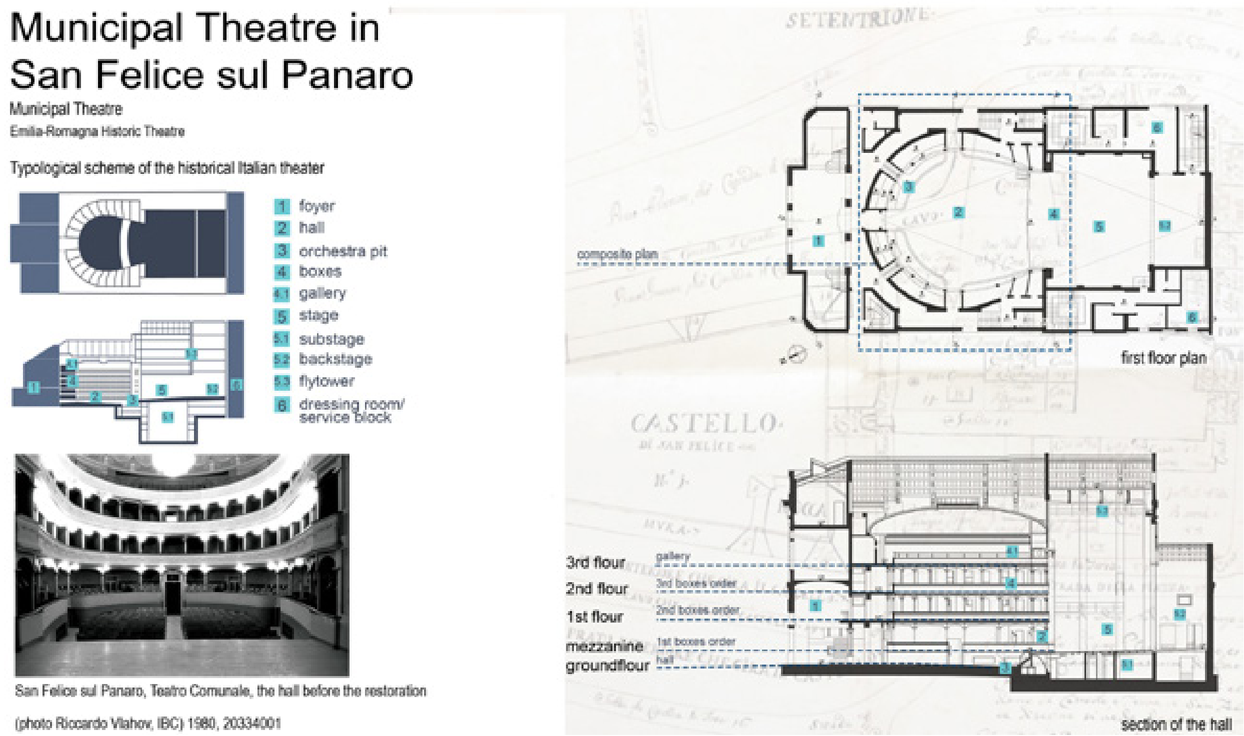


Fig. 33 The Municipal Theater of San Felice Sul Panaro - a rectangular plan with galleries characterises San Felice Sul Panaro (MO). Developed by M.Suppa

G7 **Webben Facchini Municipal Theater - Medolla (MO)**
River Theater - Boretto (RE)
Giuseppe Verdi Theater - Ferrara (FE)
Teatro Comunale 'Il Cassero' - Castel San Pietro Terme (BO)
Italia Municipal Theater - Rocca San Casciano (FC)
Laura Betti Municipal Theater - Casalecchio di Reno (BO)
Giuseppe Verdi Theater - Castel San Giovanni (PC)
Alessandro Guardassoni Theater - Bologna (BO)
San Luigi Theater - Multimedia Room - Forlì (FC)
Politeama Theater Cinema - Piacenza (PC)
Municipal Theater '900 -Tresigallo (FE)

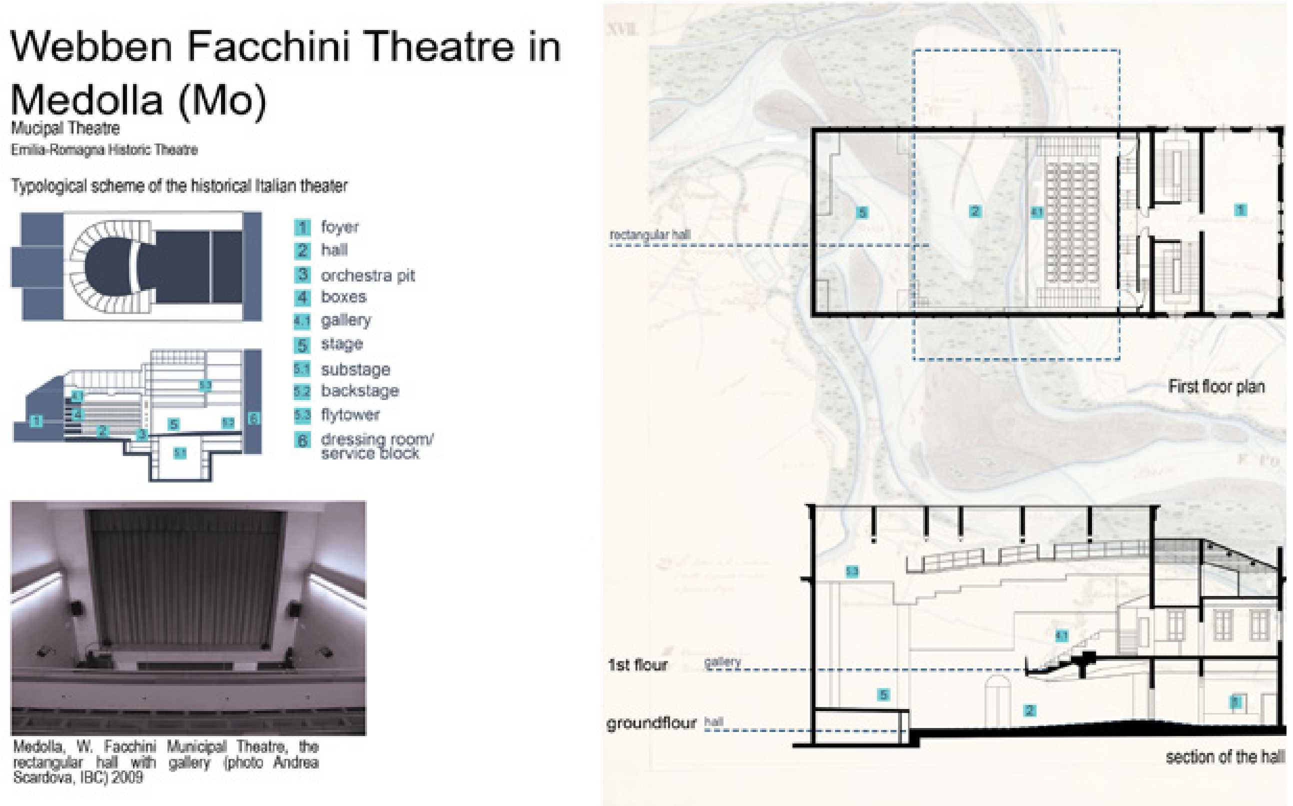


Fig. 34 Webben Facchini Municipal Theater - a rectangular plan with a gallery characterises Medolla (MO). Developed by M.Suppa

The first group (G1) includes theatres built between the late 1600s and mid-1800s characterised by a horseshoe plan with boxes [Pavarotti Municipal Theater - Freni - Modena (MO), The Municipal Theater of Carpi - Carpi (MO), Nuovo Theater - Mirandola (MO), Giuseppe Borgatti Theater - Cento (FE), Giovanni Rinaldi Municipal Theater - Reggiolo (RE), Romolo Valli Municipal Theater -Reggio Emilia (RE)]

The second group (G2) examines theaters built during the 1700s characterized by an elliptical plan with boxes [Claudio Abbado Municipal Theater- Ferarra (FE), Teatro Sociale Luzzara - Danilo Donati - Luzzara (RE), Teatro Sociale della Concordia - Portomaggiore (FE), Lorenzo Golfarelli Theater -Civitella di Romagna (FC), Ebe Stignani Municipal Theater - Imola (BO), Gioachino Rossini Theater - Lugo (RA) Municipal Theater - Piacenza (PC)]

The third group (G3) includes theatres with a horseshoe plan with galleries built in the early 1900s [Social Theater - Novi di Modena (MO), Carani Theater - Sassuolo (MO), Filodrammatici Theater - Piacenza (PC), Social Theater -Novafeltria (RN)]

The fourth group (G4) includes theatres - polyteama with semicircular plans [Storchi Theater - Modena (MO), Ludovico Ariosto Theater - Reggio Emilia (RE), Politeama Sociale - Sassuolo (MO)]

The fifth group (G5) includes theatres built in the early 1900s with composite typology [The Municipal Theater of San Felice sul Panaro - San Felice sul Panaro (MO), Arena del Sole - Bologna (BO)]

The sixth [People' Theater - Concordia sulla Secchia (MO), Herberia Theater - Rubiera (RE), Estense Hall - Ferrara (FE), Municipal Theater - Conselice (RA), Luigi Rasi Theater - Ravenna (RA)] and seventh groups (G6-G7) examine theatres of the 1900s with rectangular plans with galleries, particularly the theatres of the seventh group attributable to the 1930s characterized by the presence of only one gallery [Webben Facchini Municipal Theater - Medolla (MO), River Theater - Boretto (RE), Giuseppe Verdi Theater - Ferrara (FE), Teatro Comunale 'Il Cassero' - Castel San Pietro Terme (BO), Italia Municipal Theater - Rocca San Casciano (FC), Laura Betti Municipal Theater - Casalecchio di Reno (BO), Giuseppe Verdi Theater - Castel San Giovanni (PC), Alessandro Guardassoni Theater - Bologna (BO), San Luigi Theater - Multimedia Room - Forlì (FC), Politeama Theater Cinema - Piacenza (PC), Municipal Theater '900 -Tresigallo (FE).

The morpho-typological analysis showed that the theatre presents height variations, sometimes significant, related to the different functional-spatial conformations. This group of variables influences the seismic response of the macro-elements belonging to the four specific individual microstructural units, determining the consequent deformation and cracking picture on a global scale.

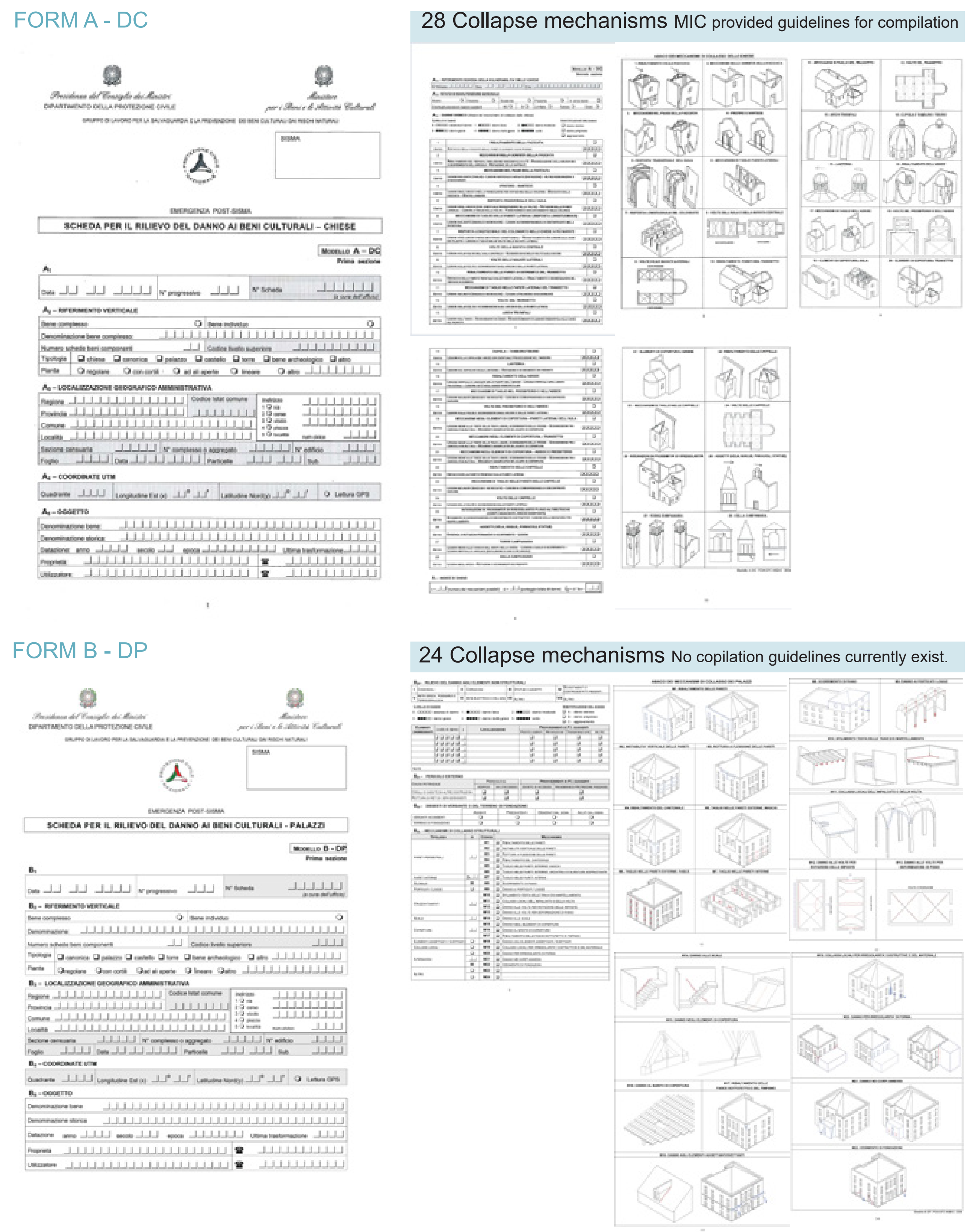
Based on these considerations and the existing standardized protocols described in the following paragraph, the implementation of the SD-T (Seismic damage that) theatres card presented in ch five paras 5.1.1 has been thought and developed.

3.3 Criticality of the Visual Detection of Historic Theatres in 2012.

The reasons related to the architectural-cultural meanings that led the Agency for Reconstruction-SISMA 2012 to select the historic theatres as the object of investigation, described in paragraph 3.1, must be added motivations closely related to the survey and assessment of seismic damage in the emergency phase.

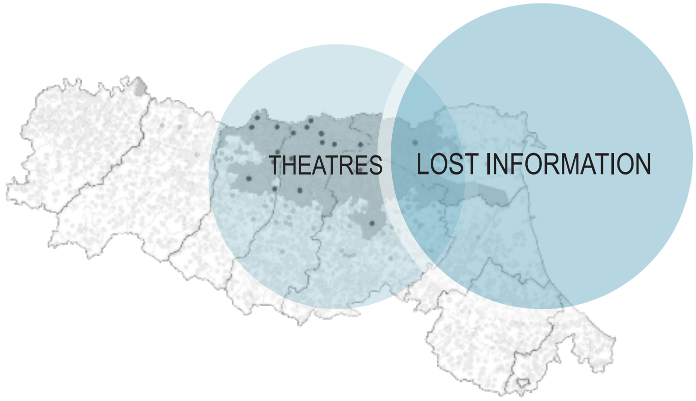
The theatres for their stereometry and altimetric articulation are attributable to the category of complex architectural typologies, together with cemeteries, castles, fortresses and towers. Unfortunately, the MiC still does not have ad hoc forms for assessing vulnerability and survey of seismic damage. The absence of a specific file for theatres meant that the post-earthquake visual surveys were carried out by adapting the two models for earthquake damage assessment made available by the Ministry - model A-DC for churches and PB-DP[6]

6 *Directive of the Minister of Cultural Heritage and Activities and Tourism Update of the directive of 12 December 2013 "Procedures for the management of activities to secure and safeguard cultural heritage in*



OBJECTIVES OF THE FILING
- to study the damage mechanisms to which the structure is sensitive
- to identify the mechanisms that the earthquake has actually activated
- to calculate damage index for each building
- to read and quantify the gravity of the effects

Fig. 35 SISMA forms are currently used for the seismic damage survey in the emergency phase—a summary of the M.I.C. file targets by the D.P.C. 2006. Developed by M.Suppa



Significances:
- Historical significance
- Landescape significance
- Metric-Geometric significance
- Morphological significance
- Environmental significance
- Technological significance

Fig. 36 Critical qualitative and quantitative information was recorded during the 2012 emergency by applying current M.I.C. procedures for earthquake damage survey in 2012 theatres. Developed by M.Suppa

for buildings. The MIC damage survey forms illustrate the identification of instabilities caused by the earthquake concerning the existing historical heritage (churches and buildings) and their graphic formulation. The development of the maps began in 1977. In 2006, during the research directed by Prof. Francesco Doglioni, they were updated and then completed in 2009 by the inter-university Consortium ReLUIS. These forms represent a methodological protocol to deal with activities related to the visual damage survey in the emergency phase (fig.35).

According to the classification reported in the card, the different structural elements identified in the building are proposed. For each agent recognised in the building, a line of the table is filled in indicating the identification of the mechanism found (from M1 to M22) and the location of the mechanism according to the code of the area (Ai) and any vertical (PEi, PIi, CSi, CAi) and horizontal (Oi, Pi, COi) elements involved. All mechanisms identified the level of activation and the eventual pre-existence of the tool (p) must be indicated, as well as the risk brought by the mechanism about the practicability (low, low with measures, high). The level of activation should be graded on five levels (absent; mild; moderate; severe; very severe; collapse).

Applying the current procedures for damage detection in theatres has caused the loss of useful information to describe the actual state of damage (an aspect that will be addressed in Chapter 4. Para 4.1). These critical issues have affected the estimation of the seismic theatre index.

Proceeding step by step, the documentary picture resulting from the expeditious surveys filed at the Agency for Reconstruction shows 31 forms relating to damaged theatres. Of these 25 concerned historical halls, mainly of Italian plant, the remaining 6 are small halls attached to parish buildings. This data constituted the first selective criterion of the macro-sample that the study analysed.

It is, therefore, of 25 damaged historical theatres with the distinctive characteristics of the Italian Hall. The visual survey of damages in the emergency phase has been performed mainly using the model B-DP - Palaces. Nevertheless, for the Municipal Theater of Pieve di Cento and the Theater of Guastalla, for whose visual survey the responsible teams of MiC have considered it necessary to implement the form B with the model A-DC (churches) to implement the form B with the model A-DC, in order to describe the state of damages exhaustively.

This interpretation, which analyses the space of the theatre halfway between a building and the hall of a church, is not entirely wrong. Although not exhaustive, it highlights

case of emergencies arising from natural disasters" – update of the Presidential Decree. C.M of 23 February 2006 (OJ 7.3.2006, n. 55) of the President of the Council of Ministers - Approval Of models for the survey Of ravages a retinue of Events calamity- Yes To goods Belonging to the heritage cultural

that this type's articulation and spatial development cannot be detected and therefore documented through adaptive models that are not specific to the geometric, morphological and constructive-structural characteristics of the theatre. In fact, the adaptive adoption of the two scheduled models for the analysis of complex architectural typologies, such as theatres, has highlighted even more its simplified nature, with the loss of quantitative and qualitative valuable information (fig.36) for the assessment of seismic damage - historical stratigraphy, materials, construction techniques, seismic history of buildings (Cosson, Ferrari 2019). Therefore, although the two scheduled tools allowed in the emergency phase a first expeditious survey, through the identification of the collapse mechanisms activated under the seismic action (28 colossus mechanisms for the A-DC form, 24 for the B-DP form), the result is an inaccurate damage survey with the estimation of the index of the damage inconsistent concerning the actual damage suffered. Consequently, the aspect has fallen on the actions of first intervention for the safety works and subsequent phases of intervention for restoration and conservation purposes.

Based on these data, in agreement with the Agenzia Sisma 2012, it was decided to analyse the macro-sample of the 25 damaged theatres.

The MIC form crital iuss will be dealt with in detail in the chapter under ch. 4 para 4.1.1.

CHAPTER 4: Forth part: Integrated Methodology

<u>Abstract</u>

The integrated workflow of surveying and damage documentation procedures was developed starting from the systematisation of data and metadata archived by the Emilia-Romagna Region Reconstruction Agency. In this sense, the behavioural analysis was conducted methodologically to correctly analyse the correlations between the architectural structure in its articulated planimetric and altimetric configuration and the structural units and the damages found related to the macro-elements.
The critical comparative analysis was organised on two overlapping information levels. The first step concerns the study of the data and information reported in the MiC - earthquake cards, sent by the Reconstruction Agency, compiled in the immediate emergency phase to survey the cultural heritage damaged by the earthquake. The forms are classified into Model A- DC (churches) and Model B-DP (palaces). As their primary objective, they identify the damage index for the disbursement of the first economic contributions to preserve damaged property. In addition, they are the basis for documentation, representation and specific diagnostic analysis of the damage by the professionals in charge of the restoration and conservation project. The second level, on the other hand, studies the data coming from the relevant R.U.P. and related to the specialised investigations carried out by the multidisciplinary teams of professionals in charge of the conservation of each historic theatre.

Cover image - chapter 4 - The case study of the Reggiolo Theater is analysed in the application of comparative methodology. Editing by M. Suppa

4.1 The extensive integrated methodoly developed

In recent decades, the conservation of cultural heritage has been a priority for both the scientific community and public administrations. However, the awareness that the historical-architectural gift is often strongly compromised by risk conditions that highlight its fragility declares the need to adopt and apply monitoring and preventive management actions by public bodies and private actors responsible for its conservation. Furthermore, in ensuring the monumental heritage is protected, is indispensable the recording and documentation of all stratigraphic changes that the monument has suffered during its life cycle. Therefore, it is a multidisciplinary and multi-criteria process by which its material and immaterial attributes can be surveyed, interpreted and represented.
Knowing an element of cultural heritage implies knowing its history, geometric shape, material and techno-constructive aspects, structure, state of conservation, and a series of factors related to the external environment in which it is located.
Therefore, the integrated documentation becomes a necessary tool to guide the complexity of the decision-making process and, thus, management in conservation, directing the actions aimed at the recovery and restoration project. The application of the integrated methodology makes it possible to connect and systematise the multiple intrinsic and extrinsic relationships of cultural heritage, recognising and prioritising the levels of protection, outlining the strategic planning and the timely delivery of management resources. In this context, integrated digital systems are essential because they support the documentation, analysis and interpretation of cultural heritage and valuable management tools if they allow and support the exchange and dissemination of data. Regarding the survey and consequent seismic risk assessment, the awareness of a partial loss or destruction of historical-architectural elements necessitates the use of the integrated approach, methods and tools that allow the development and use of integrated and implementable digital databases containing primary sources of information.
The choice of priorities for interventions on monumental historic buildings, even more so if subjected to risk factors, requires a standardised multi-criteria assessment capable of hierarchising buildings to their inspection, diagnosis and intervention priorities.
Thus, the research employs the integrated approach and tools to implement a specific integrated workflow of the integrated procedure for the seismic damage survey for the historic theatres of the Emilia-Romagna Region.
The aim is to provide a fundamental tool to the regional administration to prepare recommendation devices and methodological and practical strategies for integrated documentation to be declined on the typological variety of monuments of the regional territory. In achieving this goal, the integrated workflow-theatres presents a structure that meets the existing European standards and directives, owning the principles of the charters and international conventions developed over time. [1]
Starting from the Charter of Athena of 1931 and then with the Venice Charter of 1964 on the international level, the preparation of documents dealing with the conservation of cultural heritage began. In particular, the Charter represents the primary international document on the subject, through which monuments and historical sites are defined as those with

1 Le carte del restauro by Camillo Boito (1883). - The Papers of Athens (1931-1933). - The first Italian Charter of Restoration (1932). - Il convegno di Gubbio, o Carta di Gubbio (1960) e la Carta di Venezia (1964). - The second Italian Charter of Restoration (1972) and the Charter of 1987 (objects of Art and Culture). - The European Charter of Architectural Heritage (Council of Europe) and the definition of "Integrated Conservation" (Amsterdam Declaration, 1975). - The Washington Charter or International Charter for the Safeguarding of Historic Cities (1987). - The Map of Machu Picchu for the protection of the historical-monumental heritage (1977). - From the Carta dei Giardini Storici, or "Carta di Firenze" (1981), to the Carta italiana dei Giardini storici (1983). - The Krakow Charter (2000) or the "Principles for the conservation and restoration of the built heritage" - The restoration and the national laws for the protection (from 1909 to 1939; from the Constitutional Charter to the T.U. of 1999 then code of Cultural Heritage and Landscape (2004); to the Landscape Charter ( ) taken from the 2000 European Convention. - «Code of Cultural Heritage and Landscape» (Legislative Decree no. 42/2004)

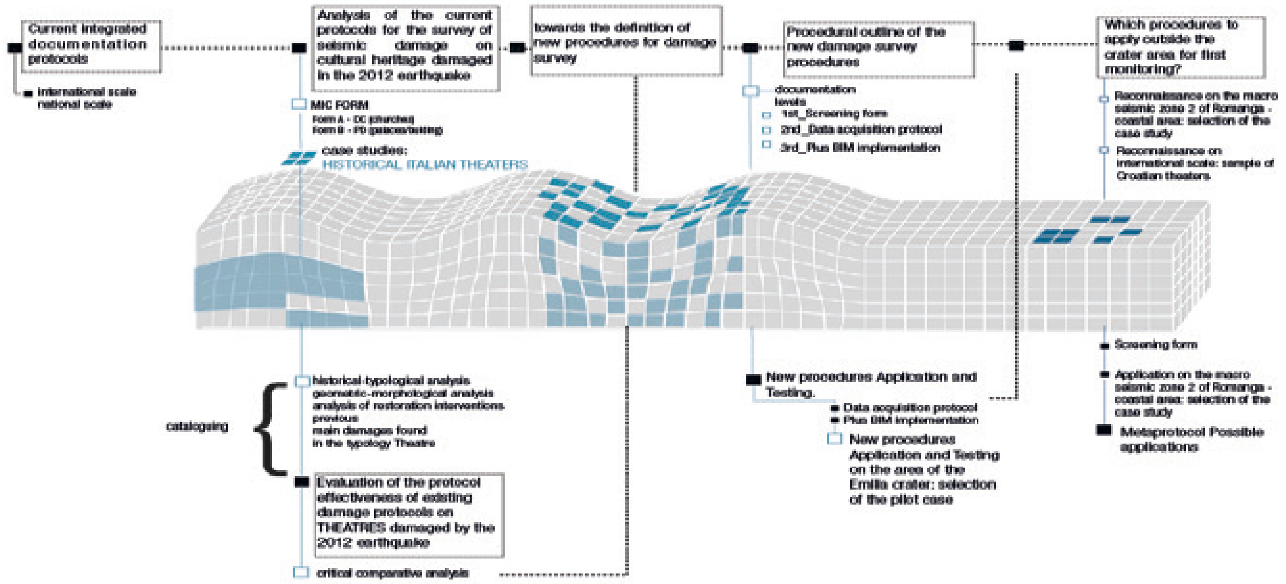


Fig.37 - extensive methodology diagram: The chart schematically shows the application of the integrated documentation methodology applied to theatres damaged by the 2012 earthquake. This methodology will be extended to theatres outside the crater, particularly the case study of the Masini Theater in Faenza. Developed by M.Suppa

historical, archaeological or aesthetic value (Venice Charter 1964, art. 9[2] and 11[3]). It also represents the first document introducing preventive conservation because it is integrated into urban and regional planning, as explained later by the Amsterdam Declaration in 1975. This framework document is followed by the ICOMOS documents relating to gardens, while the Lausanne Charter of 1990 focuses on the archaeological heritage of archaeologists. The Council of Europe Convention, adopted in Florence in 2000, for the first time dealt with the theme of the cultural landscape. In this prospectus, it is also worth mentioning the Faro Convention adopted by the Council of Europe in 2005, according to which heritage is defined as one of the fundamental human rights capable of favouring and guaranteeing the cooperation of the whole community. During the first decade of the 2000s, several recommendations focused on aspects of cultural heritage such as industrial heritage [ICOMOS, Paris 2011], historic cities and urban areas, places of cultural interest. This variety of charters and recommendations demonstrates the evolution of the concept of cultural heritage over time. It underlines the increased awareness that communities have developed towards the protection, conservation and sustainable management of the heritage. The current application of information technology and digitisation has highlighted the need to redefine the preservation strategies for cultural heritage, incorporating both tangible and intangible significances. Using codified and valid standards on a European

2 Art. 9 The process of restoration is a highly specialised operation. It aims to preserve and reveal the aesthetic and historical value of the monument and is based on respect for original material and authentic documents. It must stop at the point where conjecture begins. Any extra work that is indispensable must be distinct from the architectural composition and must bear a contemporary stamp. The restoration, in any case, must be preceded and followed by an archaeological and historical study of the monument.

3 Art.11 The valid contributions of all periods to the building of a monument must be respected since the unity of style is not the aim of a restoration. When a building includes the superimposed work of different periods, the revealing of the underlying state can only be justified in exceptional circumstances and when what is removed is of little interest and the material which is brought to light is of great historical, archaeological or aesthetic value and its state of preservation good enough to justify the action. Evaluation of the importance of the elements involved and the decision on what may be destroyed cannot rest solely on the individual in charge of the work.

scale is necessary to establish common guidelines to ensure homogeneous and coherent documentation and management of cultural heritage.
Among the central EC policies and directives applicable to the protection and management of cultural heritage related to the documentation and management of cultural heritage, the CEN/TC 346 standard of the European Committee for Standardization (CEN), a body that prepares European standards and technical specifications, should be considered.
The CEN/TC 346 standard concerns the "Conservation of cultural heritage - Survey of the conditions of real estate assets" represents a guideline for a sharing and standardised procedure to investigate the condition of the built heritage. The TECHNICAL COMMITTEE CEN/TC 346 aims to develop a European standard by providing Guidance on the data and information to be recorded, examined, documented and classified.[Fassina 2015].
Documentation is understood as surveying, identifying, protecting, interpreting, and representing an essential tool for the knowledge, awareness, and conservation of cultural heritage.
To this end, the systematic and hierarchical recording of information and data such as geolocation, the stratigraphic history of the asset, its architectural-constructive and structural characteristics, the state of conservation are indispensable. In particular, the seismic damage assessment, which is the research topic, is essential to document the asset's seismic history and the alterations due to other risk factors. Moreover, it's important to note the restoration and consolidation interventions carried out during the asset's life cycle.
Applying different methodologies and digital instruments in the thematic field of integrated documentation plays an important role. Their integration allows for variable and exhaustive outputs necessary for the predictive, non-invasive analysis of the damage survey and the state of conservation. In the context of cultural heritage at risk, integrated documentation and up-to-date digital technologies are indispensable for comprehensive cultural heritage documentation.
It should be emphasised that thanks to digital technologies, which allow for AR and VR content, a greater awareness of citizens for the protection and preservation of artistic, architectural and cultural heritage is developing in recent years. Therefore it is becoming increasingly important to implement "prevention" interventions, which allow architectural complexes of historical and artistic value to "resist" disastrous events and limit as much as possible the damage they may suffer over time in order to preserve their memory and allow reconstruction activities, substantially reducing costs and time [S. Parrinello, 2018].
For decades, cultural heritage conservation has been applying the methodologies and technologies of integrated survey and documentation systems. Based on this consideration, in the particular context of the Emilia-Romagna Region characterised by a medium-high seismic risk, it was deemed necessary to apply an extensive integrated methodology to develop a standardised procedure of conservation, management and mitigation of damage for cultural heritage. In this sense, accepting the proposal of the study sample suggested by the ARRER - the historic theatres - the research path has formulated its methodological framework starting from the definition of 4 WP in the first chapter. This chapter analyses the Wp2 related to the extensive methodology.
Therefore, the proposed extensive methodology will be analysed the 25 historical theatres damaged by the earthquake, for which we proceeded to the comparative critical analysis of the damage forms. Subsequently, 12 theatres have been selected, which constitute the inspection sample to analyse the methods and techniques of survey and representation of the damage used to support the recovery and restoration interventions. At the same time, a survey was performed on a regional scale of which area was more exposed to seismic risk. A study carried out by the Region's Geological Service shows that the coastal area of Romagna has a high level of seismic hazard. Ravenna's municipality is mainly considered moderately dangerous in liquefaction, as are the coastal cities between Lido di Savio and Misano. Instead, the danger level becomes high in Milano Marittima, Cervia, Cesenatico, Bellaria, Gatteo mare and in the area of the port of Rimini. Considering the 106 theatres surveyed on WEBGIS, the research focuses on the Romagna area's theatres between the coastal strip and the Apennine ridge (fig.1).
The same approach was applied on an international scale. The analysis fields focus on

the Croatian area, which was affected by the earthquake in 2020. Some of the historical theatres that present the same morpho-typological organisation on the Croatian national scale were identified. These structures have been located and mapped (fig. 2). However, due to sanitary restrictions caused by Covid Sar 19, these theatres were not surveyed, except for the Split Theater, of which the photographic survey of only the exterior surfaces could be performed. This paragraph presents the mapping of Croatian theatres with a zoom on the photographic documentation of the Theater of Split. This sampling, although incomplete, was included in the research to support the INTERREG project Firespill's tasks, in which ARERR participates in the partnership.
The Interreg Italy-Croatia Firespill project - Fostering Improved Reaction of Crossborder Emergency Services And Prevention Increasing Safety LeveL is funded by the Interreg V-A Italy-Croatia CBC 2014-2020 program, the specific objective 2.2 "Increasing the safety of the area concerning natural and man-made disasters" - the strategic theme 2.2.2 "Oil spills and other marine risks, fires and earthquakes". The project has 15 members RERA Development Agency of the County of Split – lead entity; Abruzzo Region; Consorzio Punto Europa; Dubrovnik-Neretva Region; ATRAC Research Center of the Primorje-Gorsky Region; Zadar County; Marche Region; Region of Istria; Sibenik-Knin County Development Agency; Puglia Region; Emilia-Romagna Region, Friuli-Venezia Giulia Environmental Protection Agency; Veneto Region; County Split – Dalmatia. The decision to present Firespill is due to the Agency for Ricostruzione within the project's partnership, in the governance experience gained in the reconstruction process management following the earthquake of 2012.
From a perspective of cross-border cooperation, the project's main objective is to improve the administrative and governmental bodies' management of emergencies due to natural and artificial disasters.
The main objectives are to increase the safety of the Croatian and Italian Adriatic basin, improve the tools and measures to prevent emergencies, and reduce the exposure of populations to dangerous situations. The risks identified are fires, oil spills and other marine

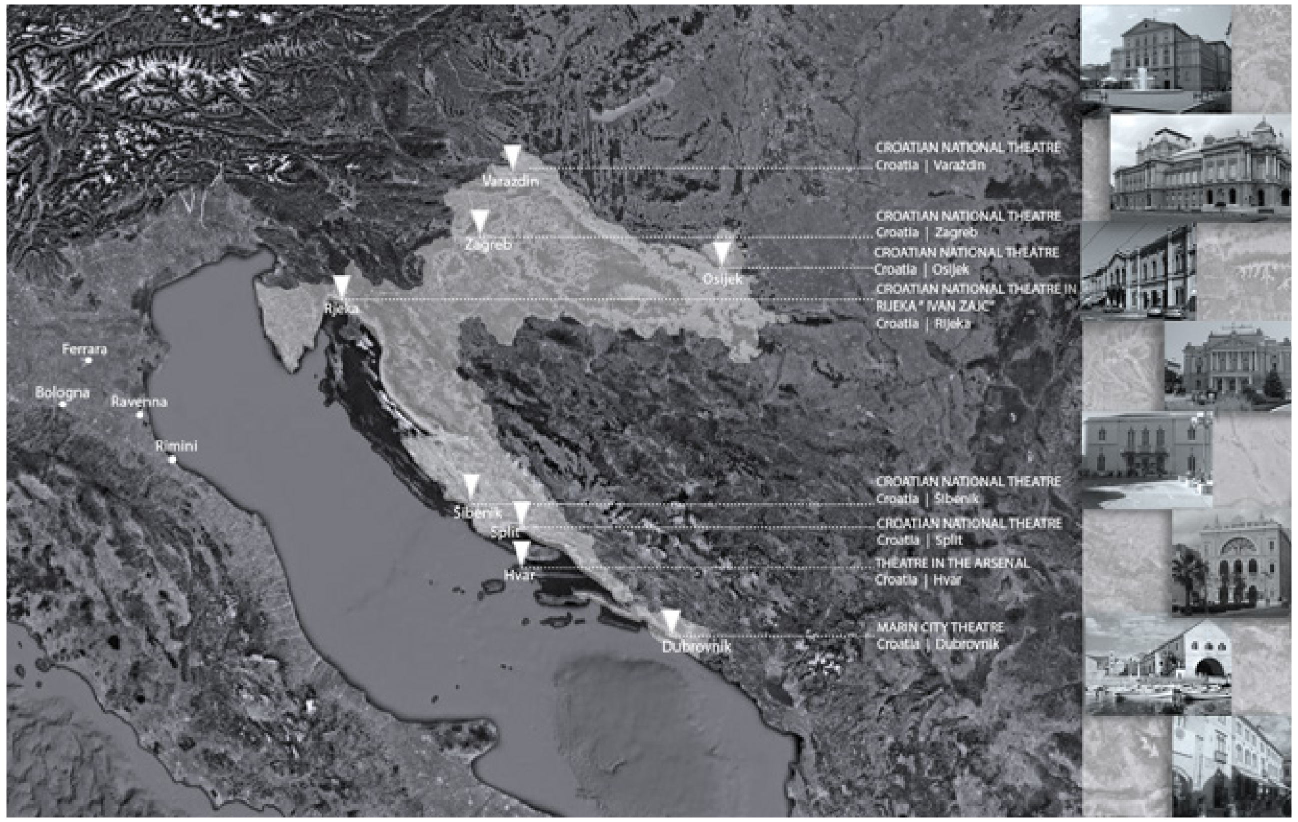


Fig.38 - The Croatian theatres mapping is included in the extensive methodology. Croatian national theatres were selected and remapped into the figure from the Tace database. Developed by M.Suppa

hazards and earthquakes.[4]
The project includes some joint activities that are implemented for each risk examined. The project aims to define a common strategy for disaster management and monitoring, mitigating and reducing natural and cultural heritage impacts. Therefore, the actions envisaged by Firespill are intended to:

1. make improvements to the existing emergency services regulatory system;

2. improve Emergency Management Systems (EMS) in terms of new and innovative solutions;

3. activate the participatory process of citizens. Specific actions are indicated for each main risk, depending on the pilot area chosen. The participatory approach of citizenship will be activated by addressing and altering the role of the population from "vulnerable element" to "active sensor" during dangerous events, to (a) obtain its contribution to the activities of Civil Protection forecasting, prevention of natural and anthropic risks, monitoring and management within its territory of life; (b) educate to correct behaviour, and a thorough knowledge of the problems at risk and (c) reduce the natural and anthropic phenomena that lead to emergencies.

4. improve the operational capabilities of emergency services organisations. The project will provide safety equipment, emergency land and sea vehicles, mobile command and control units, communication systems and the establishment of an advanced training centre. In addition, improvements in the area of governance will be achieved by comparing the civil protection legislation in force in the two countries to identify their level of homogenisation and the topics on which to intervene to improve the system's overall efficiency.[5]

The project lasts two and a half years, [6]in which the partners have the task of cooperating define an intervention common strategy to manage the emergency and, therefore, the achievement of a multi-level governance model through which to intervene to protect the natural heritage and culture in the presence of the different risk situations.
On the regional administrative scale, the Firespill project is part of the Region's Work and Climate Plan to achieve the objectives of the[7] 2030 Agenda,
The role of the Regional Agency in Firespill is to contribute to developing unitary and innovative solutions for coordinated action in the event of a risk situation, transferring the know-how acquired with the experience of risk management and monitoring both in the emergency phase the reconstruction process following the earthquake. In this context, the regional body is supported by the Department of Architecture of the University of Ferrara.[8] 's research activity. In particular, the university's contribution is linked to the themes of innovation and digitalisation aimed at proactively managing the risk caused by the climate emergency, preventive conservation, and enhancing cultural and natural heritage. In fact, for years, the TecneHuB and the DIAPRandM research centre have been engaged in projects in collaboration with the Regional Agency aimed at the documentation and management of cultural heritage at risk through the application of integrated methods and tools of BIM survey and modelling.
As part of Firespill, last October was held in the city of Split, the first presentation of the case

4 https://fondieuropei.regione.emilia-romagna.it

5 https://www.italy-croatia.eu/web/firespill

6 From 1 April 2020 to 31 December 2022

7 Labour and Climate Pact climate work pact signed in December 2020.

8 The University of Ferrara, specifically the Department of Architecture participates in the Regions-University Conference established by Regional Law no. 6 of 2004 and is engaged with the same regional body on POR FSE projects.

studies of the partners belonging to the project, the Emilian regional authority presented the three case studies that will be analysed and developed.
The Agency is responsible for the Task Force for identifying pilot actions to be studied to propose shared solutions in reconstructing the historical and cultural heritage that is the basis of our identity. With the collaboration of the University of Ferrara, the Institution coordinates the working group within Work package 4 of the project [Cocci, Leoni,2021].
The case studies were selected to respond to the different cases of risk situations. For each of them, pilot actions were identified to provide efficient and applicable solutions in case of an emergency. Considering their historical-architectural attributes and the specificity of their natural and urban context, three selected cases study in the 2012 earthquake crater area - Palazzo Schifanoia in Ferrara, Castello Lambertini in Poggio Renatico (FE) and Rocca Possente di Stellata in Bondeno (FE). They represent good examples to describe the actions of prevention, mitigation and management of seismic risk and the impacts that environmental and anthropogenic factors may constitute on the conservation and protection of the existing historical heritage. Once defined the three projects, the ARRER, assisted by the research group of the University of Ferrara, aims to implement the objectives of the Firespill project, sharing and cooperating to develop methodologies and standard practices for the protection and management of emergencies. Furthermore, to transfer the strategic-managerial and scientific experience acquired in the emergency phase and the entire post-earthquake reconstruction process, the Agency's contribution includes training, dissemination and communications actions to the partners of the Firespill project to increase awareness of political and collective realities. on the issues of safeguarding and enhancing the historical, cultural and landscape contexts.
In the specific context of the research and by the extensive methodological approach, the survey of Croatian national theatres was carried out by querying the Tace database (Chapter 2 Section 2.2.3), which maps eight historical structures below in chronological order of foundation:

1) Theater in the Arsenal - 1612 in Hvar

2) Theater in the town of Marin - 1863 in Dubrovnik

3) Croatian National Theater - 1866 in Osijek

4) Croatian National Theater in Šibenik - 1870 in Šibenik

5) Croatian national theatre - 1873 in Varaždin

6) Croatian National Theater "Ivan Zajc" - 1885 in Rijeka (Rijeka)

7) Croatian National Theater - 1893 in Split

8) Croatian National Theater - 1895 in Zagreb

The research work would have included a visual survey of Split, Rijeka and Zagreb theatres in the original objectives. Since these are Italian-style theatres, it was deemed appropriate to include them in the research context to share the methodological approach of analysis and survey on theatre factories with a similar layout to the structures analysed in the regional context of Emilia-Romagna. In this sense, to think about a complete system of theatres, it is essential to transfer the procedure's results during the research to suggest a standard methodology of survey and documentation. The produced considerations shared with ARRER can be transferred within the Firespill project as know-how to be shared for the conservation and proactive management of historic theatres. An example of acquisition for the data theatre by visual inspection and archival reporting sources is provided in Ch. 5 (DS T aplication).
However, due to the Covid Sars 2019 emergency, it was impossible to conduct a *visual survey* of the Split's theatre and prepare an adequate analysis of its state of preservation as the competent authorities did not grant access. Having defined the extensive aspects of the methodological approach, a first critical-analytical level applied to the case study

Fig.38 - views of the principal morphologies of decay present along the exterior facades of the Split Theater. Views 4 and 4.1 show a lesion running along the east fornix located between the stage area and the cavea Developed by M.Suppa

is presented in the next paragraph. The results of the critical-comparative analysis have been the starting point for the definition of the workflow of the integrated procedures for the detection of seismic damage to historic theatres (ch.5)

4.1.1 Comparative analysis: MIC form "theatre"

In the Italian context, which presents a medium-high seismic risk, the survey and analysis of seismic vulnerability represent a crucial aspect in protecting the Italian cultural heritage. Different models have been proposed in this binomial between protection and safety to quantify seismic damage (risk analysis) and earthquake emergency management [Giovanazzi and Lagomarsino, 2001]. Currently, the analysis procedures can be classified into two types: a first level that relates building types and vulnerability classes through the probabilistic approach; a second level that considers individual buildings' information through a semiotic approach [Corsanego and Petrini 1994]. Through the two methods, it is possible to obtain statistics on the distribution of damage once the level of seismicity has been defined. However, the results obtained are insufficient in mitigating and preventing damage. Therefore, in the context of the protected assets "Reconstruction" of the Emilian "crater", the digital survey approaches, methods, and tools are to be considered necessary tools to map and, consequently, monitor the state of the art of the regional heritage.
The analyses conducted, following the Emilian earthquake, on strategic buildings reveal that the masonry structures of historic buildings do not meet the levels of seismic safety identified in the legislation for new buildings. The interventions for the adaptation of these buildings represent a considerable economic burden. Therefore, it is necessary to draw up a list of priorities capable of distributing and investing the available financial resources. To this end, therefore, it is needed to optimise and implement the analysis of seismic vulnerability for strategic assets, which cannot be limited to the typological approach alone. The elaboration of a new expeditious procedure for surveying the damage of historical assets requires a high LoD within which must be included surveys on the building, the distinctive historical-architectural characteristics, the specificities of the construction systems and materials.
In the context of the issues relating to the relief of damage, a circular letter from the Ministry for Cultural and Environmental Heritage no. 1032 of 18 July 1986 and the Ministerial Decree of 19 January 1996 "Technical standards for constructions in seismic areas". The two acts underlined the importance of the relief as a preliminary phase to the restoration. This aspect is then taken up by the Ordinance 3274 of 2006, which introduces the context of "knowledge level". Depending on the type of analysis, three levels of knowledge are defined:

- LC1 Limited Knowledge (includes a geometric survey, limited in situ investigations and verifications.);
- LC2: Adequate knowledge (geometric surveys, extensive and exhaustive in situ checks are carried out on the construction details and extensive in situ investigations on the properties of the materials);
- LC3: Accurate Knowledge (the geometric survey, the investigations are extensive and exhaustive; however, the investigations are not comprehensive, but exhaustive.)

The knowledge levels are therefore defined by the geometric attributes,, the geometric characteristics of the structural elements,
quantity and arrangement of reinforcements (reinforced concrete), connections (steel), relationships between different structural elements,
consistency of collaborating non-structural elements, materials, mechanical properties of materials. Furthermore, the ordinance identifies two survey methods: summary and complete, relative to the historical built masonry buildings. The first method includes the survey of the main structural elements resistant to cuts, floor by floor, of the masonry vaults and a sample estimate of the trend and stiffness of the slabs. The second, instead, includes the complete survey of all the masonry elements, the vaults and their typology survey, the slabs performance, an accurate assessment of their stiffness and an evaluation of the loads imposed on each wall element. These prescriptions are then confused in the 2008 Technical

Standards, which reiterate the importance of supporting seismic vulnerability assessment through specific documentation methodologies for adequate knowledge of the building.
The assessment and reduction of seismic risk at the national level are regulated by the 2011 Directive, which establishes a monitoring program of the state of conservation of buildings, regarding the status of expeditious assessment envisaged – LV1 – by the NTC 2008, which returns a final value on safety to plan costs and interventions. The Directive also indicates different models for the analysis of structural behaviour and on the intervention criteria for consolidation expressed to the three levels of seismic vulnerability assessment: LV1 for a large-scale expeditious assessment with the collection of quantitative information and simplified mechanical models; LV2 for a vulnerability assessment related to the macroelements of the building, limited to local consolidation interventions: LV3 to a detailed evaluation on the overall scale of the building.
Within the legislation are specified the methods for the determination of the seismic risk class.
"The document defines eight Risk Classes, with increasing risk from letter A+ to letter G. The determination of the class to which a building belongs can be conducted according to two alternative methods, one conventional and the other simplified, the latter with a limited scope of application. The traditional method is applicable to all types of constructions. It is founded on the standard analysis methods foreseen by the Technical Norms that allow the construction Risk Class evaluation in the actual state and the state following the possible intervention.[9] Therefore, the class to which a building belongs can be determined according to two alternative methods: conventional and simplified.
The simplified method is based on a macroseismic classification of the building. It is indicated for a prompt assessment of the Risk Class of masonry buildings only. It can be used for a preliminary indicative evaluation and to evaluate the risk class to adopt local interventions.
The standard tends to consider the vulnerability assessment on a global scale. This aspect constitutes a limitation for the evaluation on a worldwide scale. In historical buildings, the direct experience shows an absence of connections between structural elements, particularly for types characterised by plug walls or planimetric and altimetric irregularities [Coisson 2014]. The specific case of theatres, which have spaces with different heights, underground surfaces distributed non-homogeneous, levels of floors at different heights, such as mezzanines - always represent a crucial problem, making the structure particularly sensitive to local collapse mechanisms.
A holistic and multidisciplinary vision, typical of the integrated approach, was the basis of the construction of the methodological system of the research because it was able to document and represent the specific meanings of cultural heritage and, in this particular case, of the Emilian historical theatres affected by the earthquake of May 2012. The integrated methodological system has made it possible to decode, interpret and have a preliminary representation of the specific grammatical characteristics of the "Theatre" typology: geometry, metric-dimensional values, morphology, constructive, material and restoration stratigraphy carried out over time and the structural macro-units that characterise its behaviour under seismic action. Identifying these factors has a decisive influence on determining the classification matrix of the characteristic elements within the analysed architectural space. It was possible to start an accurate analysis of the survey of seismic damage. Therefore, the application of the integrated method focused, in the first place, on the comparative analysis of the data collected by the post-seismic reconstruction procedures: from the Mibact forms (A-DC churches, B-DP buildings), used in the emergency phase for the *visual survey* of damage to identify the damage index and provide the first economic contributions for the safety of damaged assets, analysis and technical reports, elaborated by multidisciplinary teams of experts responsible for the restoration and conservation project. Some weaknesses in the current procedures for the survey of seismic damage for the "Theatre" typology have been highlighted by applying the critical analysis - comparative between the Mibact forms and data from subsequent inspections of professionals, elaborated for design purposes. These critical issues are due to using Form B's adaptive survey form.

9 *DM_65_del_07-03-2017_All_A.*

Form B is not developed on the spatial and structural characteristics of the historic theatre. Therefore, the 'application has generated a gap in the analysis and assessment of actual damage to the theatres. Form B, sometimes integrated with the churches of form A, detects a faulty reading under the distinctive aspects, quantitative and qualitative, of a theatre activated by the seismic action. The only qualitative information contained concerns the empirical parameters to classify the level of damage:

- Injured: slight to medium damage to the structure. The damage corresponds to lesions on the wall surfaces or very limited collapses - the collapse of architectural and decorative elements or limited wall portions.
- severely damaged: severe damage to the structure. The damage corresponds to widespread lesions on wall surfaces or limited collapses - the collapse of architectural and decorative elements or limited wall portions.
- Partially collapsed: damage of medium/high severity. Collapses of portions of masonry and part of the roofs, involving one or more macrostructures within a height corresponding to 1/3 of the entire structure of the building.
- Collapsed: collapse or severe damage to multiple macrostructures of the building, significant and widespread collapses are affecting different parts of the building for a higher altitude.

Information is insufficient because it is linked exclusively to the assessment of damage on a global scale and not linked to qualitative data such as the geometric-spatial conformation, the technological and structural system, the mechanical and physical characteristics of the materials, the architectural stratifications, the urban context and finally the data relating to the previous interventions performed. Nevertheless, the transformation stratigraphy represents an essential factor in assessing the seismic vulnerability in the comparative investigation performed at the expert investigations conducted by the teams of professionals in charge of the recovery and restoration project of the theatres. For example, the Municipal Theatre of Ferrara's cracking framework has been characterised by a considerable complexity, both for the construction characteristics of the monumental complex, which has undergone several reconstructions and restorations over the years.
To elaborate the workflow of the integrated procedure for the survey of seismic damage, those coming from all post-seismic interventions (from damage forms to specialised technical investigations) have been first analytically discretised and then hierarchised and systematised in macro-categories and subcategories to arrive at an integrated digitised metaprotocol, which had the aim of implementing the planned forms in use. Furthermore, the comparative critical analysis has identified homogeneous analytical investigation criteria and set them for complex architectural typologies such as theatres. This approach has allowed, on the one hand, a quick but exhaustive discretisation of all the valuable information for a coherent reading of the damage in the emergency phase and, on the other, the identification of an analytical process capable of supporting the subsequent steps for the development of workflow of the integrated procedure to manage the post-earthquake conservation project and preventive maintenance.
It has been articulated on two overlapping levels of information, focusing on comparative critical analysis. The first level involves the analysis of data and data reported in the Mic-earthquake forms, sent by the Agency for reconstruction, compiled in the immediate emergency phase to census the cultural heritage damaged by the earthquake. The forms are classified into two specific types: Model A-DC (churches) and Model B-DP (buildings). Their primary objectives are to identify the damage index for granting the first economic contributions to protect damaged goods. In addition, they represent the basis for documentation, representation and specific diagnostic analysis of the damage by the professionals in charge of the restoration and conservation project. On the other hand, the second level analyses the data from the competent RUP and related to the specialised investigations carried out by multidisciplinary groups of professionals in charge of conserving each historical theatre. As a result, the comparative methodological framework had to consider first the macro-sample of damaged theatres - 25 surveyed through the Mic forms - and then detail an inspection sample of 12

theatres selected by the Agency for Reconstruction that the RUP has made available their databases (fig. 3).
Some of the fields which constituted a critical qualitative information element in the present filing system's adaptive application to the theatrical typology are described below.
First of all, the B2 (fig.4) and B8 (fig.5) compilation fields; in both records, through the entries of single and complex assets, we acquire information on the structural configuration of the catalogued support in the context to which it belongs. The analysis shows that the two elements are often interpreted not univocally, which implies a reading of the theatrical building in the urban context that does not correspond to the area in which it is glued. This aspect impacts the assessment of seismic vulnerability.

Another critical aspects are noted to the field related to the "regularity" of the building (B17). Form B identifies the theatre as a regular building in its planimetric and altimetric aspects about internal and external configuration. Since the form was prepared for the seismic survey of a historic building, it does not consider the articulated altimetric-spatial organisation of a theatre (fig 6;7). Therefore, this aspect has impacted the correct reading of the morpho-typological space, reporting information that does not conform to the *morpho-typological* characteristics of theatres. However, the acquired data is interpreted and returned excessively generic and simplified. Volumes A and D (foyer, utility spaces) are confined spaces characterised by planimetric and altimetric regularity. Spaces B and C (hall and stage) are open and "free "volumes with different altimetric levels. In addition, the node of the proscenium arc is absent in the B filing, widely used, while instead, it assumes an essential role in the local and then global kinematic behaviour of the structure. It is no coincidence that all the damaged theatres have found a severe cracking picture corresponding to the proscenium arch. In fact, Being placed in an interstitial position between the two empty volumes of the hall and the stage and in direct contact with the pushing roofing system under the seismic action, several local kinematics were activated, which led to the partial collapse, cutting, and cutting breaks of the beam and overturning of the plane. The stairwells that connect the free volumes of the stalls with the box volumes of the forebody and the service block represent one of the most critical nodes in the overall behaviour of the structure under seismic action. In correspondence with them, there are lesions due to the effect of hammering.
The *morpho-typological analysis* has shown that the theatre presents elevation variations, sometimes significant, concerning the different functional-spatial conformations. This group of variables influences the seismic response of the macro-elements, belonging to the specific four individual microstructural units, determining the consequent deformation and cracking framework on a global scale.
It has been observed that the general regularity described in the form prevents a correct and coherent assessment of the seismic damage. Therefore, this field would make sense if the individual morphological-structural units consider their planimetric and altimetric variation and the specific structural characteristics of the macroelements that compose them. Defined then a clear hierarchy of structural units, also contemplating the hinge nodes, the damage assessment would be expressed more coherently because it should be expressed first on a local scale and then associated with the global scale.
The analysis of field B17 was followed by field 19 concerning identifying the materials of the structural construction system and the corresponding level of damage. The generic structuring of the record is insufficient to provide quantitative and qualitative information of the individual structural elements. For example, the information related to the load-bearing masonry is related only to the material composition: brick for all the theatre halls analysed. Sometimes the presence of concrete is recorded, information that is not directly connected to the structural unit and its macro element is lost in the analysis of the actual damage. In addition, there is a lack of data on the type of wall texture and mortars and their composition. Factors are essential in analysing and evaluating kinematics activated under seismic action. The quality control of materials and construction structures is necessary to minimise structural defects and improve the effectiveness of conservation and protection interventions. The characterisation of building materials includes all the required information identifying the structural and non-structural materials used in the building [Kioussi,2012].

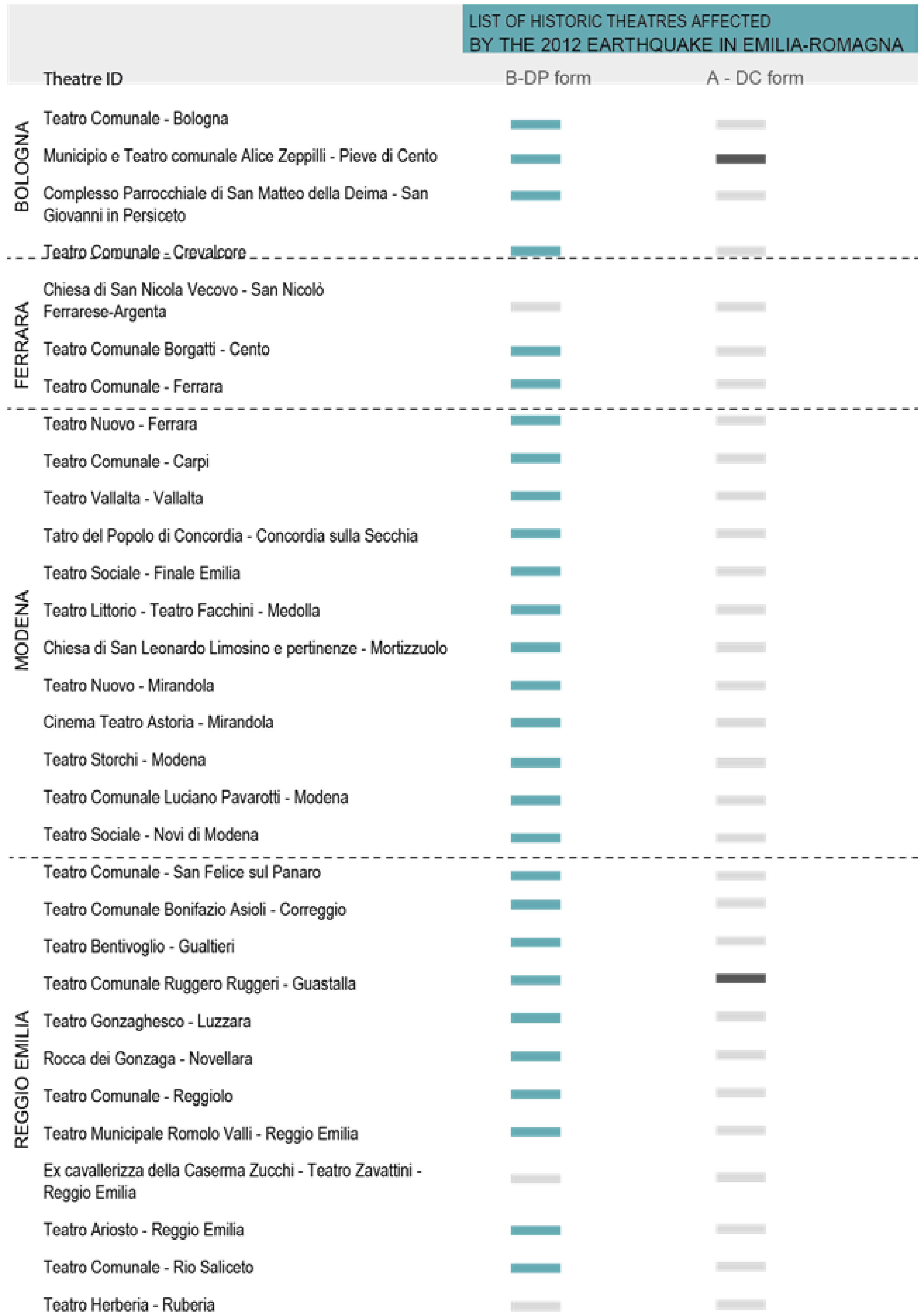


Fig. 39 The diagram shows the types of M.I.C. forms used during the 2012 earthquake emergency for the seismic damage survey of theatres. However, as can be seen, most theatres were surveyed through the B-DP form, except for two buildings where the damage survey was integrated with the A-DC form. Developed by M.Suppa

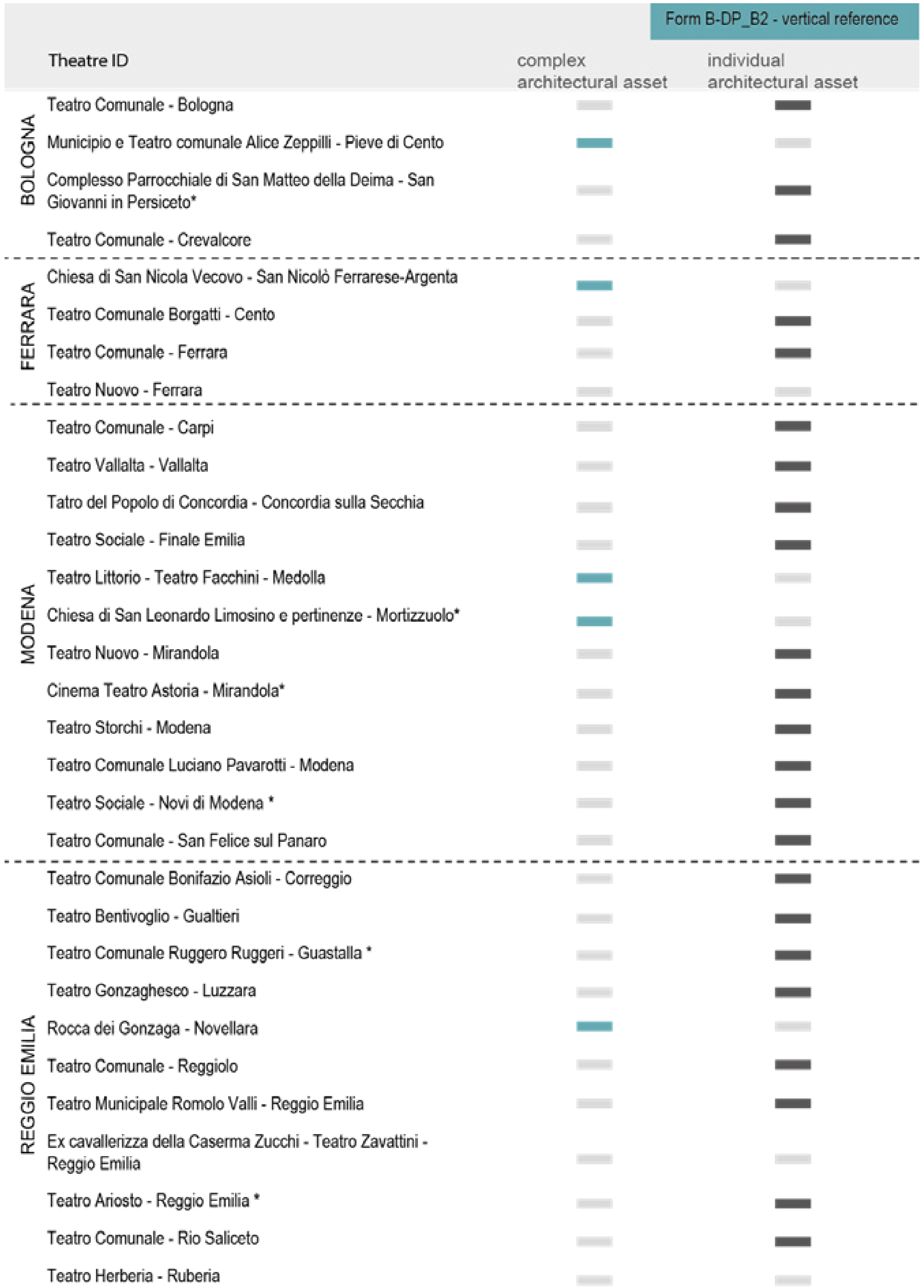


Fig. 40. The chart highlights the consistency of the asset of the surrounding urban context. In particular, the theatre is undivided support or aggregated with other buildings. (B – D.P.; record B2) Developed by M.Suppa

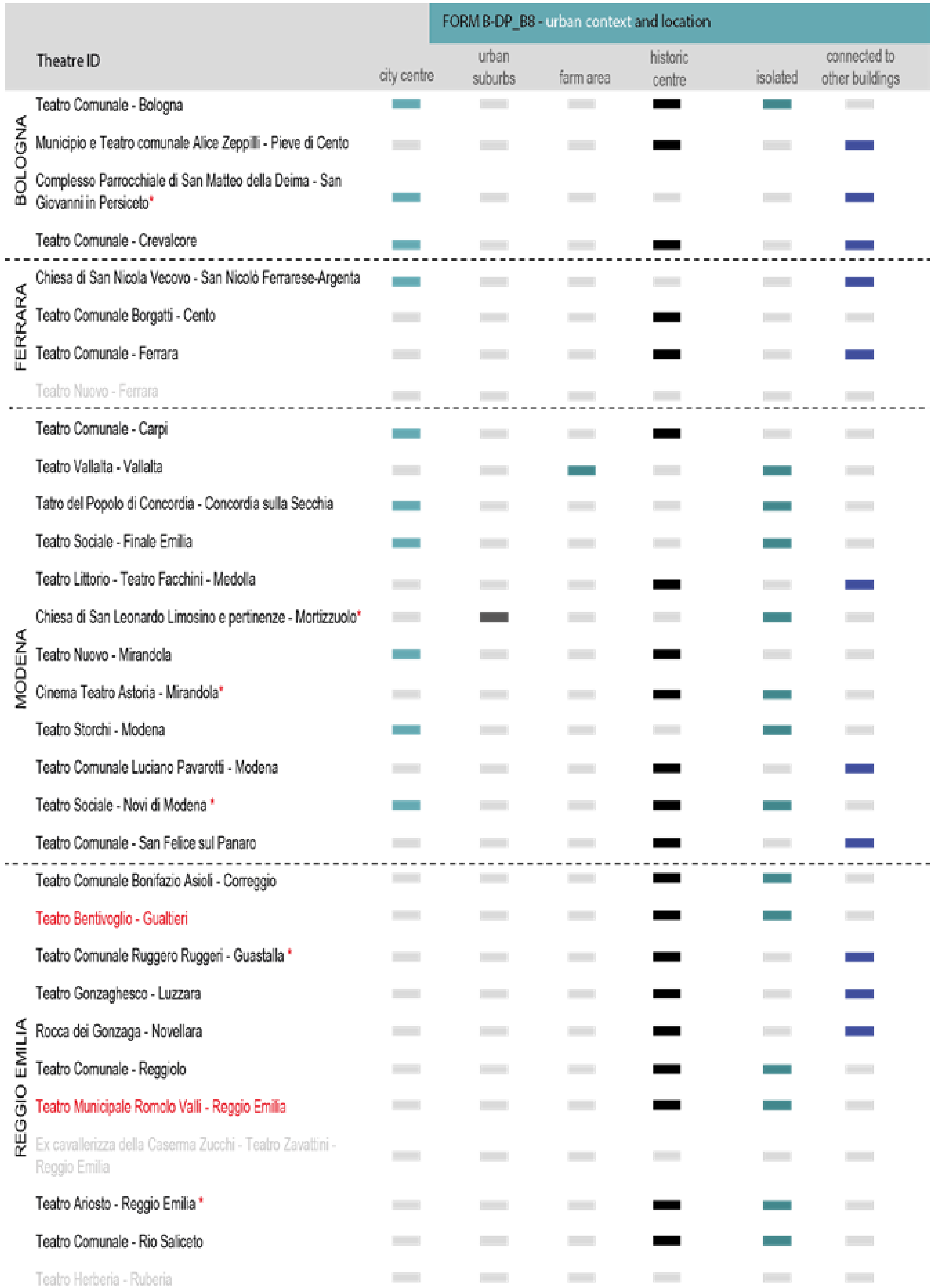


Fig. 41 The chart illustrates the theatre's location in the urban context. (B – D.P.; record B8). Developed by M.Suppa

Fig.42; 43 The diagram analyses the regularity in the elevated plane of theatres (B – D.P.; record B17). Developed by M.Suppa

Fig.42; 43 The diagram analyses the regularity in the elevated plane of theatres (B – D.P.; record B17). Developed by M.Suppa

Therefore, surveying the type of materials (fig. 8), their origin, physical and mechanical properties, composition, and processing parameters are helpful information for analysing the structure and its performance both under normal load conditions and about the kinematics induced by seismic action.
The same happens in the roofing systems, which are given general information about the construction material and whether it is a pusher structure. However, there is a lack of data regarding the typology and the specific dimensional aspects of the constructing system. The form considers only the surface. There is a lack of data regarding the covered span and the typology and dimension of the single elements that make up the constructing system. Aspects through integrated survey tools can be easily known and appropriately classified. The result is a framework of incomplete and fragmented information referred to a macro scale of damage survey linked to the evaluation of the damage index expressed on a global scale of the building. These considerations should be added that they are recorded without a clear hierarchisation when presenting detailed information. Still, the more critical aspect is the absence of a reference immediately connected to the form of the macro-elements. Relatives, horizons, stairs or roofs) are identifiable by an alphanumeric code relating to a primary schematic scatch set on-site. While supporting the investigation phase, preliminary sketches do not allow the correct recording of qualitative and stratigraphic information. The forms often examined some information deduced from the *visual inspection* (material characterisation, conditions of the good, elements of consolidation) inserted in the form of descriptive notes then not associated with the damage estimate.
The *visual procedure*, as defined, above all for complex typologies, such as theatres, while recognising its usefulness in the first post-earthquake reconnaissance. However, it is not comprehensive for the assessment phase of the actual damage suffered nor for the first phase of management of the safety worksites. It does not allow a linear, hierarchical and optimised reading of the helpful information to survey and verify the actual damage recorded. Closely connected to the B17 and B19 fields is the B23 related to the collapse mechanisms activated by the earthquake.
As formulated, the collapse mechanisms are indicated on a global scale and then referred to the individual macro-elements to show the damage index, relevant factors and interpretation of the damage (fig.9). Therefore, the simplification of the models fails to return a realistic quantification of the actual capabilities of the structure. Comparing the data derived from the forms with the professional analytical reports and diagnostic investigations shows a *visual survey*. The data and information collected following a subjective and oversimplified approach, an aspect even more evident in the optimised models of the MiC forms, where the collapse mechanisms are grouped into families concerning which the damage and vulnerability factors have globally expressed a percentage. Taking into consideration form B for the buildings,, to which the theatres,
for the most part, have been identified in the expeditious survey, the structural behaviour is not identifiable and interpretable with the identification of global mechanisms (called second way) but through local collapses (of the first way) and possible overturning of walls not effectively connected [Giuffré, 1991]. Therefore, considering the spatial elevation development with the crack pattern of the theatres, it can be said that Shape B is unable to support an adequate level of knowledge for the damage analysis of the specific type analysed. Therefore, it was necessary to evaluate the prediction of an ad hoc form capable of describing the particular attributes (dimensions, materials and state of preservation, etc.) to estimate a consistent damage index. Finally, the comparative analysis found a lack of information on the historical and evolutionary stratigraphy and any restoration work carried out over time, resulting in a lack of knowledge for documenting the asset and analysing the damage. Therefore, although the visual investigation is a fundamental step for the preliminary assessment of the health status of the asset after the catastrophic event, it must be supported by a helpful tool to provide quantitative and qualitative information. They allow exhaustive preliminary documentation of the typological, material and dimensional characteristics, historical, technical, constructive and structural of the theatre and correlate them to the damage that occurred. These considerations arising from the critical analytical process highlighted the need to apply an integrated approach to the specific typology of

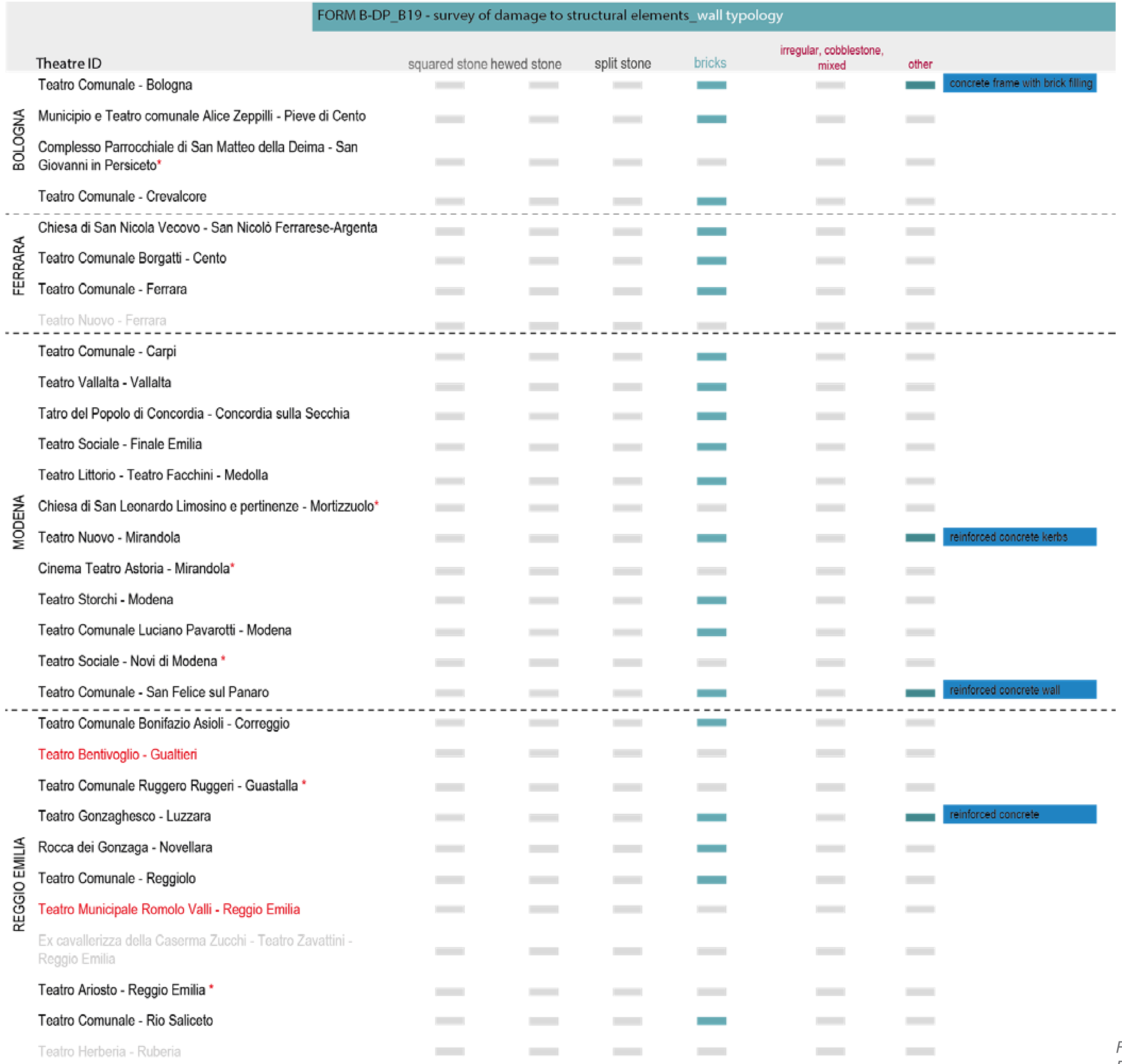


Fig. 44 The chart shows the survey of construction materials (B – D.P.; record B19). Developed by M.Suppa

MACROELEMENTS

EXTERNAL WALLS
- M1 wall tilting
- M2 vertical instability of walls
- M3 bending breakage of walls
- M4 overturning of the cantonal
- M5 cut in external walls:load-bearing wall
- M6 cutting in the interior walls: lintel and masonry on top

INTERNAL WALLS
- M7 cutting in the interior walls

GLOBAL
- M8* floor sliding

ARCADES AND LOGGIAS
- M9 damage to arcade / loggias

HORIZONTAL ELEMENTS
- M10 beam head extension and / or hammering
- M11 local collapses of the ceiling or deck
- M12 damage to the vaults by tax rotation
- M13 damage at times due to plane deformations

STAIRS
- M14 staircase damage

ROOFING
- M15 damage in the roofing elements
- M16 damage to the roofing covering
- M17 tilting of the attic and tympanum bands

JUTTING / SOARING ELEMENTS
- M18 Damage to projecting / soaring elements

LOCAL COLLAPSES
- M19 local collapses due to construction and material irregularities

INTERACTIONS
- M20 damage due to shape irregularities
- M21 damage to the attached bodies
- M22* Foundations' subsidence

OTHER
- M23
- M24

* (optimised form)
some mechanisms have been grouped together. The damages are expressed with a percetual formula

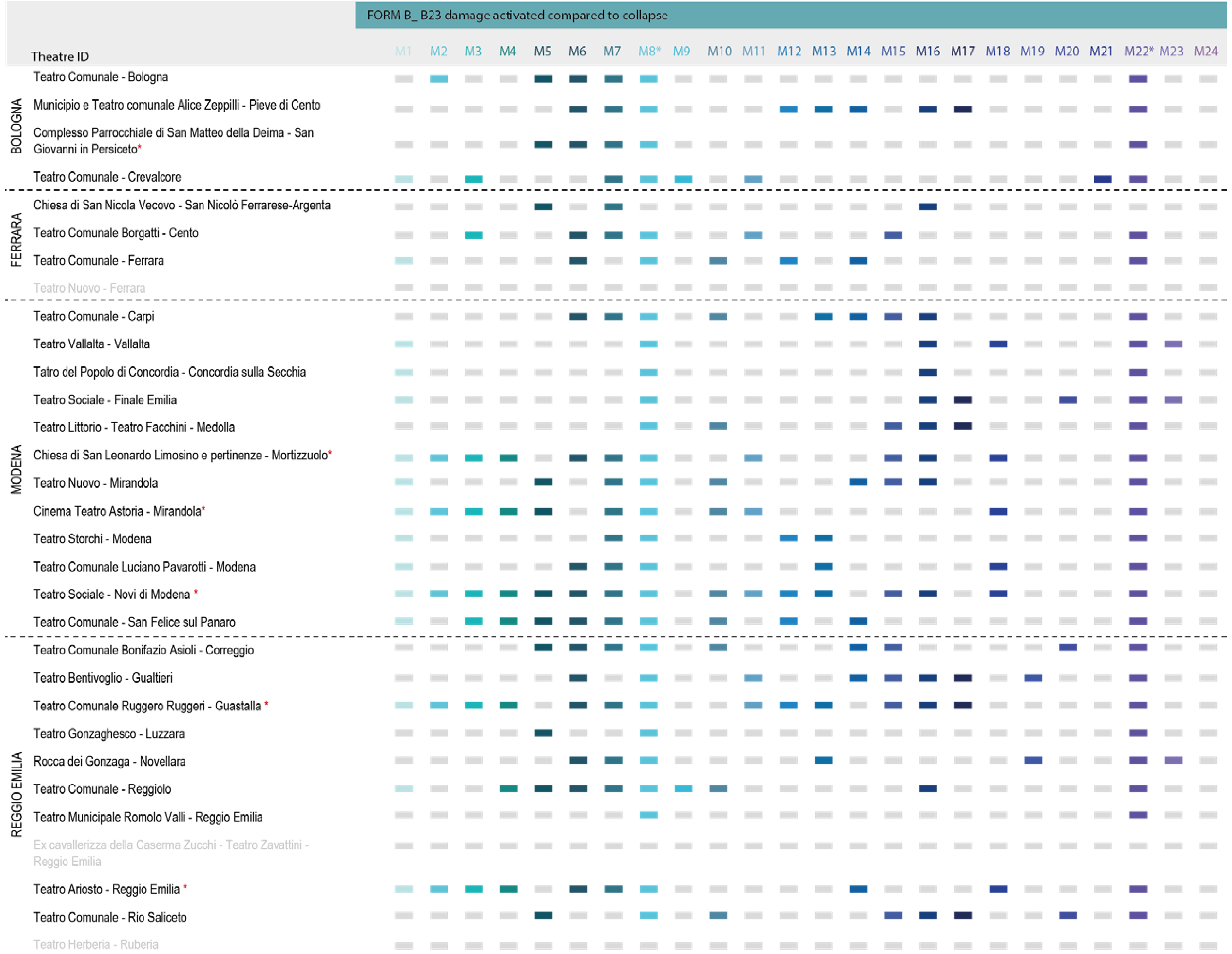
M1+ M2 + M3 + M4 first mode mechanisms - external walls

M5+ M7 breaking in the plane of the wall males

M6+ M7 breaking of the floor strips

M11+ M12 + M13 damage to the vault

Fig. 45 The diagram shows the main collapse mechanisms activated during the 2012 earthquake that affected the damage to theatres. (B – D.P.; record B23). Developed by M.Suppa



historical theatres to arrive at a coherent investigation and evaluation of seismic damage and, therefore, documentation of the theatres.

<u>4.1.2 Comparative analysis: the inspection sample</u>

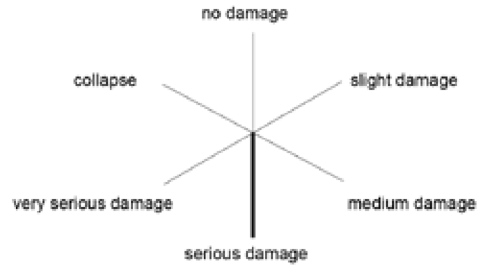
The second level of critical-comparative analysis is the study of the methods, tools and techniques for the damage survey used by the professionals for the conservation and restoration project of damaged theatres. This analytical phase involved a sample of investigation restricted to 12 damaged theatres, selected by the Agency for Reconstruction, for which documentation was requested from the RUP of competence access to historical-technical documentation. The RUP of the respective municipalities in which the halls are located provided the historical reports, the damage survey, the photographic documentation of the damage, the specialised diagnostic investigations drawn up to define the state of the damage, based on which they then set the choices and design actions.
Surveying and documenting the altimetric-spatial, stratigraphic-constructive variables of the theatres connected to the verified or verifiable seismic damage presupposes a correct acquisition of the specificities of the building, which must be interpreted about seismic vulnerability. In this perspective, both specific direct investigations and the methods of representation that must describe and read the historical and technical attributes of the monument are indispensable. The DPCM 2011 provides for the drafting of [10] “thematic tables”. The data useful for objectively evaluating the levels of knowledge and confidence factors recalled by the standard are represented [Galli 2015]. Based on the prescriptions above, detailed investigations are required on the walls and macroelements that must be returned graphically, obtaining a synthetic, analytical synoptic framework of support and responding to the behaviour models consistent with the object examined.
Therefore, the thematic tables must contain graphic elaborations such as transversal and longitudinal sections through which it is possible to read the connections between orthogonal walls and floors. Therefore, the survey of the building must be performed according to different levels of investigation according to standardised criteria. So it is that actions of anti-seismic intervention can be defined respecting the structural, physical-mechanical characteristics of building materials and the historical-architectural significance of the building. The DPCM also has specifications on the survey and analysis of degradation, which must be carried out by applying appropriate documentation and representation techniques and high survey accuracy. The diagnostic survey must also represent the activated mechanisms and consequent cracking and deformation frameworks (para 4.1.1).
The inspection sample of the historical theaters on which it waspossible to carry out this analysisincludes: the Municipal Theater of Ferrara; The Teatro Nuovo di Mirandola, The Teatro del Popolo di Concordia; the Storchi Theatre and the L. Pavarotti Municipal Theatre of Modena; The Bentivoglio Theatre in Gualtieri; Teatro Comunale G. Rinaldi of Reggiolo, Teatro Comunale of San Felice sul Panaro; Teatro del Popolo di Vallalta,the Teatro Borgatti di Cento and the Teatro Sociale di Novi di Modena (pilot case of research for the development of PiDS-T (Protointegrated neck of seismic damage –Theaters).
Four main categories of surveying targets for each theatre of the inspection sample have been identified. The comparative data are recorded: a) level of overall damage, b) methods and techniques for a metric and geometric survey, c) methods and techniques for a diagnostic survey, d) methods of damage representation (fig.10; 11, 12; 13).
From the comparative information it can be deduced that the halls examined report a medium or high level of damage such as the theaters of Modena and Reggio Emilia such as the Teatro Nuovo di Mirandola, the Municipal Theaters of San Felice sul Panaro, the Teatro di Reggiolo and the Teatro Sociale di Novi di Modena. Confirming that the regional geographical area is a narrow strip of the Modena plain, depressed from a geological point of view and called “Bassa”, between the rivers Secchia to the west and Panaro to the east. It

10 *Prime Ministerial Decree of 9 February 2011 - Assessment and reduction of the seismic risk of cultural heritage with reference to the technical standards for construction referred to in the Ministerial Decree of 14 January 2008*

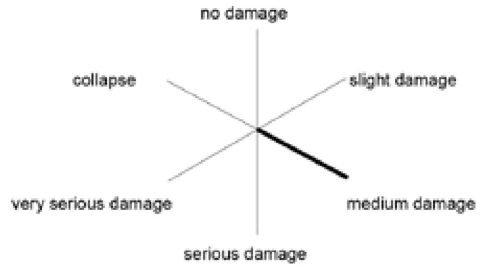
Global DAMAGE Level

Teatro Comunale in Ferrara (Fe)
Intervention phase: completed

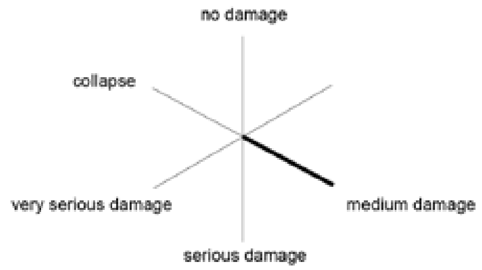
Teatro Borgatti in Cento (Fe)
Intervention phase: executive phase



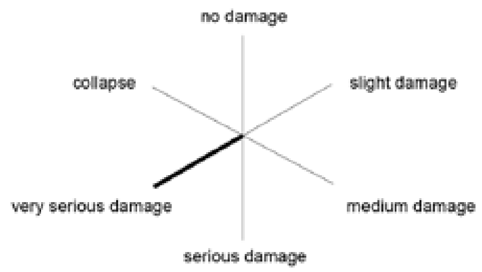
Teatro L- Pavarotti in Modena (Mo)



Teatro Comunaledi Storchi in Modena (Mo)
Intervention phase: completed



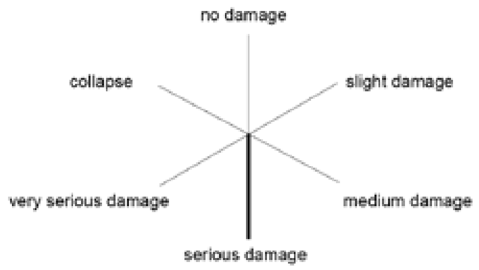
Teatro Nuovo in Mirandola (MO)
ongoing intervention



Global DAMAGE Level

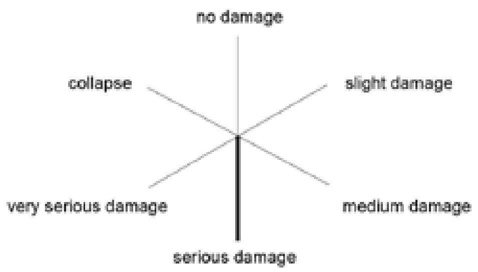
Teatro Comunale in Carpi (Mo)
Intervention phase: completed

Teatro Sociale in Novi (Mo)
Intervention phase: verification of the state of the art

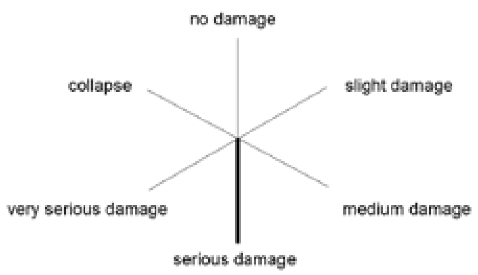


Teatro Comunaledi Facchini in Medolla (Mo)
Intervention phase: completed

Teatro Comunale in San Felice sul Panaro (M0)
ongoing intervention

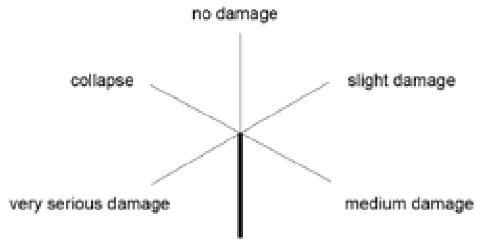


Teatro del Popolo in Corcordia sulla secchia (Mo)
ongoing intervention



Global DAMAGE Level

Teatro Comunale R. Valli in Reggio Emilia (Re)
Intervention phase: completed

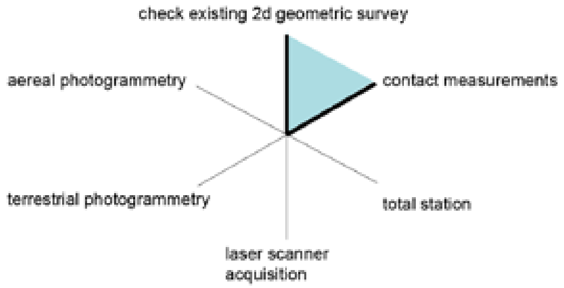


Teatro Comunale Giovanni Rinaldi in Reggiolo (Re)
Intervention phase: completed

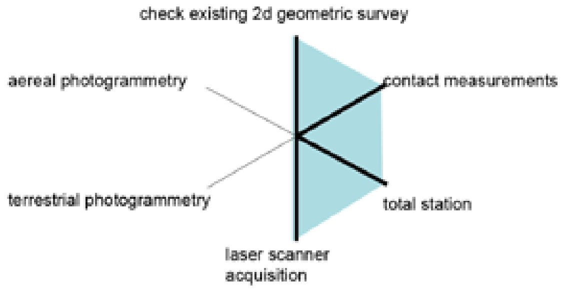
Fig. 46 The diagram shows the theatres examined to have a medium or severe level of damage. The analysis is referred to as the inspective sample. Developed by M.Suppa

Metric and Geometric SURVEY

Teatro Comunale in Ferrara (Fe)
Intervention phase: completed

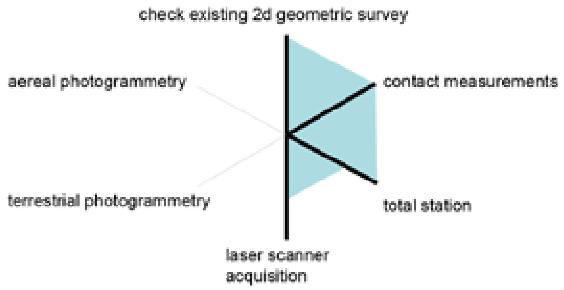


Teatro Borgatti in Cento (Fe)
Intervention phase: executive phase

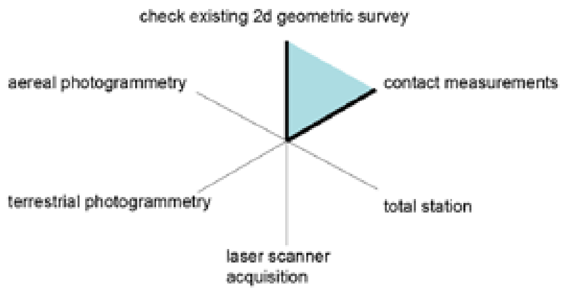


Teatro L- Pavarotti in Modena (Mo)
Intervention phase: completed

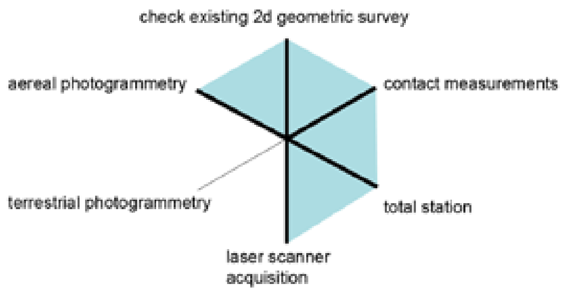
The data refer to the dimensional and geometric survey of the Plafond system.



Teatro Comunaledi Storchi in Modena (Mo)
Intervention phase: completed

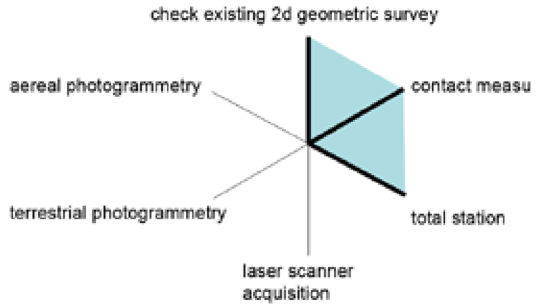


Teatro Nuovo in Mirandola (MO)
ongoing intervention

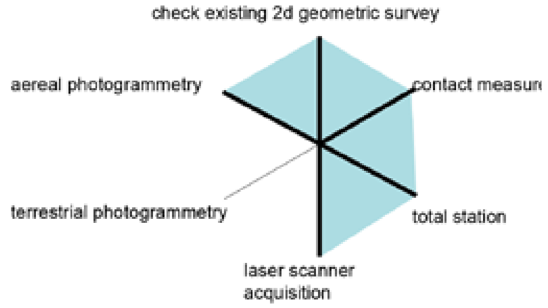


Metric and Geometric SURVEY

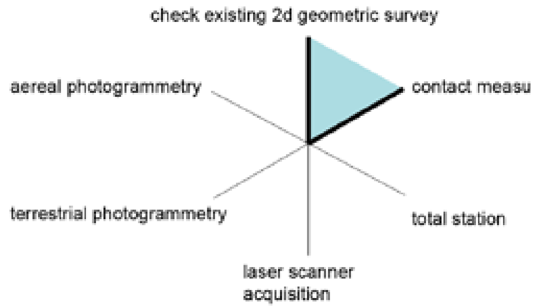
Teatro Comunale in Carpi (Mo)
Intervention phase: completed



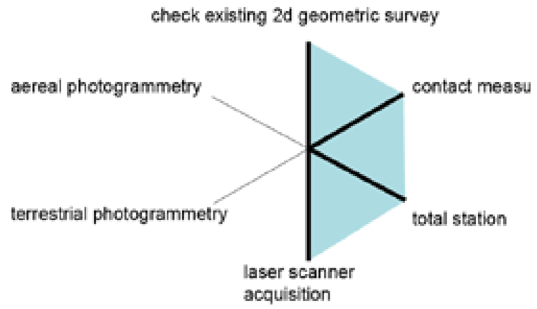
Teatro Sociale in Novi (Mo)
Intervention phase: verification of the state of the art



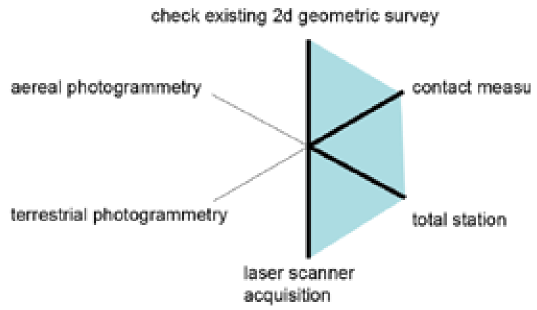
Teatro Comunaledi Facchini in Medolla (Mo)
Intervention phase: completed



Teatro Comunale in San Felice sul Panaro (Mo)
ongoing intervention



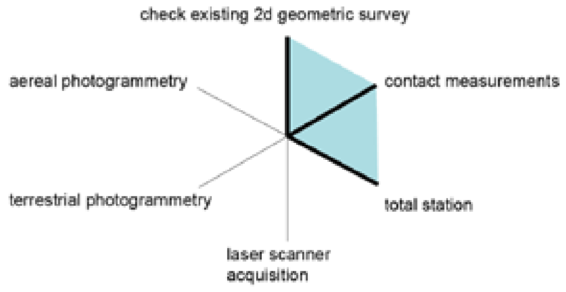
Teatro del Popolo in Corcordia sulla secchia (Mo)
ongoing intervention



Metric and Geometric SURVEY

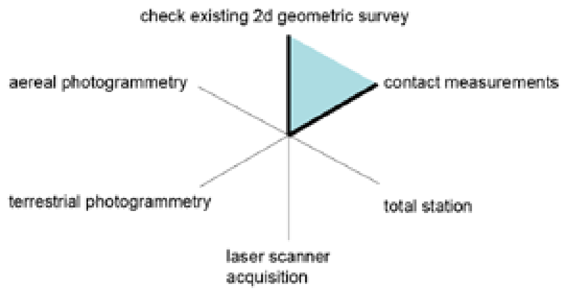
Teatro Comunale R. Valli in Reggio Emilia (Re)

Intervention phase: completed



Teatro Comunale Giovanni Rinaldi in Reggiolo (Re)

Intervention phase: completed



Metric and geometric survey ranks

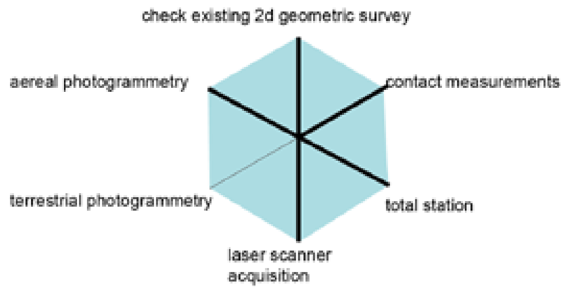
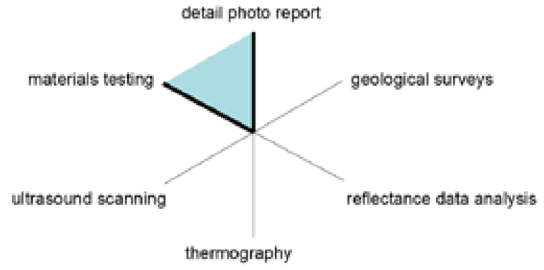


Fig.47 The diagram shows the survey techniques and methods. In most cases, the existing surveys were verified by direct measurement, supporting the implementation of the study with detailed photographic surveys. Only the theatres of Mirandola and Novi di Modena achieved such integration of survey techniques. For the L. Pavarotti Theatre in Modena survey, integrated survey techniques were applied only to analyse the plafond. The investigation is referred to as the inspective sample. Developed by M.Suppa

DIAGNOSTIC SURVEY

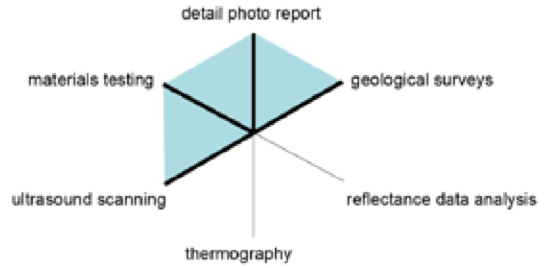
Teatro Comunale in Ferrara (Fe)

Intervention phase: completed



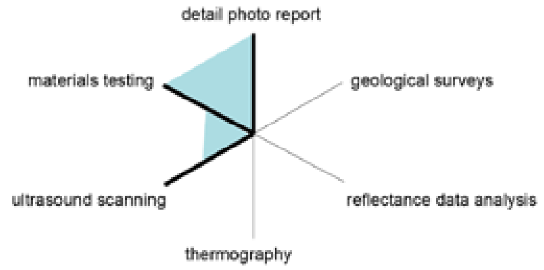
Teatro Borgatti in Cento (Fe)

Intervention phase: executive phase



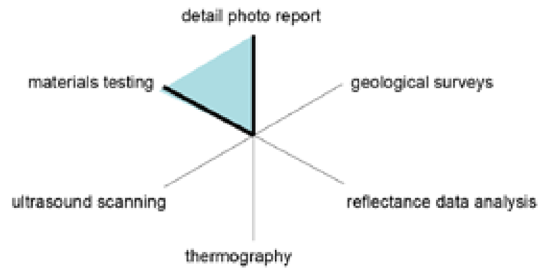
Teatro L- Pavarotti in Modena (Mo)

Intervention phase: completed



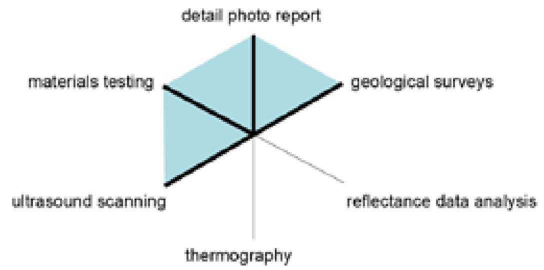
Teatro Comunaledi Storchi in Modena (Mo)

Intervention phase: completed



Teatro Nuovo in Mirandola (MO)

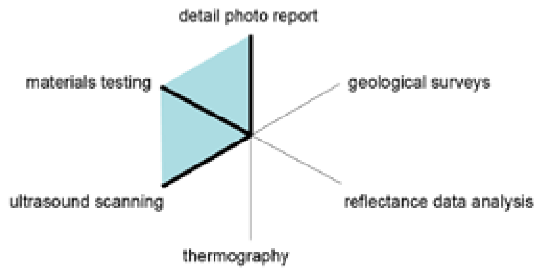
ongoing intervention



DIAGNOSTIC SURVEY

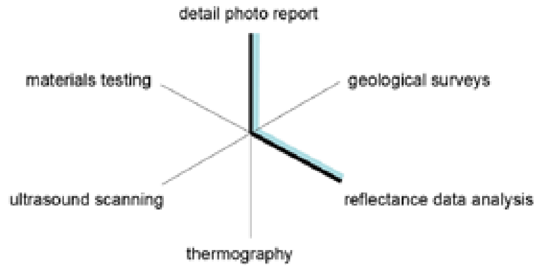
Teatro Comunale in Carpi (Mo)

Intervention phase: completed



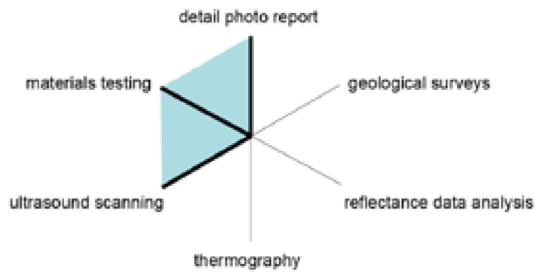
Teatro Sociale in Novi (Mo)

Intervention phase: verification of the state of the art



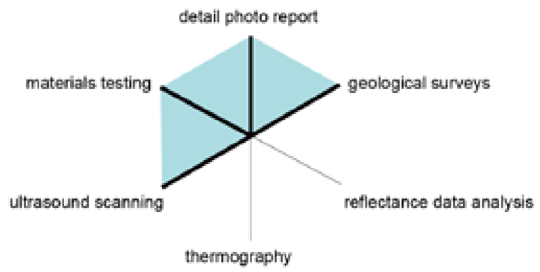
Teatro Comunaledi Facchini in Medolla (Mo)

Intervention phase: completed



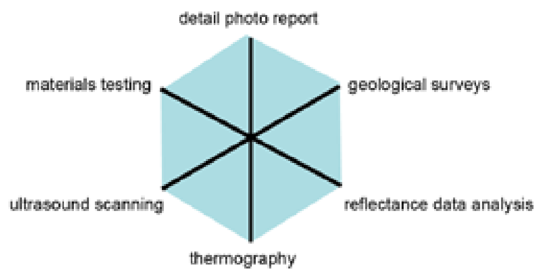
Teatro Comunale in San Felice sul Panaro (Mo)

ongoing intervention



Teatro del Popolo in Corcordia sulla secchia (Mo)

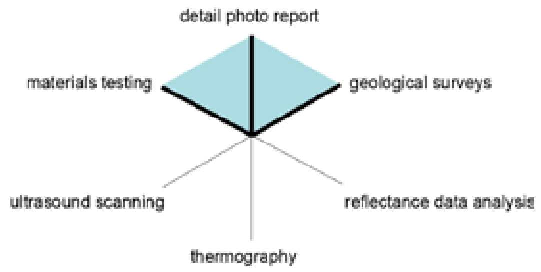
ongoing intervention



DIAGNOSTIC SURVEY

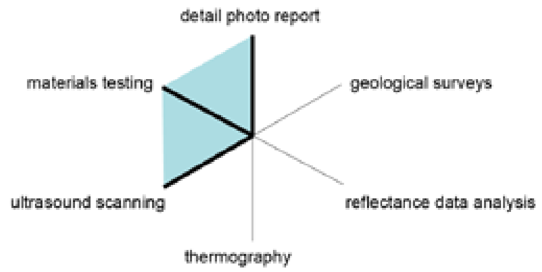
Teatro Comunale R. Valli in Reggio Emilia (Re)

Intervention phase: completed



Teatro Comunale Giovanni Rinaldi in Reggiolo (Re)

Intervention phase: completed



Diagnistic survey ranks

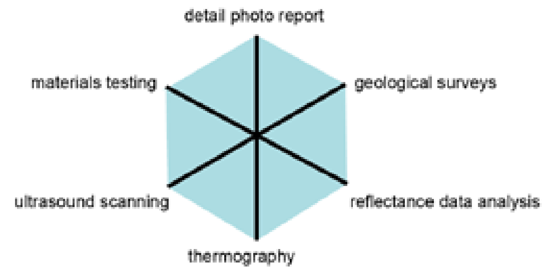
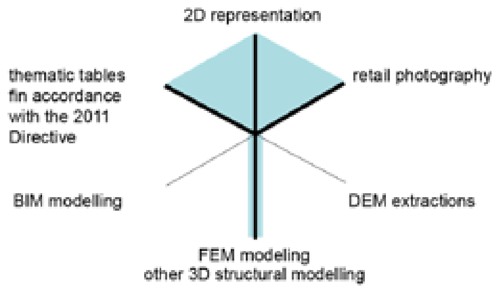


Fig.48. For almost the entire sample, it can be stated that tests on materials, ultrasonic investigations and geological surveys were carried out. Only the Teatro del Popolo in Concordia achieved all the ranks of diagnostic analysis. While for the L. Pavarotti Theatre in Modena, the data is realistic as some investigations were carried out only on the plafond system. The study is referred to as the inspective sample. While for the Novi Modena Theater, the data refer to the interrogation of the reflectance data on the point cloud, as technical investigations are still in progress. Developed by M.Suppa

REPRESENTATION

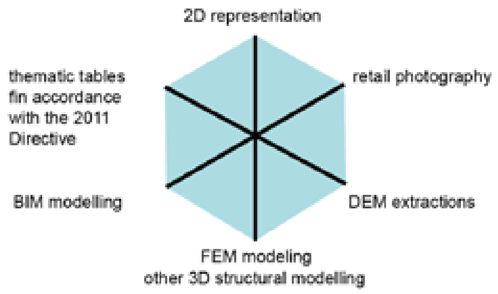
Teatro Comunale in Ferrara (Fe)

Intervention phase: completed



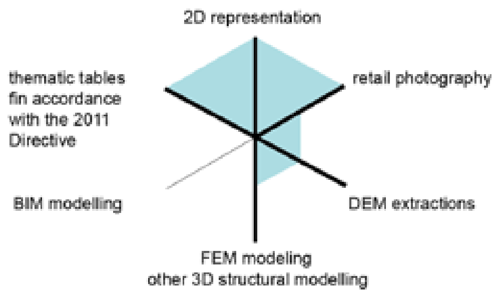
Teatro Borgatti in Cento (Fe)

Intervention phase: executive phase



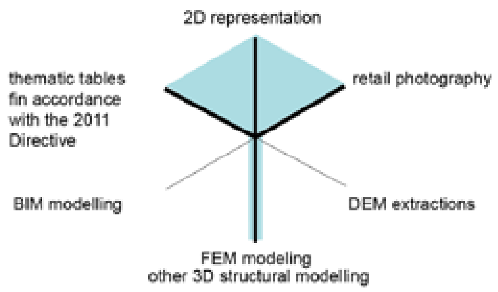
Teatro L- Pavarotti in Modena (Mo)

Intervention phase: completed



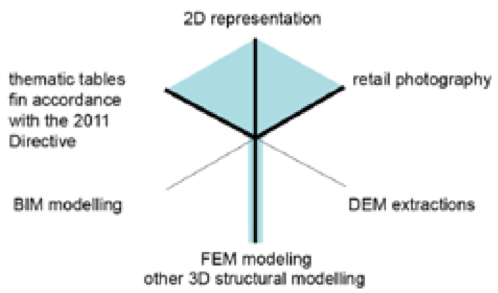
Teatro Comunaledi Storchi in Modena (Mo)

Intervention phase: completed



Teatro Nuovo in Mirandola (MO)

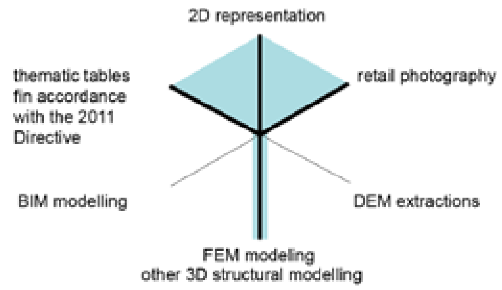
ongoing intervention



REPRESENTATION

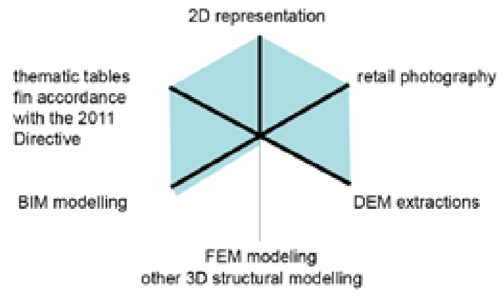
Teatro Comunale in Carpi (Mo)

Intervention phase: completed



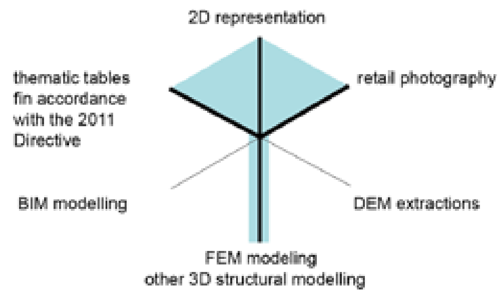
Teatro Sociale in Novi (Mo)

Intervention phase: verification of the state of the art



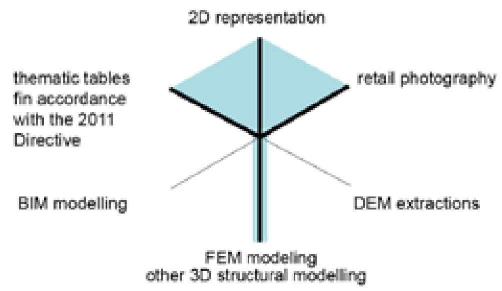
Teatro Comunaledi Facchini in Medolla (Mo)

Intervention phase: completed



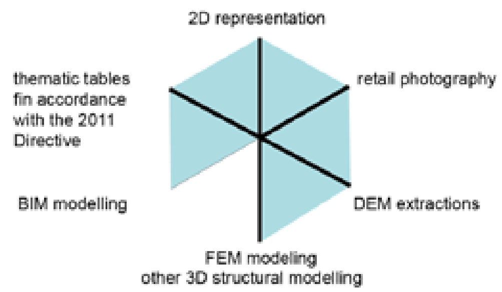
Teatro Comunale in San Felice sul Panaro (Mo)

ongoing intervention



Teatro del Popolo in Corcordia sulla secchia (Mo)

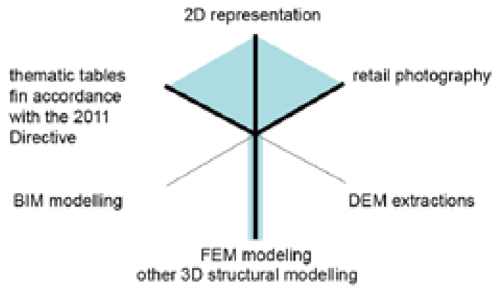
ongoing intervention



REPRESENTATION

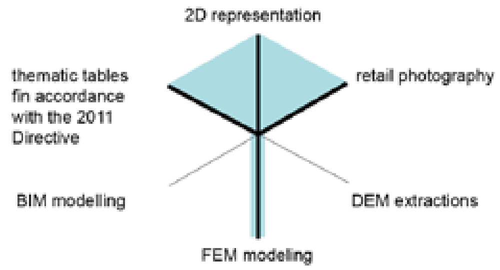
Teatro Comunale R. Valli in Reggio Emilia (Re)

Intervention phase: completed



Teatro Comunale Giovanni Rinaldi in Reggiolo (Re)

Intervention phase: completed



Representation ranks

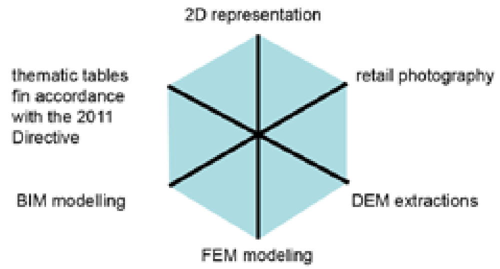


Fig.49 The diagram shows the theatres in the sample performed 2D representations with annexed photographic documentation and elaboration of the thematic tables foreseen by the 2011 regulations and 3D models for verifying the static nature of the buildings. For the Theatre of Novi and the Theatre G. Borgatti in Cento, Bim models have been elaborated to implement HMIB to analyse, document, and program the theatres. Therefore, the Borgatti Theatre is the only case in which the performance rank has been achieved in its entirety. On the other hand, the analysis results for the L. Pavarotti Municipal Theatre of Modena are partial since the static model was elaborated only for the plafond. Therefore, the analysis is referred to as the inspective sample. Developed by M.Suppa

occupies a portion of the triangular territory in which there are the major centres of Mirandola, Carpi, Finale Emilia, San Felice sul Panaro, Medolla, Concordia sulla Secchia and San Prospero [Brunetti 2016]

Concerning the second aspect, most of the metric and geometric surveys were carried out by verifying the pre-existing surveys using direct survey tools correlated by photographic documentation. The application of digital survey systems have been applied to a residual sample and have sometimes been used for the specific survey of damaged elements. The theatre of Mirandola and the People of Concordia, the Borgatti of Cento and the theatre of Novi was surveyed during the PhD research as a pilot case for verifying ISP SD-T performed with LIDAR technology. In addition to the theatres of Novi and Mirandola, a drone photogrammetric survey was realised for roofing study. The 3D digital models of point clouds, acquired with the high performance of accuracy and precision, have allowed the verification of metric and geometric characteristics of the theatres, misalignments, deformations. In fact, through the acquired morpho-metric models, it was possible to analyse out-of-lead and misalignments, it was possible to obtain through specific sections relevant information to determine the cracking picture and the deformations determined by the seismic action. In addition, the point cloud databases were of support for the setting up of diagnostic and structural investigations. In addition, a laser scanner was performed on the ceiling of the L. Pavarotti Theater in Modena, which showed extensive damage due to seismic action. The roof pushes perimetrically and, despite some props placed radially and the consolidation of the truss in the central part of the ceiling, we can see two types of instability: (a) horizontal rotations in the perimeter wall that delimits the shell, the lesions in the ground indicate the room as the wall can not adequately perform the function of containment; (b) widespread fractures in the intrados of the ceiling, with the fall of fragments of plaster and stucco: the phenomenon, associated with the deformation that has made the central part of the ceiling almost flat, denounces the excessive deformability of the wooden truss, despite the excellent state of maintenance of the wood. The deformation was considered physiological and consequent to the phenomena of “fluage” that affected the wood for a long time. Still, the new geometry had induced high states in the transverse wooden ribs.

More information is related to the third target on methods and diagnostic techniques in which are detailed analytical data and parameters of the investigations carried out to determine:

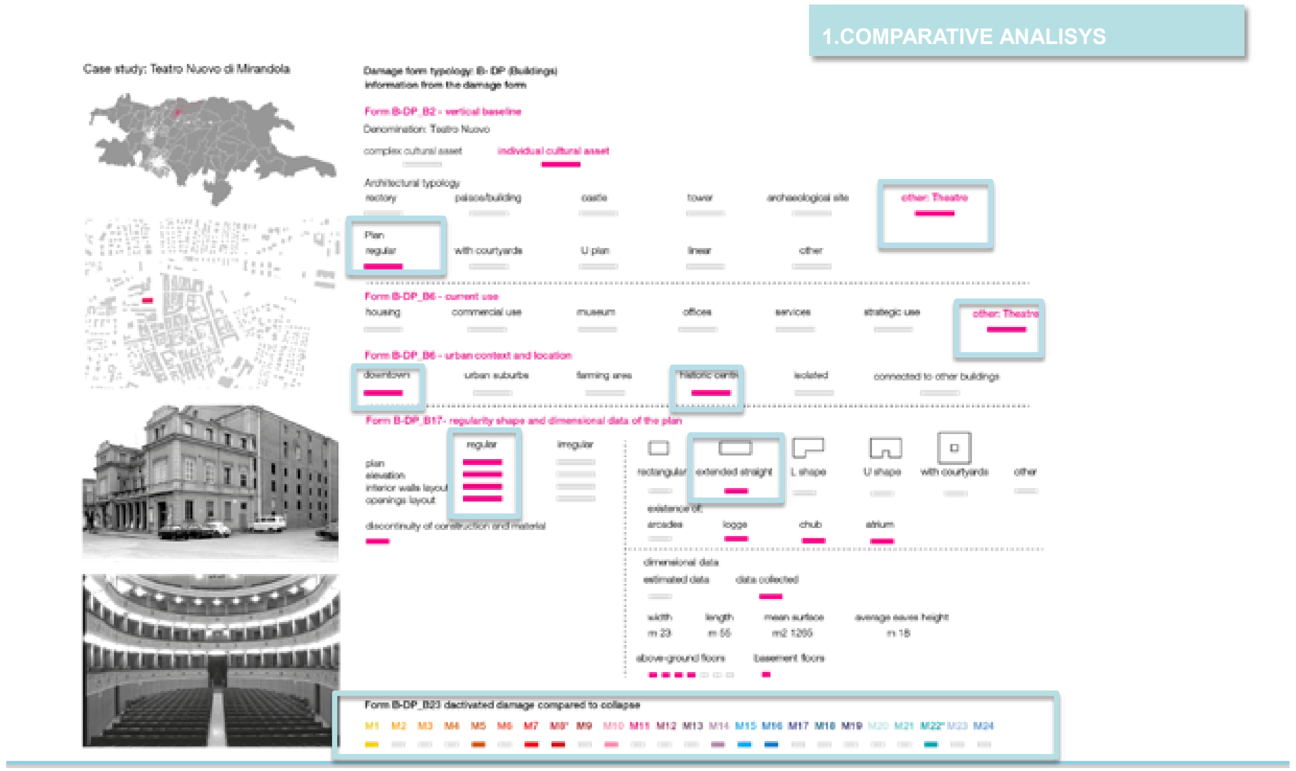


Fig.50 The Overview of the B- D.P. form records analysed in the first investigation phase. The diagram refers to the New Theater in Mirandola. Developed by M.Suppa

the structural characteristics of individual theatres; the survey of cracks; the analysis of structural elements; the study of the material aspects of the walls, the measurement of the state of tension, the identification of the attributes of deformability of the walls, the analysis of the state of degradation of wooden structures and the chemical, physical and petrographic characterisation of bedding mortars. Each professional described the test methodologies used and the results obtained, represented in the thematic tables related to precise photographic documentation. Methodologically the investigations were carried out and divided the theatres into four main macro-blocks: forebody, stalls, stage/ scenic tower, and service block, and then proceeding on different altimetric levels. Geotechnical surveys were carried out for the theatres falling within the epicentre area as the area was affected by soil liquefaction. While For all the theatre's stratigraphic investigations have been carried out on plasters and paintings and resistance tests on masonry using single jacks aimed at evaluating the loads on the wall face examined. Sections investigated with double jacks aimed at determining the elastic modulus E and the average compressive strength FM of the wall. For Teatro di Reggiolo and Teatro di Mirandola these tests have been supported by infrared thermography.Other sample analyses were carried out on the masonry to catalogue the mechanical characterisation of the material and on the mortars. For the theatre of Reggiolo, the mortars were taken to catalogue and define the compositional characteristics; then, they were analysed with an optical microscope in the laboratory. Differently from the Teatro Nuovo of Mirandola, where sclerometric investigations were carried out. Ultrasonic probes were performed on wooden elements. For some theatres, the Teatro di Reggiolo, exploratory essays have been carried out structural units - foundation structure- and macro and concrete factors - the beam of the proscenium arch. For the same theatre, other essays were carried out on the concrete floors of the boxes to verify the type, thickness, weight and type of reinforcement connecting to the walls. Tests on the concrete floors were also carried

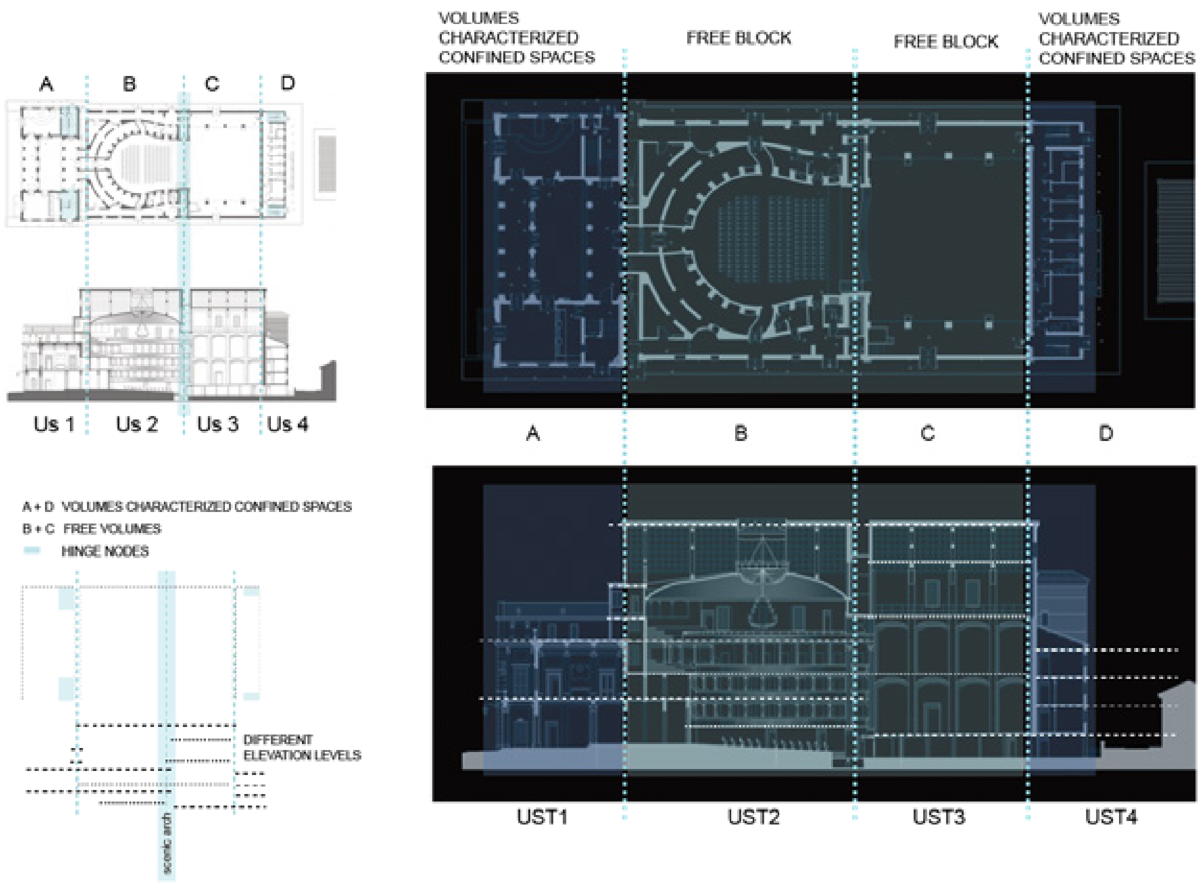


Fig.51 shows the damage reports' study showing how the theatre's volume reading was further reduced, identifying 3/4 volumetric layers. This geometric and volumetric simplification allowed a detailed reading of the damage aimed at site management, structural checks, and plant development. Developed by M.Suppa

out for the Mirandola theatre through direct non-destructive investigations using the parking meter and small tests aimed at identifying the type of steel used and the diameter of the reinforcing iron. For the survey of the degradation morphologies and the cracking framework for all the theatres, related thematic plans were presented for the precise identification of the degradations and instability revealed and photographic tables with detailed sockets. Singular is the photographic documentation submitted for the Teatro Comunale di Ferrara, for which ad hoc forms have been drawn up for the survey of the cracking picture and degradation.
Concerning the last target relating to the representation techniques for all the analysed theatres, 2d works returned in CAD were presented. The structural analysis of the theatres of Mirandola, San Felice Sul Panaro, has been realised with FEM modelling. It has highlighted the significant structural deficiencies and the central tensional and deformative states. While for the Borgatti theatre and the Novi theatre, a BIM model, both architectural and structural, has allowed documenting through non-destructive procedures state of the art related to the damaged framework.
They evaluate these four main categories of surveying targets and compare the results obtained on the case studies belonging to the restricted sample defined a quantitative and qualitative evaluation of the damage survey. Therefore, the integrated methods and investigation techniques allowed to analyse and verify the actual damage, obtaining a complete cognitive and analytical framework for the restoration and conservation project. Furthermore, the results derived from this investigation were used to develop the digital information database of the first level of the procedural workflow - SD T (ch 5. para 5.1.1.).

4.1.3 Results of analysis

In the macro sample, it is possible to observe that most of the theatres have been surveyed using the form B-PD - Palaces (Mibact forms). Instead of in only two cases - the Town Hall and the Theater of Pieve di Cento and the Municipal Theater Ruggiero Ruggeri of Guastalla - the form B has been accompanied by the Form A-DC: Churches.
This finding underscores the absence of a dedicated theatre form that caused the possibility of subjective interpretation by surveyors in both the survey of architectural-structural space and the survey of damage sustained (fig.14). The two models of archiving have been integrated, it was possible to see how applying only one, or the other model was reductive to assess the actual vulnerability. The survey carried out by combining the two forms has made it possible to highlight some of the morphological-structural characteristics of a historic theatre. In short, the forepart and the service block was surveyed with the B form, as it is similar to the building organism. The hall and the stage were investigated using A form. They are morphologically and structurally identical to the church hall. Form B identifies the theatre as a regular building in its planimetric and altimetric organisation. The Form does not consider the articulated altimetric-spatial organisation of a theatre. Therefore, this aspect has affected the correct reading of the morpho-typological space, reporting information that does not conform to the *morpho-typological* characteristics of the theatres. However, the data acquired by the RUPs are interpreted and returned in an excessively generic and simplified way.
In most cases, the experts' analyses, realised for the restoration project, support this approach to optimise damage assessment phases, site management, and preliminary and executive interventions, four distinct structural units have been identified to control and verify the static response of the macro-elements concerning the seismic action: forebody-foyer (A), hall - stalls (B), stage and backdrops (C), dressing room (D)(fig.15). This structural-morphological macro-schematisation shows how the extreme blocks, corresponding to the areas of the square and foyer and the units of the dressing rooms, behaved in a similar way to the structural scheme of a building under seismic action. While the large free volumes of the hall - the stage and the backstage - are schematically in evaluation with the free block of a church hall due to the seismic action. It has been observed that the general regularity described in the Form prevents a correct and coherent assessment of seismic damage. Therefore, to understand the space, the theatre is subdivided into morphological-structural subunits in order to consider their planimetric and altimetric variation and the

specific structural characteristics of the macro-elements. Thus, damage assessment would be expressed more coherently once a clear hierarchy of structural units has been defined, including hinge nodes. It should first be represented at a local scale and then associated with the global scale.
This aspect could allow a more coherent interpretation of the level of damage in the emergency phase and optimises the subsequent steps to secure the damaged asset and conservative intervention.
Moreover, the proscenium arch node is absent both in the macro elements of the form and in the specialised analysis. However, It has an essential role in the structure's local and then global kinematic behaviour. It is no coincidence that all the damaged theatres had a severe crack pattern corresponding to the proscenium arch. In fact, being located in an interstitial position between the two empty volumes of the auditorium and the stage, and in direct contact with the roof system pushing under the seismic action, several local kinematics were activated, leading to partial collapse, shear failure of the beam and overturning of the floor. The stairwells that connect the free volumes of the slab with the box-shaped books of the forepart and the service block represent one of the most critical nodes in the overall behaviour of the structure under seismic action. In correspondence with them, there are lesions due to the effect of hammering.
Comparing the Mic forms and the specialist appraisals presented by the professionals, some weaknesses emerged relating to the current procedures for surveying seismic damage for the "Theatre" type. These weaknesses are due to the following factors: a) subjectivity of the detector, b) expeditious nature of the model, c) application of a form adapted and not specific to the architectural typology analysed. Although factor c) is mainly considered, most theatres were surveyed using only B-DP - Palaces. Consequently, the Form of theatre damage investigation requires thinking about the correlation between the architectural structure's articulated planimetric and altimetric configuration of morphological-structural subunits and the damage related to the macro-elements.
Based on the analysis, in the first and second level of the comparative analysis, the three forms B - DP have been compared with the specialised investigations carried out by the professionals in charge of the restart project. The first one applied to the typology of buildings on which the form is set (Pinacoteca in Cento - Fe) (fig.16). The other two on the theater of Nuovo di Mirandola (Mo) (fig,17)and the G. Rinaldi Theater of Reggiolo (RE) (fig 18).
For the Pinacoteca in Cento, the following collapse mechanisms have been identified.
M5. shear in the external walls
M7. shear in the internal walls
M9. damage to porticos / loggias
M13. damage to the vaults for floor deformation
Severe damage level

For the Teatro Nuovo i. Mirandola:
M1. overturning of the facade
M3. bending failure of the walls
M10. beam head slippage and hammering
Damage level expressed on a global scale: serious/severe
Id* =0,69
*(damage index)
While for the G. Rinaldi theater in Reggiolo:

M4. overturning of the cantonal
M11local collapses of the deck or the vault
M16. damage to the covering
Level of damage expressed on a global scale: serious.
Id* =0,5
*(damage index)

From the study of the specialist's damage reports, applying the structural macro-subdivision,

Fig.52 The B -D.P. sheet was applied for the survey of the Pinacoteca di Cento. The sheet turns out to be exhaustive for the seismic damage survey. Developed by M.Suppa

Fig. 53 The damaged form applied for the Theatre of Mirandola's seismic damage survey, the card's fields from the study of specialistic investigations, do not damage the proscenium arch and the plafond. The hypothesis of implementing the B -D.P. sheet with the A-DC sheet with which the collapse mechanisms related to the picturesque arch and the palfond can be described. Developed by M.Suppa

Fig. 54 The damaged card applied for the reel of the seismic damage of the Theatre G. Rinaldi in Reggiolo, the fields of the card from the study of specialistic investigations, do not damage the proscenium arch and the cavea. The hypothesis of implementing the B -D.P. sheet with the A-DC sheet with which the collapse mechanisms related to the picturesque arch and the palfond can be described. Developed by M.Suppa

for the New Theatre in Mirandola, the investigations, analyses and images reported show that the extent of the damage due to the out-of-plumb of the sidewalls of Body C is to be considered Serious Damage. The damage caused by the triggering of the kinematic mechanism is also particularly evident from the residual lesions in correspondence of the clamps with the upwind walls where the openings of the lesions themselves range from a maximum of 3-4 cm (eaves level) to a minimum of 10-15 mm (lower floors). The lesions for overturning/sliding at the base of masonry columns are "Obvious lesions for rotation at the foot and crushing/sliding, in isolated columns, for an extension of more than 50% of the elements of a floor". They are attributable to a classification of SEVERE DAMAGE. The masonry structure presents geometric and constructive characteristics to highlight the vulnerability to the triggering of local collapse kinematics activated by seismic forces. The same state of damage found in the various parts of Body C and D allows identifying different kinematics responsible for the injuries. In particular, some "weak" wall profiles have been placed in correspondence of which the overturning of multiple and single walls and the kinematic failure by horizontal bending have been analysed. The survey of the displacements confirms that the extent of the removal occurred at the wooden beam supported by the perimeter masonry. In fact, at points A and B, it was possible to measure and compare the displacement of the truss beam with the out-of-plumb measurements of the wall. Body C also presents another severe form of damage in correspondence with the masonry pillars that support the wooden trusses of the scenic area; these pillars, at the height of the last elevation, have suffered.
The theatre R. Rinaldi in Reggiolo presents in the corner the kinematic mechanism of overturning of the cantonal due to seismic action. Through injuries with slight displacements out of the plane of the masonry, there are shear injuries along with the lintels of the openings. The lesions framework is complex. The actions of the earthquake have manifested themselves with harmful effects on the most vulnerable and valuable components. There are different degrees on the proscenium walls, with partial collapses of plaster and decorated stone elements, lacerations and fragmentations of the layers of coating of the vault lintel. There is a continuous lesion with swelling of the frescoed pictorial films on the entire vault in correspondence with the upper beam. They were passing lesions with slight displacements out of plane and shear lesions along with the external masonry of the theatre hall (B and C body). At the same time, it is possible to notice a collapse of the covering in later cement (intervention of the last decades) in the head building. These elements under the seismic action have given rise to hammering with the surrounding structures, resulting in severe injuries in the south elevation - reduced - and on the pediment cornice.

From the systematisation of the analysis data, 4 diagrams were drawn for the 4 parameters are defined. Regarding the level of damage, it can be stated that the theatres examined have a medium or severe level of damage. The Social Theatre of Novi di Modena, a pilot case for the research, was also included in the inspection sample. However, for this theatre, the specialist analyses aimed at assessing seismic vulnerability are currently underway. Therefore the results concerning the Social Theatre are partial.
The metric and geometric survey techniques used, the diagnostic surveys and the representation techniques were analysed. About the survey techniques and methods, it can be stated that in most cases, the existing surveys were verified by direct measurement, supporting the implementation of the study with detailed photographic surveys. Only the theatres of Mirandola and Novi di Modena achieved such integration of survey techniques. In these two cases, terrestrial photogrammetry was not carried out since the site conditions made it possible to acquire the totality of the data through laser scanner acquisition, reaching 90% of the data coverage. In order to optimise the survey phases of the damage in post-earthquake conditions and the choice of the most suitable instruments for data acquisition (ch.1), the data of the integrated survey techniques can be considered more than satisfactory. For the survey of the L. Pavarotti Theatre in Modena, integrated survey techniques were applied only to the analysis of the vault as described above. (fig 11)
The parameters of the diagnostic survey, except the Theatre of Novi Modena, were following the metric and geometric survey, carried out in the course of the present research, as the

analysis of the technicians on the diagnostics of the theatre is still in progress, a partial data is given, relative to the predictive studies carried out on the cloud of points. For almost the entire sample, however, it can be stated that tests on materials, ultrasonic investigations and geological surveys were carried out, and only the Teatro del Popolo in Concordia achieved all the rank of diagnostic analysis. While for the L. Pavarotti Theatre in Modena, the data is realistic as some investigations were carried out only on the plafond system (fig.12).
Concerning the last parameter concerning representation methods and tools, all the theatres in the sample performed 2D representations with annexed photographic documentation and elaboration of the thematic tables foreseen by the 2011 regulations and 3D models for verifying the static nature of the buildings. For the Theatre of Novi, too, the laser scanner survey and the predictive diagnostic analyses on the reflectance data have been elaborated, technical documents that to date constitute the survey of the state of affairs. For the Theatre of Novi and the Theatre G. Borgatti in Cento, Bim models have been elaborated to implement HMIB aimed at the analysis, documentation, and programmed maintenance of the theatres. The Borgatti Theatre is the only case in which the performance rank have been achieved in their entirety. The analysis results for the L. Pavarotti Municipal Theatre of Modena are partial since the static model was elaborated only for the plafond (fig 13).
In order to understand some of the damages that have affected the two theatres, assuming a first integration of the collapse mechanisms present in form A. for the Theater of Reggiolo has been considered the integration of the mechanism 6. tools of shear walls that in form A is related to the identification of shear injuries along the walls of the nave of a church. Compared to the picture described in the technical report carried out by Dr Ing. Francesca Sbardellati and Arch. Laila Filippi.
While mechanism three has been integrated for the Theater of Mirandola, following a direct comparison with Studio Fiorini, responsible for the structural design. Of form A triumphal arches. The most damage was found between block C and block D, which resulted in severe damage to the proscenium arch.
This has helped in the comparative analysis of the B DP formss, where the recurring collapse mechanisms have been traced, to implement those mechanisms not present in the palaces forms. Remarkably, the mechanisms associated with the cavea response,which can be considered a church hall and the proscenium arch's behaviour is similar to the triumphal arch.

4.2 Existing standard and integrated protocol analysis

"The system configured by all the buildings purposely constructed (or transformed) in Emilia and Romagna as "theatres" is entirely analogous to that of the "fortresses", the "palaces" of the power of the churches and anything else belonging to a specific building and construction typology, identifiable and inscribable in precise temporal, architectural and spatial ambits. Beyond the intrinsic meaning – formal and cultural – of the theatrical building, there is a "context" of belonging and reference from which it is, in my opinion, incorrect to disregard. This means that it is necessary to identify homogeneous and repeatable operational intervention criteria to reuse this system as a whole, just as it will be essential to identify programs/shows/activities of coordinated and aimed at the use of the theatres themselves once their recovery is completed. [Cervellati 1982]
Following the comparative analytical phase that allowed to systematise the data coming from the reconstruction, the standards were identified to develop the matrix of the workflow of the integrated procedure. It was deemed necessary to apply a multi-scalar, multi-level and multi-criteria mapping by adopting homogeneous and standardised parameters to ensure historical theatres' prevention and conservation. Using these criteria it is possible to document and return the specific geographic-spatial, typological, historical, morphological, geometric, techno-constructive, stratigraphic values, as well as the changes undergone over time for functional, plant or restoration adaptations.
Different integrated approaches have been studied and compared to define the taxonomy: the Council of Europe, ICOMOS, the Getty Conservation Institute and RecorDIM, The

Documentation Center UNESCO-ICOMOS; International committee for documentation and conservation of buildings, sites and neighbourhoods of the modern movement (Docomomo International), Istituto Centrale Del Restauro, Istituto Centrale per il Catalogo e la Documentazione – ICCD, National Archive of Monuments Information System (POLEMON), Acropolis Restoration Service, the Directive of the President of the Council of Ministers 9 February 2011 for the assessment and reduction of the seismic risk of cultural heritage concerning technical standards for construction referred to in DM 14/01/2008. In addition, the UNESCO recommendations 1954, 1970, 1972, 2001, 2003, 2005 were jointly studied[11].
The Council of Europe was the first to consider the documentation, integration, and identification of homogeneous criteria for cultural heritage knowledge, conservation, and management in the European context. The Council of Europe was the first to consider the documentation, integration, and identification of homogeneous criteria for cultural heritage knowledge, conservation, and management in the European context. In the 1960s, the Council was involved in protecting and enhancing the architectural and archaeological heritage by exchanging ideas and developing guidelines and standards, resulting in the Core Data Index to Historic Buildings and Monuments of the Architectural Heritage7 (1992) and the International Core Data Standard for Archaeological Sites and Monuments8 (1995). The standards identified primary or essential documentation information categories useful for hierarchising and classifying information for documenting historic buildings, archaeological sites, and monuments. The aim was to provide the compiler with a tool capable of classifying buildings and historical sites into nine main sessions: 1) names and references, 2) position, 3) functional type, 4) dating, 5) persons and organisations owning or responsible for the asset, 6) construction materials and techniques, 7) physical conditions, 8) protection/legal status, 9) notes. Linked to the nine categories were indicated 45 sub-sessions, some of which were mandatory. The Core Data Index is a tool that cross-references detailed information (paper and digital) with descriptions and photographs, site information, details about fixtures, people and organisations related to the history of the assets. [Bold J., ed. Council of Europe, 2009]. In 1995 the Core Data Standard had outlined seven main categories -names and references, location, type, dating, physical condition, designation/protection status and archaeological summary - and their 52 relative subcategories.
The objective of the CDS is to document the information necessary for the evaluation of a monument or archaeological site, allowing references to additional information contained in databases, documentation centres useful for the detailed documentation of monuments or sites or categories of monuments or sites. According to the "Principles for the registration of monuments, groups of buildings and sites" defined by ICOMOS in 1996, holistic documentation includes critical information regarding the main attributes and characteristics of a monumental asset to describe it as a whole and identify its meaning and main needs. Thus, the primary documentation criteria were defined, which included the following information:

a) the type, shape, geographical location and size of the monument;
b) the internal and external characteristics, where appropriate, of the monument;
c) the nature, quality, cultural, artistic and scientific significance of the monument and its components;
d) traditional and modern technology and skills used in construction and maintenance;
e) evidence to establish the date of origin, authorship, ownership, original design, extension, use and decoration;
f) evidence to establish the later history of its uses, associated events, structural or decorative alterations, and the impact of external human or natural forces;
g) the history of operation, maintenance and repairs;
h) representative elements or samples of construction materials or the site;
i) an assessment of the current condition of the monument;
j) an assessment of the visual and functional relationship between the monument and its environment;
k) an assessment of conflicts and risks arising from human or natural causes, environmental pollution, or adjacent land use.

11 Istituto Centrale per il Catalogo e la Documentazione (ICCD) Central institute with scientific and administrative autonomy with functions of research, direction, technical-scientific coordination aimed at the documentation and cataloguing of cultural heritage. In particular, according to the Decree of Organization of 7 October 2008, and the subsequent D.M. 23 January 2017, the Institute: has functions of research, address, technical-scientific coordination aimed at the documentation and cataloguing of cultural heritage; develops cartographic methodologies and coordinates the operational activities carried out by the entities in the area; manages the General Catalogue of the national archaeological, architectural, historical, artistic and ethno-anthropological heritage; protects, preserves and enhances its collections of historical photography and aerial photography, carries out campaigns to document cultural heritage; carries out training, updating, improvement and specialization activities both in the cartographic and photographic fields and organizes guided tours; ensures the coordination and promotes programs for the digitization of cultural heritage under the responsibility of the Mibact; draws up the National Plan for the Digitization of Cultural Heritage.

Compared to what is reported by the approaches illustrated, the classification theme appears central. Merriam-Webster defines it as "systematic arrangement in groups or categories according to established criteria". To maintain an integrated documentation tool, it is necessary to establish one or two maximum criteria established to the purpose of the documentation to shape the classification of a monument. In holistic documentation, one or two criteria with related sub-criteria should be sufficient to document a monumental building, standards that should be selected to apply to diverse cultural heritage over a wide range of ladders. Establishing a taxonomy capable of hierarchising information and ordering its relationships is necessary to allow this point.
Internationally
Some digital documentation protocols and the documentation standards that inform them were examined.
In 1998 FISH presented the MIDAS. The heritage standard was updated in 2007 to include geospatial information (GIS). It is based on the criteria defined by ISO 21127 (2005), the Conceptual Reference Model of CIDOC, the Documentation Committee of the International Council of Museums and the Cultural Heritage Committee of the Council of Europe.
"MIDAS. Heritage is a British cultural heritage standard for recording information on buildings, monuments, archaeological sites, shipwrecks and submerged landscapes, parks and gardens, battlefields, artefacts and eco-facts.
The data standard suggests the minimum level of information necessary for the registration of assets of the estate and covers the procedures involved in the understanding, protection and management of these assets. It is used by national government organisations, local authorities, heritage industry organisations, groups and service companies, research communities and professional contractors."[12]
MIDAS collects information on individual assets that form the historical environment (buildings, archaeological sites, areas of interest, etc.) and aims to document and manage changes in cultural heritage.
The *MIDAS*. Heritage standard is structured in three levels, where information is classified into six main categories and specific subcategories, of which some are mandatory. The following are the main categories:

1. Heritage assets: areas, monuments, artefacts and eco-facts, boats and aircraft*
2. Activities: Investigative activities, Designation and protection, Heritage management activities, Studies and consultancies, Research and analysis, Historical events
3. Information sources: Archive and bibliography, Narrative and summary, Documentation of the management activity
4. Spatial information: location, map representation
5. Time information: dates and periods
6. Actor information: Information about the actor and the role.

12 http://www.heritage-standards.org.uk/midas-heritage/

Of great relevance for the present research are the standards of the Iceberg prototype of the *EUCHIC* project, whose protocol is based on the taxonomy of historic buildings developed in the European project Perpetuate. The objective of the EU-CHIC (European Cultural Heritage Identity Card) project was to create and then test on a sample of case studies selected from the 12 countries belonging to the project the guidelines necessary for the compilation and efficient storage of data relevant to each chosen monument. The EU-CHIC Identity Card is based on a Core Data Index for architectural heritage and a Core standard for archaeological heritage. This is followed by the Council of Europe Guide 2009 on the inventory and documentation of cultural heritage [Council of Europe 2009]. The EU-CHIC scheme comprises three levels of information, which form the so-called "CHICEBERG [13][14][Ronzino, Franco Niccolucci, Andrea D'Andrea, 2013]. The aim was to develop a tool capable of supporting preventive conservation and sustainable maintenance to identify new strategies for monitoring the progressive changes in the historical and cultural heritage during their life cycle, concerning both human interventions and environmental impacts. The EUCHIC protocol is divided into three levels:

Iceberg Level 1: incorporates the structure of the Core Data Index for architectural heritage and the Core Data Standard for archaeological heritage. The data systematisation follows the Guidance on the inventory and documentation of cultural heritage of the Council of Europe 2009. It includes primary heritage data related to the identification of the property. (1. Names, references and sources, 2. Geographical location, 3. Functional typology, 4. Dating, 5. Construction, 6. The current state of conservation, 7. Constraints and legal condition or safeguard/state, 8. Risk and related subcategories).

Iceberg Level 2 concerns the set of knowledge that remains restricted access and under the control of the asset owner or the site manager: it is represented by the invisible part of the protocol. These categories of data may only be made public with the specific permission of the data owner. Although in some cases, information can be risky in terms of the security of the asset, access may be prohibited entirely.
The degree of the information reported may include detailed data regarding history, architecture, geographical information, past interventions, the current state of conservation, risks, materials and structural properties and reconnaissance techniques that are feasible for the assets under study.

Iceberg level 3 – is related to decision-making. It includes information and data for decision-making, represented by the invisible part of the iceberg, such as level 2. These categories of data may be published, or made available to the public, only with the permission of the asset owner or site operator and, in some cases, may be limited. This level involves applying procedures and using all previous input layers. Preventive conservation about the monitoring of assets and the control of environmental impact and management through the exploitation and planning of ordinary and extraordinary maintenance activities contribute to scientific decision-making support. (iceberg protocol www.euchic.eu).
The first level collects information describing the open-access asset; the second level concerns data collection with limited or no access, such as detailed data on history, architecture, previous interventions, risks. Finally, the third level of information concerns information on preventive conservation activities, environmental impact monitoring, and asset management by planning ordinary and extraordinary scheduled maintenance activities.

13 The Project develops a strategy and selects more efficient methods and tools for the harmonization of criteria and indicators to be addressed to monitor environmental changes of material cultural heritage, buildings and monuments, including "natural" deterioration processes and human interventions. The final achievement of the EU CHIC project, after further dissemination activities, provides new procedures for the conservation of cultural heritage and the harmonisation of criteria for the future adaptation of heritage to the new requirements. This important issue, which involves common policies, should be addressed at European level

14 (www.perpetuate.eu).

In digital documentation, mention should also be made of the *LIDO* standards based on CDWA Lite, MuseumDat, CIDOC CRM and SPECTRUM consisting of records consisting of wrapper elements and datasets. The information is classified into seven categories through which the information about the object is provided.[15]
Finally, the *CARARE* scheme was created with metadata to the CARARE service of an organisation's online collections, the inventory database of monuments and digital objects. The scheme describes monuments and events related to monuments and information service resources. [Ronzino, Amico, Niccolucci, 2011]
In the international context, several integrated protocols of advanced diagnostics developed to draw guidelines to survey the effective degradation processes causing the asset's vulnerability were also examined. According to the requirements of a typical diagnostic study and structural analysis methodology, they were generated by a need to apply quality control in building and conservation materials and structures and harmonise with the appropriate standards to minimise structural defects and improve the effectiveness of conservation and protection interventions. [Maietti et al.].
These protocols introduce indices of need:
a) Inspection necessity index. It arises from the need for a tactical inspection of buildings to assess their condition
b) Index of need for diagnosis. Uses information from diagnostic and intervention studies.
c) Index of need for intervention. It is developed based on diagnostic studies, inspection bulletins and environmental studies (A. Moropoulou et al. 2003; A. Kioussi et al. 2011; A. Kioussi et al. 2013).
These indices help support the decision-making process to define conservation interventions, the socio-economic impact, and the sustainability of the interventions to obtain strategic conservation planning.
In this sense, *the 2011 Directive (Annex A)* was examined on a national scale through which the standards of documentation and damage survey are identified and on an international scale, the Heritage Care protocol "Monitoring and preventive conservation of historical and cultural heritage" (SOE1/P5/P0258).[16]

The *HeritageCare* protocol systematises the phases of inspections and monitoring to ensure proactive management of goods. These planned inspections aim to mitigate the processes of deterioration and damage. The protocol provides a sustainable scheduled maintenance methodology. The objective of the protocol, articulated in several levels of integrated inspection for preventive conservation, always remains to provide and support decision-making processes to ensure integrated and sustainable management of the built cultural heritage. Heritage Care defines three service levels: *Service Level 1 - StandardCare, Service Level 2 - PlusCare, and Service Level 3* - TotalCare. It uses dedicated web-based and mobile applications designed by the inspection protocol that keeps track of the conservation status of the buildings inspected over time and notify the interested parties in case of risk factors. Through geomatic techniques, digital models of the studied buildings created in the Heritage Building Information (HBIM) environment were developed for accurate mapping and damage diagnosis. HBIM models made it possible to share, view and update the information necessary to know the state of conservation. This choice has made it possible to streamline the process of management and prevention of the inspected goods [M.G. Masciotta et al.].
Finally, the DAP (Data Acquisition protocol) developed within the project is analysed in integrated digital documentation. The DAP is developed to provide a protocol linked to the 3D survey of complex architectures to optimise the large amount of data acquired and the long processes in the production of 3D digital models. Through the documentation and digitisation

15 The service resource is the platform Europeana

16 the project HeritageCare Property was launched within the Interreg-SUDOE programme co-financed by the ERDF to develop an integrated and sustainable strategy for the preventive conservation of cultural heritage built in South-West Europe. This project involves three countries (Portugal, Spain and France), eight beneficiary partners and 11 associated partners.

of 9 case studies the *INCEPTION* protocol addressed issues related to the complexity of heritage sites, the accuracy of 3D models, the integration of metadata and semantics into the 3D model, integration with additional information such as images, structural analysis data, materials, conservation documents, etc., archiving of 3D digital documents using widely accepted standards The *DAP* taking up the integrated documentation criteria focuses in particular on the management, storage and archiving of data, with the aim of preparing an optimised procedure for the survey of assets or monumental sites using 3D acquisition tools; Provide a workflow for a consistent development of investigation procedures for tangible cultural heritage and a set of instructions and guidelines for data collection, presentation and storage; Provide a tool that can guide a 3D data acquisition procedure that can generate 3D models accessible to a wide range of users; Improve the accuracy and efficiency of 3D data acquisition through the integration of documentation and tools; To support a cost-effective and time-saving procedure; Serve as a basis for improving the capabilities of data acquisition technologies and documentation tools; To bridge the gaps between technical fieldwork and modeling in 3D data acquisition. [Maietti & all].
It is divided into eight main phases (workflow):

1. Scanning plan;
2. Health and safety;
3. Termination requirements;
4. How to register;
5. Control network;
6. Quality control;
7. Control and verification of data;
8. Data storage and archiving.

The 8 phases of the workflow represent control steps - an indicator of activity - which aim to verify the survey. Each control verified is associated with an evaluation rank consisting of measurable indices. The indicators, not always mandatory, allow classifying the survey into four evaluation categories depending on the relevant activities.
Based on the above principles and to document the sample of the damaged theatres protected by the Emilian Crater, it was necessary to define a matrix of values and meanings specific to the object - type, shape and size, geospatial, historical-artistic information, technological-constructive information. For the setting of the criteria matrix of considerable importance were both the integrated protocols described above, which made it possible to establish the structure of the taxonomy: essential information for the monument (general description, type, location, etc.), property and legal status, historical documentation, architectural documentation, geographical documentation, contextualisation concerning its environment and construction time, documentation of diagnostic studies to assess the condition of the building material, documentation of structural health assessment, documentation of conservation and protection interventions, documentation of vulnerability studies and damage analysis and management and maintenance planning. As important were the data derived from the critical-comparative analysis that highlights the fragmentation and the gaps of the current procedures due to the absence of an ad hoc survey form for the type studied.
In the Italian context, the ICCD standards represent the tool for cataloguing and documenting cultural heritage. The ICCD cataloguing regulations have been present since 1999 with version 1.0 and updated to 2015 with version 4.0. They aim to acquire archaeological, architectural and landscape knowledge, historical, artistic and demo-ethno-anthropological heritage. The ICCD has developed an articulated system of standards: tools and rules to implement cataloguing according to homogeneous criteria at the national level. The adoption of standard practices is, in fact, the necessary prerequisite for the sharing of information among the many subjects (public and private) operating in the field of cultural heritage, to create the heritage catalogue provided for by the Code of Cultural Heritage and Landscape (Legislative Decree 42/2004 and subsequent.m amendments, art. 17). [17]

17 *http://www.iccd.beniculturali.it/it/standard-catalografici*

The cataloguing structure allows to fill in the cataloguing slips that are divided concern three general categories of goods:
• MOVABLE goods: objects and artefacts that can be moved in various ways; they can also be "immobilised by destination", that is, they are firmly embedded in the context in which they are located (such as a fresco painting on a wall or a walled tombstone in a structure, etc.);

• REAL ESTATE: in the cartographic field, this is how the assets hooked and incorporated to the ground (buildings, territorial spaces, etc.) are defined, which present, in general, a consistent spatial development;

• INTANGIBLE assets206: they constitute that part of the heritage represented by ephemeral performances (traditional festivals, musical and choreographic performances, theatrical performances, craft techniques, oral literature, etc.), captured at the time they take place and of which it is possible to maintain memory only through the audio-visual recovery that fixes them stably, crystallising them; they are defined as "immaterial" because what is preserved, catalogued and protected is not the good itself (as in the case of movable and immovable property, "physically" available) but its manifestation documented through photographic, audio, video images. [R. Tucci, 2018].

The form is organised in 9 disciplinary sectors:
- archaeological heritage
- architectural and landscape heritage
- demo-Ethno-anthropological assets
- photographic goods
- musical goods
- natural heritage
- numismatic goods
- scientific and technological goods
- historical and artistic heritage.

Today, the catalogue forms defined by the ICCD are divided into 30 types, each identified by an identification code, which explains their scope of application. Although data structure rules have been developed for each form, the data is arranged in a set of homogeneous sections named paragraphs.
Each paragraph is divided into records, some of which are obligatory, through which information is collected:

- information on the identification of the asset,
- information on the property and its location,
- data on documentation and origin of the asset,
- information on the structure of the building and its parts,
- information on the activities that took place at the time of the survey
- restrictions on use,
- administrative information.

The ICCD regulation defines three visibility levels regarding information access: low confidentiality - open access, medium confidentiality - related to private data and, therefore, with limited access, and high confidentiality for confidential data.
Regarding seismic vulnerability at the Italian national scale, the Prime Minister's Directive of February 9, 2011, for "Seismic Risk Assessment and Cultural Heritage Reduction." It guides seismic risk assessment and reduction of protected cultural heritage on technical standards for construction (called NTC). The normative device aims "to specify a path of knowledge, assessment of the level of safety against seismic actions and design of possible interventions, conceptually similar to that provided for unprotected buildings, but appropriately adapted to the needs and peculiarities of the cultural heritage; the purpose is

to formulate, as objectively as possible, the final judgment on the safety and preservation guaranteed by the seismic improvement intervention.” Notably, the document refers only to masonry buildings” [DIR.2011].
It recognises that vulnerability analysis and seismic risk assessment are fundamental to the conservation and safety of cultural heritage; therefore, the same provides information on the methods – non-binding – to be applied for surveying and documenting goods damaged by seismic action. Of particular relevance for the development of integrated workflow was the study of Annex A of the same legislation, which identifies the documentation standards for the survey, analysis and assessment of seismic risk. The document sections give guidelines regarding the knowledge and appropriate building modelling concerning site hazards, building use, and the ability of the structure to respond to seismic action. Furthermore, the Guideline defines the safety requirements for the historical and artistic architectural heritage. The reference limit states, to safeguard the safety of the building and people (1. Lifesaving Limit State, SLV) and the functionality (2. Damage Limit State, SLD), as well as the damaging of the movable assets located inside the architectural building (Artistic Heritage Damage Limit State, SLA).
Consequently, three different levels of seismic safety assessment are foreseen:

LV1: for seismic safety assessments to be carried out on a territorial scale on all protected cultural assets;
LV2: for evaluations to be adopted in the presence of local interventions on limited areas of the building (defined in the NTC as repair or local intervention);
LV3: to plan measures affecting the global structural functionality (described in the NTC as improvement measures) and when an accurate seismic safety assessment of the building is necessary. Part. 6 indicates the criteria for seismic improvement interventions to mitigate the damage, the intervention techniques and their effectiveness, and their impact on the conservation of the artefact.[18]

Directive within Annex A Part II - Schedographic modules and their structure, defines the criteria for the documentation of seismic risk. 4 modules are identified with the alphabetical abbreviation, each of which corresponds to a macro-area of compilation for the documentation of the artefact and the seismic survey:

1. FORM A - Identification Data. It aims to identify the artefact uniquely. The identification occurs through three fundamental parameters: denomination, toponymy, cadastral data. The Decree of the Ministry defines the structure of the data for Cultural Heritage and Activities of 28 February 2004, as amended by Legislative.M Decree of 28 February 2005, issued in agreement with the Agenzia del Demanio and relating to the criteria and methods for verifying the cultural interest of the publicly owned real estate, under art. 12 of Legislative Decree 42/2004 Code of Cultural Heritage and Landscape. [Directive 2011].

2. FORM B. Sensitivity factors. It contains the data necessary to determine the relationships between the artefact and the territorial context to classify certain sensitivity factors. [Dir. 2011]. This macro-area collects information about the dimensional characteristics, location, soil composition, accessibility, and use.

3. FORM C - Morphology of the Elements. It aims to identify and describe the structural elements by recognising morphology, typology, construction techniques, and materials. [Dir.2011].

4. FORM D - State of Conservation. It classifies and describes the damage phenomena of individual structural elements. [Dir. 2011] This section is dedicated to analysing seismic damage related to identifying structural units.

On the other hand, Annexe B focuses on the behaviour of the masonry of historic buildings,

18 *Dir.2011*

to which the methods of analysis are identified.
Furthermore, Annex C contains the methodological framework of the seismic damage survey of churches, identifying the main macro-elements and the related collapse mechanisms.
Based on the documentation standards included in the protocols analysed, documentation criteria and survey criteria for the historical theatres of Emilia-Romagna have been developed within the research, with specific reference to the field of seismic damage survey. In conclusion, considering the different levels of information documenting damaged cultural heritage or particular risk conditions, the research proposes the integrated multi-level and multi-criteria approach for development. The development of the workflow of the integrated procedure for seismic - theatre damage survey articulated on three complementary information levels, which is the subject of the next chapter. Although focused on the architectural typology of historic theatres in Emilia, the developed protocol, based on catalographic survey standards, and integrated documentation, codified both internationally and nationally, presents a skeleton adaptable to other complex typologies such as castles and cemeteries, etc.

CHAPTER 5 Fifth Part: Integrated Procedures Workflow for the seismic damage survey applied to theatres in the Emilia Romagna region.

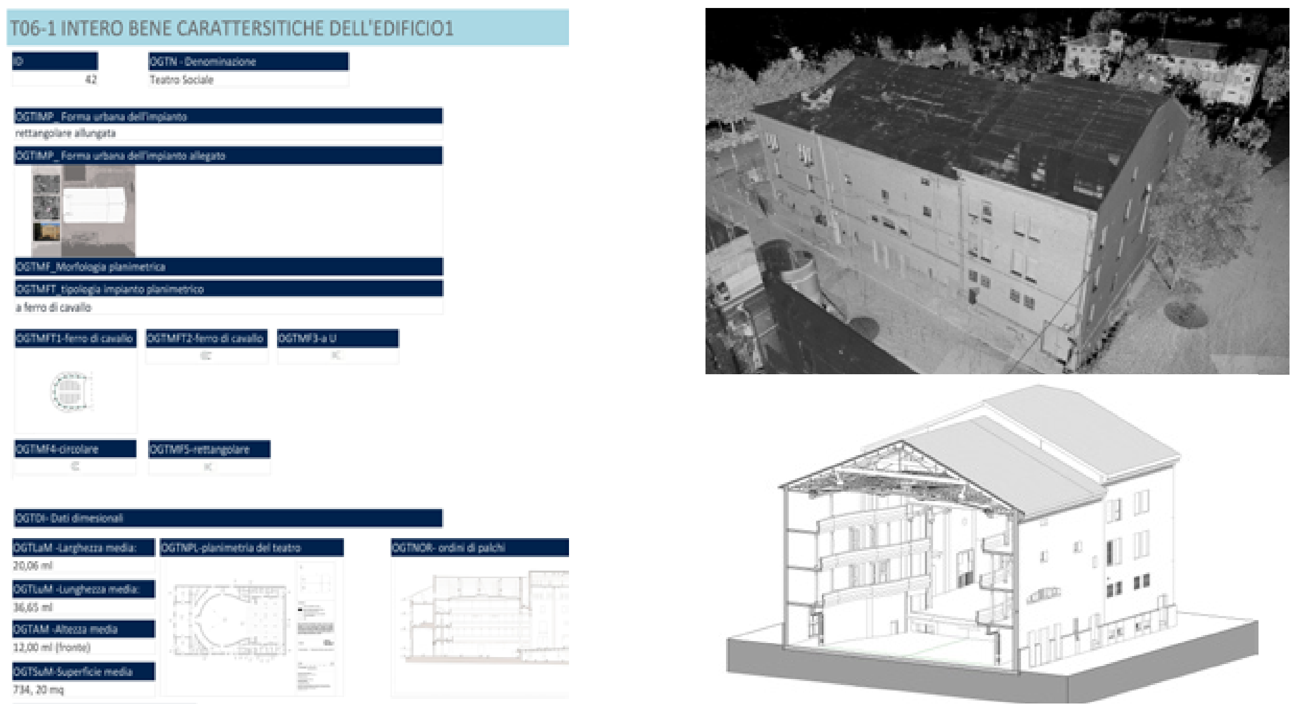
Abstract

This chapter illustrates the workflow of integrated procedures for preventing and mitigating hazards related to potential states of emergency. The research made use of the holistic, interdisciplinary approach of integrated documentation. The protocol is organised into three survey levels.

L1 (Screening Level) represents the digitised implementation of the models for surveying MIC damage used in 2012- models A-DC and B-PD -designed on the typology architecture analysed. The digital tool is named SD T (Seismic Damage - Theatres) and represents the matrix of a single digital database related to the 106 historic theatres surveyed on a regional scale. The SD T is structured in 13 main categories based on the ICCD sheets and by implementing the models mentioned above. Within it, all known information and data related to each theatre. The purpose of the DS T is to provide a digital registry of each theatre to optimise the data acquisition and damage status surveying phases during emergency operations.

L2 (Survey Level) using integrated survey tools - laser scanning and digital photogrammetry provides a survey protocol for data acquisition aimed at the survey of seismic damage to obtain 3D morphometric models intended as a database that can be consulted and implemented over time. The survey protocol reiterates the DAP (Data Acquisition Protocol) of the INCeption perfect and is calibrated to the specificities of seismic damage survey of historic theatres. In addition, within the second workflow level, guidance is provided for the coding, interpretation, and representation of data acquired under the 2011 Directive.

L3 (HBIM PLUS Level) is the manifold of the first and second levels. Specifically, the information collected from the SD T and the data acquired and processed in L2 are used to realise HBIM parametric models, which are then linked to the platform HBIM semantics of the INCEPTION project. At this workflow level, emphasis has been placed on the information layer (LOI) that parametric BIM models can include by developing a dedicated set of rules on seismic damage. The choice of having HBIM models are intended to overcome the limitations of MIC tools and trace the damage survey directly and punctually on the shape datum of the cultural asset.



Cover image - chapter 5 - The three levels of the integrated procedural workflow for damage analysis. Processing by M. Suppa

5. Integrated Procedures Workflow for seismic damage survey setting up

After the emergency phase, the Agency for the Reconstruction - Earthquake 2012 considered the need to start a research path together with the Universities of Ferrara and Parma to set up the implementation of the current procedures for seismic damage survey about three typologies of complex architecture: castles, cemeteries and historic theatres. Based on ARRER's focus on the historical theatres of Emilia-Romagna, the workflow of the integrated procedure for the seismic damage survey of theatres was developed. The workflow is intended as a set of guidelines defined ad hoc for the damage survey of theatres to optimise the seismic damage survey phases. Optimising the survey phases is a fundamental step to prepare the first safety interventions during the emergency and the cognitive basis for the analytical study of the damage aimed at the restoration project. However, the lack in 2012 of a seismic damage survey form specially prepared for theatres led to some critical issues in assessing the damage index for this complex architectural typology, often inconsistent with the actual damage.
Based on this assumption, the research has adopted the homogeneous criteria of the integrated approach as a guide for developing the seismic damage survey metaprotocol of the historic theatres of the Emilia-Romagna Region.
The application of the integrated methodology is, in fact, the essential requirement for the knowledge, decoding and interpretation of the tangible and intangible meanings of the cultural heritage to be preserved. In chapter 4.1, it was described that the preparation of an integrated survey protocol represents the indispensable element for the development of shared strategies aimed at the evaluation and management of seismic damage. Adopting and applying an integrated survey protocol makes it possible to document quantitative and qualitative information levels and connect them according to a classification hierarchy once homogeneous standards have been codified. These different levels of information, according to the "principles for the registration of monuments, groups of buildings and sites" [ICOMOS 1996], consist of a series of critical information regarding the attributes and main characteristics of a monument, necessary to define the cultural asset as a whole and to identify its primary meanings and needs. In general, holistic documentation "should include some or all of the following information: type, shape and size of the monument; internal and external features of the monument; natural, qualitative, cultural, artistic and scientific significance of the monument and its components; traditional and modern technology and skills used in construction and maintenance; evidence to establish the date of origin, authorship, ownership, original design, extension, use and decoration; evidence to establish the later history of its uses, associated events, structural or decorative alterations, and the impact of external human or natural forces; the history of management, maintenance and repairs; representative elements or samples of the construction materials or the site; an assessment of the current condition of the monument; an assessment of the visual and functional relationship between the monument and its environment; an assessment of conflicts and risks from human or natural causes, and from environmental pollution or adjacent land uses". [Maietti et al., 2019]
The *integrated workflow* is a compendium of procedures articulated in three levels structured on a multi-level and multi-criteria integrated logic. It aims to define an ad hoc survey procedure to survey seismic damage for theatres, to suggest and guide future and regular monitoring operations of the regional historical theatres to ensure planned maintenance and proactive conservation. Because of these aims, the research developed in the specific disciplinary field of the survey has considered it essential to adopt the holistic, integrated approach to document, record and classify the tangible and intangible attributes of theatres and correlate them to the main mechanisms of seismic damage. In this perspective, the *integrated workflow* intends to use digital techniques and tools. It is possible to optimize and uniform the surveying, collecting, hierarchizing, interpreting and representing data needed for assessing seismic vulnerability and, consequently, to guide the conservation interventions in a logic of collaborative management.
The objective of the research was to prepare a single, standardized and homogeneous tool for the documentation of seismic damage that encompasses different phases and levels of investigation: from visual inspection to integrated digital data acquisition and the consequent discretization and metric and geometric representation of the architectural attributes of the theatre (metric and dimensional data, technological, material and structural characteristics, conservation conditions) and of the cracks and deformations, up to the creation of a parametric model structured based on data and information collected in the first two levels. These operations, articulated on different integrated levels of investigation, ensure comprehensive documentation of the theatres, those damaged by the earthquake and those on a regional scale present dangerous conditions. This last aspect is introduced to verify some workflow levels for preventive monitoring.
The development of a single workflow arises from the need, given the results of the critical-comparative analysis, to standardize and organize the entire investigation and assessment process of seismic damage for regional protected theatres simultaneously, avoiding duplication of procedures and systems for collecting information. In this sense, the workflow intends to optimize the work of all actors in the process of reconstruction MIC survey teams, administrative and technical bodies.
The workflow presented has been designed against five preliminary actions described below and summarized in the following scheme (fig.55).
The first phase was dedicated to identifying the actors to whom the integrated procedure is addressed. First of all, the institutional bodies responsible for protecting theatres on a national and regional scale: Ministry of Cultural Heritage (MiC), Superintendence and Agency for the Reconstruction of the Emilia-Romagna Region, particularly the Office for the Coordination of Interventions on Cultural Heritage. Then follow the local administrations that own the historic theatres falling within their territory of competence. Together with the institutional bodies, the private owners of some theatres, managed by private associations, were then considered. This category also [1]includes professionals and research centres to whom specialised studies and analyses aimed at the recovery and conservation project are delegated. Finally, the possible users of the information related to the asset were included: students, PhD students, researchers, experts in cultural production and non-expert users. This last category of actors has been an inclusive enhancement and use of theatres and their information.
The second phase examined all the archived data, which merged into the critical-comparative analysis. In addition, the existing national and international cataloguing approaches and the existing digital data storage systems in Italy and the Emilia-Romagna Region were also studied.
The third phase focused on the morpho-typological analysis of the theatre and the damage that can result from seismic action. The awareness of this aspect was deduced from the comparative critical analysis of the inspection sample of the 11 damaged theatres. As a result, the taxonomic classification matrix has been identified concerning these two factors. The selected criteria are two: the first is related to identifying the mechanisms of collapse found due to the seismic action, which, based on the subdivision into seven structural units, involved the identification of 40 collapse mechanisms. The second criterion concerns the state of conservation and, therefore, the identification of the degradation morphologies that can negatively impact the behaviour of the building in the event of an earthquake, accelerating total or partial collapse and the aggravation of cracking patterns. Through this taxonomic matrix, in which the two selected parameters are interlaced with each other, the objective is to provide the indispensable
information obtained from the relevant activities for the preliminary evaluation of the pathologies and damages observed, able to trace a cognitive and diagnostic picture of the asset's state and guide the first mitigation actions to reduce the consequences of seismic damage.
The fourth phase consists of the *integrated workflow* structure for seismic damage survey Theaters development. The workflow is divided into three complementary levels

1 Among the most important Italian associations we find AGIS - The Italian General Association of Entertainment-, founded on 7 December 1945, who it brings together trade associations, federations and foundations and is present on the national territory with regional and interregional unions.

Integrated Procedures Workflow for the seismic damage survey - Historic Thaetre in Emilia-Romagna

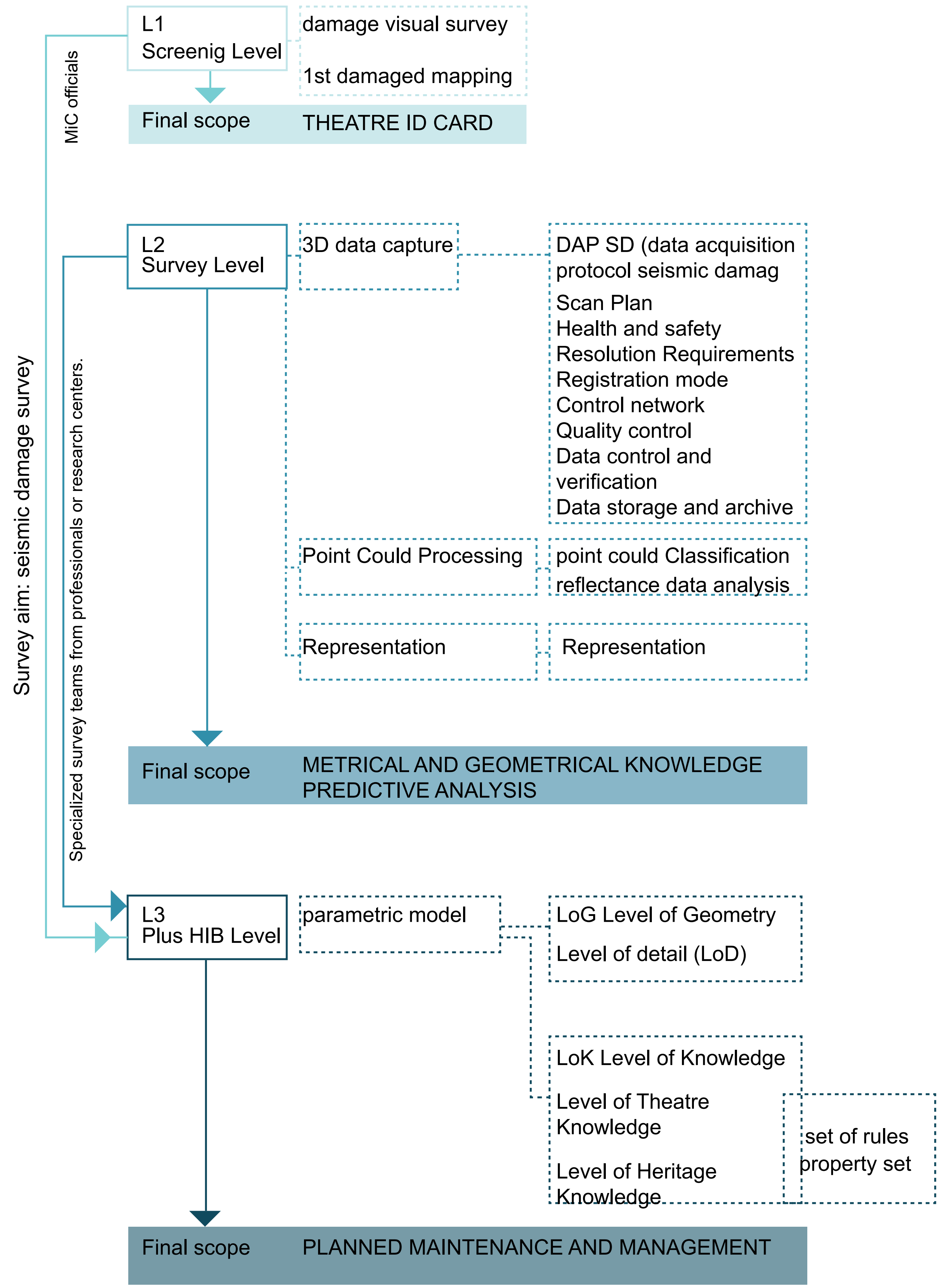


Fig. 55 The chart shows the workflow of integrated procedures for seismic damage survey of the historic theatres in the Emilia Romagna region developed during the research. Developed by M.Suppa

of documentation: L1 *Screening Level*, L2 *Survey Level*, L3 *Plus HBIM* Implementation. For each layer, data collection and processing criteria are defined to ensure the precise decoding and classifying of the genetic structure of each theatre -morphological-geometric, technological-material and structural characteristics. – to ensure the assessment of seismic damage and degradation condition.

The final goal is to process the acquired and processed data and information within a single, implementable and interoperable HIM semantic database, providing exhaustive documentation of the studied objects. Using the semantic HBIM platform can enrich data and metadata necessary for the knowledge of cultural heritage, specifically of historic theatres. It provides a collaborative flow tool that optimises the decision-making process for planning interventions, planned maintenance, and management of regional theatres. The three levels perform the function of order, guiding and verifying the classification, acquisition, hierarchisation and management of the complexity of the data and quantitative and qualitative information acquired to ensure a survey of the damage effectively documented, interpreted and represented.

The *Screening* Form– level 1 allows visual screening of the theatre. This level aims to provide an identity card of the theatre through the compilation of the digital meta form DS-T (damage screening – theatre), a digital tool for collecting the visual survey data. At this layer, all the essential information concerning the history of the theatre converges identification, localisation, type, property and legal status, historical documentation, geometric documentation, documentation of materials and the construction – structural system, history of conservation and protection interventions previously implemented on the building, seismic history of the building, usability. This information was implemented during the inspection by the data relating to the survey of the collapse mechanisms activated because of the seismic action and the degradation morphologies that could negatively impact the vulnerability of the building, triggering aggravations of the deformative cracking framework. Furthermore, the DS-T involves the background information collected in institutions and private owners' archives. This aspect implies starting the data digitalisation of paper archives. Meanwhile, if they are still missing or digital data are already present, systematise them in the Access MC database applying the DS-T.

In addition, damage and deterioration phenomena that may influence the worsening of the seismic vulnerability of the theatre will be investigated through inspection. This information corpus is divided into categories subcategories of mandatory fields to be filled in. Finally, the obligation is to arrange the necessary information into level 2 as a support base for the geometric and diagnostic analytical survey. In this first inspection phase of the seismic damage, the survey, as required by national legislation, is the responsibility of the teams of MIC officials, who will have the task of surveying the damage verified and explaining the damage index.

The Data seismic Acquisition Protocol -level two provides for applying the specific DAP DS-T instrument. The DAP developed within the INCEPTION[2] project introduces parameters for surveying seismic damage. Therefore, the information collected in level 1 is integrated to obtain accurate morphometric models for the metric and geometric survey to identify misalignments out of lead that could affect the structure due to the earthquake. Therefore, provide a detailed mapping of the damage and the primary degradation morphologies related to seismic vulnerability to control and monitor significant parameters that influence the need for the acquisition, interpretation, and return of the verified seismic damage. By applying methods and technologies of integrated survey responding to specific phases of acquisition and control parameters of data processing, we want to obtain a parameterisation of the state of the damage that occurred for each theatre. Therefore, depending on the

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2 The INCEPTION project has been applied under the Work Programme Europe in a changing world – inclusive, innovative and reflective Societies (Call—Reflective Societies: Cultural Heritage and European Identities, Reflective-7-2014, Advanced 3D modelling for accessing and understanding European cultural assets). This research project has received funding from the European Union's H2020 Framework Programme for research and innovation under Grant Agreement no. 665220; Horizon 2020 Framework Programme [665220].

methods and integrated technologies applied, a matrix of indicators is prepared to classify the survey in the classes defined by the INCEPTION protocol. The models elaborated and processed will be the basis for finite element analysis for structural evaluation and modelling in a disciplined BIM environment within the third level. The DAP DS T is aimed at specialised research centres and professionals in the survey sector.

The *Plus HBIM* Implementation - the third level integrates and processes all data collected from previous levels by elaborating an HBIM digital model with properties specific to the level of detail (LOD) and the level of information (LOI) to the seismic damage. The research focuses on the level of data implemented in BIM, particularly on the classification and coding of the specific architectural, technological and structural elements of the theatre and Pset ad hoc to classify damage, degradation conditions and materials. Considering that damage modelling in the BIM environment still presents open solutions, existing protocols have not yet found a broad consensus [Azenha et al.2018].

The parametric model filling data, including data and information from the workflow levels, is enriched on the semantic platform through multimedia links, hypertext, and digital archives (Getty).

The fifth and final phase consists of implementing the INCEPTION platform with models that meet the criteria of the Plus HBIM Implementation. The use of INCEPTION's HBIM platform aims to exploit the potential of BIM design to have a global analytical framework that directs the restoration project and is a control and verification tool for the subsequent phases of maintenance and preventive conservation of regional historical theatres.

It is concluded that using the integrated methodological approach, the following objectives of the *integrated workflow* have been set, which in the first instance aim to:

Provide an *ad hoc* form to survey the seismic damage of the historical theatres protected on a regional scale.

Standardise methods and tools for the integrated survey of seismic damage for protected historical theatres

Optimise the workflow for the survey phases and then manage the operational and decision-making process.

Implement the SEMANTIC DATABASE of INCEPTION about the case studies analysed and the homogeneous parameters defined for the survey and mitigation of seismic damage.

The objectives defined in turn are indicated in the perspective of:

increase awareness of introducing integrated digital survey systems as tools for verifying the state of health of the theatre over time.

Define preventive measures for conserving and monitoring the regional historical heritage, particularly the theatres that are places of cultural fruition and are spaces of cultural production. Therefore, proactive protection has positive repercussions both on the social and economic levels.

Promote more coordinated actions between public administrative institutions and the technical-scientific community. As a result, the procedures for surveying and mitigating the damage are increasingly efficient to guarantee the protection of historic buildings using advanced technological systems.

5.1 Setting up L1 – Screening Level

5.1.1. Implementation of Mibact forms: Meta form for Damaged historical Theatre (DS-T)

The *Screening Level* (L1) of the Integrated Procedures workflow has its operational tool for detecting seismic damage during the visual inspection, the SD-T meta-module. The SD T was designed and built downstream of the morpho-typological and comparative analyses. It was developed in Italian as a proposed damage survey tool for the Italian Ministry of Culture. Therefore, the database created in Microsoft Access has categories and subcategories set in the Italian language. The DS T is a documentation module, which collects the essential information related to the monument: identification, location, typology, ownership and legal status, historical documentation, dimensional data, information about external

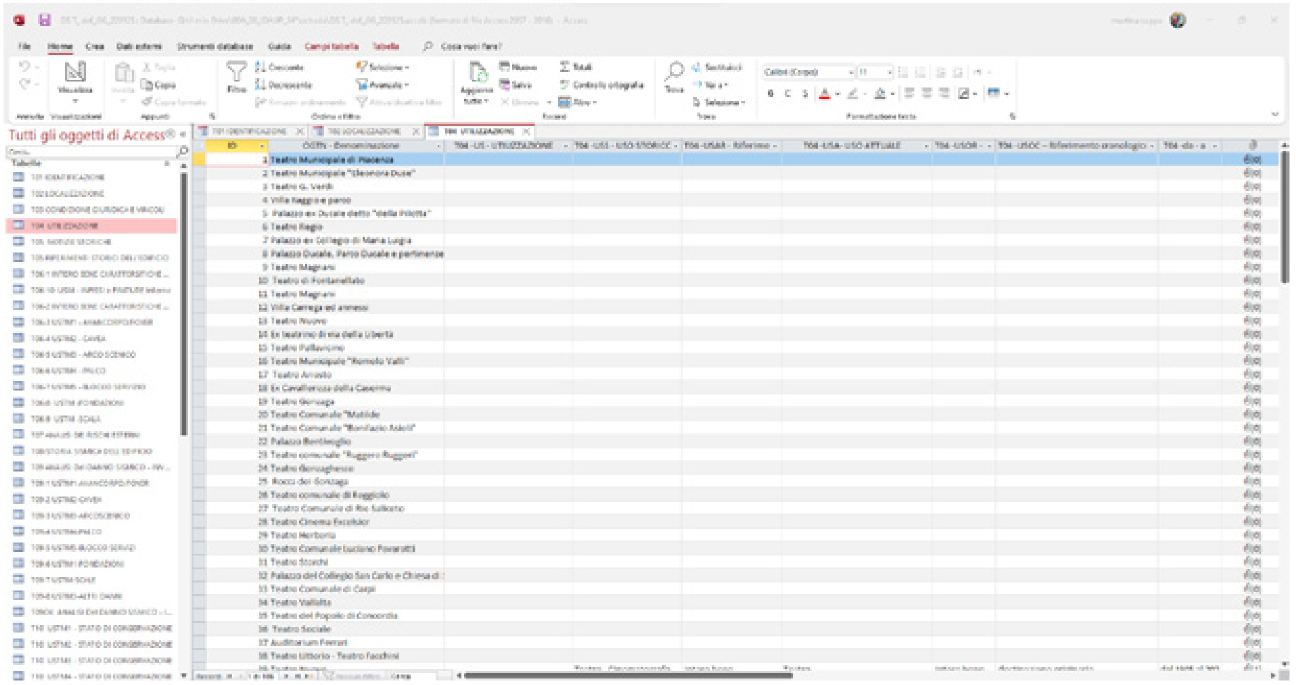

Fig.56. The database was developed in Microsoft Access. It represents the digital content of the SD T - meta form for the visual damage survey of theatres. Developed by M.Suppa

risks, information about previous consolidation interventions to identify the main collapse mechanisms and the degradation conditions caused by the earthquake and to estimate the actual damage index. This basic information has been organised based on the standardised European and national protocols analysed in ch. 4, para 4.3. In this perspective, therefore, the meta-module SD T represents the proposed implementation of the current modules MIC - A DC churches, BD P buildings, expressly set to detect the seismic damage of regional protected theatres.

The SD T is a digital tool (fig 57-58) that can collect the known data about listed regional theatres to have support during the emergency phase because it facilitates the work of the MIC functions in information retrieval. In addition, the meta form can be used in the regular inspection to monitor the "qualitative-conservative" parameters that may compromise the asset's convertible and secure status of the asset. In this order, the SD T was tested to survey the seismic damage of the Teatro Sociale di Novi di Modena, damaged in 2012, and on the Masini Historical Theatre of Faenza, located outside the crater area of 2012.

The selection to surveying the Masini Theater with the SD T procedure comes from what has been described in the first paragraph of chapter 4, because the theatre is located in Faenza, in the Romagna region, halfway between the coastal area and the Apennine ridge, between seismic zone 2 and 3 of the regional scale.

The SD T is the core of the informative DATABASE developed using Microsoft Access software.

The DATABASE is organized in 13 main categories (fig.59-59.1-7): SDT01 - identification; SDT02- constraints-legal status; SDT03 - location; SDT04 - use; SDT05 - history; SDT06-architecture _analysis; SDT07- external risk analysis; SDT08-building seismic history; SDT09-seismic damage analysis; SDT10 state of preservation; SDT11-damage index and cost estimate; SDT12- usability; SDT13-sharing data for decision support.

The decision to develop the computer DATABASE (image data and ds) with Microsoft Access is linked to the needs of the Agency for Reconstruction, which required a working database easily interoperable with the digital GIS platforms already in use in the regional digital portal (fig.56).

The purpose of the Access digital archiving was to group and classify the information of the 106 regional protected theatres surveyed by the former MIBACT secretariat. Within a digital archive that could be implemented over time. Interoperability with GIS systems also allows ARRER to generate thematic maps of the inheritance of historical theatres, aimed both at

preventive conservation and valorisation, by creating ad hoc cultural paths.
Within the DATABASE, the theatres have been catalogued according to the provincial order, following the census structure of the IBC (1982) proceeding from the province of Piacenza, Parma, Reggio Emilia; Modena, Bologna, Ferrara, Ravenna, Forlì-Cesena. They have been assigned an ID, which associates the theatre to its specific SD T.
The SDT01 category collects information relating to the identification of the theatre; therefore, the following data are entered a: a) to the identification code taken in the web gis of cultural heritage, b) the unique code of the Mib; c) the identification of the region in which the property is located d)the name of the Municipality and the Province where the theatre is located; (e)the actual and historical naming (taken from the 1982 IBC census) of the property; f) information regarding the earthquake: date of the last seismic event, damage suffered, procedures and equipment used for the visual survey; g) qualification of the ownership of the asset, h) classification of the asset; i) name of the filing body and related code.
Within the SDT02 category, it merges the information concerning the asset's constraining status, reporting the details of the provision and any graphic documentation. SDT03, on the other hand, defines the location of theatre employing geographical, postal, political, and cartographic criteria. Information relating to a) administrative location with the geographical or administrative subdivision (region, province, Municipality); b) Address: this section provides the postal address of the asset, the toponymy of the road corresponding to the address at which the asset is located (alphanumeric, unique, optional), house number, name of the locality and the city; c) cartographic references with identification of geographical coordinates; d) cadastral references; e) information on the characteristics of the site.
The SD04 category reports the asset's intended use data and functionality, both current and historical and relative to the time.
While inside the SDT05 converge all the written, iconographic, and photographic sources that document the history of the theatre. Information is recorded such as a) the dating of the building; b) the name of the designer; c) the historical stratigraphic evolution; d) the interventions implemented over time on the theatre, structural, conservative, plant engineering.
The categories of DST06, 09 and 10, compared to those described so far divided into categories and subcategories, have a different structure, because starting from them, the SD T provides for the beginning of investigations and inspections requiring more detail and compliance with the architectural and structural structure of the theatre. Thus, these categories have information subsections concerning the structural breakdown of 6 UST (structural subunits theatre). The subcategories of the mandatory fields in which the information is to be recorded are then connected. Before describing the content of the SD T 06/09/10, a clarification is introduced on the advisability of unpacking the theatre into seven structural subunits. The proposed articulation of 6 UST stems from the comparative critical analysis conducted on the inspection sample of the eleven damaged theatres. The competent RUP and the ARRER have provided and shared the documentation produced following the 2012 earthquake (ch 4. para 4.3). The macrostructural simplification criterion, adopted by professionals, helps to analyse finite elements with FEM modelling and the management of construction phases. From the comparative critical analysis on the inspection sample, four central structural units are identified: body A-forebody; body B- hall; body C – stage and backstage; body D – utility space.
Considering the Italian theatre's morpho-typological characteristics is proposed the employing and amplifying the structural macro-division of the whole theatre to provide a parameterisation of the damage index.
Therefore, the structural unities of the proscenium arch and the foundation system are added and examined to the four structural units. The proscenium arch constitutes a structural hinge knot between the hall and the stage; therefore, it is a point of connection between the two free volumes, showing a behaviour under the telluric action that must be investigated as an element and about the neighbouring structural units
Thus, the proscenium arch constitutes a structural hinge node between the hall and the stage; it is a hinge node between the two free volumes. Therefore, it is suitable to singularly analyze it during the visual investigation because it shows, under the telluric action, a

T05 - RE - NOTIZIE STORICHE

T05 -RENS - Notizia sintetica

costruzione

T05 -RENF - Fonte

bibliografica

T05 -RENFT - Fonte -TESTI

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7. U. Montanari, Teatro di prosa e drammaturgia dal XVI al XX secolo, Cento 1994, p. 875-927;
8. A. Orlandini, Il teatro in musica e i suoi luoghi, in: Storia di Cento dal XVI al XX secolo, Cento 1994, p. 929-965;
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T05 - RENF-collegamento

https://bbcc.ibc.regione.emilia-romagna.it/pater/loadcard.do?id_card=26949

T05 -RENFTI - Fonte-ICONOGRAFIA

T05 -RENFTI _allegato

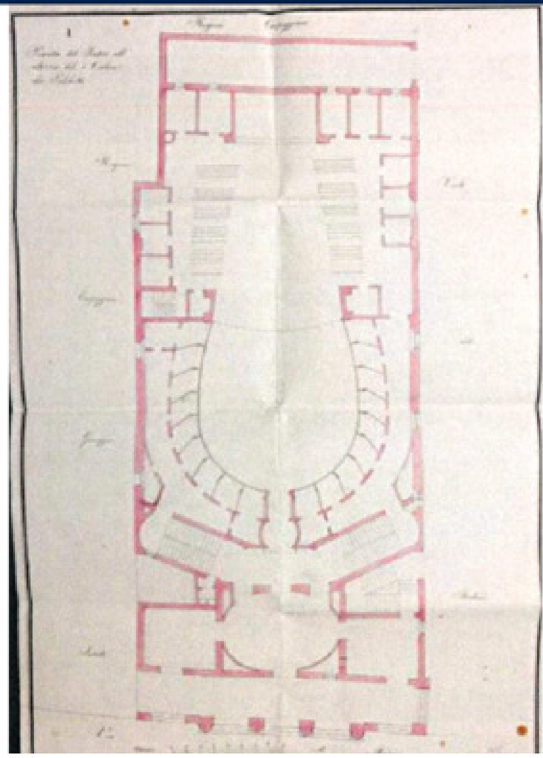


Fig. 57. The SD T of the G. Borgatti Theatre(Cento - Fe). In particular, the category T05 related to the historical information collected is illustrated. Developed by M.Suppa

behaviour proper to the arch structure (like the triumphal arch of the churches that separates the hall from the clergy, from the apse or even from the transept). Therefore, it must be investigated as a UST independent of itself and in connection with the near structural units. In this way, an estimate of the damage on the local scale of the structural unit is identified, which will be added to the damage index of the other structural units to provide a parameter of the global scale more in line with reality.

In section T09, the survey of the damage is isolated, not as structural units, the vertical connections (stairs). They are configured as hinge nodes between volumes of confined spaces and “free volumes.” Therefore they are identified as a sub-system of the UST. The stairs have been decomposed by macroelements that have been associated with dedicated collapse mechanisms.

The survey of damage to the foundation system aims to control the structure’s failure. Because of the significant liquefaction phenomena of the land that occurred with the 2012 earthquake, it was appropriate to analyse the foundation system as a sextant unit to record the geological characteristics of the land on which the structures rest and the type of foundation system to evaluate the damage index consistently. Both aspects will be covered in the same chapter in the description of the SDT09 category.

The structural partion into six structural subunits to estimate a coherent damage index is one of the innovative elements of the *SD-T metaform* (Seismic Damage-Theatre) compared to current procedures and represents the constant spatial-structural reading of the theatre typology for all *three levels* of the *integrated workflow*. As described above, the global assessment of seismic vulnerability, especially for complex architectures, often determines an evaluation of the damage index that is not entirely consistent with the actual damage reported following the seismic action. The introduction of *6 UST* (Tab.1) allows to survey, classify and document parameters closely related to seismic behaviour, such as information on the quality of materials, construction system, degradation morphologies present that affect the seismic response of the building, contributing to the activation of specific collapse mechanisms. Furthermore, it means having a damage index for each of the structural subunits, the sum of which will indicate the global index. This aspect optimises the safety operations, as the SD T provides the screening of the most damaging UST, for which it is possible to prepare the most appropriate intervention on time, with the consequential preparation of an adequate provision of the necessary economic resources to be implemented in front of the intervention.

Tab.1 the theatre UST

UST 1 -forepart/foyer [it language: avancorpo]
UST 2 -hall/cavea [it anguage: cavea]
UST 3 -proscenium arch/scenic arch [it anguage: arco scenico]
UST 4 -stage and backstage [it language: palco e retroplaco]
UST 5- utility space [it language: blocco servizi]
UST 6-foundations [it language: fondazioni]

It is defined the master categories for each where dedicated subcategories were outlined for capturing the essential data and information necessary for mapping the post-earthquake health of the theatre.

Thus, the SDT06 Theater is divided into eight subsections: the first investigates the characteristics of the outer casing. Information is acquired on the shape of the urban system, the dimensional data, the altimetric development, the material aspects of the external masonry, the covering mantle, the presence of valuable elements on the façade, and the photographic abacus of the exterior finishes. On the other hand, the remaining seven subsections analyse the theatre considering the macro-hierarchy into seven structural units. Each theatre portion is identified by mapping the general dimensional characteristics of the individual sub-unit, material, and construction attributes. The mapping of materials and the construction technique of the masonry males, the abacus prepared by the Emilia-Romagna

Region has been assumed and included in the meta form. Likewise, in the section, hall UST2 was included to survey and document the plafond system, representing an architectural peculiarity of the theatres, an abacus showing its shape and construction design. Each structural sub-unit is divided into sub-categories related to the macro-elements -USTM- that compose it. Each macro-element has been coded according to the specific material-technical characterisation. Lastly, subsection SDO6 contains a subsection that analyses the interior finishes of the theatre, intending to establish a ranking through the development of a schedule listing the same finishes to survey and record all qualifying architectural elements for the preservation of the asset.

On the other hand, SDT07 analyses and documents the possible external hazards in the area where the theatre is glued. With this category, the risk analysis opens it follows the SDT08, which introduces the specificity of analysis of the seismic damage of the SD T. In fact, it collects information relating to the seismic history of each theatre. However, the DT08 implementation aims to capture the earthquake history of each theatre, representing a snapshot of the primary damage suffered by the structure during past earthquakes. Therefore, information regarding the date of the most recent seismic event, the reported damage regarding the identified UST and describing the actions taken following the disaster and the author will be stored within these categories. With the SDT05, which records the historical stratification of the theatre and the conservative interventions carried out over time, the SDT08 aims to make traceable backwards every operation carried out on the theatre that can impact the seismic vulnerability of the theatre the asset. In this sense, the obligatory nature of the fields mentioned above acquires greater relevance because it helps scan an adequate level of high knowledge of the theatre.

The category in which the survey data of the seismic damage must be reported is the SDT09 consists of nine subsections: the first analyses the outer casing then follows seven sections relating to the 6 UST, and finally, there is the section where the detectors will document damage to non-structural elements (decorative architectural elements of the prospectus, and loggias and porches in this first session, in adding to the updated 2018 regional seismic zoning and list of municipalities’ seismic classifications, surveyors will be required to identify damage along the surfaces of the exterior envelope. For each prospectus, the meta form shows the mechanisms of collapse that can be activated for the macro elements of the external load-bearing masonry. The separation of the outer shell from the seven structural sub-joints was necessary because, in case of inaccessibility to the internal premises of the theatre, the detectors can perform the visual analysis of the damage in compliance with safety regulations. Therefore, only the collapse mechanisms surveyed and activated because of the earthquake will have to be documented regarding identifying the damage. This rule also extends to the remaining sections of category SDT09. The following records are divided into the 6 UST indicated above. The characterising macro-elements to which the relative collapse mechanisms are associated for each sub-community have also been identified. According to the proposed methodological approach of hierarchical structure partition, compared to 28 contained in the A-DC form 22 in the B-DP form of the 2012 used procedures, other actionable collapse mechanisms cloud be identified (fig.3). In particular, specific mechanisms related to the ceiling vault and the scenic arch have been identified for UST 2 and UST3. Furthermore, for the USTM of the horizons, tools linked to the vaulted systems were considered.

The level of damage will be classified according to the six class[3]:

1. No damage
2. Slight damage: slender cracks in the plaster, falling small pieces of plaster
3. Moderate damage: minor injuries in the walls, falling large pieces of plaster, tiles, injuries to chimneys, falling parts of chimneys
4. Strong damage: wide and deep lesions of the walls, falling chimneys
5. Destruction: openings in the walls, parts of buildings can collapse, the internal walls

3 the classification of the European Macroseismic Scale 1998, Classification of damage to masonry and reinforced concrete buildings, is taken up

collapse
6. Total damage to buildings - collapse

For each category section, the detector will have to evaluate the damage index, thus immediately identifying the portion of the theatre that has suffered the most damage. The safety measures must be implemented urgently.

Then, the global damage index will be the summation of the single index of the sections of the SDT09 category, adding the parameters referred to the morphologies of degradation (analysed in SDT10) that following the earthquake might be aggravating multipliers to the stability of the entire theatre or its parts.
Therefore, in category SDT10 for each UST, ten degradation phenomena have been identified that can be closely linked to seismic damage. They have been selected within the 20 classes defined by the UNI EN Standards – Recommendation UNI 11182[4] Lexicon for describing macroscopic alterations and degradations of stone materials – the meta form shows only the morphologies closely related to the damage (Tab 2).

Tabella 2. table of possible morphologies related to seismic damage

Alveolization is a severe form of degradation because it compromises the resistance of the stone material: it manifests itself with the formation of cavities of very variable size and often interconnected with each other. It is generally found in composite rocks, formed by different minerals (such as granite, breaches, sandstone with many impurities) and is due to the other resistance to atmospheric agents.
Disintegration mainly concerns mortar, stucco, and plaster and consists of decohesion characterised by the detachment of granules or small parts of material under minimal mechanical stress. If the disintegration is severe and advanced - to reduce the mortar to a pulverulent material without mechanical strength - it is called pulverisation.
Detachment - Form of degradation typical of plasters and mosaics, consisting in the division of one or more layers from the support and/or from a less superficial layer. However, it can also concern rocks with apparent layers, including the blackboard or some types of sandstone. The detachment is very harmful because if not treated quickly, it can lead to the fall of material with dangers of damage to things or people and/or the loss of entire portions of the surface.
Efflorescence - Formation of substances generally whitish in colour and crystalline, filamentous or pulverulent appearance on the material's surface or inside it (and in case we speak more appropriately of sub efflorescence). Often due to the soluble salts present inside the material, it is very harmful because - if not removed - it can cause injuries, scales, detachments, disintegration and fall of parts.
Erosion - Loss of surface portions of a material mainly due to wear, chemical corrosion, or atmospheric agents, particularly wind, frost, and rain. It mainly concerns mortars, plasters, and sandstone.
Fracturing, Cracking, or Injury consists of forming continuity solutions in the material, with the possible mutual displacement of the parts. Often due to atmospheric agents (particularly to the alternation of frost/thaw cycles) and/or too high mechanical loads, it is hazardous because it compromises the material's resistance and - if not treated - preludes to the fall of parts.
Lack - Generic term referring to the fall or loss of parts, especially if not decorated, such as bricks or stone blocks. If, on the other hand, the lack concerns decorated surfaces (frescoes, mosaics, decorated plaster, bas- survey s, stucco, etc.), it is defined as a gap.
Pitting is a form of degradation quite like alveolarisation that involves the formation at close range of blind holes, numerous and close, characterised by cylindrical shape and dimensions of a few millimetres. If not treated properly, it can compromise the stone's mechanical strength, causing cracking, detachment, and falling parts.
Swelling - Consists of a localised lifting of a layer of the material. It concerns fragile stone slabs (for example, portions of surface coatings or wall plates), very layered stones (such as some types of sandstone) and layers of plaster: in the latter cases, it is an obvious indication of detachments and lifts, and if not treated it preludes to the fall of portions of the material.
Scagliatura - Refers to the total or partial detachment of small parts of material with irregular shape and thickness called flakes. It often occurs in correspondence with continuity solutions of the material and can be provoked and/or aggravated by efflorescence and subefflorescence.

4 Standard UNI 11182 - Natural and artificial stone materials. Description of the form of alteration - Terms and definitions, expands, updates, and replaces the previous lexicon NORMA.L 1/88 (Regulations for Stone Products).

Within this class, the evaluation of the quality of mortars is also contemplated. The analytical data of 2012, in fact, report that often total and partial collapses or cracked paintings interesting the walls were due to the inconsistency of the mortars; therefore, it was considered appropriate to include this quality control parameter. The assessment of the state of conservation about the damage in the screening phase has not been introduced as an objective analytical parameter, as the inspection that will be carried out is visual. The qualitative indicator of the degradation conditions must be related to the seismic damage or about the possible risk phenomena that these may trigger or aggravate. Consequently, the detector is called to indicate the intervention times to heal the degraded part. This field is correlated by Query to category SDT11, in which the overall damage index is estimated. Therefore, always through Query will flow the indices of partial damage previously estimated in the sections of SDT09. In the same category, the surveyor must also indicate the damage cost estimate through an (id=d/5n) function and suggest the first safety measures.
Category SDT12 provides information about accessibility to the urban sector in which the property is located and the property itself and information about the building feasibility.
The last category, SDT13, shows the identification data of the owners of the information collected, responsible for managing and sharing data.
In terms of collecting the information flow, the SD T is structured to manage two levels of information, always hierarchical in categories and subcategories of data, in different documentation times. The first level of information contains data that can already be traced to the state and private-public archives, digital and not. The main categories ranging from SD T01 to SD T08 include information through which it is possible to trace the knowledge of the asset.. Several of the data regarding the identification, constraints status, location, historical stratification, use and architectural attributes of the property are partly digitised and included in the ICCD national databases, or the regional ones from PATER to the Emilia-Romagna Cultural Heritage GIS web, to the GIS platforms of the regional geological system, instead, are still in paper form. Through the SD T, the challenge is to systematically digitise all the essential information of the regional historical theatres helpful in mapping the main grammatical characteristics – from architectural to structural aspects, of historical stratification about previous earthquakes – to offer each theatre a seismic identity.
Digitalization also makes it possible to optimise the timing of the expeditious methodology in the field, especially in the emergency phase. Furthermore, this facilitates the inspection and processing of those data that must be traced to digital or paper archives of municipalities and superintendencies so that officials can focus attention on the survey and documentation of the seismic damage carried out on-site in the aftermath of the seismic event. Therefore, to achieve this objective, it has been fixed the requirement to fill in the data management and sharing fields from category SDT01 to SDT08 and SDT13. The compilation of information is the responsibility, in compliance with current legislation, to the officials of the superintendencies that have legal ownership to access the report of the cultural heritage.
In the MC Access master database, to check the success and accuracy of data entry, a "chromatic-semaphore" control marker was foreseen. It monitors the exhaustivity of acquired information per theatre and the validation of SD T delivery in the emergency phase.
The green light corresponds to the totality of the requested and acquired data, yellow to an informative partiality, and red to the incompleteness information (Appendix SD T categories).
If the obligation has its meaning in the event of a disaster, as it allows to have data that in the emergency phase should be found highly quickly, think of the information on the location of the asset, a fortiori constitute an essential parameter in the ordinary planning phase of conservation. Applying the SD T means to sanitise the current basic information and

implement it periodically with regular inspections to obtain a corpus of data that represent an updated history of the state of health of the asset. Therefore, inserting the obligatory compilation of the basic documentary categories of the SD T makes it a proactive tool for the mitigation of seismic.
The data acquired in the first information layer systematised in the MC Access database may be used to enrich the regional Web Gis platform. They are translated into georeferenced spatial data, obtaining overlapping thematic maps through which it is possible to trace a physical and geographical survey of the 106 Italian halls. In concert with the Agency for Reconstruction, it was hypothesised to implement the WebGIS of Cultural Heritage - Emilia-Romagna, born in the aftermath of the earthquake. The elaboration of overlapping thematic GIS maps, enriched by SD T data related to the material characterization, technological systems, damages that occurred in 2012, data recorded in the application of SD T in regular inspections, etc correlating them with other external risks data could be the basis for defining planned and strategic actions for seismic risk mitigation and prevention

The second layer of information is most closely correlated to seismic damage surveying and consists of categories SDT09 to SDT11 and their subcategories. Under this tier, all seismic damage information captured by MIC officials during post-earthquake inspections is collected and classified.
There are two main innovative aspects of this level, which is articulated according to the two criteria of the taxonomic matrix, compared to the current procedures in the survey and coding of seismic damage. The first has been partly described above and concerns the six structural subunits, the second, consequential to the first, is closely linked to the evaluation of the damage index. The damaged index is expressed about the collapse mechanisms activated in each structural subunit and the degradation morphologies surveyed that could incur in the aggravation of the state of vulnerability of the asset. Into DS T, it suggests analysing the seismic damage for each subunit, which is characterised by its USTM macroelements to which the relative collapse mechanism is associated.
Also, there is the obligatory compilation for these fields, essential for the SD T to be transmitted to the following workflow layer. However, the transmission can be made by the

Fig. 58. SD T of the G. Borgatti Theatre.The figure shows the possibility of digitising the form during the Emergency Phase. Developed by M.Suppa

SD T [SURVEY DAMEGE THEATRE] / L1 /METAFORM		SD T (SCREENING LEVEL)
IDENTIFICATION ▸ T01	ID	
	T01 - CODG codice gid	Gid code
	T01 -CODGIS codice webgis	Webgis code Mic
	T01 -OGTN - Denominazione Attuale	Current Name
	T01 - OGTNDN2012 danno sismico 2012	Seismic damage 2012
	T01-CTSKDS 2012 compilazione scheda del danno2012	Damage form2012compilation
		Damage form acquired
	T01-TSKDS_tipo di scheda del danno acquisita	last survey
	T01- STA - ultimo rilievo	Last survey
	T01_ATTRIL-attrezzatura rilievo	Survey equipment
	T01_DITRI_ditta responsabile del rileivo	Firm survey
	T01_TEAMRI - operatori del rilievo	Survey operators
	T01STA- aggiornamento scheda stato di fatti	Update of the state of facts
	T01 -NTSKDS - nuova tipologia di scheda	New form type
	T01-NCT - CODICE UNIVOCO	UNIVOCAL CODE
	T01-NCTR - Codice regione	Region code
	T01 -NCTN - Numero catalogo generale	General catalog number
	T01 -ESC - Ente schedatore	Filing entity
	T01 -ECP - Ente competente	Competent authority
	T01 - OGT - OGGETTO	OBJECT
	T01 -OGTD - Definizione tipologica	Typological definition
	T01 - OGTQP - Qualificazione della Proprietá	Property Qualification
	T01 -OGTNQP - nominativo della proprietà	Name of property
	T01 -OGTNA denominazione 1982	Denomination 1982
	T01 -OGTCLS - classificazione del bene	Property classification
LOCALIZATION ▸ T02	PVC - LOCALIZZAZIONE GEOGRAFICO-AMMINISTRATIVA	PVC - LOCATION
	T02 -PVCS - Stato	State
	T02-PVCR - Regione	Region
	T02 -PVCPID-ID PROVINCIA	D PROVINCE
	T02 -PVCP - Provincia	Province
	T02 -PVCCID -ID Comune	ID Municipality
	T02 -PVCC - Comune	Municipality
	T02 -PVCI - Indirizzo	T02 -PVCI - Address
	T02 -PVCI TL- Toponomastica localitá	Toponymy locality
	T02 -PVCITS - Toponomostica stradale	Street toponymy
	T02-PVCICON_edifici confinanti	Adjacentbuildings
	T02 -CS - LOCALIZZAZIONE CATASTALE	CADASTRAL LOCATION
	T02 -CTL - Tipo di localizzazione	Type of location
	T02-CTID_identificativo Catastale	adastral Identifier
	T02 -CTSC - Comune	Municipality
	T02 -CTSF - Foglio/Data	Sheet/Date
	T02 -CTSN - Particelle	Parcels
	T02 -CTSP - Proprietari	Owners
	T02 -Allegato catastale	Cadastral appendix
	T02 -GP - GEOREFERENZIAZIONE	GEOREFERENCING
	T02 -GPI - Identificativo Punto	Point Identifier
	T02 -GPL - Tipo di localizzazione	Location Type
	T02 -GPDPX - Coordinata X	X coordinate
	T02 -GPDPY - Coordinata Y	Y coordinate
	T02 -GPM - Metodo di georeferenziazione	Georeferencing method
	T02 -GPT - Tecnica di georeferenziazione	Georeferencing technique
	T02 -GPP - Proiezione e Sistema di riferimento	Projection and Reference System
	T02 -GPB - BASE DI RIFERIMENTO	REFERENCE BASE
	T02 -GPBB - Descrizione sintetica	Brief description
	T02 -GPBB2 - Descrizione sintetica	Brief description
	T3 -GPBB2 - COLLEGAMENTO	LINK

Fig. 59 Structure and organisation of the categories sub-sections of the meta sheet for seismic damage assessment for theatres - SD T. Developed by M.Suppa

LEGAL STATUS ▶T03

CONDIZIONE GIURIDICA GIURIDICA E VINCOLI	LEGAL STATUS
T03 -CDGG – Indicazione generica	Generic indication
T03 -CDGS – Indicazione specifica	Specific indication
T03 -CDGI - Indirizzo	Address
T03 -NVC - PROVVEDIMENTI DI TUTELA	PROTECTIVE MEASURES
T03 -NVCT - Tipo provvedimento	Type of measure
T03 -NVCE – Estremi provvedimento	Extremes of measure
T03 -STU - STRUMENTI URBANISTICI	URBAN PLANNING INSTRUMENTS
T03 -STUT - Strumenti in vigore	Instruments in force
T03 -STUN - Sintesi normativa	TSummary of regulations
T03 -ALLEGATI	ANNEXES

USE ▶T04

T04 -USS - USO STORICO	HISTORICAL USE
T04 -USAR - Riferimento alla parte	Reference to the part
T04 -USA- USO ATTUALE	CURRENT USE
T04 -USOR - Riferimento alla parte	Reference to part
T04 -USOC – Riferimento cronologico	Chronological reference
T04 -da - a	From - To
T04 -DOCF - Documentazione Fotografica	Photographic documentation
T04-RENFF-riferimento fotografico	TPhotographic reference

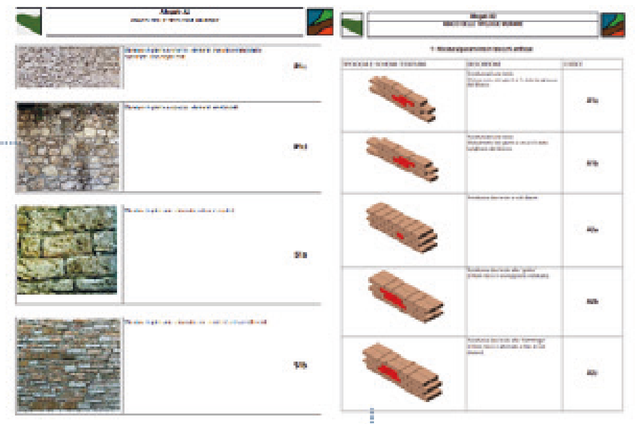
HISTORY OF THE BUILDING ▶T05

T05 - RE - NOTIZIE STORICHE	RE - HISTORICAL NEWS
T05 -REN - NOTIZIA	REN - NEWS
T05 -RENS - Notizia sintetica	RENS - News summary
T05 -RENF - Fonte	RENF - Source
T05 -RENFT - Fonte -TESTI	RENFT - Source - TEXTS
T05 - RENF-collegamento	RENF-connection
T05 -RENFTI - Fonte-ICONOGRAFIA	RENFTI - Source-ICONOGRAPHY
T05 -RENFTI _allegato	RENFTI _attachment
T05-RTNFTIN-AUTORE DEL RIFERIMETO	AUTHOR OF THE REFERENCE
T05 -REL - CRONOLOGIA, ESTREMO REMOTO	T05 -REL - HISTORY, REMOTE EXTREME
T05 -RELS - Secolo	RELS - Century
T05 -RELI - Data	RELI - Date
T05 -PNR - Riferimento alla parte	PNR - Part reference
T05 - PNRPORZ - se altro idicare quale porzione	PNRPORZ - if another identity which portion
T05 - AUTR – Riferimento all'intervento (ruolo)	AUTR - Reference to intervention (role)
T05 -AUT - AUTORE	AUT - AUTHOR
T05 -ATB - Fonte dell'attribuzione	ATB - Source of attribution
T05 -AUTN - Nome scelto	AUTN - Name chosen
T05 -AUTA - Dati anagrafici	AUTA - Master data
T05 -ATB - AMBITO CULTURALE	ATB - CULTURAL FIELD
T05 -ATBM – Fonte dell'attribuzione	ATBM - Source of attribution
T05 -PNR - Riferimento alla parte	PNR - Reference to the part
T05-OGTMOD - TRASFORMAZIONI	OGTMOD - TRANSFORMATIONS
T05-MODP-periodo della tradormazione	MODP-period of transformation
T05-MODPNR-rifermento alla parte	MODPNR-reference to part
T05-MODDES-descrizione dell'intervento	MODES-description of the intervention
T05-MODAT- allegati tecnici	MODAT- technical annexes
T05-RTNFAR-archivio	RTNFAR-archive

Fig. 59Structure and organisation of the categories sub-sections of the meta sheet for seismic damage assessment for theatres - SD T. Developed by M.Suppa

MORPHO-TYPOLOGICAL FEATURES THEATRE ▶T06

OGTDI- Dati dimesionali	Dimensional data
OGTIMP_ Forma urbana dell'impianto	Urban shape
OGTNP_Numero dei piani	Number of floors
OGTMF_Morfologia planimetrica	Morphology planimetric
OGTMFT2-ferro di cavallo	horseshoe
OGTMF3-a U	a U
OGTMF4-circolare	circular
OGTMF5-rettangolare	rectangular
OGTNDAL-Dati altimetrici	Altimetric data
OGTNOR-Numero degli ordini dei palchi	Number of boxes orders
OGTNPL-planimetria del teatro	Planning of the theater
OGTLaM -Larghezza media:	Average width:
OGTLuM -Lunghezza media:	Average length:
OGTAM -Altezza media	Average height.
OGTSuM-Superficie media	Average area
OGTDQD - supporto del dato	data support
T06 -OGTINE- caratterisitche involucro esterno	T06 -OGTINE- characteristics of the external shell
T06 -OGTINEMU- caratterisitche murataura esterna	T06 -OGTINEMU- attributes of the exterior walls
T06 -OGTINEMU - Tecnica di esecuzione	T06 -OGTINEMU - Execution technique
T06 -OGTINECOTi_tipologia di copertura	T06 -OGTINECOTU_typology of coverage
T06 -OGTINECOTi_specifiche tipologia di copertura	T06 -OGTINECOTi_covering type specifications
OGTINECOSPS-comportamento struttura portante della copertura	behavior of the supporting structure of the coverage
T06 -OGTINECOma_materiali della coperuta	roofing materials
T06 -OGTINEEL_elmenti caratterizzanti	characterizing elements
OGTINEmuEC-elementi di consolidamento	consolidation elements
T06 -OGTINEFI_Finiture esterne	external finishes
T06 -OGTINEFIPo-porte	doors
T06 -OGTINEFIFi-finestre	windows
T06 -OGT_OGTIN-oggetti integrati	integrated objects



MORPHO-TYPOLOGICAL FEATURES UST ▶T06

T06 -UST1- Avancorpo/Foyer	Forebody/Foyer
T06 -USTM1 -Larghezza media	Average width
T06 -USTM1 - Lunghezza media	Average length
T06 -USTM1 -Altezza media	Average height
T06 -USTM1 - Macroelementi	Macroelements
T06 -USTM1- Muratura portante	Bearing masonry
T06 -USTM1- Materiali	Materials
T06 -USTM1 - Tecnica di esecuzione	Execution technique
T06 -USTM1- Strutture di orizzontamento	Slabs/Vault
T06 -USTM1 -Riferimento altimetrico	Altimetrical Reference
T06 -USMT1NA-ambiente	Room
T06 -USTM1 - Materiali e tecnica costruttiva	Materials and construction technique (horizon)
T06 -USTM1 - Pareti divisorie	Partition walls
T06 -USMT1NA-ambiente	Room
T06 -USTM1-riferimento alla parete	Reference to the wall
T06 -USTM1 - Copertura	Roff
T06 -USTM1 - Sistema di Copertura	Roofing System
T06 -USTM1 - Sistema di copertura Materiali	Roofing System Materials
T06 -USTM1_materiali della coperuta	Covering materials
T06 -USTM1 - Copertura spingente	Pushing cover
T06 -UST2- Cavea	T06 -UST2- Hall
T06 -USTM2 -Larghezza media (muratura)	T06 -USTM2 -Average width

CODING LEVEL
LG Basement Floor
GF Ground floor
01 First Order of Stages
02 Second Order of Stages
03 Third Order of Stables
04 Gallery
M1 Mezzanine Floor 1
M2 Mezzanine Floor 2.

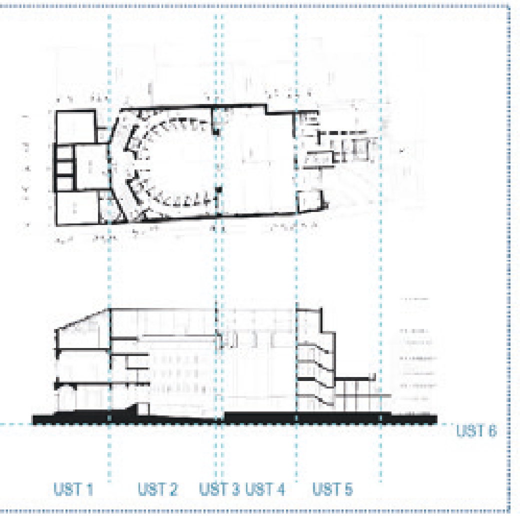


Fig. 59.1 Structure and organisation of the categories sub-sections of the meta sheet for seismic damage assessment for theatres - SD T Developed by M.Suppa

MORPHO-TYPOLOGICAL FEATURES
UST
T06

T06 -USTM2 - Lunghezza media	Average length
T06 -USTM2-Altezza media	Average height
T06 -USTM2 - Macroelementi	Macroelements
T06 -USTM2- Muratura portante	Bearing masonry
T06 -USTM2- Materiali	Materials
T06 -USTM2- Tecnica di esecuzione	Execution technique
T06 -USTM2- Struttute di orizzontamento	Slab/Vault
T06 -USTM2 - Riferimento altimetrico	Altimetrical Reference
T06 -USMT2NA-stanza	Room
T06 -USTM2 - Materiali e tecnica costruttiva	Materials and construction technique
T06 -USTM2 - Pareti divisorie	TPartition Walls
T06 -USTM2 - Pareti divisorie materiali	Partition walls materials
T06 -USMT2NA- Corridoi	Corridors
T06 -USTM2-riferimento alla parete	wall reference
T06 -USTM2 - Pareti palchi e gallerie	Stage and gallery walls
T06 -USMT2NA-numero del palchetto	boxes numeber
T06 -USTM2-riferimento alla parete-palchi/gallerie	reference to the wall-pallets/galleries
T06 -USTM2 - Pareti gallerie materiali	Material gallery walls
T06 -UTSM2Pla - Plafone/Voltone	Plafone/Vault
T06-UST2PlaLU_Largezzza	Largeness
T06-UST2PlaLU_Lunghezza	Length
T06 -USTM2Pla - Superficie	Surface
T06 -USTM2Pla- materiali e tecniche costruttive	materials and constructive techniques
T06 -USTM2 - Orditura del Plafone	Plafone's warping
T06 -USTM2 - Copertura	Roof
T06 -USTM2- Sistema di Copertura	Roofing System
T06 -USTM2 - Sistema di copertura Materiali	Roofing System Materials
T06 -USTM2_materiali della copertura	Covering Materials
T06 -USTM2 - Copertura spingente	T0Pushing cover

T06 -UST3- Arco scenico	Proscenium arch
T06 -USTM3 -Larghezza media (muratura)	Average width
T06 -USTM3 - Lunghezza media (muratura)	Average length
T06 -USTM3-Altezza media(muratura)	Average height
T06 -USTM3 - Macroelementi	TMacroelements
T06 -USTM3- Muratura portante	Bearing masonry
T06 -USTM3- Materiali	Materials
T06 -USTM3- Tecnica di esecuzione	Execution technique
T06 -USTM3- Struttute di orizzontamento	Slabs/vault
T06 -USTM3 - Riferimento altimetrico	Altimetrical Reference
T06 -USMT3NA- Ambienti laterali	Lateral enviroment
T06 -USMT3NA- Arco	Proscenium Arch
T06 -USTM3 - Materiali e tecnica costruttiva	Materials and construction technique
T06 -USMT3NA- Pareti divisorie -	Partition walls - Prosecium Arch
T06 -USTM3 - PA materiali Arco	Materials Prosecium Arch
T06 -USTM3-riferimento alla parete	reference to the wall
T06 -USMT3NA- Pareti divisorie_Ambiente Laterale	Partition walls_Later enviroment
T06 -USTM3 - Pareti divisorie materiali _Ambiente Laterale	Walls partition materials _Later enviroment
T06 -USTM3-riferimento alla parete _Ambiente Laterale	reference to the Later enviroment wall

T06-UST4- Palco	Stage
T06-USTM4 -Larghezza media	Average width
T06-USTM4 - Lunghezza media	Average length
T06-USTM4 -Altezza media	Average height
T06-USTM4 - Macroelementi riferiti	Referenced Macroelements
T06-USTM4- Muratura portante	Supporting masonry

Fig. 59.2Structure and organisation of the categories sub-sections of the meta sheet for seismic damage assessment for theatres - SD T. Developed by M.Suppa

MORPHO-TYPOLOGICAL FEATURES
UST
T06

T06-USTM4- Materiali	Materials
T06-USTM4 - Tecnica di esecuzione	Execution Technique
T06-USTM4- Struttute di orizzontamento	Slabs/Vault
T06-USTM4 -Riferimento altimetrico	Altimetric Reference
T06-USMT4NA-stanza	Room
T06-USTM4 - Materiali e tecnica costruttiva	Materials and construction technique
T06-USTM4 - Pareti divisorie	Partition Walls
T06-USMT4NA-Ambiente	Room
T06--riferimento alla parete	Wall reference
T06-USTM4 - Copertura	Roofing
T06-USTM4 - Sistema di Copertura	Roofing System
T06-USTM4 - Sistema di copertura Materiali	Roofing System Materials
T06-USTM4_materiali della coperuta	Roofing Materials
T06- - Copertura spingente	Pushing cover

T06-UST5- Blocco servizio	Utiluty space
T06-USTM5 -Larghezza media	-Average width
T06-USTM5 - Lunghezza media	Average length
T06-USTM5 -Altezza media	Average height
T06-USTM5 - Macroelementi	Macroelements
T06-USTM5- Muratura portante	Supporting masonry
T06-USTM5- Materiali	Materials
T06-USTM5MU- materiali allegati	Attached materials
T06-USTM5 - Tecnica di esecuzione	Execution Technique
T06-USTM5- Struttute di orizzontamento	Slabs
T06-USTM5 -Riferimento altimetrico	Altimetric Reference
T06-USMT5NA-Ambiente	Room
T06-USTM5 - Materiali e tecnica costruttiva	Materials and construction technique
T06-USTM5 - Pareti divisorie	Partition Walls
T06-USMT5NA-Ambiente	-Room
T06-USTM5-riferimento alla parete	wall reference
T06-USTM5 - Copertura	Roof
T06-USTM5 - Sistema di Copertura	Roofing System
T06-USTM5 - Sistema di copertura Materiali	Roofing System Materials
T06-USTM5_materiali della coperuta	Covering Materials
T06-USTM5 - Copertura spingente	Pushing cover

T06 -USM6 -Fondazioni	Foundations
T06 - USM6FT -Terreno soggetto a fenomeno di liquefazione	Soil subject to liquefaction phenomenon
T06 -USTM6R_Rifermento all'unità strutturale	Reference to the structural unit
T06 - USMF6Mu- Sistema di fondazione	Foundation system
T06 - USM6FQM-Materiali del sitema di fondazione	Materials of the foundation system
T06 -USM6FT - Tipologia di fondazione	Type of foundation
T06 -USM6FLa - Tecnica di esecuzione	Execution technique
T06 -USM6FTIT_tipologia di terreno	type of terrain

EXTERNAL HAZARDS
T07

T07 - OGTNRE-Presenza Rischi Esterni	Presence of External Risks
lrischio idrogeologico - frane	Hydrogeological risk - landslides
rischio idrogeologico - alluvioni	hydrogeological risk - floods
rischio di tipo industriale	industrial risk
altre minacce naturali	other natural threats
minacce antropiche	anthropic threats

Fig. 59.3 Structure and organisation of the categories sub-sections of the meta sheet for seismic damage assessment for theatres - SD T. Developed by M.Suppa

SEISMIC HISTORY ▶T08

T08 -STSD-Data Degli Eventi Sismici Pregressi	Date Of Previous Seismic Events
T08 - ZONS- Zonizzazione Sismica	Seismic Zoning
T08 -RIFUST-Riferito All'UST	UST
T08 -DESRIF-Descrizione Del Danno Relativo All'UST	UST Damage Description
T08 -INTV-Descrizione Dell'intervento	Intervention Description
T08 -INTAU-Autore Dell'intervento	Intervention Author

EXTERNAL HAZARDS ▶T09

T07 - OGTNRE-Presenza Rischi Esterni	Presence of External Risks
lrischio idrogeologico - frane	Hydrogeological risk - landslides
rischio idrogeologico - alluvioni	hydrogeological risk - floods
rischio di tipo industriale	industrial risk
altre minacce naturali	other natural threats
minacce antropiche	anthropic threats

DAMAGED SURVEY ▶T09

T09 -MuE_MURATURA PORTANTE ESTERNA	Bearing Masonry
T09 -MCMCRE_Analisi dei meccanismi	Analysis of mechanisms
T09 -MuE-N -prospetto NORD	NORTH Front
T09 -MuEMC-N_meccanismi di collasso	collapse mechanisms
T09 -MuE-S -prospetto SUD	SOUTH Front
T09 -MuEMC-S_meccanismi di collasso	collapse mechanisms
T09 -MuE-W -prospetto OVEST	WEST Front
T09 -MuEMC-W_meccanismi di collasso	collapse mechanisms
T09 -MuE-E -prospetto EST	EAST Front
T09 -MuEMC-E_meccanismi di collasso	collapse mechanisms
T09 -QUOTDs - Quota livello danno	amage level elevation
T09 -USTMLDA_LIVELLO DI ATTIVAZIONE DEL DANNO	USTMLDA_LEVEL OF DAMAGE ACTIVATION
T09 -IDSP_INDICE DEL DANNO PARZIALE	INDEX OF PARTIAL DAMAGE
T09 -OGTINEFI_FINITURE ESTERNE	EXTERNAL FINISHES

UST 1- 4-5

T09 -USTM_1/4/5	USTM1_1/4/5
T09 -Mul_MURATURA PORTANTE INTERNA	NTERIOR Bearing Masonry
T09 -MulRA-Riferimento altimetrico	ALTITUDE REFERENCE
T09 -MulA-codice ambiente	-environment code
T09 -Mul_np_numero della parte interna rilavata	number of the reworked internal part
T09 -MulMC_meccanismi di collasso della muratura portante interna	collapse mechanisms of the internal load-bearing masonry
T09 -USTMPa - PARETI DIVISORIE	DIVISION WALLS
T09 -PaRA-Riferimento altimetrico	Altimetric reference
T09 -PaA-codice ambiente	environmental code
T09 -Pa_np_ numero della parete divisoria	partition number
T09 -PaMCO_meccanismi di collasso della parete interna	collapse mechanisms of the internal wall
T09 -USTMO- STRUTTURE DI ORIZZONTAMENTO	SLAB/VAULT
	typology
T09 -OT- tipologia	affected environment code
T09 -OMC-codice ambiente interessato	collapse mechanisms horizon structures
T09 -OMC_meccanisimi di collasso strutture di orizzontamneto	ROOF
T09 -Co-COPERTURA	roofing sector
T09 -CoSET_ settore copertura	roofing collapse mechanisms
T09 -CoMC-meccanismi di collasso copertua	T09 -USTMLDA_LEVEL OF DAMAGE

Fig. 59.4 Structure and organisation of the categories sub-sections of the meta sheet for seismic damage assessment for theatres - SD T. Developed by M.Suppa

DAMAGED SURVEY ▶T09

UST 1- 4-5

T09 -USTMLDA_LIVELLO DI ATTIVAZIONE DEL DANNO	USTMLDA_LEVEL OF DAMAGE ACTIVATION
T09 -IDSP_INDICE DEL DANNO PARZIALE	INDEX OF PARTIAL DAMAGE

UST 2

T09 -USTM2-	USTM2
T09 -Mul2_MURATURA PORTANTE INTERNA	INTERIOR Bearing Masonry
T09 -MuRA2-Riferimento altimetrico	Altimetric reference
T09 -MulA2-codice ambiente	environment code
T09 -Mul2_np_numero della parte interna rilavata	number of the internal raised part
T09 -MulMC2_meccanismi di collasso della muratura portante interna	collapse mechanisms of the internal load-bearing masonry
T09 -USTMPa2 - Pareti divisorie	Partition walls
T09 -PaRA2-Riferimento altimetrico	Altimetric reference
T09 -PaA2-codice ambiente	environmental code
T09 -Pa2_np_ numero della parete divisoria	partition wall number
T09 -PaMC2_meccanismi di collasso della muratura portante interna	collapse mechanisms of the internal load-bearing masonry
T09 -O2- STRUTTURE DI ORIZZONTAMENTO	SLABS/VAULT
	typology
T09 -OT2- tipologia	environment code
OA2-codice ambiente	collapse mechanisms of horizon structures
T09 -OMC2_meccanisimi di collasso strutture di orizzontamneto	
T09 -PL2_PLAFONE/VOLTA	PLAFONE/VAULT
T09 -PL2-meccanismi di collasso plafone	mechanisms of collapse ceiling
T09 -Co2-COPERTURA	ROOF
T09 -CoSET2_ settore copertua	roofing sector
T09 -CoMC2-meccanismi di collasso copertua	roof collapse mechanisms
T09 -USTMLDA_LIVELLO DI ATTIVAZIONE DEL DANNO	LEVEL OF DAMAGE ACTIVATION
T09 -IDSP_INDICE DEL DANNO PARZIALE	INDEX OF PARTIAL DAMAGE

UST 3

T09 -USTM3-ARCO SCENICO	USTM3-PROSCENIUM ARCH
T09 -Mul3_MURATURA PORTANTE INTERNA	INTERIOR Bearing Masonry
T09 -MulRA3-Riferimento altimetrico	ALTITUDE REFERENCE
T09 -MulA3-codice ambiente	environment code
T09 -Mul3_np_numero della parte interna rilavata	number of the reworked internal part
T09 -MulMC3_meccanismi di collasso della muratura portante interna	collapse mechanisms of the internal load-bearing masonry
T09 -USTMPa3 - PARETI DIVISORIE	DIVISION WALLS
T09 -PaRA3-Riferimento altimetrico	Altimetric reference
T09 -Pa31A-codice ambiente	environment code
T09 -Pa3_np_numero della parte interna rilavata	number of the inner raised part
T09 -PaMCO3_meccanismi di collasso della parete interna	mechanisms of the collapse of the inner wall
T09 -USTM3A - Arco	Arch
AMC3-meccanismi di collasso arco scenico	mechanisms of collapse scenic arch
T09 -O3- STRUTTURE DI ORIZZONTAMENTO	SLABS/VAULT
	typology
T09 -OMC3- tipologia	environmental code
T09 -OMC3codice ambiente	
T09 -OMC3_meccanisimi di collasso strutture di orizzontamneto	collapse mechanisms horizon structures
T09 -USTMLDA_LIVELLO DI ATTIVAZIONE DEL DANNO	LEVEL OF DAMAGE ACTIVATION
T09 -IDSP_INDICE DEL DANNO PARZIALE	INDEX OF PARTIAL DAMAGE

Fig. 59.5Structure and organisation of the categories sub-sections of the meta sheet for seismic damage assessment for theatres - SD T. Developed by M.Suppa

DAMAGED SURVEY ▶T09

T09 -USMF-FONDAZIONE	FOUNDATION
T09 -USMFSE_settore fondazioni	foundation sector
T09 -FMCG-meccanismi di collasso fondazioni (globale)	mechanisms of foundation collapse (global)
T09 -USTMLDA_LIVELLO DI ATTIVAZIONE DEL DANNO	LEVEL OF DAMAGE ACTIVATION
IT09 -DSP_INDICE DEL DANNO PARZIALE	INDEX OF PARTIAL DAMAGE

UST 3

T09 -USMSC -SCALA	STAIR
T09 -SC-Riferimento altimetrico	Altimetric reference
T09 -RIFUMTS- analisi simica unità strutturali del teatro	seismic analysis structural units of the theatre
T09 -ORsc-orientamento	orientation
T09 -MCGSC-meccanismi di colasso scala	mechanisms of collapse scale
T09 -USTMLDA_LIVELLO DI ATTIVAZIONE DEL DANNO	LEVEL OF DAMAGE ACTIVATION
T09 -IDSP_INDICE DEL DANNO PARZIALE	PARTIAL DAMAGE INDEX
T09 -USTGLOB_DANNI GLOBALI	TGLOBAL DAMAGES
T09 -USTMAD_ALTRI DANNI	OTHER_DAMAGE
T09 -RIFPAVUST-RIFERIMENTO AL UST	REFERENCE TO UST
T09 -USTMADPAV_DANNI AL PAVIMENTO	FLOOR_DAMAGE
T09 -USTMADAD_DANNI ALL'APPARATO DECORATIVO	DAMAGE TO THE DECORATIVE PART
T09 -RIFPAVDES-DESCRIZIONE	T09 -RIFPAVDES-DESCRIPTION
T09 -OGT_OGTIN-oggetti integrati	integrated objects

UST 6

CONDITION SURFACES ▶T10

T10- USTM 1/2/3/4/5	T10- USTM 1/2/3/4/5
T10-ANASUP_ANALISI DELLE SUPERFICI	SURFACE ANALYSIS
T10-MuE-superficie esterna	external surface
T10-DEGRMuE_morfologie di degrado	degradation morphologies
T10-STMuEQ-Qualità della malta	Mortar Quality
T10-MuECRDS_Classe di rischio rispetto al danno sismico	Risk class concerning seismic damage
T10-MuETSTRI_tempi di intervento	times of intervention
T10-MuI-supercie intrena	MuI-Intrena Surfaces
T10-MuIRA-Riferimento altimetrico	Altimetric reference
T10-MuIA-codice ambiente	environmental code
T10-MuI_np_numero della parte interna rilavata	number of the internal part reworked
T10-DEGRMuI_morfologie di degrado	morphologies of degradation
T10-STMuIQ-Qualità della malta	Grout Quality
T10-MuICRDS_Classe di rischio rispetto al danno sismico	Risk class concerning seismic damage
T10-MuITSTRI_tempi di intervento	times of intervention

GLOBAL DAMAGE INDEX ▶T11

T11 -IDSG_INDICE DEL DANNO GLOBALE	GLOBAL DAMAGE INDEX

Fig. 59.6 Structure and organisation of the categories sub-sections of the meta sheet for seismic damage assessment for theatres - SD T. Developed by M.Suppa

SAFETY AND ACCESSIBILITY ▶T12

T12 - AGIBILITA'	T12 - SAFETY
T12 -AGCS_Caratteristiche Del Sito	T12 -AGCS_Site Characteristics
T12 -GPBPO – Posizione	T12 -GPBPO - Location
isolato	Isolated
aggregato	aggregate
T12 -ACCLO2012 -Accessibilita' Al Sito	T12 - ACCESSIBILITY
accesso pedonale	pedestrian access
accesso carrabile	vehicular access
accesso con altezza inferiore a 4 m	access with height less than 4 m
accesso con mezzi pesanti	access with heavy vehicles
rete viaria idonea in relazione al rischio	road network suitable about the risk
parcheggio nelle vicinanze	parking nearby
spazia aperte	open spaces
altro	other

DECISION SUPPORT DATA ▶T13

T13 -DATPROP-Proprieta' Del Dato	T13 -DATPROP-Data Ownership
T13 -DATARC-Archiviazione Del Dato	T13 -DATARC-Data Archiving
T13-NDATARC_Nominativo Del Responsabile	T13-NDATARC_Data Manager Name
T13-DATAUSO-Utilizzazione Del Dato	T13-DATAUSAGE-Data Use

Fig. 59.7 Structure and organisation of the categories sub-sections of the meta sheet for seismic damage assessment for theatres - SD T. Developed by M.Suppa

competent body responsible for the protection action (MIC and Agency for Reconstruction) only if all the information required to assess the state of damage suffered both on a local and global scale is present. The meta form has the primary function in a state of emergency to guide the first operations of securing the building and establish the disbursement of funds for the interventions to be performed.
In conclusion, although the SD T was designed for the case studies, it can be extended and applied to all theatre buildings belonging to this architectural typology, both on a national and international scale. First, however, implementing some categories of documentation that are subject to variables related to the specificities of the territory, such as materials and construction systems.

5.1. 2 Application of the meta form SD -T

<u>5.1.2.1 Emergency phase: pilot case of Social Theatre of Novi (Modena)</u>

The Teatro Sociale di Novi di Modena has been surveyed using the meta form in July 2020 through two important campaigns carried out on the site on 16 and 17 July and from 24 to July 29, 2020. In fact, in the autumn of 2019, the theatre, except for the expeditious survey carried out through the damage form – model B DP – in the reconnaissance operations of the cultural heritage damaged by the 2012 earthquake coordinated by the Mibact teams, had not been the subject of any analytical survey (fig.60). Therefore, in concert with the Agency for Reconstruction, a case study pilot was selected to validate the three information levels of the integrated procedure workflow.
Regarding the damage data recorded by the optimised version form B, used for the Social Theater, the evaluation of activation's collapse mechanisms is expressed in percentages on a global scale.
This element that has conditioned the estimate of the damage index, probably due to the percentage criterion, was unexpressed. In response to this evidence, it was decided to choose the Social Theater of Novi (fig.61) as a case study for developing and validating the proposed integrated form to survey the damage suffered. The Social Theater of Novi geographically, on a regional scale, is in a nodal point between the different provinces of Emilia and Lombardy, so much so that linguistically the history of the theatre is influenced by the formal linguistic codes of Reggio Emilia and Mantua. From the ministerial and municipal archival materials consulted, there is no official document action to reconstruct the construction phases of the building faithfully. The historical reconstruction of the theatre was carried out based on local studies, texts and [5]newspapers. However, the Municipal Archives showed a deliberation of the Provincial Council in 1926, which established the land's sale by the Municipality to several citizens, forming a society for the building of a theatre on Viale dei Martiri della Libertà. A previous resolution of 1919 n had preceded this act. May 4 on, 1919, certifies the authorisation to proceed with the design of a municipal theatre. The 1982 IBC census shows the theatre was built from 1923 to 1929 based on the young architect Pietro Pivi di Piove, named Ermes (Novi 1903). From the masonry to the carpentry and joinery works, the whole building was realised by novese craftsmen. Of the original drawings, there is not much left, if not of the glossy photographed S. Gherardi di Novi relating to the project of a foundation plinth, of truss of the roof and a detail of the steps, by P. Pivi.

The theatre knew an intense theatrical activity for the first three years of life. Then it was transformed into a cinematograph in 1995 when it became municipal property from the proven property. This new intended use involved the transformation of some reduced halls to accommodate the machinery still present on site. The decorative system remains unchanged until the seventies of the twentieth century. It's shown by some photographs of the time that portray the boxes and railings decorated in floral style, destined that in the years to come for lack of funds for the maintenance of the same, to be covered entirely by pink plaster today still visible. The theatre was increasingly abandoned until carnival

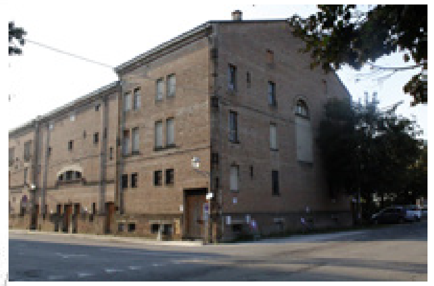
5 *"Il Falco"*

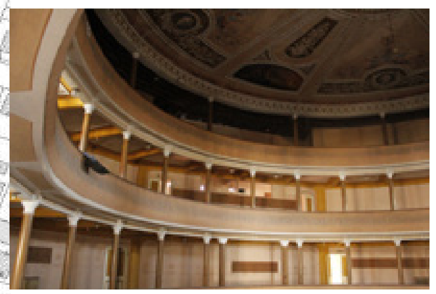
MASTER DATA OF THE SOCIAL THEATRE OF NOVI IN MODENA

Province: MO
Municipality: Novi di Modena
Address: Novi Modena Via Martiri della Libertà 2
Name: Social Theatre

Technical data

Type of plan: horseshoe plan with galleries
Current use: uninhabitable





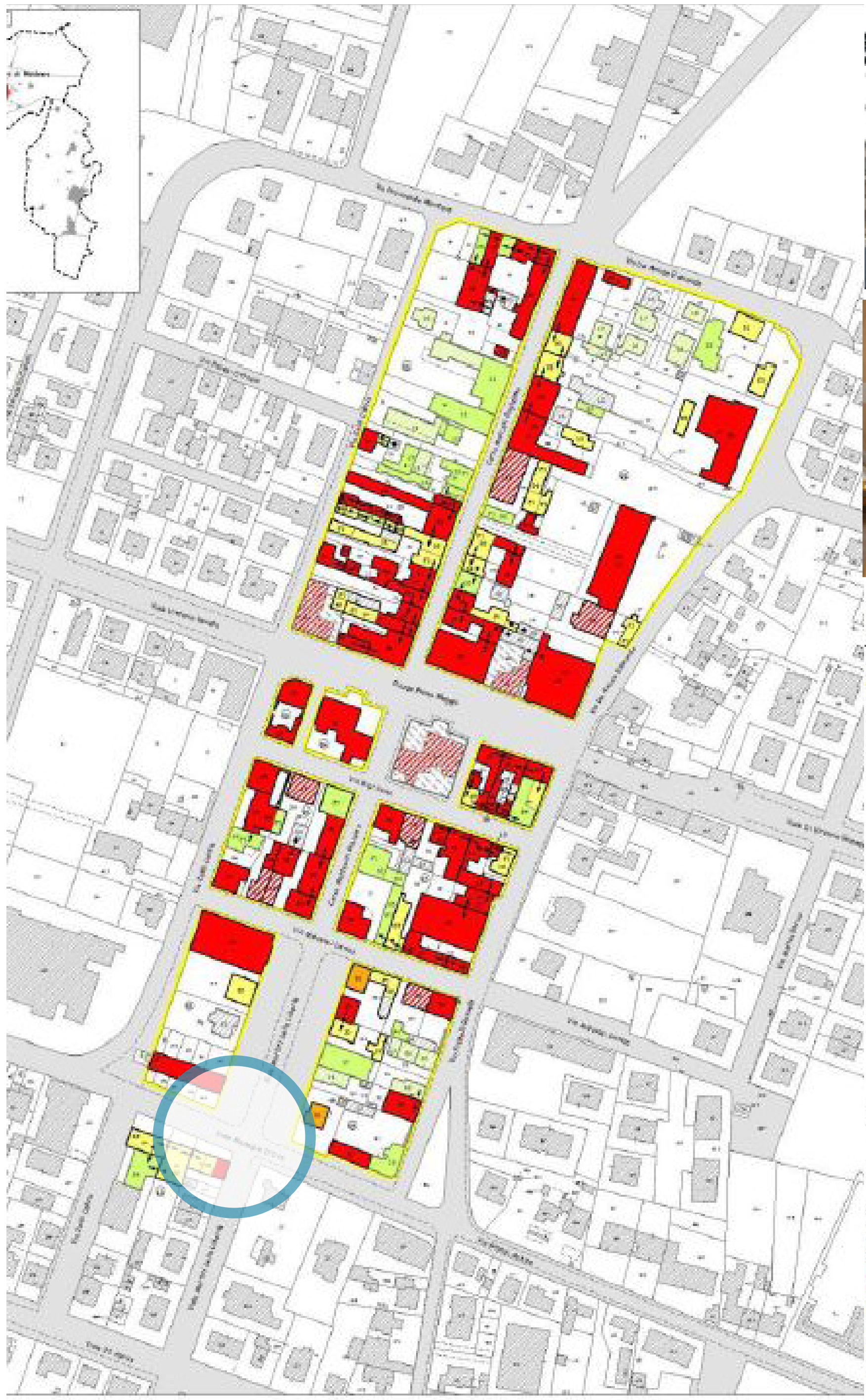


Fig. 60. 1st draft cognitive framework Reconstruction plan of the municipality of Novi di Modena. From Munipality of Novi archive

Fig. 61 Novi, Social Theatre, the hall towards the stage (photo Riccardo Vlahov, I.B.C.) 1980, 30156099. Image from https://bbcc.ibc.regione.emilia-romagna.it/pater/

celebrations were occasionally used during the eighties. Analysing the decorative apparatus, by Salvarani (1882-1953), a native of Carpi, is of late Art Nouveau origin. Nevertheless, the hall environment's painted decorations remain, particularly at the top of the plafond and the scenic arch. The decorative paintings of the vaulted ceiling are the most important: "the dome, radially divided into sectors is characterised by four masks that represent, Pain, Serenity; Sadness and Hilarity,[6]and four panels that follow the cardinal points that portray Dance, Music; Tragedy and Comedy (fig.62,63,64)."[7]
These Figurative decorations of the masks identify and allow to know the building's function, together with the clock placed over the scenic arch marking the time of the performance. These elements represent a natural decorative rouge of the Italian theaters.
The symbol of the "Sociale" is on the walls and the extrados of the ceiling. It is also present in the Storchi Theater (1889) in Modena, which, together with the Carpi Theater, are the ones to which the Novi Theater mainly refers. In the foyer instead, we find on the walls of the central environment two stucco decorations by Giovanoli, placed diametrically concerning the other and representing Dance and Music, of unmistakable Liberty style (fig.65,66).
Externally the theatre is characterised by a skin of bricks and exposed faces. The main front is dialled in three blocks, of which the central one is slightly projecting. Along the central body on the ground floor, three arches, with wooden doors supported by Deco-style railings, lead to the internal foyer.
Horizontally the façade along Via Dei Martiri Della Libertà between the first and second levels is punctuated by a notched string band, which breaks the monumental austerity of the building. There are three arched high bay windows above the stringcourse. The central surface closes with a tympanum. On it is written the date of the construction of the theatre "MCMXXVI" and the theatre's name. The lateral bodies are symmetrical and have a wooden door surmounted by a brick platform on the ground floor, while on the upper level, there is a

6 These subjects are recurring reasons widespread in most theaters at theItalian style. The masks of Tragedy and Comedy for example, they are found along the main prospectus of the Phoenix of Venice (1792).

7 Social theatre of Novi of Modena, thesis of Silvia Manicardi, 2004-2005, University of Parma, Degree in Conservation of Cultural Heritage.

Fig. 62-63-64 Novi, Teatro Sociale, Velarium (plafond) decorative details. Photographic survey dated July 2020. Ph M. Suppa.

three-mullioned window (fig.67).
The whole building runs a plinth of about 150 cm high and 45 cm thick. On the four façades, the elegant wrought-iron buttresses in the corner can be seen. Along the north façade of Via Demos Malavasi, the rhythm of penises and voids is very regular. A first protruding block that externally closes the volume of the forebody has linguistic similarities with the front of the main one: on the second level, we find, in fact, again the three-light window. Along the central part, in correspondence with the second-order of the boxes, there is an arched hole. While at street level, three openings correspond to the secondary exits of the theatre. On the same façade at the utility space, the front brakes and advances concerning the corresponding volume with the hall. It is marked by elongated rectangular openings, arranged regularly, many of which have been walled up over time.
The rear façade and the south façade have a more compact formal composition, lightened by a regular distribution of window compartments. The south façade, inaccessible to the public as it borders the garden of the house confined to the area of the theatre grounds, unlike the north façade has a homogeneous curtain wall, protruding only in correspondence with the volume of the forebody. Although more essential and discreet than the linguistic examples of the same type, the Deco style can be reconstructed along the external facades, with wrought iron railings. These railings reproduce sinuous spiral lines and geometries not attributable to the floral style typical of Art Nouveau.
As the theatre's exterior composition describes, there is close correspondence within the theatre's exterior and interior. The interior's functional syntax is echoed in the envelope's volumetric scansion of advancing and receding surfaces. Overall, the structure consists of three floors above ground, a basement (proscenium) and a partially accessible attic; the supporting structure of the theatre is entirely in load-bearing masonry.
Internally, the theatre is characterised by the hall's plant, the horseshoe, and develops altimetrically on three orders of loggias. The stalls could accommodate 388 seats, while in the first order, there were 135 seats, and in the second and third, 130. The stage develops to a depth of 12.50 meters, and below it is the proscenium with 9 meters deep and height of 8.40 ml. The utility space, including the dressing rooms, as two compact, symmetrical blocks, is located adjacent to the stage. Probably, but there is no written documentation, if not oral, until the seventies. The theatre had a mystical gulf for the orchestra then probably eliminated

Fig. 65-66 Novi, Teatro Sociale, interior decoration of the entrance hall. Photographic survey dated July 2020. Ph M. Suppa.

to reach a greater capacity of seats in the stalls. Based on Dr Manicardi's graduation work, it could be read that in 1940 the Novese surveyor Vaccari intervened for maintenance work on the theatre, during which the foundations built with recycled materials were also inspected. This notice showed the testimony in the Society of Masons' minutes, where they report the building of the theatre was built in the total economy.[8]
The documentation of Vaccari, now preserved by Mrs Emilia Maria Zanetti, daughter of one of the founding members, has only the technical drawings of the Teatro Sociale available.
In 1997, the theatre underwent some consolidation work on the roof, suffering from water infiltration. These infiltrations had provoked relevant collapses in the ceiling of the third order: "All the wooden covering, in consideration of the years of exercise is the one most in need of maintenance, with substitution of parts eventually damaged and reinforcement of others certainly fatigued. Moreover, doubts of stability still arouse the dome of the stalls both for a belonging loss of central curvature and for the appreciable deformations of the perimeter beams of impost"[9]. During the works, the substitution of the planking and the mantle of tiles in brick has been previewed, the reinforcement of the rods of the wooden trusses with new reticular structures in open section steel profiles, and the location of new Polonceau trusses cooperating with the original wooden ones. In addition, the support feet of the ribs were refined, "originally limited to 4 large tie rods hanging from the key of the central truss and as many anchored to the headwalls and struts of the same, with the insertion of numerous chains in stamped steel plate". In the restoration of 2009, an anchorage of consolidation between the ribs and plaster shell system is performed with laying the extrados of the canopy of bands of fibreglass mesh and epoxy resins that form a "hood."[10]
The poverty of building materials and some restoration interventions carried out during the nineties of the last century have represented during the 2012 earthquake, the main factors that led to the damage to the theatre.
As defined by the screening form to control seismic damage, the theatre has been divided into the seven sub-structural units described above. This schematisation was adopted to identify the units characterised by confined environments with regular levels from the units characterised by free spaces, analyse the structural behaviour and estimate a coherent index of the damage of the individual bodies and then of the entire building. This structure

8 In the same minutes the troubled phases of the construction of the Social Theatre of Novi are documented, in which there were problems related to the right dell paymenta manpower, to generate a slowdown in the closure of the works, established in the resolution of 1926 by the end of the same year.

9 A.U.T.C.N.M. Unigroup Project (February 29, 1996). Technical Report

10 Barbara Brunetti, I plafoni lignei dei teatri storici in emilia. Materiali, tecniche costruttive, elementi di vulnerabilità, tesi di dottorato ciclo XXVIII, Alma Mater Studiorum – Università di Bologna, ICAR19, 2016

Fig. 67. Novi, Teatro Sociale, Novi, Teatro Sociale, main front on via dei Martiri della Libertà September 2020. Ph M. Suppa.

has been incorporated into the service tool (SD) of the first information layer of the screening form. The following information levels then transpose the same methodology (fig.68).
Before the integrated survey campaign carried out with LIDAR technology and area photogrammetry for the survey of the roof, the expeditious and photographic survey was performed during the months and July (using two types of cameras: Canon EOS 1Ds SLR camera, 50mm f lens; Canon EOS 1200 D SLR camera, 40 mm lens) aimed at documenting and a first survey of the state of conservation and damage following the seismic event.
During the first visual inspection, each structural subunit was identified with its code in the preliminary sketches, and each room was assigned a numerical code.
The preliminary investigations have made it possible to obtain a series of fundamental data to the knowledge of the building and its formal, material, and constructive characteristics.
The survey plan is focused on the seismic damage analysis, the study of materials consistency and degradation condition of the building to have a high-precision metric-morphological graphic support and mapping of the primary morphologies of degradation and structural damage found because of the earthquake.
The most significant seismic damage that is found for the historic Theater of Novi di Modena highlights the presence of critical structural deficiencies: 1) Upper portions of the perimeter load-bearing walls having great height and length (high free light) without the presence of stiffening elements such as floors or bracing walls; 2) Simple supports of beams (without the presence of connections); 3) Non-clamped partitions; 4) Summit portions of masonry stressed by the thrusts of the roof; 5) Floors with poor resistance. 6) partial collapse of the roof in the structural unit of the forebody; 7) partial collapses of the ceiling and false ceiling in the gallery.
Most of the injuries and deformations are located along the extrados of the plafond (UST 2 room macroelement), resulting in damage to the decorative finishes in the gallery area. The excessive vulnerability of the entire wooden structure of the ceiling, which by its static nature should be flexible, would have been aggravated by the recent restoration interventions carried out at the end of the nineties. During the last restoration interventions, a camorcanna ceiling in FRP was made, making the radial wooden system hyper-rigid.

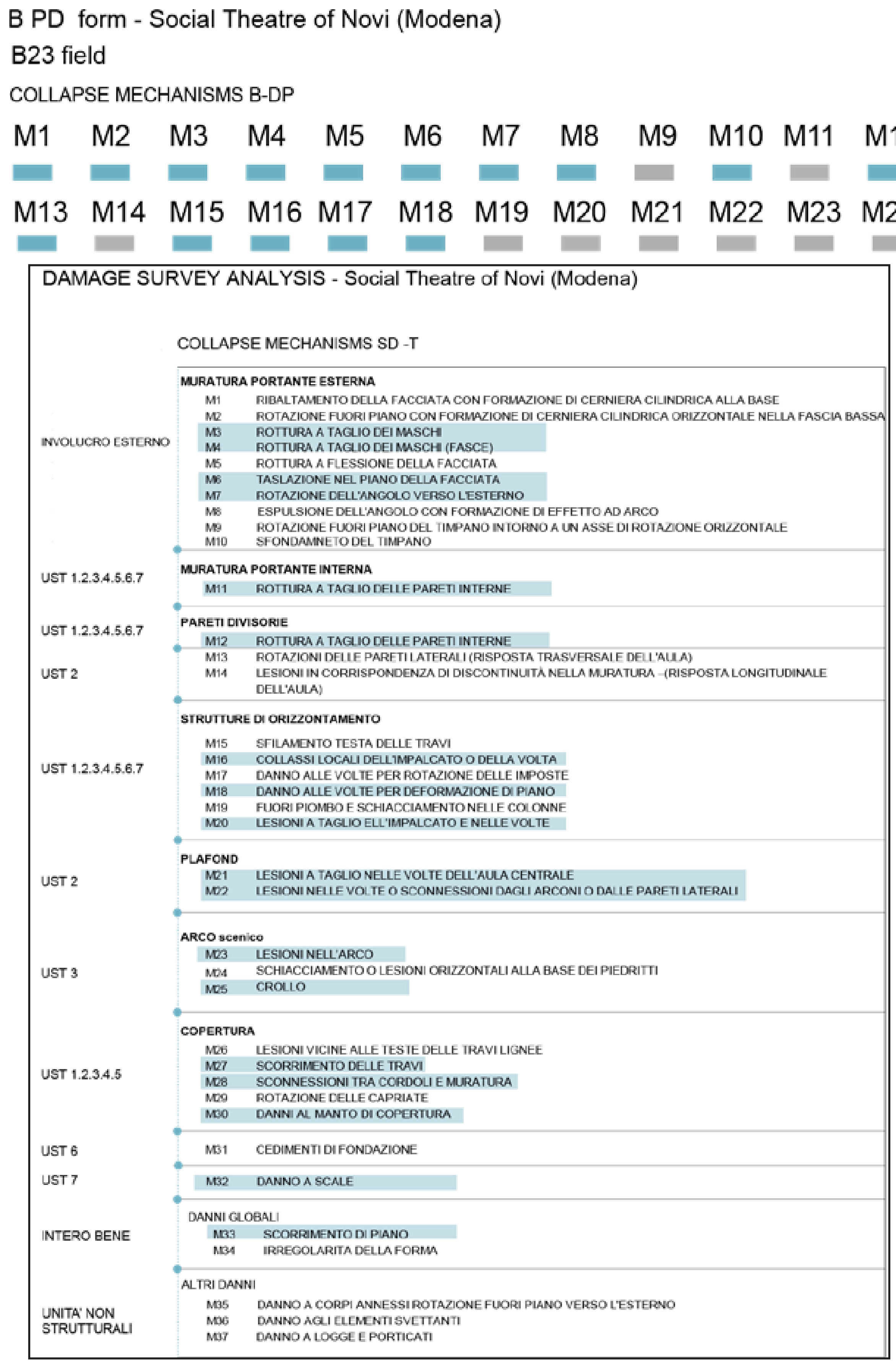


Fig. 68 Above are the collapse mechanisms detected with the B-DP following the earthquake. Below, the figure illustrates the new mechanisms identified in SD T, taking into account the morpho-typological characteristics of the theatre (SD T is written in Italian because it is a tool developed for the Emilia Romagna Region). Developed by M.Suppa

T01 IDENTIFICAZIONE

ID	gid	codice
42	1774	036028_C

T1 NCTR - Codice regione	T1 -Provincia no	T1-Comune
8	MO	Novi di Modena

T01 - OGT - OGGETTO

T01 -OGTN - Denominazione Attuale
Teatro Sociale di Novi di Modena

T01-NCT - CODICE UNIVOCO

T01 -NCTN - Numero catalogo generale

T01 -OGTNA denominizazione 1982
Teatri Sociale

T01 - OGTNDN2012 danno sismic
✔

T01- STA - ultimo sisma
20-29/05/2012

T01 -OGTD – Definizione tipologica
Teatro Storico

T01 - OGTQP - Qualificazione della Proprietà
Proprietà pubblica -Comunale

T01 -OGTNQP - nominativo della proprietà
Comune di Novi di Modena

T01 -OGTCLS - classificazione del bene
individuo

T01-CTSKDS 2012 compilazione scheda del danno2012
✔

T01-TSKDS_tipo di scheda del danno acquisita
B-DP

T01 -NTSKDS - nuova tipologia di scheda
DS-T_L1

T01-STA - ultimo rilievo
rilievo fotografico 15-28/07/2020; rilievo laser scanner+drone 14-19/09/2020

T01_ATTRIL-attrezzatura rilievo
Fotocamera reflex 1Ds Canon EOS, obiettivo f 50mm; Fotocamera reflex Canon EOS 1200 D, obiettivo 40 mm; scanner Leica C10 per gli esterni e BLK360 per gli interni

T01STA- aggiornamento scheda stato di fatti
30/08/2021

T01 -ESC - Ente schedatore	T01 -ECP - Ente competente
038 DA	S143

Fig. 69. SD T - Novi theatre data identification. The record codes follow and implement ICCD standards. This aspect was introduced to link SD T data with existing MIC databases. Developed by M.Suppa

T05 NOTIZIE STORICHE

ID	OGTN - Denominazione
42	Teatro Sociale

T05 - RE - NOTIZIE STORICHE

T05 -RENS - Notizia sintetica

costruzione

T05 -RENF - Fonte

bibliografia

T05 -RENFT - Fonte -TESTI

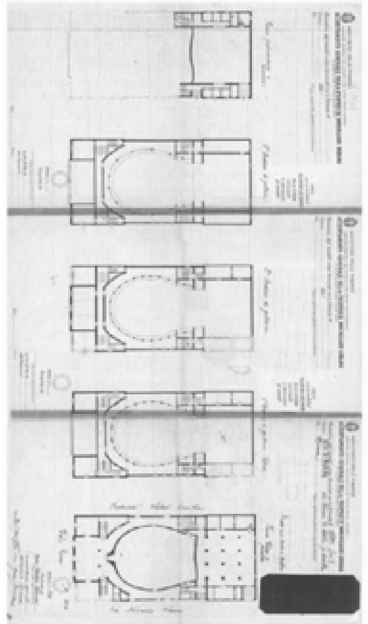
1. V. Bigi, La banda a Novi. Cento anni di attività, a cura della Società Filarmonica novese nel centenario della fondazione, Novi di Modena,1980.
2. Le stagioni del teatro. Le sedi storiche dello spettacolo in Emilia Romagna, acura di L. Bortolotti, Istituto per i Beni Culturali della Regione Emilia Romagna, Bologna, 1995,p. 207.
3. Novi e i novesi. Ricerca su mezzo secolo di vita di un paese attraverso le immagini fotografiche, a cura di D. Ferretti , S. Gherardi, G. Sala , Comune di Novi di Modena, 1983.
4. Teatri storici. Dal restauro allo spettacolo, Nardini Editore, 1997.
5. Teatri storici in Emilia Romagna, a cura di S.M. Bondoni, Istituto per i Beni Culturali della Regione Emilia Romagna, Reggio Emilia, Grafis, Industrie Grafiche S.r. l. Bologna, 1982, p. 205.
6.L.Bortolotti, Luoghi d'arte contemporanea nei teatri della regione, in: Luoghi d'arte contemporanea in Emilia-Romagna. Arti del Novecento e dopo, seconda edizione aggiornata, a cura di C. Collina, Bologna 2008, p. 45-57.

T05 - RENF-collegamento

https://bbcc.ibc.regione.emilia-romagna.it/pater/loadcard.do?id_card=27007

T05 -RENFTI - Fonte-ICONOGRAFIA

T05 -RENFTI _allegato



T05-RTNFTIN-AUTORE DEL RIFERIMENTO

Vaccari -1940

T05 -REL - CRONOLOGIA, ESTREMO REMOTO

Fig. 70 SD T - Novi theatre historical information data. The record codes follow and implement the ICCD standards. This aspect is introduced to connect the SD T data with the existing MIC databases. Developed by M.Suppa

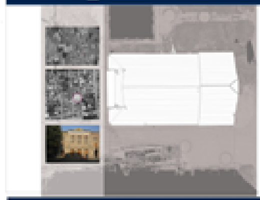
T06-1 INTERO BENE CARATTERSITICHE DELL'EDIFICIO1

ID	OGTN - Denominazione
42	Teatro Sociale

OGTIMP_ Forma urbana dell'impianto

rettangolare allungata

OGTIMP_ Forma urbana dell'impianto allegato



OGTMF_Morfologia planimetrica

OGTMFT_tipologia impianto planimetrico

a ferro di cavallo

OGTMFT1-ferro di cavallo

OGTMFT2-ferro di cavallo

OGTMF3-a U

OGTMF4-circolare

OGTMF5-rettangolare

OGTDI- Dati dimesionali

OGTLaM -Larghezza media:

20,06 ml

OGTLuM -Lunghezza media:

36,65 ml

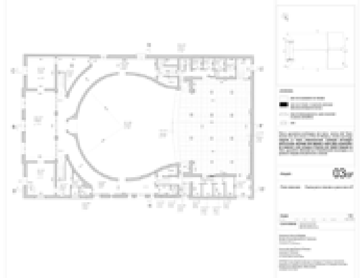
OGTAM -Altezza media

12,00 ml (fronte)

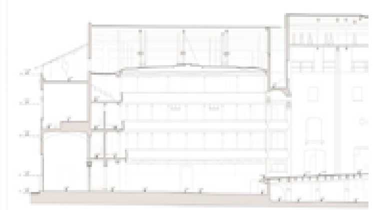
OGTSuM-Superficie media

734, 20 mq

OGTNPL-planimetria del teatro



OGTNOR- ordini di palchi



OGTNOR-Numero degli ordini

3 ordini di palchi

OGTNP_Numero dei piani

3 pianti fuori terra; piano interrato; sotto tetto

OGTRPN - riferimento alla parte

intero bene

OGTDQD - supporto del dato

rilievo Laser scanner -leica C10 esterno - interno cavea e primo piano avancorpo, BLK360 inter

Fig. 71 SD T - - Novi theatre the characteristics of the building data. The record codes follow and implement the ICCD standards. This aspect is introduced to connect the SD T data with the existing MIC databases. Developed by M.Suppa

Another body affected by the seismic action was the scenic arch (UST 3 of the SD T), a hinge point between the structural unit of the stalls, the ceiling system, and the stage. Partial collapses and a remarkable cracking pattern were found along the arch direction and lesions at the attachment point between the scenic arch and the gallery frame. The same environments placed at the extremes of the scenic front has suffered collapses of the false ceiling in "arelle" and plaster.
Excessive deformability of the horizontals is surveyed in the forebody's rooms 003, 004, 005 in correspondence with the second boxes order , affected by partial collapses of the ceiling and a significant cracking picture. Since these environments have been the subject of modifications for functional adaptations of the cinema theatre, non-negligible lesions are visible along the providing nets denoting the scarce clamping with the load-bearing masonry. The forward subunit (TSO1) was also affected by the roof's partial collapse in the above rooms.
In correspondence of the third-order (north-east quadrant), particularly damaged is the staircase (2), hinge between the UST 1 (forebody)and the UST2 (hall), with a significant cracking picture along with the attachment of the perimeter walls to the ceiling and local collapses of the ceiling itself. The data were recorded in the field using preliminary scatch and photographic reports.
The expeditious survey operations of the degradation morphologies connected or aggravated by the seismic event were also accompanied by a high-definition photographic cataloguing of all the surfaces, creating a database (general views, detail, and "macro"), fundamental documentation of the state of the building at the time of the survey.
The Diagnostic Survey phase consisted of an overview of the building and the preliminary sketch drafting to identify the materials' characteristics and the correlated degradation morphologies. Taking as an essential reference the document UNI 11182, an abacus has been drawn up consisting of the list of the primary degradation morphologies identified strictly related to the damage.
In the specific case of social theatre, the morphologies of degradation identified are relative portions of the structure that have immediately highlighted significant structural deficiencies and the natural response of materials to atmospheric agents. Efflorescence casting is some morphologies of degradation surveyed on the external surfaces, located mainly in the upper part of the theatre (between the second and third-order), which are in a high state of degradation, especially in the face of the collapse of the roof. Mirrored to these must be added, detachment, stains along the internal perimeter surfaces that are closely connected to a relevant cracking framework in correspondence with the attachment between the ceilings and the load-bearing masonry.
The visual investigation has allowed us to recognise the types of degradation associated with the whole and macroscopically damages since it is a building of limited dimensions.
However, given the complexity and stratification of the forms of degradation surveyed ted, the state of conservation will be the subject of further study or in the second information layer of the workflow, alongside the visible reading of the intersection of the reflectance data from scanning photographic documentation.
The appendix presents the SD T performed for the Theater of Novi (Fig. 69, 70.71),. In addition, the SD T 3 of the Borgatti theatre in Cento is presented damaged by the earthquake of 2012 (fig.57). Despite the information being surveyed and different methodologies, it has been systematised using the screening form's classification and data hierarchy scheme.
The identification of the environments will be helpful to support the photographic survey. It must also be assumed in the Data seismic Acquisition Protocol and, Plus HBIM Implementation levels to have a homogeneous information classification. For each room, moreover, the walls must be numbered. This aspect serves to identify for this specific category the presence of movable objects or decorative and pictorial elements of value to be documented for conservation.

Fig. 72 Theatre A. Masini di Faenza, main front in Piazza della Molilenna. Photographic survey dated September 2021. Ph. M. Suppa.

5.1.2.2 Ordinary Phase: pilot case: Masini Theatre in Faenza (Ravenna)

The Masini theatre in Faenza (RA) has been selected among the historic Emilian theatres to test and validate the *Damage Screening* Theatre for preventive maintenance actions in managing and mitigating seismic damage (fig.72). The theatre was surveyed in September 2021 through the application of the SD T.
On behalf of the Academy, the Masini theatre was designed by the architect GiuseppePistocchi (1744-1814) between 1780 and 1787. Moreover, it occupies the southwest corner of Molinella square, chosen by the General Council of the Municipality and the cardinal, who granted the theatre's construction on the condition that Pistocchi designed it. The theatre's construction was signed by the notary act of August 19, 1780, and the building's phases proceeded uninterruptedly until 1783, when funding was exhausted. Finally, after the financial intervention of the Magistracy, the work can be completed in 1787, and in May 1788, there was the official inauguration. The Masini Theatre designed by Pistocchi consists of a portico, a large foyer, and horseshoe-shaped stalls that develops altimetrically in three tiers of boxes and a gallery. Singular is the planimetric layout of the hall that, while adopting the horseshoe scheme, is fixed to the geometric matrix of the circle. The boxes and the gallery are inscribed in three concentric circles. Of great formal and decorative importance is the background wall of the stalls, where Pistocchi adopts an articulated figurative composition to the decorative uniformity of the balconies, proposing a formal distinction of the four orders of boxes, also underlined by the configuration of the columns that rhythm the boxes. The four orders are divided into twenty boxes plus the individual one; each order is characterised by its decorations. The first order placed above the high base presents the boxes rhythmed by "pestane2 columns, metopes characterise the second to basso-rilievo, made by Antonio Trentanove. It is unique in the Italian rooms, and these are gilded terracotta bas- survey s depicting mythological subjects and prominent figures of Roman history. The third order has railings, while the gallery that is identical to the fourth-order has a unique fence and is rhythmic by statues leaning lying, lining the pillars depicting the gods of Olympus and some muses. On the gallery rest through a system of pointed arches, the perimeter walls of the plafond, whose extrados is decorated centrally by a rose window with allegorical figures around it. The stage has dimensions equal to the audience and has an extensive service space with the scene's backdrop.
Over the centuries, the Masini has been the subject of many interventions. Starting from

1826, general cleaning of the room was necessary due to the blackening of the oil lamps. The Municipality proposed the halving of the central stage and the two proscenia with double height. The proposal was rejected following the advice of the Bolognese architect F. Antolini as it altered the original architecture. However, it has realised several interventions under the direction of Antonio Argnani. He proposed: the strengthening of the ceiling, the restoring of some parts of the sculptures that crowned the gallery, the new gilding, and the restoration of the polished plaster on boxes' walls. In 1827 Pasquale Saviotti painted a new curtain, still on site today. In 1938 it was decided to extend the original portico consisting of five intercolumnar and bring it to nine. This intervention was followed in 1845 works of consolidation of the roof by Pietro Tomba.
Due to a severe degradation condition, the theatre underwent a series of significant interventions between 1850 and 1853. These included a proposal by engineer Bosi to raise and enlarge the ceiling resting on the gallery's balcony and fix the new support on the perimeter walls of the gallery. This intervention allowed the realisation of a room for the set designers located in the hall.
Other interventions included the refinement of the plafond decorations, the replacement of the scenic arch with a straight lintel and the flooding of the proscenium, which involved the demolition of the proscenium boxes, which then rebuilt in a backward position. Also, the forepart and foyer' spaces have been affected by enlargement interventions through the demolition of the short walls replaced by Doric columns that support the lintel. Even the hall in this period undergoes interventions with the accentuation of the horseshoe shape. In 1869 another restoration work by Ing, A. Ubaldini, who re-proposed the original arch, was

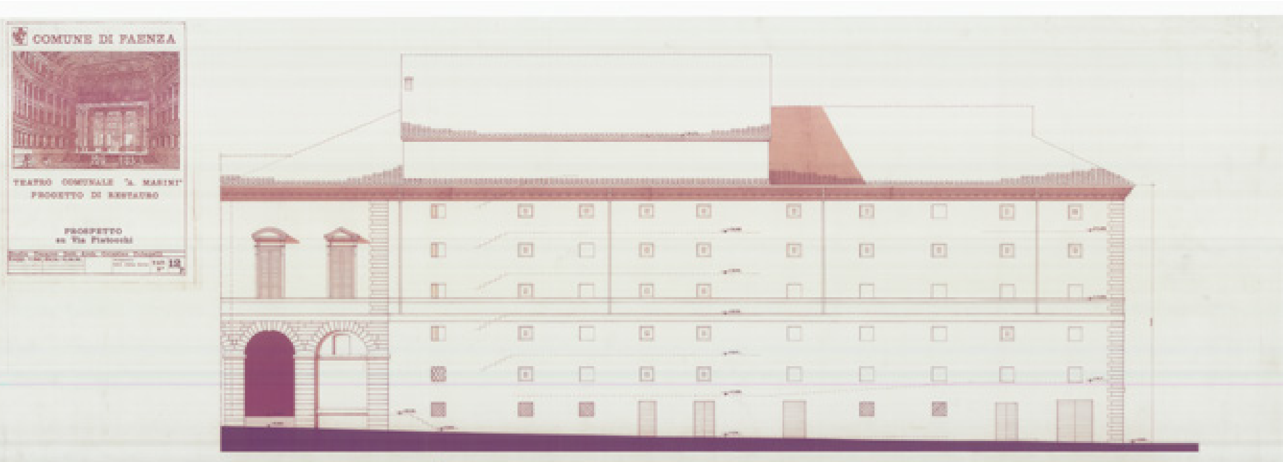


Fig. 73 Theatre A. Masini di Faenza, Theatre A. Masini di Faenza, elevation on via Pistocchi. Archive drawings provided by the RUP of Faenza.

executed. The early twentieth century and the second post-war period were followed by interventions of arrangement of the service rooms and corridors of disengagement that led to the boxes.
The main front of the Masini, on Molinella square, is divided into two orders. Compact with entire walls, the upper band is punctuated by gable windows. The lower strip at street level is marked by a colonnade of ten Ionic columns supporting the tabla bear with a dedicatory epigraph. Under the arcade of the theatre, there are five architraved doors.
At the end of the 1983-84 season, the theatre was closed for further restoration work and adaptation interventions in compliance with safety and fire regulations which constituted the most significant risk factor for the Masini. Therefore, it was necessary to adapt the safety exits, which did not alter the original architectural layout. This is also thanks to an internal staircase built for the caretaker's accommodation located at the gallery's height, which allowed to prepare the safety exits at the level of the boxes avoiding the alteration of the internal space. The most critical interventions have concerned the floors restoration, which was in a severe state of decay, renovated in wood in the boxes while making the corridors beaten Venetian. As a result, the gallery has been adopted the typical "cotto". In addition, the

Fig. 74-75-76-77. Theatre A. Masini di Faenza views the hall; on the right, detail of the Pestana columns of the third order of boxes. Photographic survey dated September 2021. Ph. M. suppa.

building had a structure at the limit of the static, so it was carried out by the Faenza architect Crispino Tabenelli, a project of general consolidation. The vault of the ceiling, in wattle, was fireproof and a passage was prepared to reach the chandelier, also restored. The Wattle structure and the stage remain original and reinforced over time.
Other interventions have affected the boxes where the wallpaper has been removed, placed on the original "marmorino", replaced by pink plaster. In addition, numerous interventions adaptation of the plant and integration of services for the dressing room body were placed symmetrically on the sides of the stage.
In the hall/cavea now characterised by blue ties, restoration of the decorative apparatus has been realised.
Today, the theatre managed by Accademia Perduta, one of the associations belonging to the AGIS – Generaland Italian Association of Entertainment, is again after the lockdown period due to the spread of Covid-Sars 19 open to the public.
The theatre is part of the virtual network of natural spaces, which has created a digital platform to systemise the theatre production centres operating in Italy from their places. A project that arose within the pandemic underlined the difficulties of the entire company of the show's workers continuing to produce and offer culture. In order to overcome the physical impossibility of being actors and spectators of the scene, anTAC – National Association of Stable Theatres of Contemporary Art, with the support of the MIC, the Regions and local authorities of the national territory, wanted to enhance the potential of spaces and meeting times through the digitalisation of its heritage with the dual objective of mapping and testing

the consistency of production spaces, as well as multiplying the surfaces of contact with the public, beyond geographical boundaries, through a synoptic tool. The web platform will allow enjoying areas of production, work and theatrical creation through virtual tours made with laser technology. The application of integrated digital survey systems will make it feasible to have the morphometric data of the theatres surveyed ted and equipped oneself and then offer hypertext content contained in tags within the tours. An open-source archive can be updated over time and available on any device.
Therefore, being the first theatre in the Emilia-Romagna Region to be part of the network, it was decided to include it within the verification tests to validate the SD T for the regional historical theatres.
The survey campaign carried out last September made it possible to have a framework of the state of health of the theatre. The interior spaces have a good state of preservation except for the corridors on the ground floor. Along the passages are visible phenomena of rising damp, related to the geographical location of the theatre that rises above two canals but is visibly in a state of aggravation after the forced closure due to the health emergency.. The non-use of spaces during the pandemic has generated the failure to monitor the morphology of degradation, and consequently, it worsens.
Externally, however, the structure presents especially on the rear front, and the long one parallels Pistacchi street phenomena of detached plasterwork, leaching and stains that affect the plastered surfaces. At the same time, a good state of conservation has cost along the surfaces of Via Pistacchi and Molinella square.
In other circumstances, the cracking pattern of the structure deserves particular attention. Shear cracks are visible along the back front, particularly evident in correspondence of the window compartment and the front's upper central axis. The phenomena found outside are even more marked in the internal environments of the theatre, corresponding to the former caretaker's house. During the visual inspection supported by photographic documentation (CanonEOS 1200 D SLR camera, 40 mm lens), it was possible to ascertain the presence of visible cracks passing along the wall apparatus and at the connection between the masonry and the floors. The same staircase to access the apartment caretaker in September 2020 was closed because it was unusable (fig. 74-75,76,77). Other lesions were surveyed along the extrados of the plafond, particularly at the point of attachment between the vault and the scenic arch, along which similar phenomena occur. Having a detailed picture of the statics of the Masini was allowed to inspect the intrados of the ceiling. The inspection documented the decay of the wooden elements supporting the roof; some are completely broken.
Therefore, it is advisable to intervene for their replacement. While ad hoc inspections should be provided to verify the extent of the cracking framework and launch an integrated survey campaign aimed at monitoring the stability of the theatre, acting in a proactive prevention act for risk mitigation. The information collected throughout the survey campaign and the documents found at the Faenza Municipality have been included and systematised within the SD T (fig.78,79,80,81,82).

T01 IDENTIFICAZIONE

ID	gid	codice
84		

T1 NCTR - Codice regione	T1 -Provincia no	T1-Comune
8	RA	Faenza

T01 - OGT - OGGETTO

T01 -OGTN - Denominazione Attuale: Palazzo Comunale e Teatro Masini

T01-NCT - CODICE UNIVOCO:

T01 -NCTN - Numero catalogo generale: 00206000

T01 -OGTNA denominizazione 1982: Teatro Masini

T01 - OGTNDN2012 danno sismic: ☐

T01- STA - ultimo sisma:

T01 -OGTD – Definizione tipologica: Teatro Storico; Teatro storico in Palazzo storico

T01 - OGTQP - Qualificazione della Proprietà: Proprietà pubblica -COmunale

T01 -OGTNQP - nominativo della proprietà: Comune di Faenza - (gestione attività teatrali - Accademia Perduta - Romagna Teatri Soc. COOP. A.R.L

T01 -OGTCLS - classificazione del bene:

T01-CTSKDS 2012 compilazione scheda del danno2012: ☐

T01-TSKDS_tipo di scheda del danno acquisita:

T01 -NTSKDS - nuova tipologia di scheda: DS-T_L1

T01-STA - ultimo rilievo: 07/09/2021 rilievo fotografico

T01_ATTRIL-attrezzatura rilievo: Fotocamera reflex Canon EOS 1200 40 mm

T01STA- aggiornamento scheda stato di fatti: 10/09/21

T01 -ESC - Ente schedatore	T01 -ECP - Ente competente
038 DA	S42

Fig. 78 DST- Masini Theatre - data identification. Developed by M.Suppa

T05 NOTIZIE STORICHE

ID	OGTN - Denominazione
84	Palazzo Comunale e Teatro Masini

T05 - RE - NOTIZIE STORICHE

T05 -RENS - Notizia sintetica

bibliografia

T05 -RENF - Fonte

T05 -RENFT - Fonte -TESTI

A. Placci, Ristretto istorico sulla costruzione del nuovo teatro di Faenza, Lugo 1840;
G. Pasolini Zanelli, Il teatro di Faenza, Faenza 1888;
A. Messeri - A. Calzi, Faenza nella storia e nell'arte, Faenza 1909;
C. Rivalta, Fasti e glorie del Teatro Comunale dalla Morichielli (1788) ad Angelo Masini (1888), Faenza 1922;
Questa Romagna, a cura di A. Emiliani, Bologna 1968, II, p. 105 sg.;
G. Ricci, Teatri d'Italia dalla Magna Grecia all'Ottocento, Milano 1971, p. 238;
Giuseppe Pistocchi (1744-1814) architetto giacobino, a cura di E. Godoli, catalogo della mostra, Firenze 1974;
F. Farneti - S. Van Riel, L'architettura teatrale in Romagna 1757-1857; Firenze 1975, p. 92-102;
M. Tafuri, Teatri e scenografie, Milano 1976, p. 112-113;
D. Lenzi, Cosimo Morelli e Giuseppe Pistocchi architetti teatrali, in: Architettura in Emilia-Romagna dall'Illuminismo alla Restaurazione, atti del convegno, Firenze 1977, p. 23-34;

T05 - RENF-collegamento

https://bbcc.ibc.regione.emilia-romagna.it/pater/loadcard.do?id_card=26955

T05 -RENFTI - Fonte-ICONOGRAFIA

T05 -RENFTI _allegato

T05-RTNFTIN-AUTORE DEL RIFERIMENTO

T05 -REL - CRONOLOGIA, ESTREMO REMOTO

Fig. 79. DS T - Masini Theatre - field related to historical news. Developed by M.Suppa

T05 RIFERIMENTI STORICI DELL'EDIFICIO

ID	OGTN - Denominazione
84	Palazzo Comunale e Teatro Masini

T5 - AUTR – Riferimento all'intervento (ruolo)

progetto

T5 -AUT - AUTORE

T5 -ATB - Fonte dell'attribuzione

bibliografica

T5 -AUTN - Nome scelto

Giuseppe Pistocchi

T5 -AUTA - Dati anagrafici

1744-1814

T5 -ATB - AMBITO CULTURALE

neoclassico

T5 -ATBM – Fonte dell'attribuzione

a cura di S.M. Bondoni, "Teatri Storici in Emilia Romagna", Istituto per i beni culturali della Regione Emilia-Romagana, Grafis Industrie Grafiche S.r.l, Bologna 1982

T5 -OGTPNR - Riferimento alla parte

intero bene

T5-OGTMOD - TRASFORMAZIONI

T5-MODP-periodo della trasformazione

restauri 1850-53; 1869; 1908, 1984-1990.

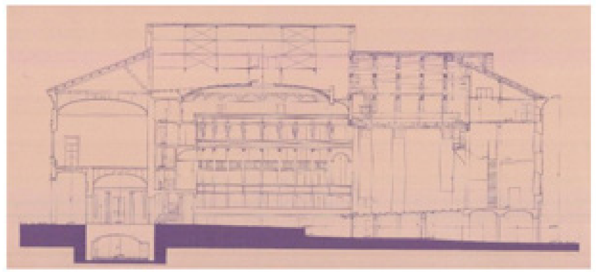
T5-MODPNR-rifermento alla parte

restauri 1850-53: Avancorpo, Cavea, Arcoscenico (Ignazio Bosi); 1869: Arcoscenico (Achille Ubaldini); 1908: Lacali di servizio e corridoi (Tramontani); 1984-1990: adeguamento normativa anticendio e sicurezza, opere di consolidamento (C. Tabenelli)

T5-MODDES-descrizione dell'intervento

restauri 1850-53: rialzo e l'allargamento del soffitto;allargamento del boccascena, per la qual cosa si rese necessario l'abbattimento dei palchi di proscenio, che furono poi ricostruiti in posizione arretrata, e la demolizione del grande arcoscenico, sostituito da architrave

T5-MODAT- allegati tecnici



Sezione longitudinale.

T5-RTNFAR-archivio

archivio comunale

Fig. 80. DS T - Masini Theatre - field related to historical references. Developed by M.Suppa

T06-1 INTERO BENE CARATTERSITICHE DELL'EDIFICIO1

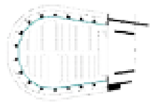
ID	OGTN - Denominazione
84	Palazzo Comunale e Teatro Masini

OGTIMP_ Forma urbana dell'impianto
rettangolare; rettangolare allungata

OGTIMP_ Forma urbana dell'impianto allegato

OGTMF_Morfologia planimetrica

OGTMFT_tipologia impianto planimetrico
a ferro di cavallo

OGTMFT1-ferro di cavallo	OGTMFT2-ferro di cavallo	OGTMF3-a U
		

OGTMF4-circolare	OGTMF5-rettangolare

OGTDI- Dati dimensionali

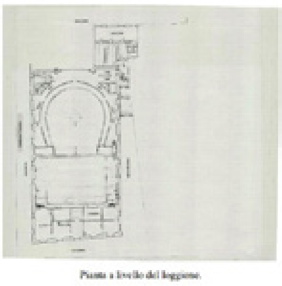
OGTLaM -Larghezza media:
213 ml

OGTLuM -Lunghezza media:
492,5 ml

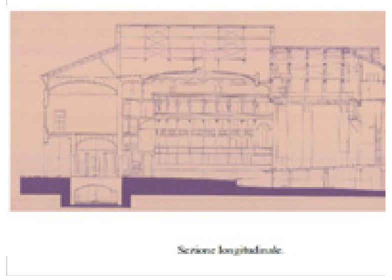
OGTAM -Altezza media
13,80 ml (stimato)

OGTSuM-Superficie media
105319 mq

OGTNPL-planimetria del teatro



OGTNOR- ordini di palchi



OGTNOR-Numero degli ordini
4 ordini palchi; loggione

OGTNP_Numero dei piani
3 pianti fuori terra; piano interrato; sotto tetto

OGTRPN - riferimento alla parte
intero bene

OGTDQD - supporto del dato
dati rilevati

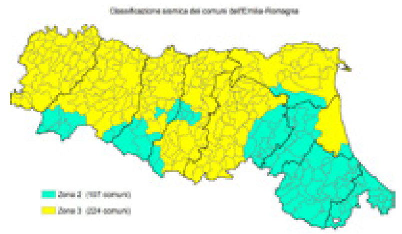
Fig. 81. DS T - Masini Theatre - building characteristics. Developed by M.Suppa

T09 ANALISI Del DANNO SISMICO - INVOLCRO ESTERNO

ID	T1 -OGTN - Denominazione Attuale
83	Palazzo Comunale e Teatro Masini

ZSR_zona sismica regionale
zona 2

ZSR_mappa



ZSR_elenco comuni

ZRSAG_aggiornamento della mappa zona sismica ER
Delibera Num. 1164 del 23/07/2018

MuE_MURATURA PORTANTE ESTERNA

MCMCRE_Analisi dei meccanismi

MuE-N -prospetto NORD

MuEMC-N_meccanismi di collasso

MuE-S -prospetto SUD

MuEMC-S_meccanismi di collasso
M1; M4; M7

MuE-W -prospetto OVEST

MuEMC-W_meccanismi di collasso

MuE-E -prospetto EST

MuEMC-E_meccanismi di collasso
M7

QUOTDs - Quota livello danno	USTMLDA_LIVELLO DI ATTIVAZIONE DEL DANNO
cornice; fascia del secondo livello; timpa	GRAVE

T09-7 USTM-SCALE

RIFUMTS- analisi simica unità strutturali del teatro
USTM5-BLOCCO SERVIZI

USMSC -SCALA

SC-Riferimento altimetrico
Livello galleria; Sottotetto

ORsc-orientamento
EST; SUD

MCGSC-meccanismi di colassoscala	USTMLDA_LIVELLO DI ATTIVAZIONE DEL DANNO
M32; M33	GRAVE

AMCGA- analisi dei meccanismi di collasso attivi
Le lesioni corrono parallelamente allo sviluppo della rampa in muratura.

Fig. 82. DS T - Masini Theatre - Damage analysis of the external envelope and stairs. Developed by M.Suppa

5.1.2.3 Ordinary Phase: Croatian pilot case: The Croatian National Theater in Split

The Croatian National Theater in Split (fig. 83, 84, 85) was built in 1893, according to the design of architects Emilio Vecchietti and Ante Bezić. The theatre has a horseshoe-shaped floor plan, and inside it has decorations executed by Eugenio Scomparini, Napoleon Cozzi and Josip Var-vodić. In the early 1920s, the building underwent its first transformation. At the same time, in 1928, during the Kingdom of Yugoslavia, the theatre was merged with the Sarajevo National Theater and renamed "National Theater for Western Regions." Finally, in 1940 the Theater building was again restored. In 1941 successfully begun work on the Theater was interrupted by the Italian occupation. On July 1, 1945, after the liberation, the Split National Theater was founded, the core of which represented the Dalmatian People's Liberation Theater, based on the island of Vis in 1944. In February 1970, the theatre building was almost destroyed by fire. In March 1978, under the supervision of architect Božidar Rašica, an extensive renovation of the building was initiated, including the expansion the building. The official opening of the new building took place on May 19, 1980.

The first visual survey conducted on the Split Theater is shown in the DS (fig.86, 87, 88, 89). The Theater, whose facades were renovated in 2021, presents a good state of preservation. Despite this, some degradation phenomena are present along the south face with colour alterations, detachment and differential plaster degradation, and dripping events. Also visible is a superficial lesion running along the theatre's elevation at the junction point between the cavea and the stage area. The west facade, characterised by a concrete block, presents runoff, chromatic alteration, surface deposition, and local localised efflorescence phenomena of the upper part. However, detachments of material are not present. The north facade presents localised rising damp phenomena in the lower leg, chromatic alterations of the plaster present along the basement strip and localised dripping at the beginning of Porinova Street. The east façade, on the other hand, appears free of deterioration alternations and morphologies.

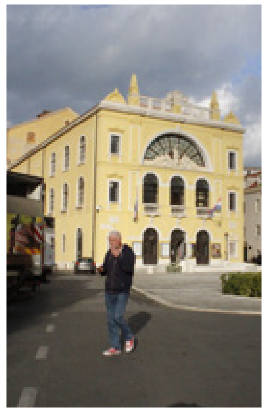


Fig 83. The urban location of the Croatian national theatre in Split. Image from Google Maps

Fig. 84 The main front on Trg Gaje Bulata. Ph by M. Suppa

Fig. 85 Views of the Croatian National Theater in Split. Ph by M. suppa

T01 IDENTIFICAZIONE

ID: 7

T1 -Provincia no: Split

T1-Comune: Split

T01 - OGT - OGGETTO

T01 -OGTN - Denominazione Attuale: Croatian National Theater

T01-NCT - CODICE UNIVOCO:

T01 -NCTN - Numero catalogo generale:

T01 -OGTNA denominizazione passata: National Theater for Western Regions

T01 - OGTNDN2020 danno sismic: ☐

T01- STA - ultimo sisma:

T01 -OGTD – Definizione tipologica: Cinema; Teatro Storico

T01 - OGTQP - Qualificazione della Proprietà: Proprietà pubblica -COmunale

T01 -OGTNQP - nominativo della proprietà: Contea Spalato

T01 -OGTCLS - classificazione del bene: individuo

T01-CTSKDS 2012 compilazione scheda del danno2012: ☐

T01-TSKDS_tipo di scheda del danno acquisita:

T01 -NTSKDS - nuova tipologia di scheda: DS -T

T01-STA - ultimo rilievo: 2021/10/17-19

T01_ATTRIL-attrezzatura rilievo: Canon EOS 1200 D

T01STA- aggiornamento scheda stato di fatti: 2021/10/20

T01 -ESC - Ente schedatore: UniFE

T01 -ECP - Ente competente: RER

Fig. 86 DS T - Croatian National Theater in Split - data identification. Developed by M.Suppa

T04 UTILIZZAZIONE

ID		OGTN - Denominazione
7	7	Croatian National Theater

T04 -US - UTILIZZAZIONE

T04 -USS - USO STORICO
teatro

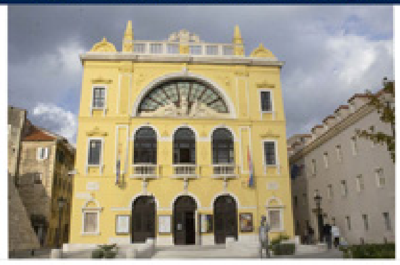
T04 -USAR - Riferimento alla parte
intero bene

T04 -USA- USO ATTUALE
teatro

T04 -USOR - Riferimento alla parte
intero bene

T04 -USOC – Riferimento cronologico

T04 -da - a
1890-2022

T04 -DOCF - Documentazione Fotografic	T04 -DOCF - Documentazione Fotografica
	

T04-RENFF-riferimento fotografico
1- https://www.theatre architecture.eu/db.html?filter%5Blabel%5D=&filter%5Bcity%5D=&filter%5Bstate_id%5D=55&filter%5Bon_db%5D=: 5Bon_map%5D=1&searchMode=&searchResult=year&theatreId=1527; 2 M-Suppa 2022.10.18

Fig.87 DS T - Croatian National Theater in Split - data use Developed by M.Suppa

Fig.88 DS T - Croatian National Theater in Split - historical data e references. Developed by M.Suppa

T05 RIFERIMENTI STORICI DELL'EDIFICIO

ID	OGTN - Denominazione
7	Croatian National Theater

T5 - AUTR – Riferimento all'intervento (ruolo)
main architect

T5 -AUT - AUTORE

T5 -ATB - Fonte dell'attribuzione
bibliografica

T5 -AUTN - Nome scelto
Emilio Vecchietti, Ante Bezić

T5 -AUTA - Dati anagrafici
Emilio Vecchietti 1830-1901;Ante Bezić 1849-1906

T5 -OGTPNR - Riferimento alla parte
intero bene

T5-OGTMOD - TRASFORMAZIONI

T5-MODP-periodo della trasformazione
Restoration/renovation of the theatre in 1921, 1935,1940, 1970, 1978, 1980

T5-MODPNR-rifermento alla parte
1970: the building was destroyed by a large fire, mainly auditorium theater

T5-MODDES-descrizione dell'intervento
theatre auditorium and stage renovation 1978-1979

T06-1 INTERO BENE CARATTERSITICHE DELL'EDIFICIO

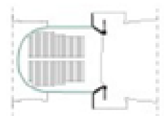
ID	OGTN - Denominazione
1	Croatian National Theater Municipale di Pia

OGTIMP_ Forma urbana dell'impianto
rettangolare allungata

OGTIMP_ Forma urbana dell'impianto allegato

OGTMF_Morfologia planimetrica

OGTMFT_tipologia impianto planimetrico
a U

OGTMFT1-ferro di cavallo	OGTMFT2-ferro di cavallo	OGTMF3-a U
		

OGTMF4-circolare	OGTMF5-rettangolare

T07 ANALISI DEI RISCHI ESTERNI

ID: 7

OGTN - Denominazione: Croatian National Theater

T07 - OGTNRE-Rischi ESTERNI rilevanti

T07 -OGTNRE-Ppresenza Rischi EST: ☑

T07 -OGTNRET -TipoRischi ESTERNI: altre minacce naturali

T07 -OGTNRET -TipoRischi ESTERNI: incendi

T12-AGIBILITA'/ACCESSIBILITA

ID: 7

OGTN - Denominazione: Croatian National Theater

T12AGIBILITA': ☐

T12 -GPBCS_CARATTERISTICHE DEL SITO: in piano

T12 -GPBPO - POSIZIONE:

T12 -GPBCU: centro storico

T12 -GPBAC2021 - ACCESSIBILITA' AL SITO: accesso carrabile; accesso pedonale

T12 -GPBAE - ACCESSIBILITA' ALL'EDEIFICIO: accessibile

Fig.89 DS T - Croatian National Theater in Split - External risk and accessibility analysis. Developed by M.Suppa

5.2 Setting up the L2- Survey Level

The previous section of the L1 damage screening protocol emphasized that systematic documentation is an indispensable part of a comprehensive vision for cultural heritage protection and preventive management in the specific case of historic theatres. Level1 is the first information, where the necessary data describing the monument, its characteristics, geospatial information, possible transformations undergone in its life cycle, structural attributes related to the damage, and the state of preservation are collected. This body of data requires a greater degree of metric-geometric detail and diagnostic analysis to identify more accurate interventions for the conservation and seismic improvement project.
Therefore, the *Suvey Level* (L2) has the functionality to acquire and discrete the geometric-dimensional data obtained using techniques and methods of the integrated 3D survey and representing the state of the art of geometric variations and post-seismic cracking framework. The L2 integrates the data previously collected from the visual survey, implementing the information related to the dimensional geometric aspects deduced in the screen level from the archival documentation. By applying the integrated survey systems, the data of the previous surveys are verified, updating the state of affairs following the earthquake. This aspect allows documenting the discretional geometric analysis of the cloud of points the deformations and lesions that the theatre has suffered due to the earthquake. Furthermore, the database of three-dimensional models, through which qualitative and quantitative data can be analyzed, allows long-term geometric memory management. Therefore, the morphometric model, which can be inspected and integrated at any time, offers support for the verification and preparation of actions aimed at monitoring and conservation of the asset and can be aimed at enhancement and accessible use.
Starting from this premise, in the Survey level, the morphometric models 'requirements are highlighted and defined. In this sense, the objective is to optimize, through a standardized workflow, the phases of the decision-making process on specialized investigations and interventions to be prepared for the conservative restoration of historic theatres.
In order to develop integrated procedures that optimize the survey of the damage, concerning the case study object of the research, and that are of support to the work of the agencies involved in the process of reconstruction of cultural heritage (MiC, superintendence, ARRER, and Joint Commission) the research proposes the approach to systems and techniques of the integrated survey. Furthermore, this proposal considers the 3D surveys advantages offer in order to reduce physical inspections on-site and the availability to operate on morphometric models manageable and implementable over time, which allow implementing strategies of prevention and maintenance.
The first aspect analyzed in this paragraph is the requirements the three-dimensional models will satisfy. The research uses the procedure defined by the European project INCEPTION, developed by the University of Ferrara and 14 partners. In particular, the study uses the DATA ACQUISITION PROTOCOL (DAP) procedure defined within INCEPTION, setting it on the specificities of the damage survey of theatres. The aspect translates into directing the application of the measure considering the attributes of the type studied and the levels of accuracy, reliability, and optimization related to the survey of seismic damage.
The application of DAP, which in the research is referred to as DAP SD (data acquisition protocol for seismic damage), aims to:
1. Identify an integrated procedure for data acquisition using finalized digital survey techniques suitable to provide a tool to guide detectors as a standard procedure for 3D acquisition to obtain reliable, usable and optimized morphometric models for seismic damage survey. These parameters are relevant so that the point cloud is a dimensional database exploitable to extract quantitative data and perform qualitative investigations of interpretation and representation of the data concerning the deformation, cracking, and degradation morphologies closely related to the seismic damage suffered.
2. Identify a procedure that can evolve into a standardized methodology within the path of documentation, conservation, and management of cultural heritage on a territorial scale. In this sense, it is offering competent bodies in the field of cultural heritage protection the advantages of using ICT for better monitoring and verification of the life cycle of the

Theatre					
tecnology	outdoor			indoor	
	area	surface	roof	spazius area (foyer/hall/stage)	narrow area (boxes - serive body)
close range terrestial photogrammetry	●●	●●	‡	●●●	●
close range arial photogrammetry	●●●	●●	●●●	●	‡
static Laser scanner	●●	●●●	‡	●●●	●●

Fig. 90. Diagram of possible integrated 3D data acquisition techniques based on theatre typology. Developed by M.Suppa

building. In this sense, the formation actions must be considered to be that in the procedure standardization should be in the field to ensure the models' usability to the actors of asset reconstruction and management. For public administrations, therefore, for the procedure to become a consolidated practise, research, without going into detail, suggests training through ad hoc courses using open-source cloud management software.

Integrated survey systems and technologies supporting seismic vulnerability assessment allow 3D models with high geometric and radiometric accuracy to support and implement historical documentation, preservation, cataloguing, and diagnostic maps for subsequent monitoring phases. They provide the opportunity to compare and have a digital morphometric database to support project operations and the restoration site. In general, in the documentation of seismic damage of cultural heritage, specifically for complex typologies such as historical theatres, it is necessary to have an integrated approach using different 3D digital acquisition technologies able to provide precise and accurate data at high resolution, optimizing the time and operations of acquisition, reducing site visits, obtaining a three-dimensional database on which to operate to perform predictive analysis aimed at studying the damage (fig.90). In the specific field of application of this research and other documentary purposes, it should be noted that digital acquisition systems (TOF and PS) are not exhaustive, presenting several limitations. Therefore, the integration of different approaches is suggested: a) the use of the total station (EDM) for the construction of the topographic network to support the survey; b) aerial photogrammetry to obtain data of inaccessible environments or coverage; c) digital photography to support a visual-spatial reconstruction of the asset under study and for the precise mapping of damage and the state of preservation. Photogrammetry produces surveys in which overlapping images and control create a three-dimensional representation of the

subject from which the required detail is generated[11]. Terrestrial photogrammetry can be a supplementary or alternative technique to acquisition using LIDAR technology. There are specific data acquisition protocols for photogrammetric surveying: a) the parallel protocol suitable for flat objects such as surface and area photogrammetry; b) the convergent protocol used for moving assets for 360° captures, and c) the cross-protocol for detailed acquisition. These types of protocols are essentially defined and depend on the object of the survey. Specific rules and parameters must be followed, i.e., the number of frames to be captured, shooting planning, and shots overlapping. In addition, the lens system, focal length, exposure, and, therefore, the relationship between lens aperture, ISO and shutter

11 D. Andrews, J.Bedford and P. Bryan, *Metric Survey Specifications for Cultural Heritage. Historic England 2015*

speed must be considered.

In addition, the lens system, focal length, exposure, and, therefore, the relationship between lens aperture, ISO, and shutter speed must be considered. The same acquisition methodology should be regarded as for aerial photogrammetry, mainly used and valuable for the survey on the territorial scale of the damages caused by the earthquake. This technique may require several manual interventions or 'editing' in case of factors related to poor lighting or a complex morphology to be detected or predominant vegetation. In addition, the accuracy of the survey depends on parameters such as scale (flight altitude) and image resolution (camera characteristics), camera characteristics and flight altitude, presence of shaded areas, and surface morphology. However, the application of this method allows to optimize the acquisition time and generate accurate DTMs of areas that are not easily accessible.

Regarding accuracy control for image-based surveys, the guidance in Historic England[12] [2015] noted in section 4.2.1 and related to accuracy.

Image control points should be provided with a 3-D accuracy of

(a) ±3mm;

(b) other (specify).

In addition, a list of 3-D coordinates shall be provided in the survey report. For photogrammetric and orthophotography surveys, a minimum of four coordinated control points observed directly in the field shall be provided for each model. Where possible, targets should be placed on the fabric and should be no larger than 60mm × 40mm; no thicker than 0.5 mm; and have a matte, non-reflective surface finish [4.2.2]. Images should be captured in RAW format.

The same document also defines indications for photogrammetric processing concerning the representation scale, which refers to the accuracy of the final line width of the generated vector data. Based on the model of standard architectural scales, a line width of 0.18 mm is used. The document, however, details the following specifications:

for the output scale of 1:50, 9mm actually

for the output scale 1:20, 4mm in reality

for output scale 1:10, 2mm in reality.

With that said, the following are the specific requirements and properties that are required of 3D digital models according to the procedure defined by DAP Inception:

1. accuracy is closely related to the geometric data collected are accuracy and quality. Both are related to the purpose of the survey. Accuracy is closely dependent on four factors: a) the type of equipment used; b) the field or terrain of the object to be scanned in 3D, c) the post-processing algorithms used by various software) internal environmental factors, illumination. (Maietti et al.). Environmental variables and instrument calibration must also be considered when evaluating accuracy.

2. Reliability represents the ability of the survey to meet standards and be good long-term support. Through reliability, the quality of the survey is assessed, i.e., the ability to constantly update a survey database during daily use for routine actions, the ability to perform integrations, updates and upgrades to a survey, having constantly advancing hardware and software that keep pace with rapid technological updates. [Maietti et al,2018].

3. visualization, layers (easy and fast visualization; optimal 3D representation including details)

4. portability: the choice of a portable technique that fits the accessibility problems for many heritage sites, such as lack of electricity or location constraints, etc.;

5. low cost: affects both users and providers);

6. rapid acquisition:

7. application variation.

8. flexibility: possibility of application in different conditions related to the size and complexity of the monument.

The application of DAP DS establishes specific requirements. The first is to develop the purpose of the survey, which, in the case analyzed, aims to acquire data to investigate the

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Activity indicators and their metrics for each phase foreseen by the Data Acquisition Protocol (INCEPTION).
Set the evaluation categories applicable for the DAP DS

	A+	A++
Scan Plan		
General site plan	■	■
Aquisition data	■	■
inspection oh the survey site	■	■
Simulation of the gital livelling of the building	■	■
Refistration mode and overlapping scan	■	■
Wheater condition recording		■
Selection of istruments	■	■
Equipment calibration		■
Helth and safety		
Safety conditions and equipment	■	■
Resolution requiriments		
Level of detail: density and accurancy	●	●
Data voids	●	●
Field of view		■
Geolocation	■	■
Registration mode		
Automatic + prealigment		
Morpfhologic		
Morphologic + control network	●	
Automatic with inertial platform+comoass+ barometr	●	
Inertial Platform + control network	●	●
Automatic with integrated GPS		
Automatic with integrated GPS+ Inertial platform+ compass+ barameter	●	
Automatic with integrated GPS + compass+ barameter	●	
Targets	●	
Target + control network	●	●
Control Network		
Control Networks projects	■	■
Evaluation on the positioning of topographical geodetic marks		■
Control network intererrelations: topographic, GPS and 3d Survey	■	■
Control networks validation for angle and incidence		■

	A+	A++
Quality control		
Survey documentation	■	■
Documentation forms for each 3D scan station		■
Documentation forms for each control network station		■
Documentation forms for each geodetic mark or benchmark	■	■
Homogenization of reflectance data by different instruments		■
Influence of the incidence angle on the reflectivity index		■
Illustrative diagrams outlithing the position scan situations and control points		■
Additional image data	■	■
Texture image data		■
Additional image Paronoramic data	■	■
Data control and verifcation		
Panoramic view as on filed cheking	■	■
Control network analysis and verication		■
3D model registrations analysis and istruments reports		■
Summary outliting all known data voids	■	■
Redudancy Hardware		■
Data storage and archive		
Point clouds data formats	■	■
Other data format	■	■
Metadata and Paradata		■
Data Beckup, Data archiving and recovery procedures	■	■
Orginal data preservation	■	■

Fig. 91. The survey evaluation categories selected for the DAP DS. The A + and A ++ evaluation requirements to obtain 3D digital acquisitions with a high level of accuracy, a tolerance LOD and point cloud resolution expressed on the scale factor, aimed at structural, technological, and conservation survey. Developed by M.Suppa

damage of the theatre. It presupposes, therefore, the identification of two main objectives to be achieved in the application of information level 2: the survey and the documentation. Consequently, it is advisable to define survey categories that, in the context of 3D digital acquisition, rather than being related to the design phase, focus on the post-processing phase. Then, the visualization, interpretation/reading, and analysis of the collected data are implemented. At the same time, once the category of investigation is identified, which will focus on aspects of seismic damage, it is appropriate to define the scale factor related to the final graphic representation and the instrument's sensitivity. Therefore, using what has been established by Inception, the categories of investigation are reported, relevant to the purposes of the research, defining the characteristics of the integrated multilevel approach to detect the damage of historical relationships.

1. Architectural Investigation: analyzes the structural and geometric attributes of the theatre - interior and exterior - to develop traditional 2D technical drawings and a BIM model to investigate form and morphology. This investigation is crucial in guiding the theatre's design choices and maintenance and management planning. In addition, the architectural survey should capture the decorative and figurative details present. The scale factors defined are 1:10 and 1:5. While for the overall geometric and structural characters, the scales 1:100 and 1:50 will be used.
2. Structural Surveys. This category aims to perform metric and morphological investigations regarding geometry in the structural units of the theatre, focusing on construction details to obtain documentation to support structural analysis. Therefore, the focus of this category will be investigating deformation and cracking of masonry, identifying misalignment to have analysis support survey of damage, and the building behaviour under earthquake. For this survey, the identified scales are 1:100, 1:50, and 1:20. In addition, it must be accompanied by a photographic campaign through which it is possible to survey the environmental location of the deformations and cracks detected.
3. The survey of construction technologies allows a metric and geometric survey of technical and structural details. The morphological geometric survey must be integrated with other diagnostic techniques such as thermography, thermo-fluid survey, Blower Door Test. The scale parameters established are 1:20 and 1:5.
4. Survey aimed at Conservation: it is a survey of the architectural survey and is usually carried out in conjunction with the structural survey. It seeks to analyze the geometric features of the interior and exterior of the theatre to develop plans, elevations, and sections in 2D and 3D BIM models to obtain documentation aimed at the restoration project. Conservation survey, based on a metric survey. The survey aimed at Conservation has analysed the surfaces, materials, and state of conservation. It, therefore, must be integrated by a photographic campaign, material analysis, thermographic survey, spectrophotometry. Scale factors are generally 1:50 and 1:20 (for diagnostic mapping).
5. Survey aimed at the documentation: the object of the survey is the analysis of 2D technical drawings and BIM parametric models. The purpose of the survey is to analyze the evolutionary stratigraphy of the theatre in its specific architectural attributes and the urban context. The scale factor established is 1:100.

The choice of the survey category is strictly related to the definition of the project requirements: time, cost, level of detail (LOD), and interoperability. In addition, the size, the scale of the subject, the complex form of the type, the materials, the surface structure, the state of damage and preservation whose information in short terms was acquired in the DS T and the urban scale must be considered. In addition, since the DAP DS is applicable following a seismic event, accessibility should be evaluated. However, environmental parameters such as obstructions, natural and artificial lighting, and weather conditions should be considered. These indicators allow choosing the most suitable surveying technique to be applied and to control the upstream surveying pipeline. A comparative scheme of application of the different digital acquisition methods for the specific characteristics of the arrangement is presented below (tab.3).
Once these premises have been established, the Inception workflow is presented, subdivided into the following eight steps that will be set up and checked by step in the survey project:

Scan Plan
Health and safety
Resolution Requirements
Registration mode
Control network
Quality control
Data control and verification
Data storage and archive

The eight phases of the round neck initiation represent control operations to verify the survey performed. A grade is defined for each step. The indicators are not all mandatory. They depend on the survey evaluation category to be implemented, which is linked to the survey purpose and thus the necessary data to be acquired. The Inception protocol defines the following four assessment categories.

B: This is the minimum assessment category to comply with the INCEPTION platform. It is intended to be used for elementary buildings or to create sparsely detailed BIM models for the
digital reconstruction aimed at VR, AR, and visualization purposes. In this case, the metric value
of the model is less important than the morphological value.

A: This evaluation category is suitable for documentation purposes where metric and morphological values are equivalent in impacting the survey that needs to be previously planned and designed. The process of recording captured 3D data cannot rely solely on the morphological method but should be enhanced by a topographic control network or GPS data.
A+: This assessment category is the most appropriate for conservation purposes because only surveys conforming to this category could be a valuable tool for restoration projects that need correct metric data. BIM models and 2D CAD drawings up to 1:20 scale are available from these surveys. The project phase is more important than the previous categories to plan and manage the survey campaign and choose the right technical tools to perform the data acquisition. The management and correction of metric errors are based on topographic techniques, especially for recording different scans. The documentation phase will be developed by organizing Metadata and Paradata. Quality control elements are integrated into the process.
A++: This evaluation category is suitable for very complex buildings where the acquisition process needs to be documented and tracked to gain maximum control over the data or when monitoring processes developed in a non-continuous time frame are performed. Category A++ suits multidisciplinary investigations involving multiple technicians working simultaneously or sequentially with different capture and precision tools. The A++ category allows one to analyze how an analysis was performed at each stage: in addition, this capability will enable integrating an investigation at different times.

The survey evaluation categories are closely related to the survey categories. The survey categories selected for the DAP DS must satisfy the A + and A ++ evaluation requirements to obtain 3D digital acquisitions with a high level of accuracy, a tolerance LOD and point cloud resolution expressed on the scale factor, aimed at structural, technological, and conservation survey.
This aspect has been summarized in the tab. Below is indicated the workflow for the digital acquisition for research purposes. Therefore, the digital survey requirements are reported about the achievement of the A+ and A++ categories, ensuring the characteristics of the morphometric model's reliability, usability, and effectiveness (fig.91).
The setup of the control network that supports data acquisition represents one of the main pieces that inform the survey design, also aimed at point cloud registration. For accurate

registration over a large area and to georeference the entire area to a national site or grid, some control points will typically be coordinated by TST. This provides the control points' location with a precision of about 5-10 mm, usually sufficient for an entire site [Historic England 2018]. The network records scans on a standard grid of control points, which must be at least 3 per scan. The more points contained in a single scan, the stronger the network. An alternative method is represented by direct georeferencing; the cloud is automatically georeferenced, knowing each scan's position and the instrument's orientation. Consequentially to this, it must be said that in case of the survey of structures reporting damage, the identification of control points, target of laser acquisition, according to the document of Historic England at paragraph 1.6 of section 1 must be defined by:
1.6.1 ground markers
The use of nails, permanent station markers, etc., is subject to the approval of the mark and its location. Inserting any marker may require Scheduled Monument Consent (SMC) and shall not be done without customer permission.
1.6.2 surface mounted targets. Surface-mounted targets, such as photographic inspection or laser scanning, shall be no larger than 200 mm by 200 mm and shall be attached only with an approved adhesive that allows removal without damage to the surface.
As well as in section 7.2.11 Lenses and Recording. In which it is specified that registration of scans shall be performed using either:
(a) control targets placed within each scan; and
(b) a cloud-to-cloud approach without targets.
The type of targets that may be used, their placement around a site, and the method of observing the laser scan are all discretionary. They must, however, be:
1. not so large as to obscure important tissue details;
2. positioned away from the main surface to be detected;
3. not attached to any important historical tissue;
4. arranged to minimize data gaps in the point cloud; and
5. removed at the end of the survey, either upon completing the site work or after obtaining the record. The method statement should describe the proposed recording objectives and approaches.
Refer to Chap. 1 for standard specifications for collecting, recording, and archiving laser scan data.
Once acquired, the data is processed within software designed for the visualisation and processing of the point cloud. For the management of the point cloud of the pilot case, the software Leica Cyclone has been used. Once the cloud alignment and registration have been performed, the model is hierarchised into portions of clouds corresponding to the structural units indicated in the screening level that are referred to as specific layers. The main layers on which the 2D graphic representation is set to follow the description codes:

LG_ Basement Floor
GF_ Ground floor
01_ First Order of Stages
02_Second Order of Stages
03_Third Order of Stables
04_ Gallery
M1_Mezzanine Floor 1
M2_Mezzanine Floor 2.
ZZ _roof

The code of the levels is adapted to the altimetric conformation of the theatres since from the case history of the sample application analysed, the historical theatres in Emilia can vary from a 2 to 4 order of boxes, where the four order often coincides with the gallery. Notwithstanding this variability, the research suggested this methodology that will also be taken up in 2D representation and parametric modelling HBIM.
Segmentation is a process of grouping cloud points into multiple homogeneous regions with similar properties, and classification as labelling of these regions" [Grilli, Menna, and

Remondino 2017] represent a valuable method for analysing acquired data. The adoption of this method facilitates the interpretation of the model by isolating the portions of the theatre that need an analysis to verify the geometric deformational changes resulting from the earthquake. DEM extractions to analyse the reflectance data to catalogue, interacting with sensible value variations on the scale of false colours, the primary morphologies of degradation connected to the post-seismic cracking framework are possible performed isolating single cloud's portion. In addition, the cloud's hierarchy allows visualizing and understanding the spatial – altimetric variation of the theatre. This aspect is advantageous in the representation step.
The graphic elaborations also aimed to realize the thematic tables required by the Directive 2011 are elaborated in CAD. The representation in the AutoDesk environment is still considered indispensable compared to the 2D drawings extracted from the BIM model. There are still several limits to the parametric model's modelling of the crack pattern and geometric deformations (discussed in paragraph 5.3). Exporting orthoimages from the morphometric model, the 2D graphic elaboration can be performed. To 2D representation, it's also possible to import the point cloud in AutoCAD and export the cloud in the E57 (general purpose) and LAS (aerial) formats concerning this last step.
They allow importing and reworking by most software suites. The point cloud exported in E57 must be imported into Autodesk RECAP software and saved in the program extension format to import directly into AutoCAD.
The purpose of the survey must guide the phase of geometric discretion of the data and the graphic representation. According to the above, the scale of the model appropriate for architectural drawing is set by the factor 1.50. While the technical and structural details are used, the scale factors are 1.20 up to 1.5. To the global damage representation, the 2D elaborations must be defined on a scale of 1.50. These elaborations will have to be finalized to describe the state of the damage; therefore, the graphic restitution will have to represent the geometric variations suffered after the earthquake. For eventual representative details of potions that require a specialized investigation zoom, it is necessary to opt for a scale factor of 1.20 up to 1.10.

<u>5.2.2 Testing of the DAP DS: the pilot case Social Theatre of Novi in Modena</u>
<u>5.2.2. 1 Laser scanning survey of the Social Theatre of Novi in Modena: a methodological approach</u>

From 14 to 19 September last year, the Theatre (fig.92) has carried out the three-dimensional acquisition of the architectural apparatus using laser scanner technology, making it possible to obtain metrics and geometric information with a high degree of accuracy and precision in an optimized working time (fig.93).
The integrated methodologies applied in surveying the theatre have also resulted in in-depth analysis and inspection of the earthquake damage to deliver a highly detailed seismic damage assessment. Therefore, the relevant project was oriented by integrating the different methods: a)The 3D laser scanner is applied to obtain a metric 3D model; b)The topographic method is applied to record the different scans and define an overall framing network. c) HD Photo for the comprehensive documentation of the building, the phases of the survey, and the state of conservation. d) The Macroscopic diagnostic survey to analyse the surfaces conservative state. e)The Integration of reflectance data by time-of-flight 3D scanning. For the surfaces, conservative state macroscopic investigations.
This methodology documents the state of damage and conservation of the building and directs the restoration project of the same. The diagnostic survey was divided into the following phases:
a) preliminary studies and research on the building,
b) the diagnostic survey in the field,
c) "post-processing" phase of the data collected, analyzing the degradation morphologies and surface characteristics through the definition of a specific abacus and preliminary investigations have allowed obtaining fundamental data to the knowledge.
Primarily to photographic survey and instrumental integration as a support for the visualization

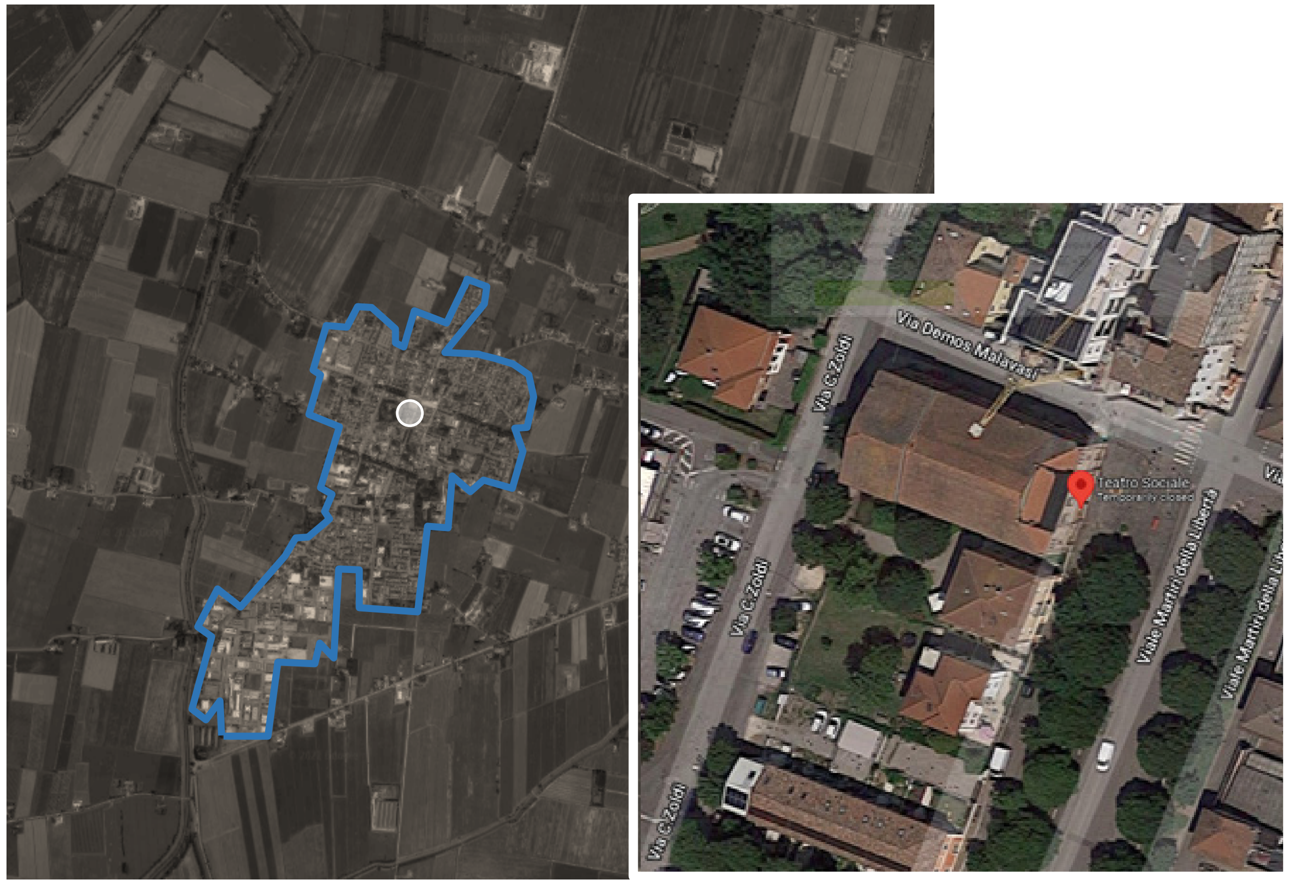


Fig. 92. The geographical location of the Social Theatre of Novi di Modena, geographic reconnaissance through Google Maps.

and representation of the characteristic areas, the investigations have been divided into the following phases belonging to the screening form (L1) summarized below:
- macroscopic scale analysis (localization, context, orientation, analysis of the surroundings, and other characteristic elements, etc.).
- the study of the geometry and the formal and compositional aspects of the building.
- the analysis of materials and construction techniques.
- the preliminary analysis of the material characteristics
- the preliminary analysis of macroscopic morphologies of degradation.
- the analysis of the damage following the earthquake.

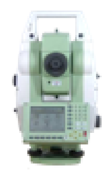
<u>5.2.2. 2 The Metric and geometric survey aimed at the damage recogniction</u>

The laser scanner survey of the Theatre responds to the dual need to be primarily a source of documentation of the architectural organism of its formal grammar and specific spatial metric attributes. However, in the particular case of the Social Theater, it constituted the knowledge and analysis tool of the geometric-structural altercation that happened after the quake and the conservation state modifications caused by the earthquake.
The integrated, holistic approach for the survey was fundamental for an artefact with a complex internal spatial-altimetric articulation. Furthermore, the Data seismic acquisition protocol procedure allowed the choice of methodologies and tools suitable for an investigation that aimed at studying the geometric-structural aspects aimed at diagnosing the state of damage and conservation.
For the geometric survey of the Social theatre, time-of-flight laser scanner technology and aerial photogrammetry were used. The adoption of the laser scanner was dictated by the versatility of high-precision data acquisition with reduced times. The high precision and density of the point cloud make it possible to obtain morphometric models that allow describing, in the restitution phase, the geometric characteristics and details of the historical building, as well as the construction aspects, materials, misalignments, deformations and

Fig. 93. The Laser scanner survey campaign was carried out in September 2020 using Leica C10 and Leica BLK 360 laser. Developed by M.Suppa

alterations suffered by the artefact over time. The need to provide a three-dimensional survey aimed at understanding the cracks and deformations caused by the earthquake had to be satisfied, required the adoption of a multi-scalar approach and a multi-level knowledge of the geometric-morphological complexity of the theatre to guide the subsequent phases of the post-earthquake restoration and reconstruction project. The survey campaign involved a team of two operators for five working days. The Data acquisition was achieved using: the Leica C10 and BLK360 time-of-flight laser scanner. The survey operations were hierarchized by first carrying out the survey project's planning, integrating the topographic survey and then the laser acquisition stations. In this phase, the representation scale for the entire building was chosen. The scale factor selected is 1.50 so that the geometric-formal aspects of the

Lot area (sqm)	-
Building gross surface (sqm)	734, 20 sqm
TOPOGRAPHIC SURVEY	
Equipment (n, model)	Leica Geosystems TPS 1202
Survey time (h)	2 h
Closed polygonal (n)	1
Polygonal vertexes (n)	25
Least squares compensation (sq in mm)	3 mm
LASER SCANNER SURVEY	
Equipment (n, model)	Leica ScanStation C10 + BLK 360
Survey time (days/months)	5 days
Laser stations (n)	310
Acquired Targets (n)	50
Spatial coordinates (n)	3.316.937.012
Average registration value (mm)	3 mm
AERIAL PHOTOGRAMMETRY SURVEY	
Equipment (n, model)	DJI MAVIC MINI
Focal lenght	4.49
Focal	35 mm 24
Image size	4000x2250
Survey time (h)	60 min
Images (n)	192
Acquired Targets (n)	5
Dense cloud	2.600.000
Average registration value (mm)	3 mm




Tab. 3. Data from the integrated survey was carried out for the theatre of Novi di Modena. The characteristics of the instrumentation used and the data processing information are listed. Developed by M.Suppa

theatre and the geometric deformations caused by the telluric action could be graphed. At the same time, for the details, it was defined as the minimum scale of representation 1.20. The georeferenced topographic network was realized using the Leica Geosystems TPS 1202. A closed polygon has been built from inside the theatre's auditorium, proceeding through the entrance close to the outside and secondary open polygonal reverses for control points second-level target networks. 25 points were collimated, corresponding to the targets used for the acquisition stations (No. 6). The theatre exterior was surveyed through the same instrument in high resolution, while the interior environments were surveyed with the BLK360. The data was processed within Leica's Cyclone software. Instead, the coverage survey was acquired with drone DJI MAVIC MINI (the survey data are summarized in (tab.3). The individual scans were aligned and recorded manually, taking advantage of the different stations; .it was possible to acquire 90% of the theatre. The extrados portion of the attic of the forebody environment 03.01.02 has incomplete scan data, while the data of the foundation system is absent because of inaccessible.
Once the registration was completed, the cloud explored through multiple cognitive, diagnostic, and conservative levels was hierarchized into the five structural subunits of SD T (L1).
The integrated methodology applied, with the application of topographic survey and 3D digital survey compensated to the least-squares with a mean square deviation of 3 mm at the vertices, has allowed obtaining a complex morphometric model. This model is helpful in morphometric knowledge of the theatre spaces as the wooden ceiling system, the scenic arch, the scenic tower area with the survey of the trellis, the stairs connecting the cavea/hall with the utility space that have a different morphology (fig.94;96). In addition, however, also to appreciate and study the geometric deformations of the supporting structures (macro elements of the screening form), the ceiling vault, and the closing frame of the vault itself. The latter elements have been the subject of two-dimensional representation work in AUTOCAD.In order to know in detail the planovolumetric development of the theatre and connect it to the damage reported following the earthquake, the cloud has been divided into the following structural subunits: 1. forebody, 2. cavea / hall, 3—proscenium arch, 4. stages, 5. utility space (fig. 95). In addition, Under-unit 6 non were surveyed because they were not accessible, while the stairwells were defined. Each subunit was assigned to a dedicated layer so the overall theatre model space could be navigated and interrogated for the analysis needs in its entirety or individual portions. This procedure made it possible to carry out detailed extractions of the profiles of relative sections to proceed with the discretion and interpretation of the metric and geometric data and the decoding of deformations and cracks. In addition, a sub-hierarchization was applied for the theatre's exterior surfaces to

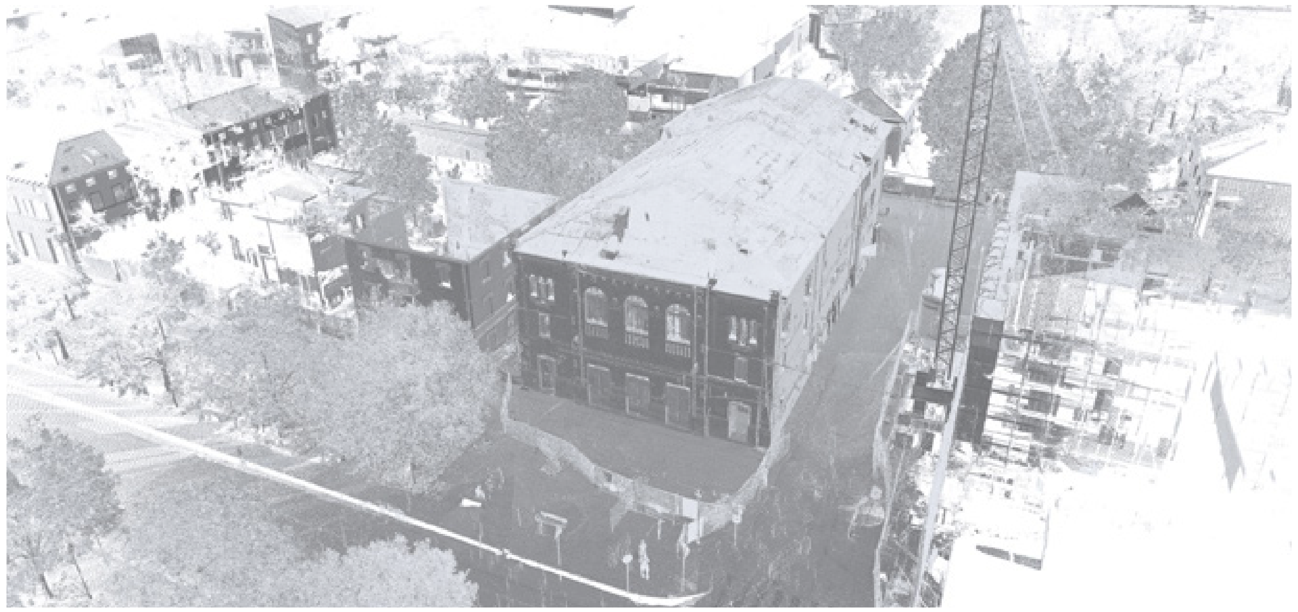


Fig. 94. The view image of the new points of the theatre of Novi di Modena. Developed by M.Suppa

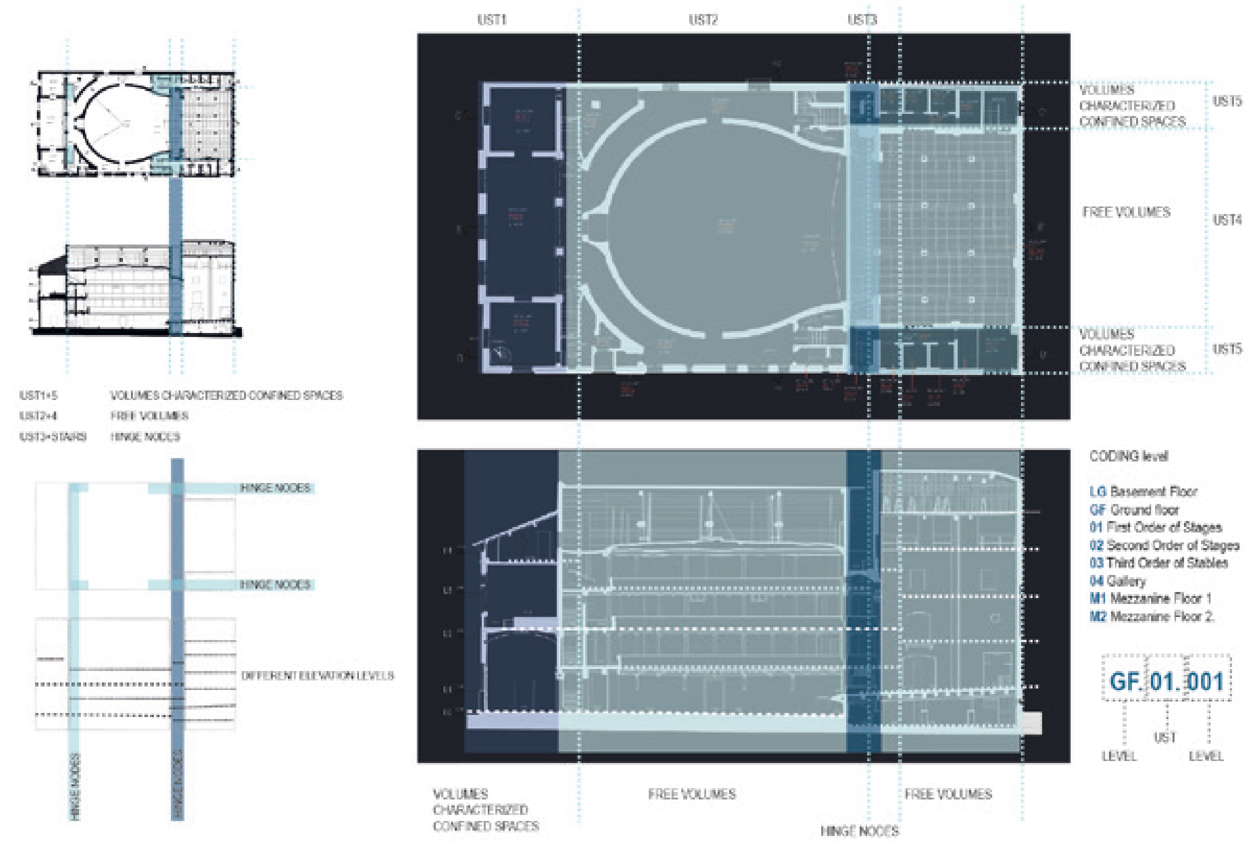


Fig. 95. Coding of the graphic representation used. Developed by M.Suppa

extract Ortho tiff immage for the state of conservation analysis.
The individual portions of the cloud were exported in the open e.57 format and delivered to the municipal administration to verify and query the model. Through the open-source software CloudCompare for point cloud management.

5.2.2. 3 Representation phase

Once the data was processed in Cyclone, through the extraction of DEM sections on the horizontal and vertical plane, the following 2D works were returned to scale 1.50:

- 01_Urban overview table - scale 1: 100
- 02_Ground Floor - scale 1: 100
- 03_Ground Floor_Stalls - scale 1:50
- 04_First Order - scale 1:50
- 05_Second Order- scale 1:50
- 06_Third order_Loggione - scale 1:50
- 07_Roof plan - scale 1:50
- 08_Cross section AA'- scale 1:50
- 09_ Longitudinal Section BB' - scale 1:50
- 10_Section long. Staircase body 1 CC' - scale 1:50
- 11_Section long. Staircase body 2 DD'- scale 1:50
- 12_East Front- scale 1:50
- 13_North Front- scale 1:50
- 14_West Front- scale 1:50
- 15_South Front - scale 1:50
- 0A_Photographic survey report (Appendix A)
- 0B_ Damage survey (Apprendix B)
- 0C_Decay survey (Appendix C)

The drawings were systematized in the following tabs (TaB_01; 02; 03; 03.1; 04; 05; 06; 07; 07.1; 08)
Each theatre space was identified following the codify described in para 5.1.1 In the 2D representation
Through geometric discretization, it was possible to document and measure the deformation and cracking picture surveyed in the SD T. in order to describe both the planovolumetric articulation of the theatre, five levels of the section were fixed along the z-axis and 4 levels of the section along the y axis, so that the geometric and morphological characters of the theatre could be described. UST2 displaced more than 5 cm in the northeastern sector, which resulted in a consistent extended cracking framework of attack between the vault and the third order. This displacement has determined the lesion in several points of the cornice of the velarium that present an off-axis of about 7.1 cm in northeast sector portions . However, several collapses occurred in the northern sector and connected with the proscenium arch. The triggering mechanisms are related to the cross and longitudinal hall reaction.
The most extensive damage is related to the behaviour of the vault of the stalls, of which the loss of the central curvature is evident. The ceiling has a size of 13, 7x15 m, with a ratio of the maximum span and deflection of the vault less than 5 cm. The vault rests on a polygonal structure, consisting of a series of pavilion spindles, which discharge directly on the concrete columns of the third order. The load-bearing rib system follows the vault's meridian course and is rhodium-plated following a radial pattern.
From the discretisation of the cloud, it was possible to verify that the vault has a slightly lowered curvature and a small arrow structurally. The vault is set and rests directly on the colonnade of the last order (gallery) characterised by a double span (intercolumn:4 meters) than those of the lower orders (intercolumn about 2 meters), for which there are no containment elements. For this reason, the outward thrusts fall exclusively on the wooden floor of the gallery ceiling (in wire mesh and plaster), which rests directly on the double-headed wall males, while the internal thrusts are absorbed by the truss system on which the ribs of the vault are placed. Therefore, the external pressure falls exclusively on the gallery's ceiling (reinforced by metal mesh), resting directly on two-headed masonry walls. In contrast, the internal thrusts are absorbed by the truss system aboard which are placed the vault ribs. From the representation, it emerges that the vault of the Novi theatre in Modena has a resistant section of 4.5 cm. Therefore, the excessive slenderness and under-sizing of the section of the vault have favoured the loss of the same geometry, causing internal lesions not negligible along with the frame of the gallery, especially in the northeast quadrant. As a result, the loading system is weak since the gallery column does not support the point supports of the centring on the wooden edge beams, which from the model analysis are excessively deformed. The geometric instability of the wooden plane system of the drum has therefore caused a vertical translation on the columns of the last order and not on those of the first and second orders that do not present crushing mechanisms nor foundation failures. Therefore, compression lesions of the drum can be observed along with the perimeter bands of the vault. It confirms the excessive vulnerability of the entire wooden structure, which should be flexible by its static nature; it would appear to have been aggravated by the recent remaining efforts during which a "camorcanna[13]" in FRP was realised. As highlighted in the report on degradation, this intervention has also triggered a thickening of visible humidity on the pictorial apparatus of the volt (see paragraph on Diagnostic survey. Although characterized by a high mechanical performance, FRP materials have rigidly transformed the system of wooden slab members. "The system dramatically changes the mechanical behaviour from a structure in which the camorcanna hangs from the ribs to a structure more like a ribbed shell, where the camorcanna is called upon to perform structural tasks previously absent."[14]

13 The camorcanna is a reinforcement system based on extrados "hoods." In the past, they were made of jute cloth and plaster to consolidate the fabric of canes and plaster and reinforce the wooden ribs. Today, this system has been replaced by bands of composite materials (FRP), or mo-no-directional fiberglass or epoxy resin, applied in bands over the entire surface of the vault.

14 QuagliarinI E., D'Orazio M., Recupero e conservazione di volte in "camorcanna". Dalla "regola dell'arte" alle tecniche di intervento, Alinea, Firenze 2005 p. 95

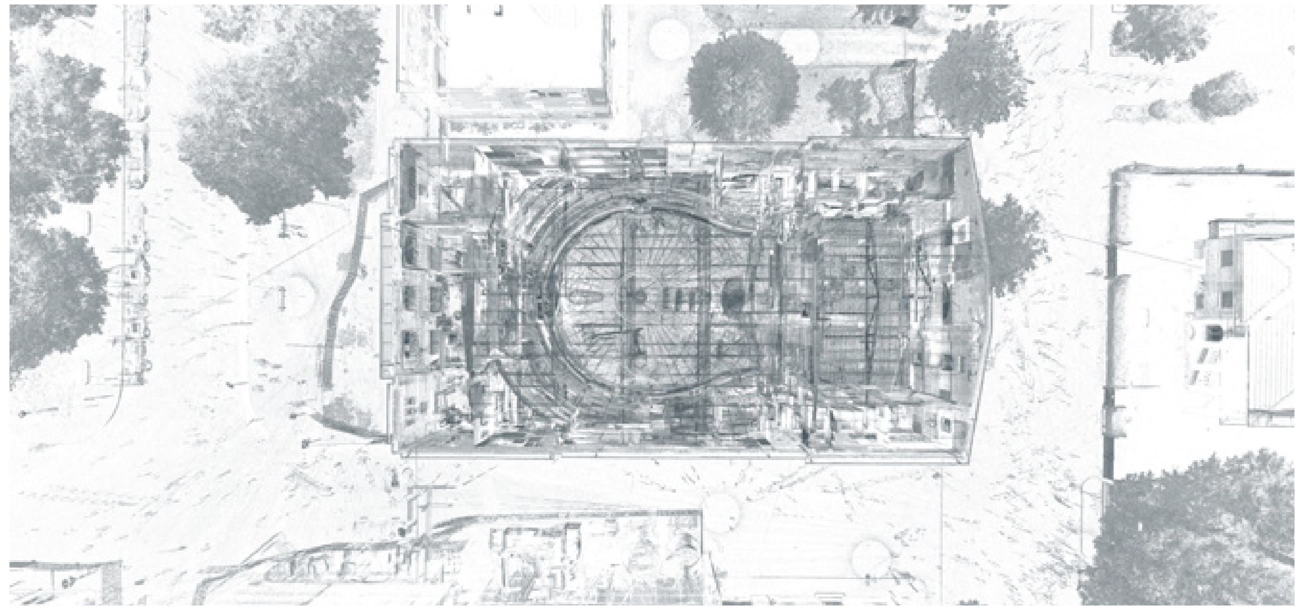


Fig. 96. The ortho tiff image of the new points of the theatre of Novi di Modena. Developed by M.Suppa

At the connection with the subunit of the proscenium arch, lesions are visible along the extrados of the vault.
Evident collapses instead have affected some rooms of the front body, the three rooms placed on the second-order of boxes. At the connection with the subunit of the proscenium arch, lesions are visible along the extrados of the vault.
Evident collapses instead have affected some rooms of the front body, the three rooms placed on the second-order of boxes. The environment 02.01.06, following the partial roof collapse, has found the floor collapse for a surface of 5 square meters. In the same room, there are lesions along the perimeter walls. The one confining with room 0.2.01.05 presents a passing lesion.
Both rooms 02.01.05 and 02.01.04 have a significant crack structure in place, covering both the perimeter walls and the upper part of the ceiling. Other collapses were found in the rooms flanking the proscenium arch where part of the attic's extra dose collapsed, leaving the "incannucciate " visible. The proscenium arch noted the following: the overturning of the wall behind the cavea, with partial collapse of the masonry not made of homogeneous materials along this direction. While along the opposite wall, lesions were detected near the tip of the arch.
Particularly damaged are the stairwells along the northern front of the theatre that have cutting lesions along the perimeter walls and partial floor collapses at the level of the last order of boxes.
Regarding the external front damages, the shear cracks along the theatre's north and south elevations in correspondence with the windows have been observed and documented by the photographic survey campaign. At the same time, a significant cracking framework is visible on the back of the theatre, particularly along the axis of the cantons that connect the back wall of the theatre with the north and south front. Testifying the misalignment of the back wall of the stage, whose section, verified on the morphometric model, appears to have been reduced by plant upgrading interventions after the construction period and not by the subsequent tightening to be surveyed misalignments of not less than 2 cm. The main front has lesions along the high end of the prospectus at the collapse of the eastern sector of the roof (body 1 forebody) and of the environments, 02.01.04-05-06 described above.

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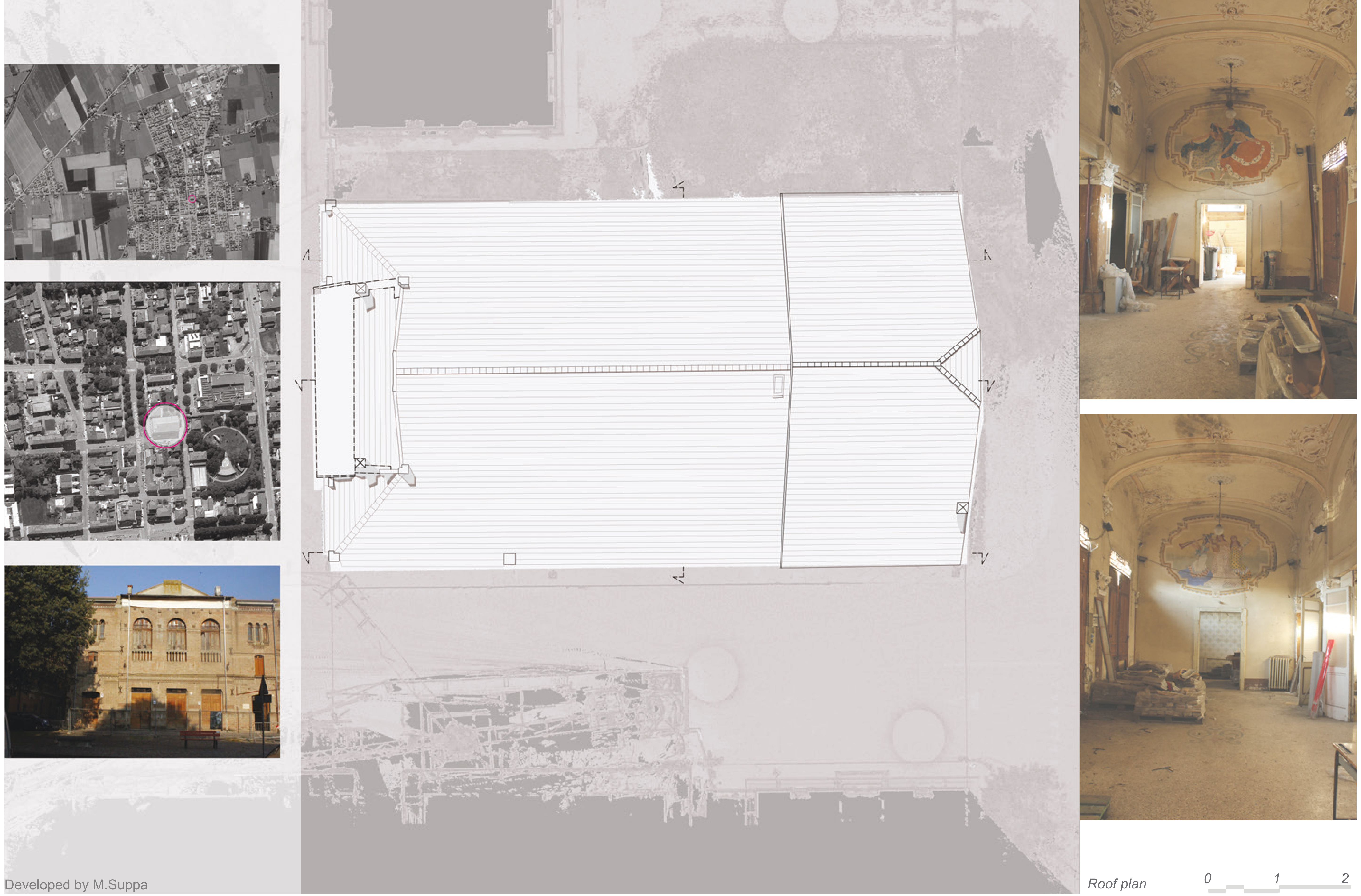
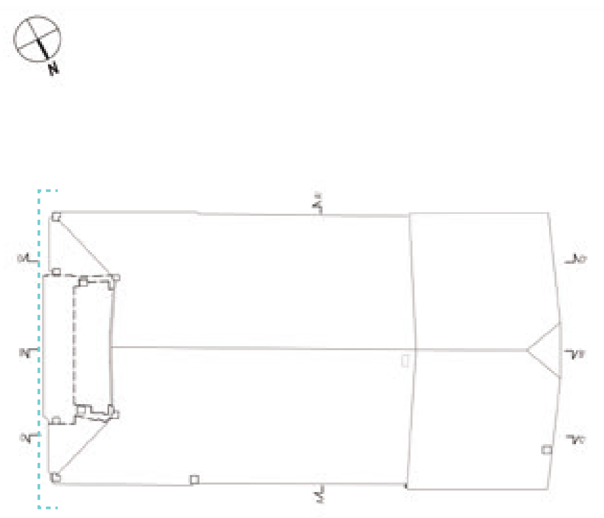
TaB_01_Urban overview table



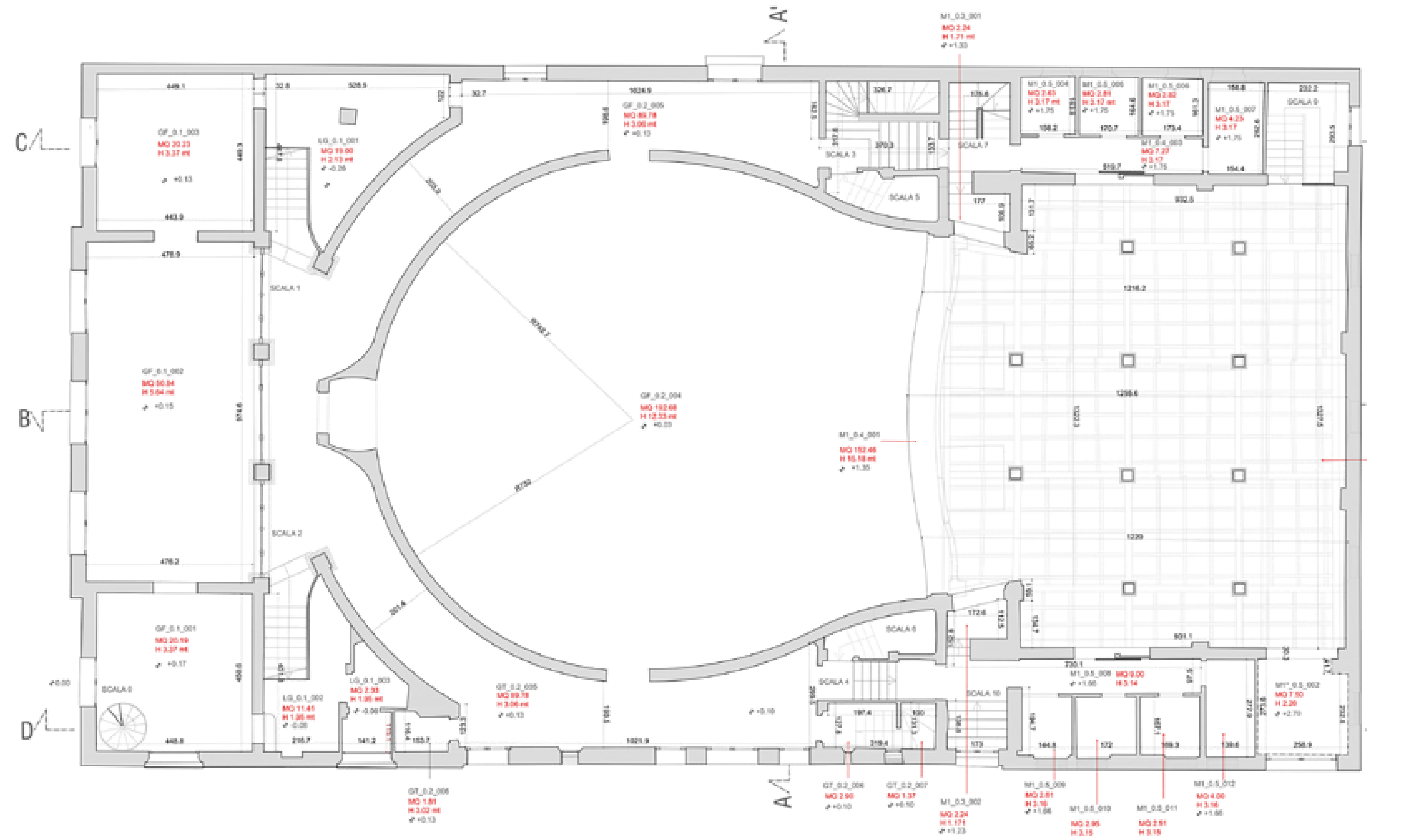
Developed by M.Suppa

TaB_02_Ground Floor_Stalls/East Front

2D graphics based on the discretisation of metric and geometric point cloud data



East Front via dei Martiri della libertà street

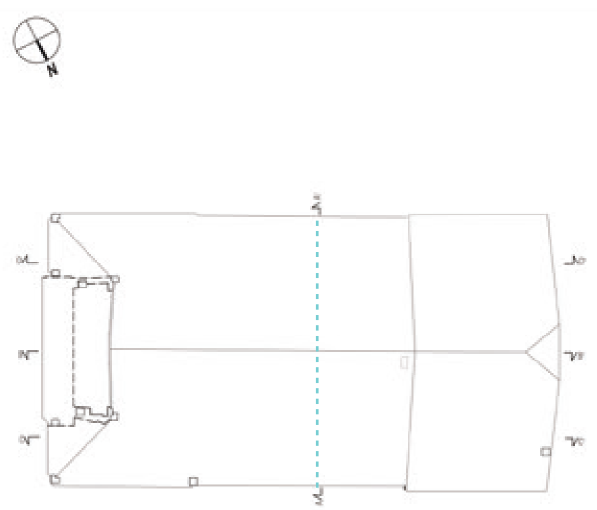


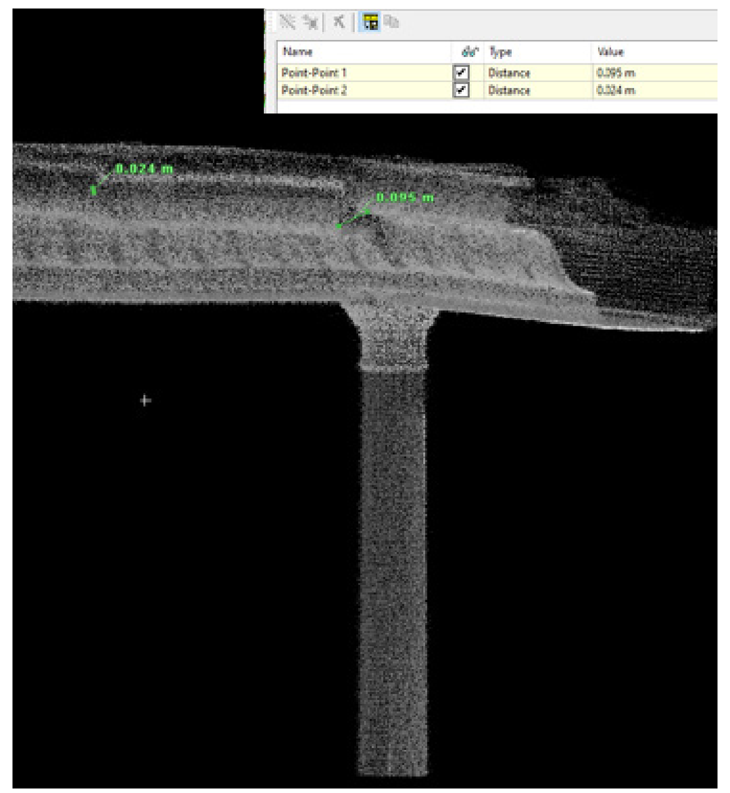
Ground floor _Stalls plan

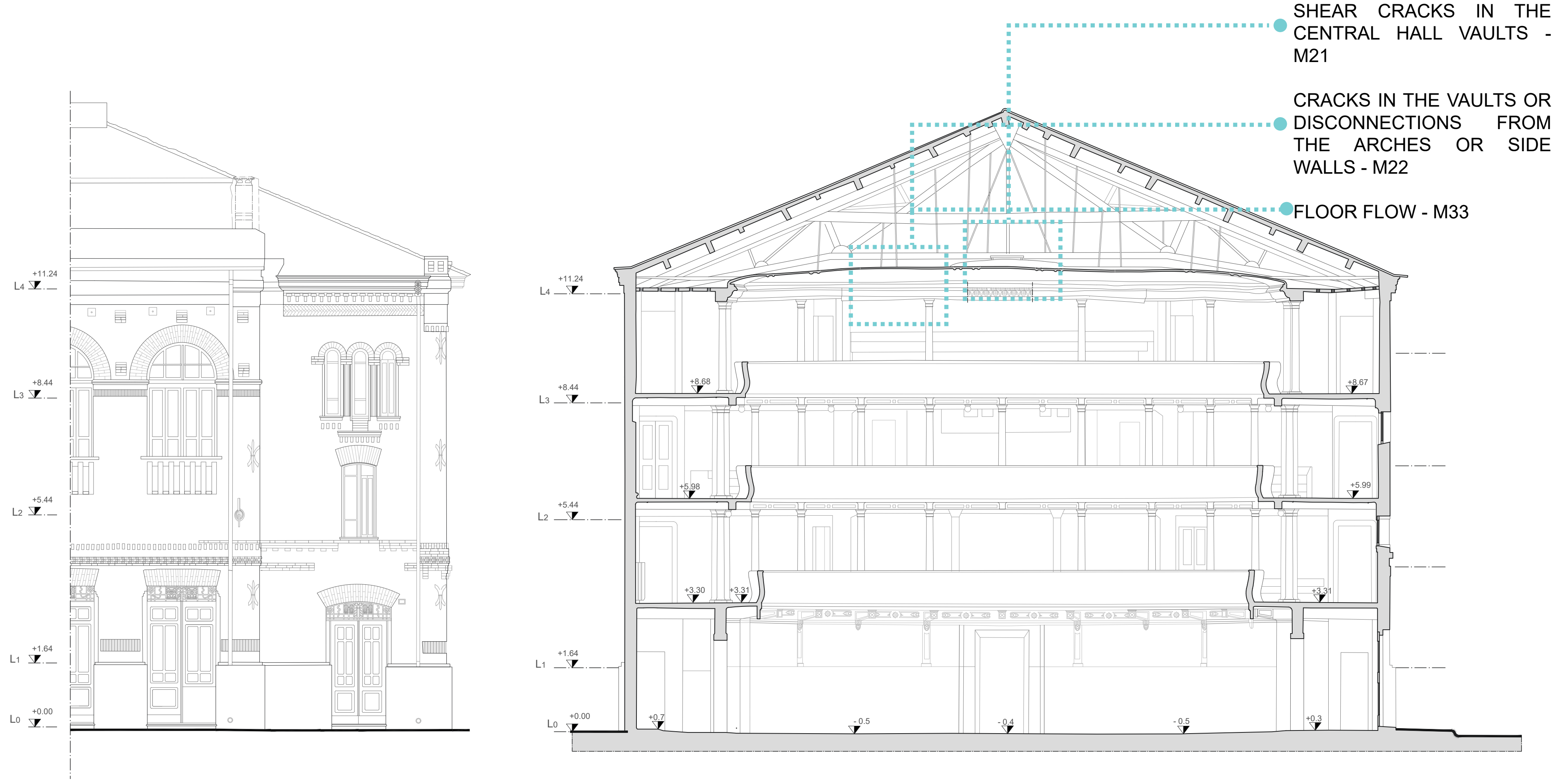
Developed by M.Suppa

TaB_03_Cross section AA'

2D graphics based on the discretisation of metric and geometric point cloud data



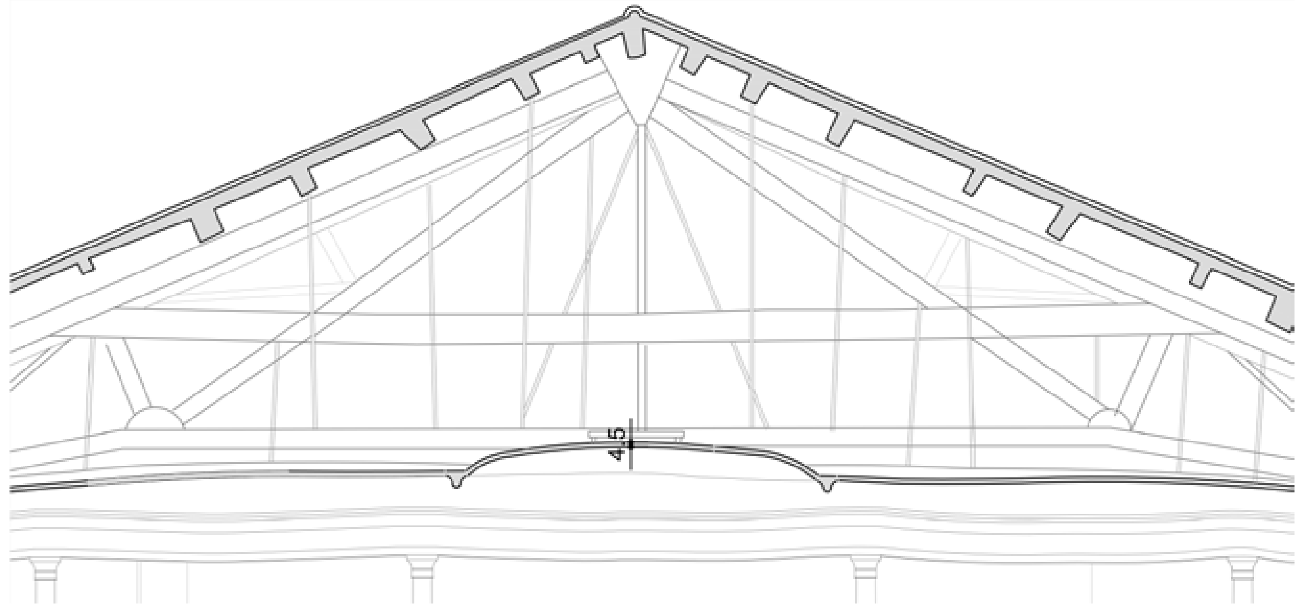




Cross section AA'

TaB_03.1_Cross section AA'- plafond detail

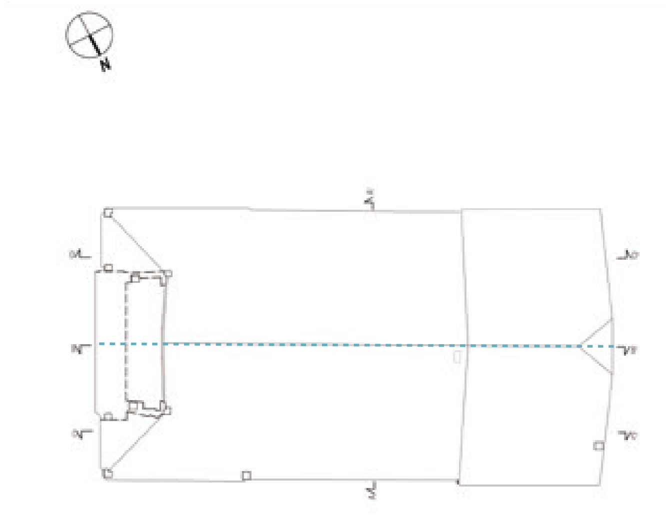
2D graphics based on the discretisation of metric and geometric point cloud data

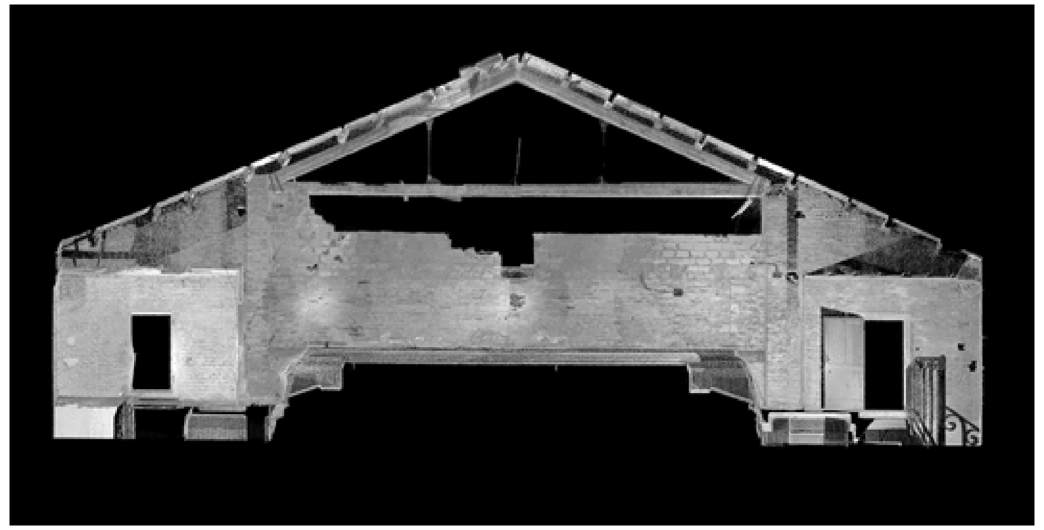


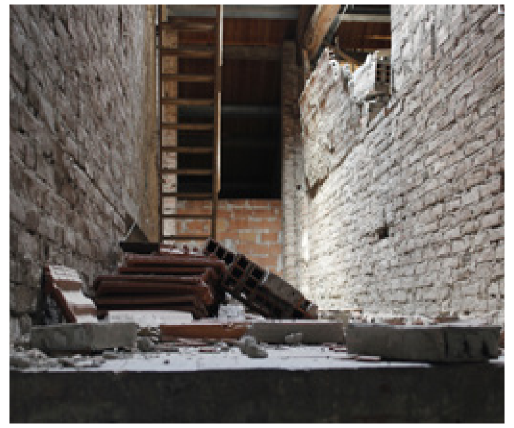
detail of the ceiling vault resistance section

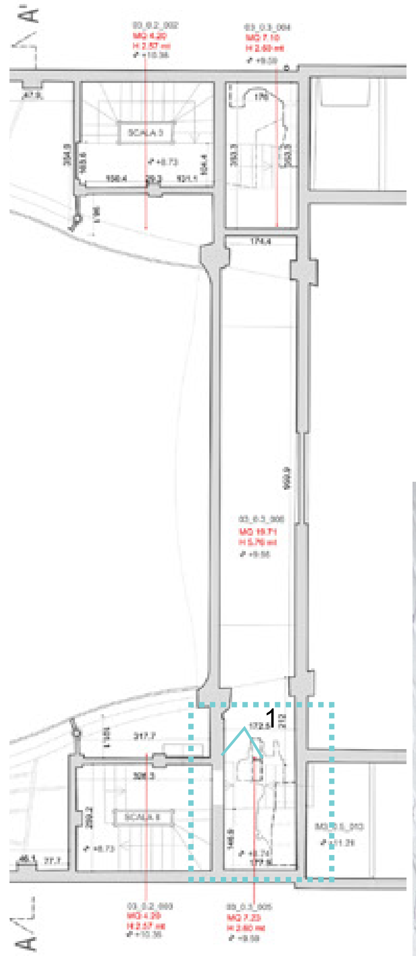
TaB_04_Longitudinal Section BB'

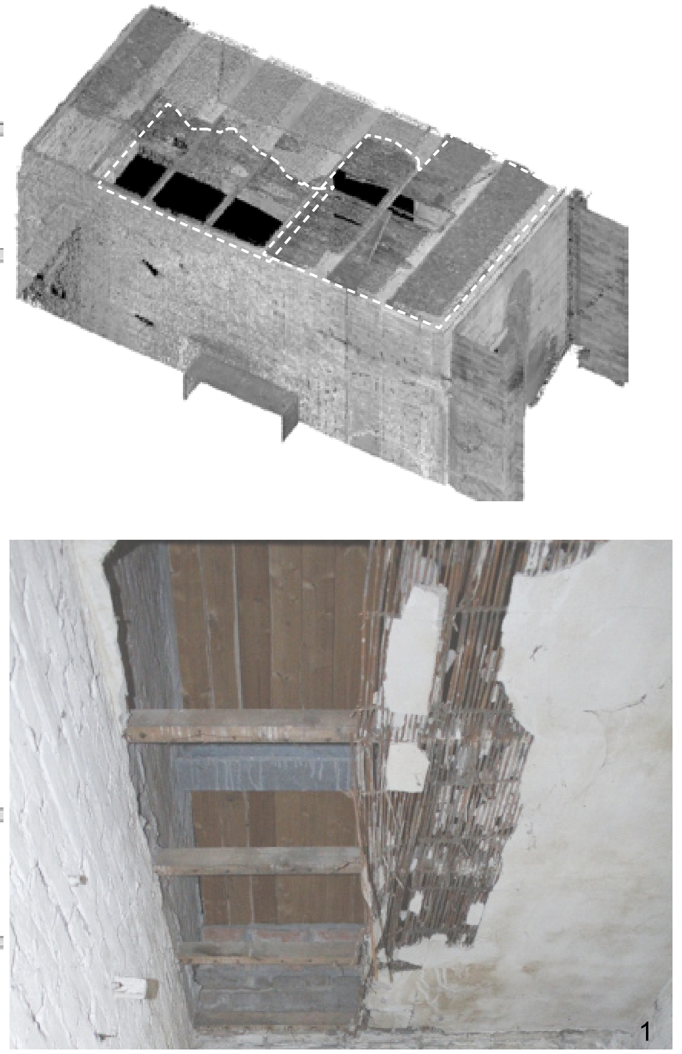
2D graphics based on the discretisation of metric and geometric point cloud data

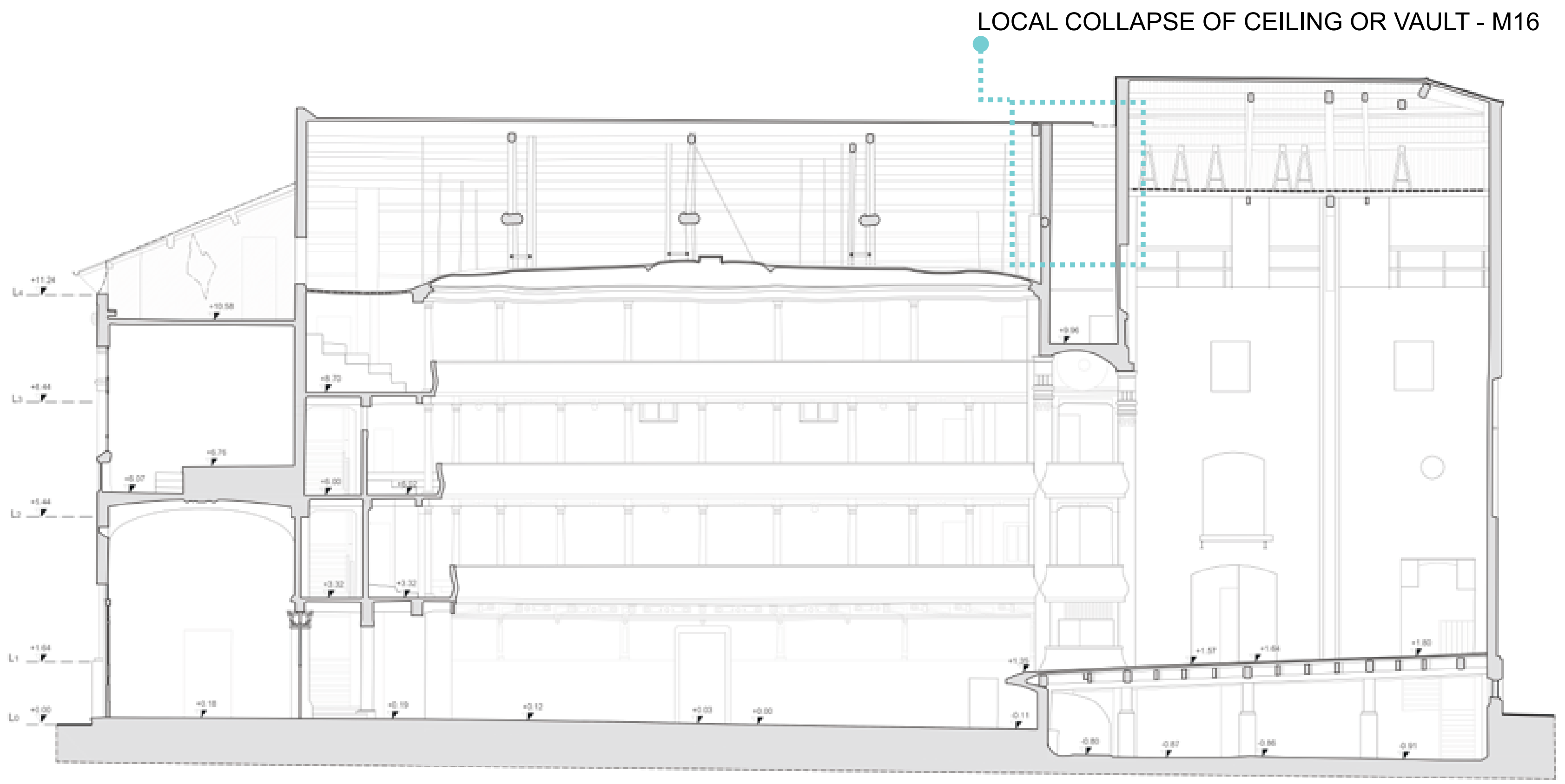










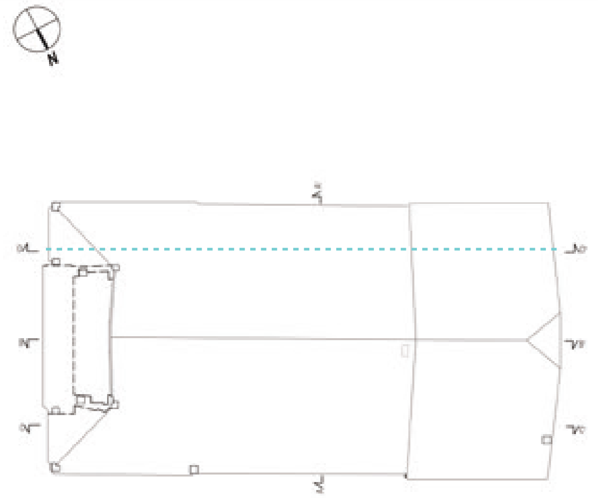


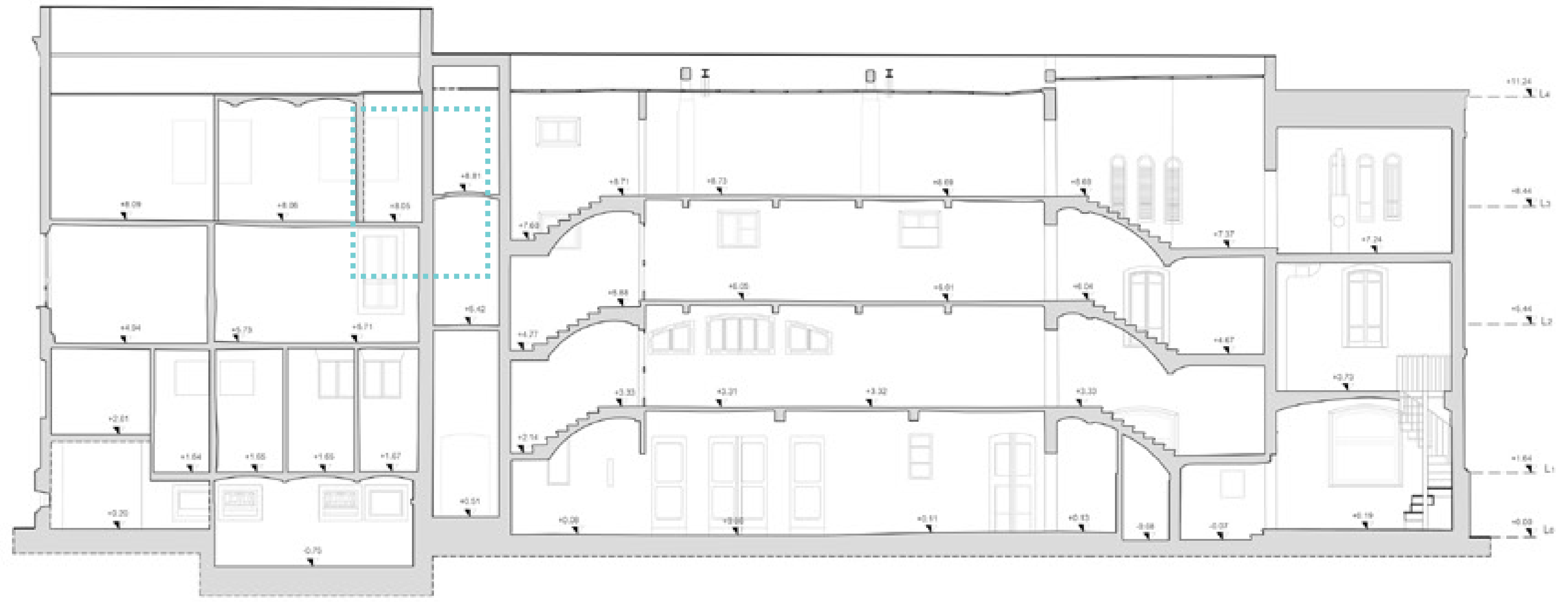
Developed by M.Suppa

Longitudinal Section BB' 0 1 2

TaB_05_First Order plan/Section long. Staircase body 1 CC'

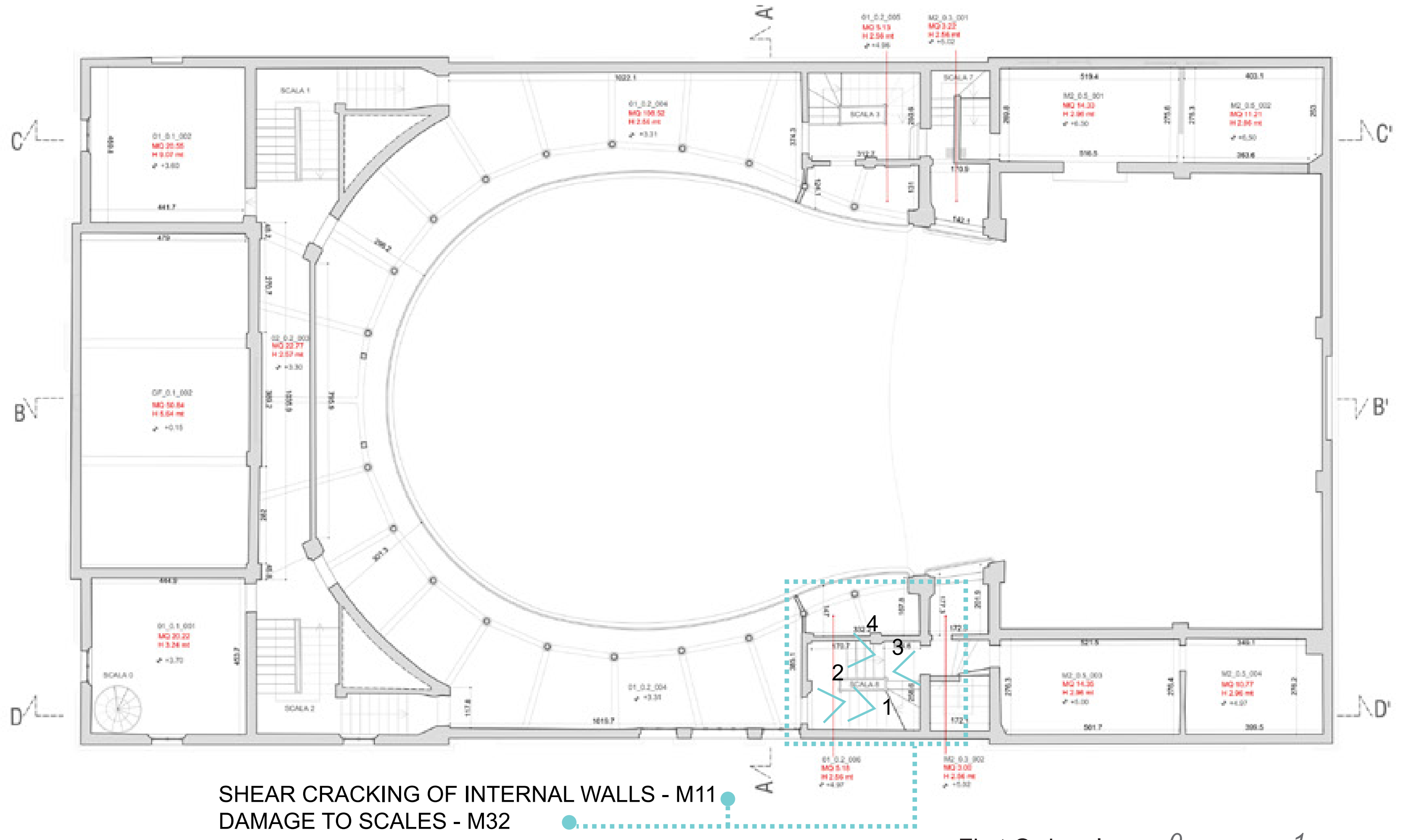
2D graphics based on the discretisation of metric and geometric point cloud data





Long Section_Staircase body 1 CC'

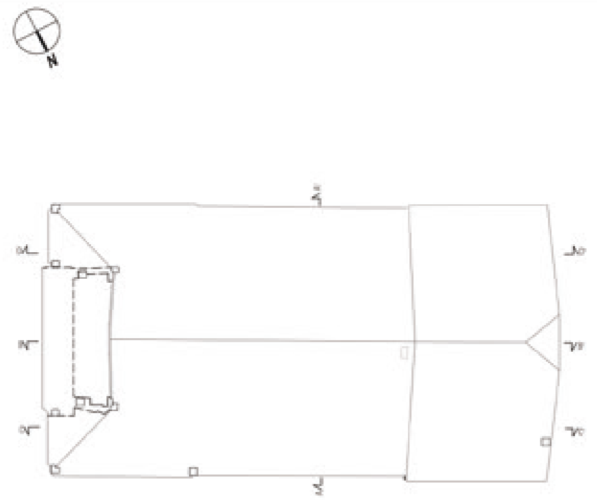
Developed by M.Suppa

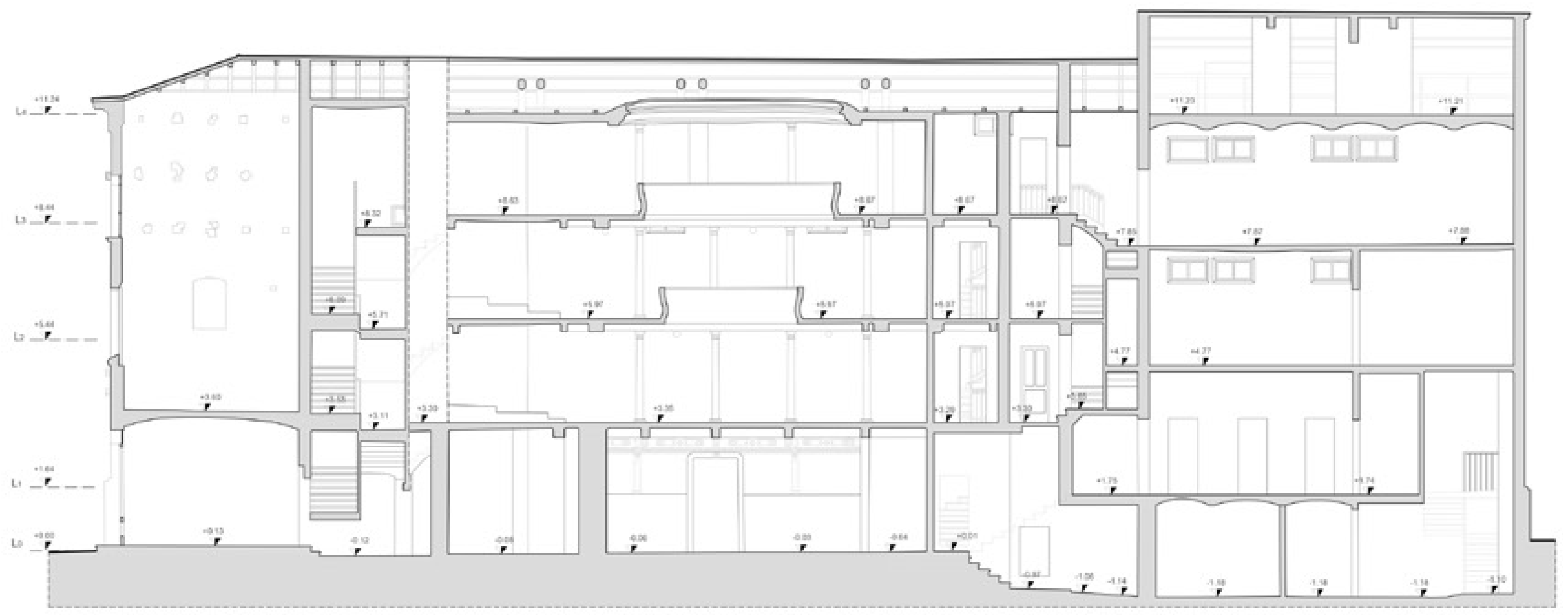


First Order plan

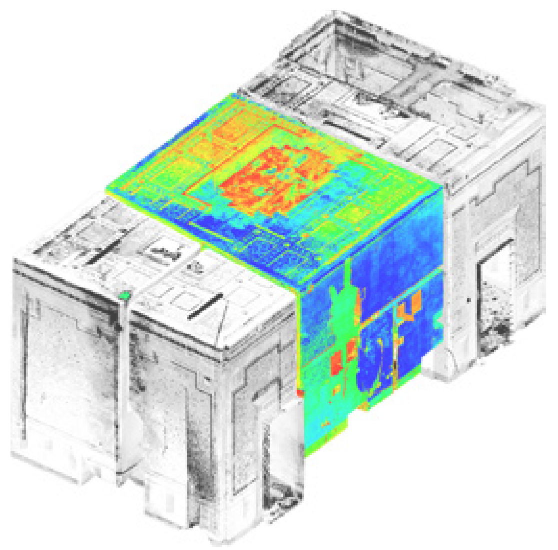
TaB_06_Second Order plan/Section long. Staircase body 2 DD'

2D graphics based on the discretisation of metric and geometric point cloud data

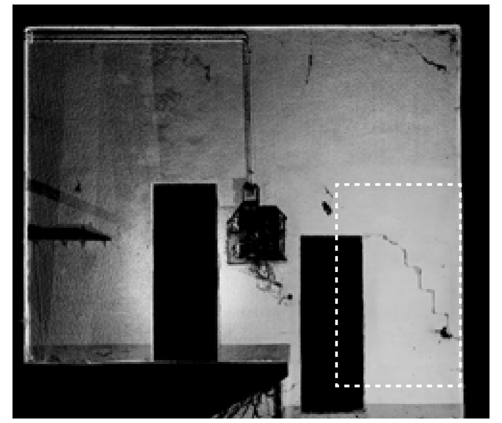




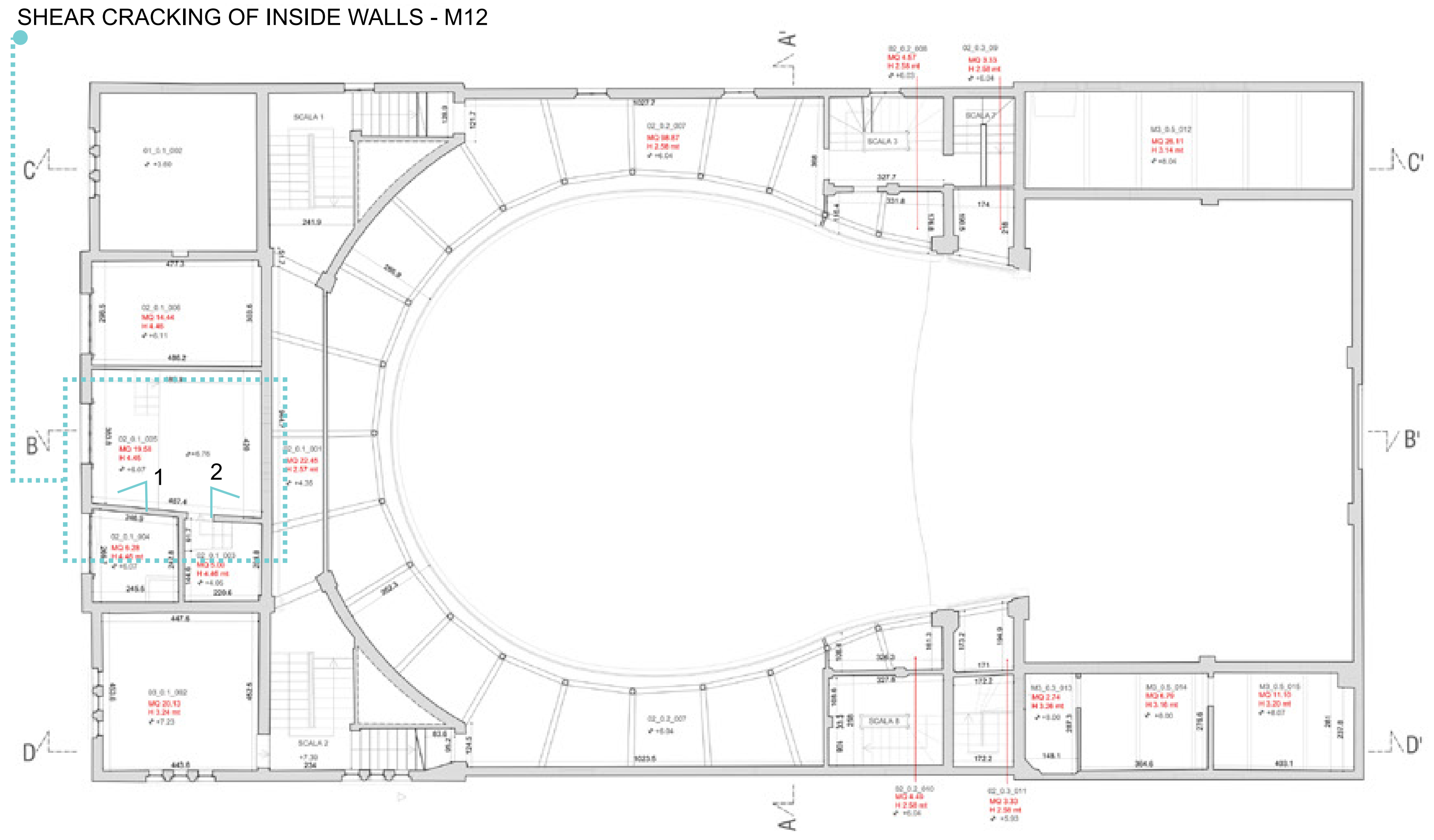
Long Section_Staircase body 1 DD'



Developed by M.Suppa



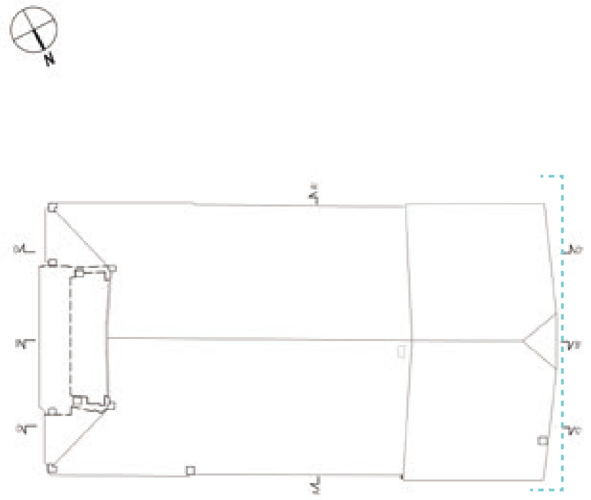
reflectance values
colord method from scanner:
grayscalee
min: 0,10
max:0,60
gamma:0,65

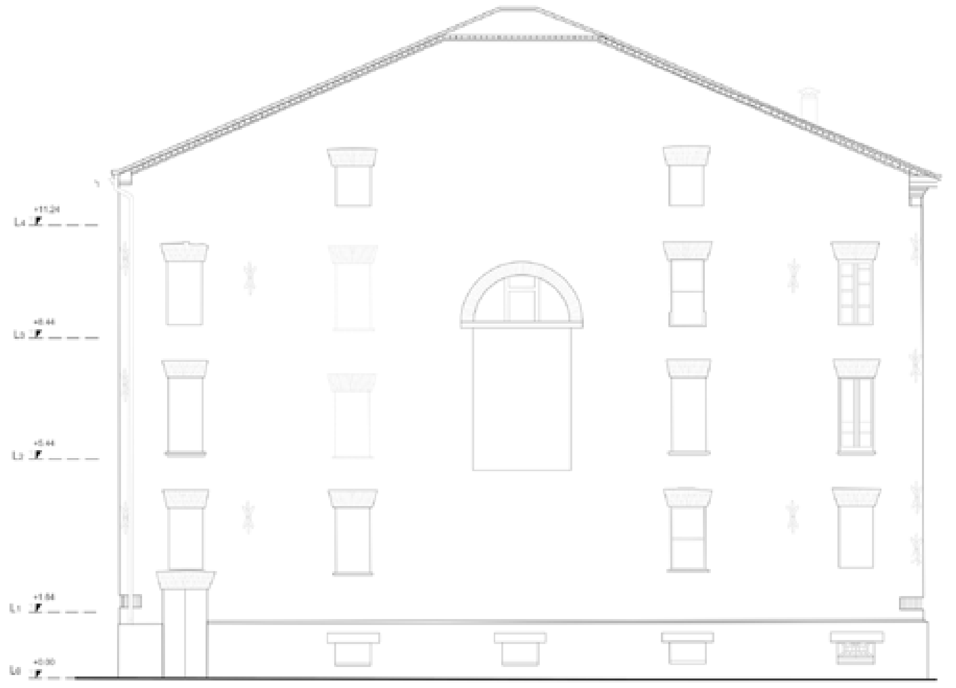


Second Order plan

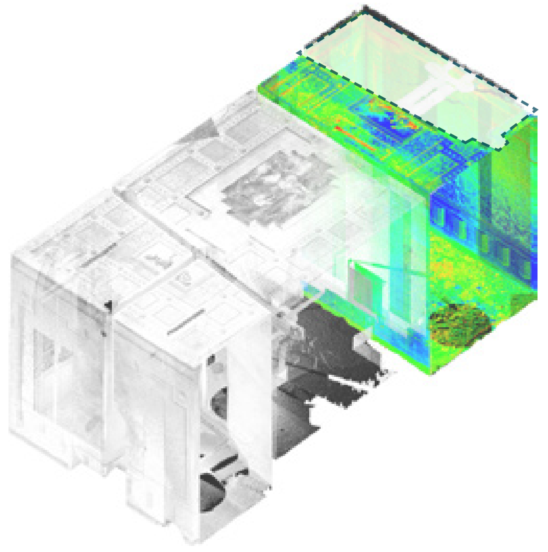
TaB_07_Third Order plan/West Front

2D graphics based on the discretisation of metric and geometric point cloud data



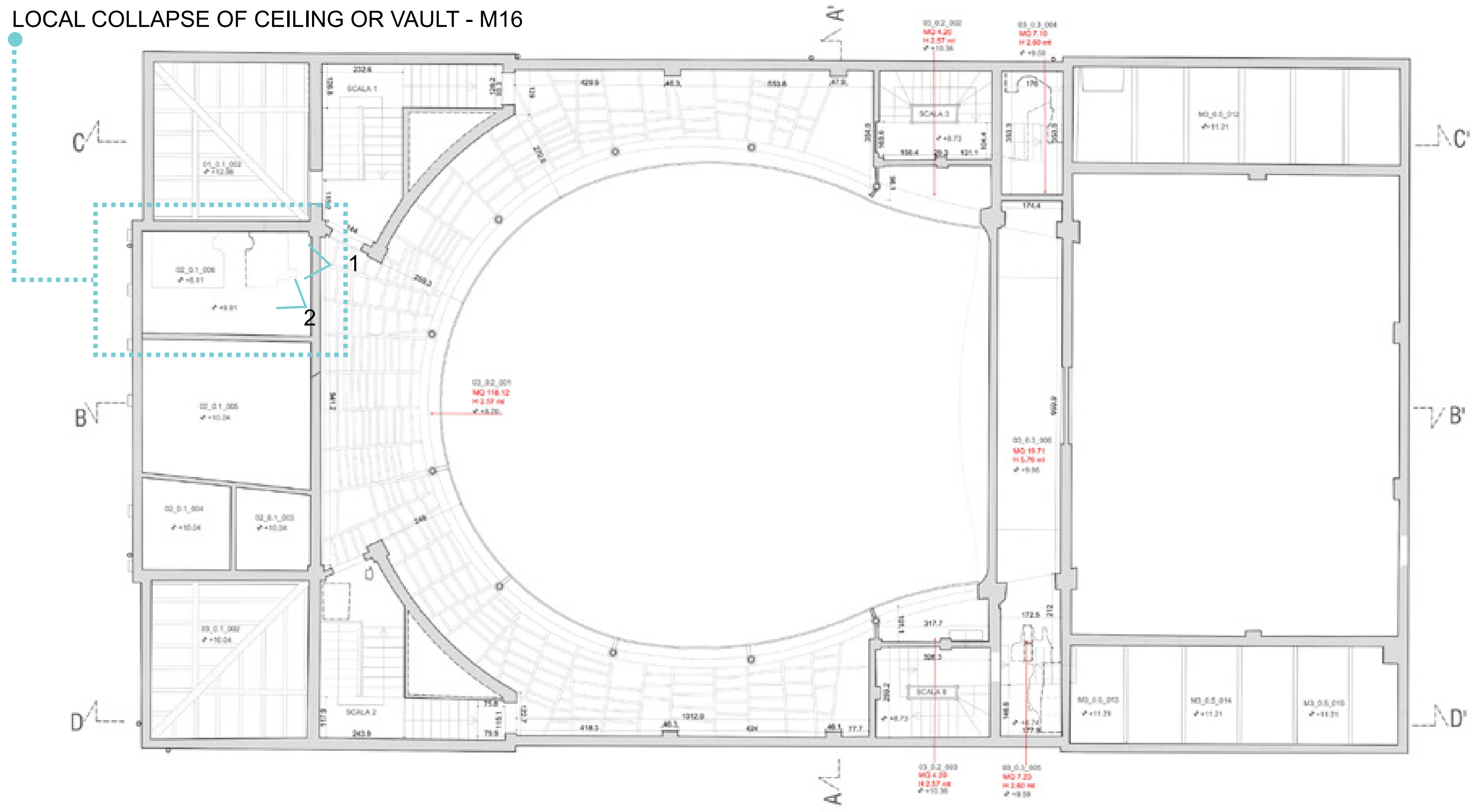


West Front C. Zoldi street



Developed by M.Suppa

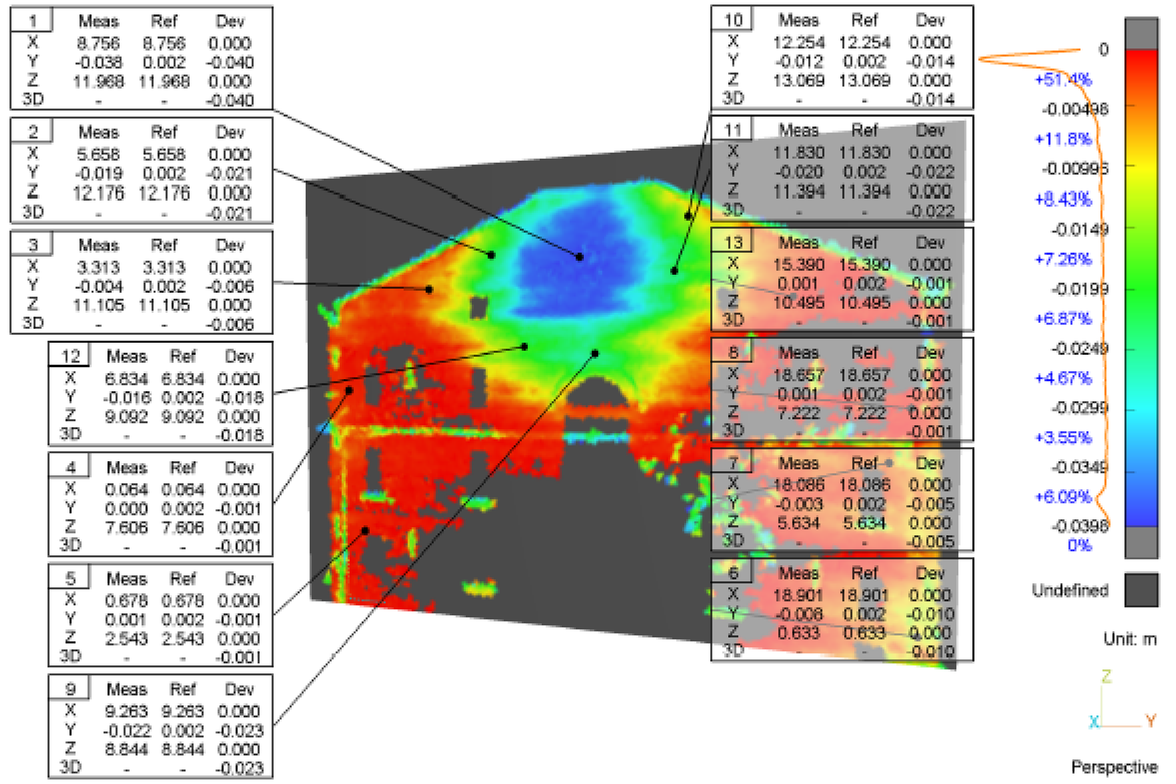
LOCAL COLLAPSE OF CEILING OR VAULT - M16



Third Order plan

0 1 2

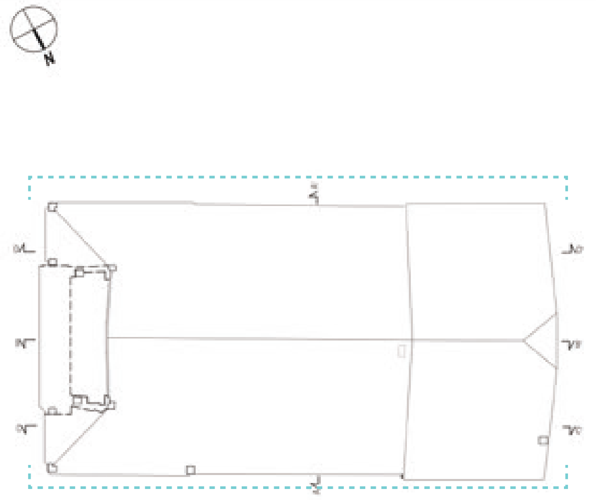
TaB_07.1_Deviation analysis along the y-axis of the west front

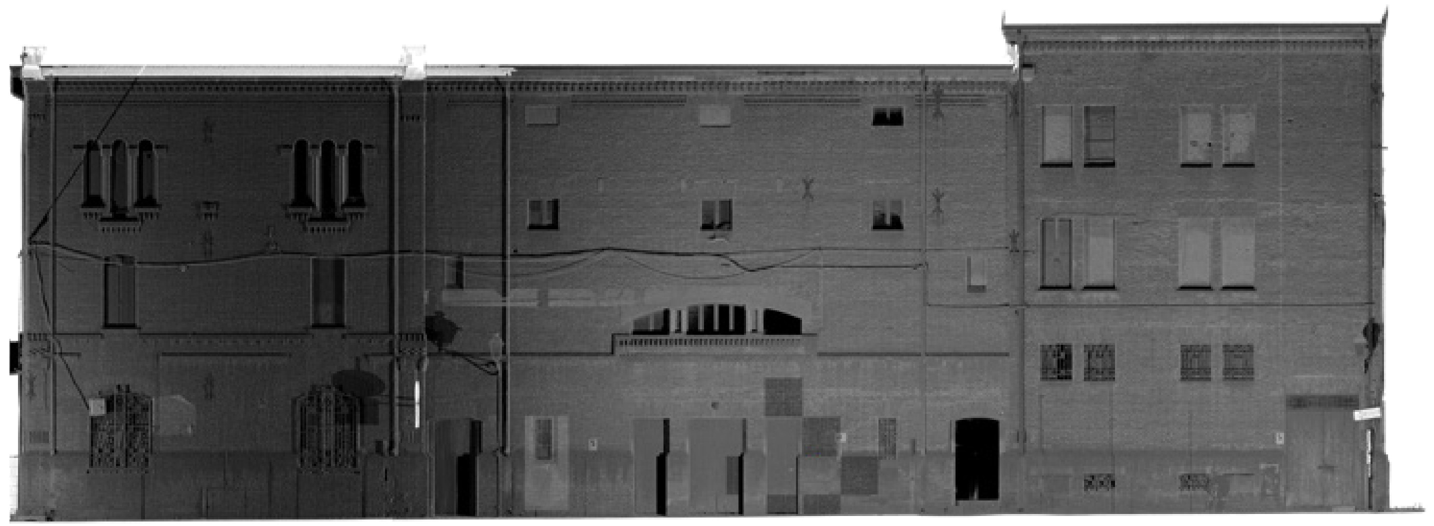


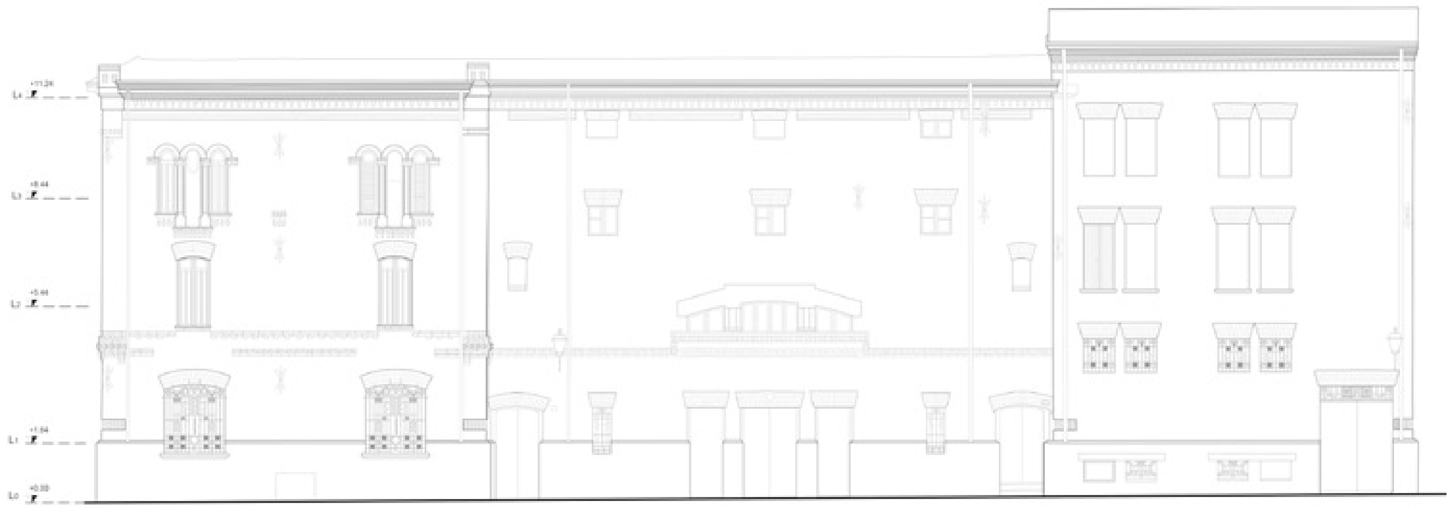
id	name	Meas X (m)	Meas Y (m)	Meas Z (m)	Ref X (m)	Ref Y (m)	Ref Z (m)	Dev X (m)	Dev Y (m)	Dev Z (m)	Dev 3D (m)	Tol- 3D (m)	Tol+ 3D (m)	Note 3D
1	Label #1	8.75584	-0.0382	11.96789	8.75584	0.00155	11.96789	0	-0.03975	0	-0.03975	-0.1	0.1	- -
2	Label #2	5.65809	-0.01914	12.17611	5.65809	0.00155	12.17611	0	-0.0207	0	-0.0207	-0.1	0.1	-
3	Label #3	3.31323	-0.00433	11.10467	3.31323	0.00155	11.10467	0	-0.00589	0	-0.00589	-0.1	0.1	☺
4	Label #4	0.06414	0.0001	7.60634	0.06414	0.00155	7.60634	0	-0.00145	0	-0.00145	-0.1	0.1	☺
5	Label #5	0.67804	0.00055	2.54261	0.67804	0.00155	2.54261	0	-0.001	0	-0.001	-0.1	0.1	☺
6	Label #6	18.90072	-0.0082	0.63305	18.90072	0.00155	0.63305	0	-0.00975	0	-0.00975	-0.1	0.1	☺
7	Label #7	18.08605	-0.00339	5.63393	18.08605	0.00155	5.63393	0	-0.00495	0	-0.00495	-0.1	0.1	☺
8	Label #8	18.65728	0.00092	7.22151	18.65728	0.00155	7.22151	0	-0.00063	0	-0.00063	-0.1	0.1	☺
9	Label #9	9.26291	-0.02172	8.84406	9.26291	0.00155	8.84406	0	-0.02328	0	-0.02328	-0.1	0.1	-
10	Label #10	12.25382	-0.01212	13.06913	12.25382	0.00155	13.06913	0	-0.01367	0	-0.01367	-0.1	0.1	-
11	Label #11	11.82985	-0.02004	11.39351	11.82985	0.00155	11.39351	0	-0.0216	0	-0.0216	-0.1	0.1	-
12	Label #12	6.83351	-0.01634	9.09203	6.83351	0.00155	9.09203	0	-0.01789	0	-0.01789	-0.1	0.1	-
13	Label #13	15.38956	0.00075	10.49483	15.38956	0.00155	10.49483	0	-0.0008	0	-0.0008	-0.1	0.1	☺

Developed by M.Suppa

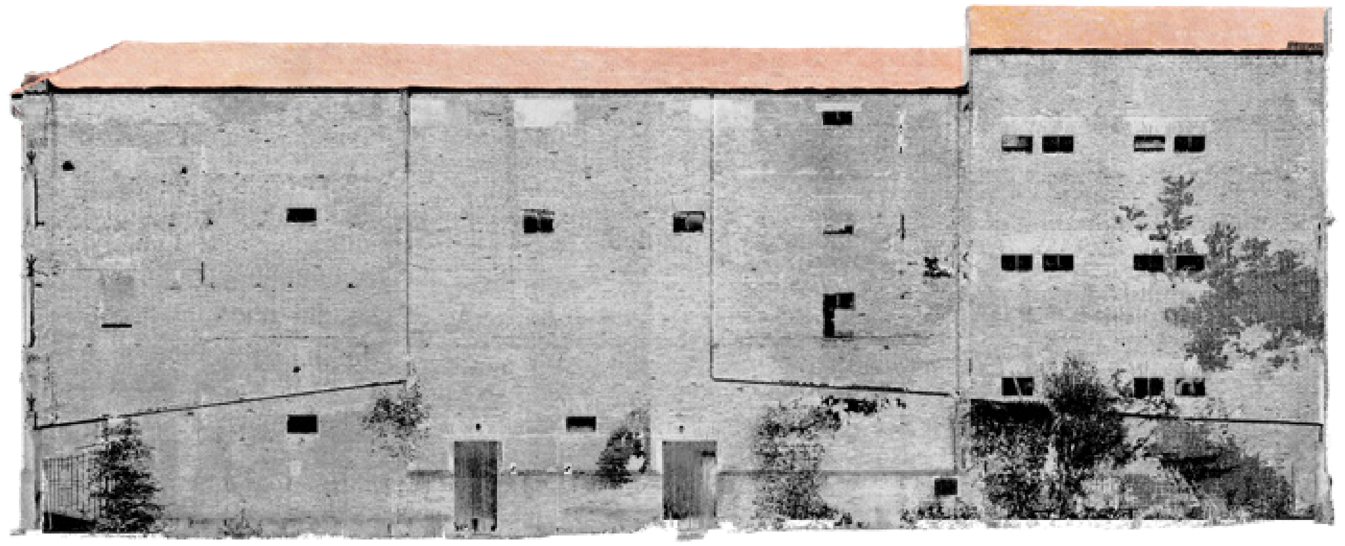
TaB_08_Third Order plan/North Front

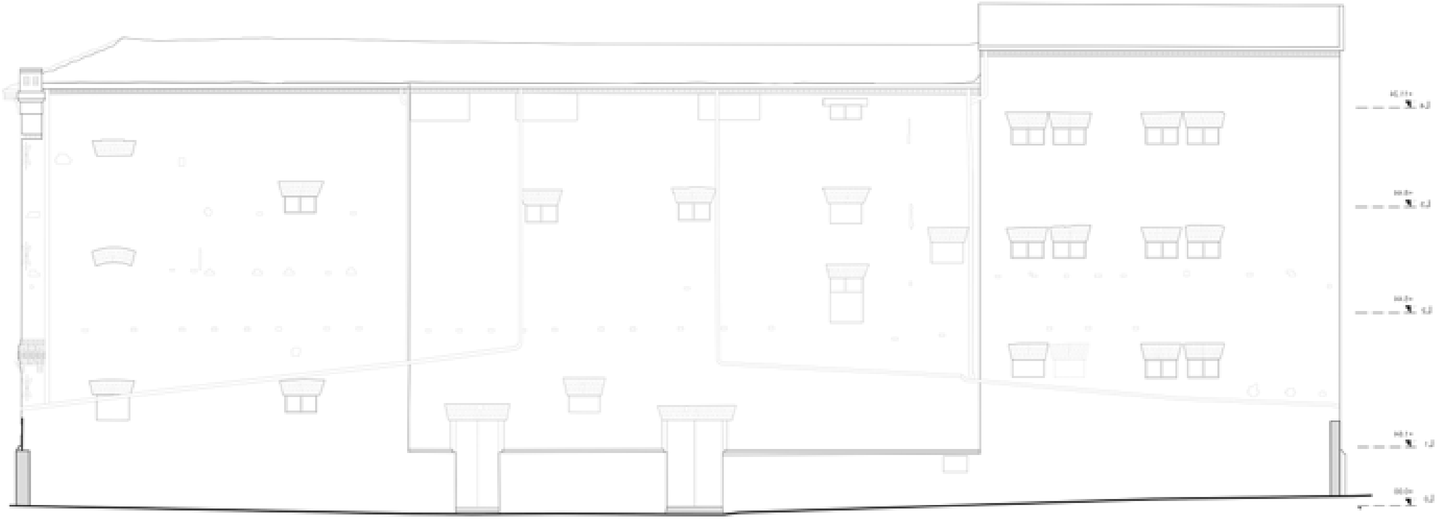






North Front





South Front 0 1 2

Developed by M.Suppa

5.2.2. 4 The Diagnostic survey: analysis of surfaces using intensity value

The diagnostic survey was divided into the following phases: a) preliminary studies and research on the building, b) diagnostic survey in the field, c) "post-processing" phase of the data collected, analyzing the degradation morphologies and surface characteristics through the definition of a specific abacus and preliminary investigations allowed to obtain fundamental data to the knowledge of the building and its formal characteristics, material and construction, and construction technologies of the time of realization. The preliminary investigations have made it possible to obtain a series of fundamental data to the knowledge of the building and its formal, material and constructive characteristics. The diagnostic survey is closely focused on analysing the seismic damage suffered and on the need to document the material consistency and the state of the theatre's conservation to gain a high precision metric-morphological graphic support and a mapping of the primary degradation and structural damage morphologies found after the event. Starting from this premise that directed the integrated diagnostic survey project of the theatre, an analysis was performed on the four elevations of the theatre. A sample area was selected to allow coherent graphic restitution of the results of the integrated investigations. The analysis of the sample area, chosen concerning the damage suffered by the building because of the earthquake, constitutes a representative model of the integrated diagnostic survey methodology and graphic restitution of the surface characteristics (fig.97). Primarily to photographic survey and instrumental integration as a support for the visualization and representation of the distinct areas, the investigations were divided into the following phases: - macroscopic scale analysis (localization, context, orientation, analysis of the surroundings, and other characteristic elements, etc.); - the study of the geometry and the formal and compositional aspects of the building; - analysis of materials and construction techniques; - preliminary analysis of the material characteristics - preliminary analysis of the macroscopic morphologies of degradation. - analysis of the damage following the earthquake. The diagnostic investigation is performed through photographic cataloguing in HD. a database with general, detailed and "macro" views has been created to document the state of the building. The photographic catalogue has been valid support for graphic representation. The diagnostic survey phase was preceded by an overall survey of the building and the drafting of general preliminary sketches, which support preliminary identification of the characteristics of the materials and the corresponding degradation morphologies. The abacus of the principal degradation morphologies identified closely related to the damage, highlighting at the same time surface degradation phenomena not directly related to seismic damage, not negligible for the state of conservation of the theatre is realised in accordance with UNI 11182 standard. In the specific case of social theatre, the degradation morphologies identified are relative portions of the structure that have undergone high deformation or that have highlighted the presence of critical structural deficiencies 1) Upper portions of the perimeter load-bearing walls having great height and length (high free light) without the presence of stiffening elements such as floors or bracing walls; 2) Simple supports of beams (without the presence of connections); 3) Non-clamped partitions; 4) Summit portions of masonry stressed by the thrusts of the roof; 5) Floors with poor resistance. 6) partial collapse of the roof in the structural unit of the forebody;

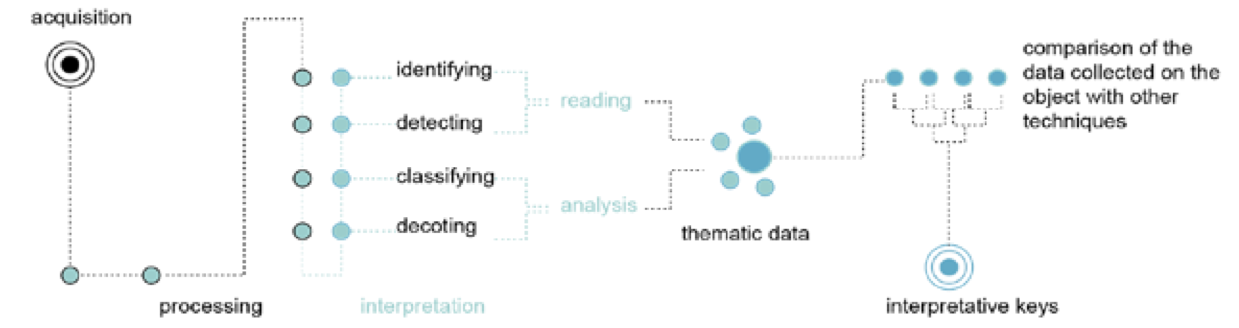


Fig. 97 Methodological diagram of the interpretative analysis of the point cloud to draw the map of surface degradation. Developed by M.Suppa

7) partial collapses of the ceiling and false ceiling in the gallery; and the natural response of materials to atmospheric agents (fig. 98; 99; 100). Biological patina, efflorescence, drippings are some of the morphologies of degradation analysed on the external surfaces, localized mainly in the upper band of the principal elevation (between the second and third-order), to which must be added, detachments of plaster and patches of cracks, deformations, along the surfaces of the internal perimeters (fig. 102;103).

Intrinsic causes
• design defects
• at the construction site

Extrinsic causes
• natural
• Earthquake 2012
• long acting
• direct action • indirect action
• anthropic action

Degradation
• chemical
• physical/mechanical.

The methodology of subdivision of degradation morphologies identifies five categories: degradation of a physical-chemical nature, degradation of a chemical nature due to environmental conditions, biological degradation, structural degradation, and anthropic action. Each morphology can be assigned a code corresponding to the graphic return layer. The visual investigation allows recognising the associated types of degradation as a whole and macroscopically since it is a building with small dimensions. However, given the complexity and stratification of the forms of degradation surveyed, crossing the scanning reflectance data with the three-dimensional HDS photographic documentation allows extracting specific elaborates helpful in identifying the pathologies on which to intervene in the restoration project.
Phases of survey of the internal environments: Abacus of the primary morphologies of degradation.
The general state of conservation of the external surfaces was surveyed by integrating macroscopic visual investigations and the reflectance data obtained by the 3D laser scanner survey, considering the specificities of the building in historical-chronological terms. The analysis included: the correlation between degradation and geographical location, considerations about exposure and orientation, materials, execution techniques, and seismic damage (based on descriptive information and not on specific characterization investigations).

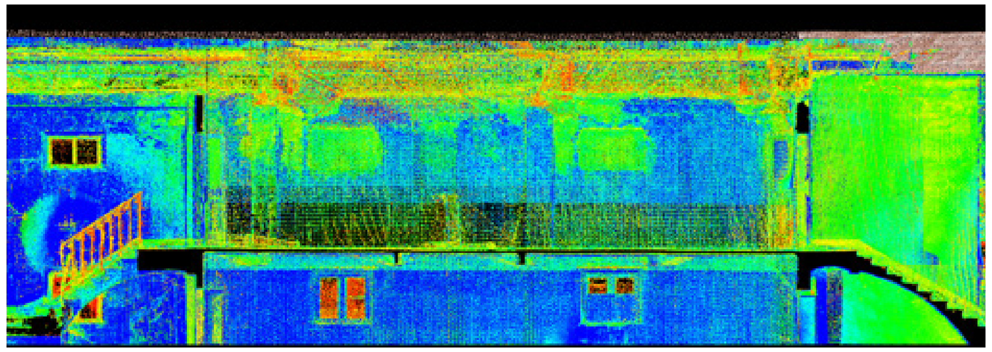
5.2.2.5 Processing of the intensity value

The architectural survey employing three-dimensional scanning technology integrated with diagnostic investigations and designed pursuing a methodological procedure of critical approach can form the basis for using three-dimensional laser scanner instruments to extract evaluation information on architectural surfaces. The high-density survey for the construction of three-dimensional models can allow not only to constitute, over time, an archive of the historical memory of architecture but can also be used for protection and conservation purposes and as a support for any restoration processes. An important field of investigation of integrated documentation is the study of the characteristics of architectural surfaces and related degradation morphologies. In this field of analysis, a methodology of in-depth analysis and interpretation of the acquired data is required regardless of the instrument used and with solid critical-interpretive implications. The interdisciplinary investigation from geometry obtained from the three-dimensional time-of-flight scanning to the integration of the architectural survey with the high-definition digital photographic survey, up to the

implementation with the characterization data of the surfaces of the historical architectural artefact, the analysis of the state of preservation, the spectrophotometric investigations, etc., represents a path that allows to use and critically evaluate the data acquired during the laser scanning. The possibility of using this technology for diagnostic purposes is given by the fact that on each individual point surveyed, together with the three-dimensional metric data, different “levels of information” are recorded, some discriminated during the acquisition phase, such as the intensity mesh (i.e. the refinement of the surveyed points, in direct relation to the scanning distance), others automatically acquired by the instrument, such as the reflectance data, recognition for which the instrument is calibrated in order to recognize the targets, useful references to the recording of the different scans in a The physical phenomenon that is the basis of the measurement (the flight time, or the time that elapses between the moment in which the laser beam is emitted by the instrument, hits the surface and returns) makes it easy to deduce that the reflected beam of light acquires not only a geometric type of information but also a spectral type of data: each surveyed d point is defined by the coordinates x, y, z and by the reflectance data, spectral response that is emitted by the material in contact with the laser light frequency, in the green band, with a wavelength of 830 nm, specific to the instrument used for the internal survey of the Social theatre (Leica BLK360 Laser Scanner), while for the survey of the exterior (Leica Laser Scanner C10) the wavelength is considered to be 532 nm. The knowledge of this data, although limited to a particular value, allows the collection of information for homogeneous areas to the angle of incidence and the type of surface material; the change in intensity from point to the point of the reflected beam of green light can be used to draw information on the materials and the degradation of the investigated surface. The reflected beam will always have a lower intensity than the incident ray, especially depending on the reflection geometry on the façade and the characteristics of the point of impact (nature of the material, its surface processing, state of degradation). Unlike geometric characteristics, surface qualities are not uniquely determined. They become coherent and interesting components only if critically interpreted. So only if performed with a systematic and well-documented methodology, the reading of the reflectance data can allow a completely non-invasive and as objective as possible monitoring. This methodology must be in a certain sense “calibrated” through a comparison with specific investigations and any parameters of conversion of reflectance data, and above all through a comparison with other data acquired on the same categories of materials/components. However, it is important to emphasise that the surface qualitative data is always connected and correlated to the three-dimensional metric one and that in this correspondence lies an element of innovation and restorative security. According to the metric-morphological survey, it is possible to achieve orthophoto-like visualizations. The reflectance data are labelled in false colours (the software dedicated to the instrument associates a colour to the measured reflectance values) or in grayscale; and on which to add any other layers (high-resolution photographic images, photographic infrared, thermographic information, ultraviolet, etc.) to build on the three-dimensional metric model also the references of a multispectral database. Based on these elaborations, it is possible to extract thematic tables (in 3D or 2D vector format depending on the purpose of the project) to visualize the surface areas that have different responses in the reflection of the laser beam. These areas can be selected in various ways by using false-colour maps and varying the number of reflectance intensity levels intended to analyze. After obtaining the visualization of the reflectance data, it is advisable to carefully compare it with the real colour photographic analysis (and with other investigations that may be available) for a first evaluation of the characteristics of the materials, on the evaluation of the state of conservation and the macroscopic forms of degradation. The reflectance range can be divided into several levels to discriminate the various areas of the wall facing. Using a chromatic scale associated with the image and showing the false colours attributed by the software discriminates the areas marked by greater or lesser reflectance. The elaboration of the reflectance data acquired in the survey can therefore highlight inhomogeneous areas on which to deepen the investigations. The spectral data in the green band certainly can represent a further evaluation element for conservative purposes. However, it must always be considered together with the results of other investigations and bearing in mind that each situation can have peculiar characteristics

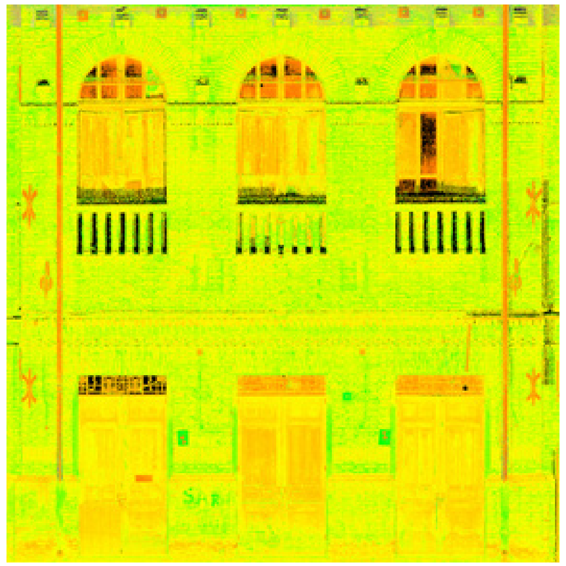
that must be carefully considered. In an integrated database logic that can be queried according to different reading levels, it is possible, in addition to geometric consistency, to request specific qualities, such as metric, chromatic, historical-documentary, conservative, using the data obtained from three-dimensional scanning.
The following are some elaborations of the reflectance data performed on a sample basis on the internal and external surfaces of the theatre (the other elaborations with thematic tables are present in Appendix C). The interpretation of the data of degradation morphologies is described below (fig. 101).

Interpretative data of reflectance values.
1) Red: patina, casting
thick orange: spot
2) red: stain, organic patina on brick
dense red: casting on the surface and plastered
orange: casting
Green: Detachment
3) Red: brick surface
blue: surface deposit on the plastered surface (not taken into analysis in degradation because it is not related to damage)
thick orange: spot
4) Dense blue: efflorescence
cyan: casting, organic patina
green: biological colonization
5) cyan: detachment of plaster
yellow-orange: spot
green: organic casting and biological patina.

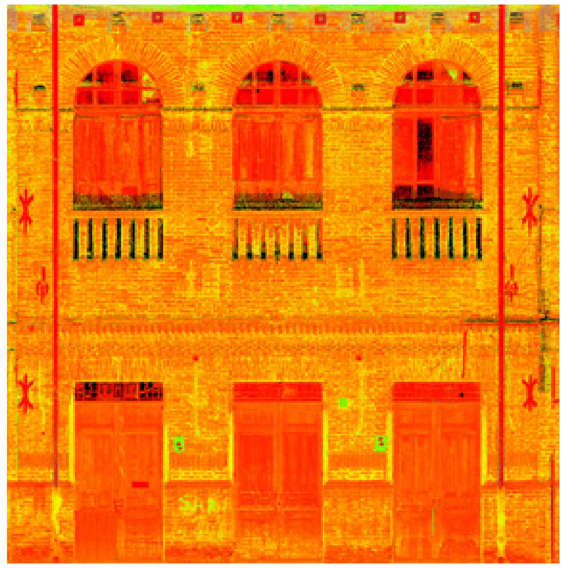


reflectance values
method colord from scanner: multi hue
min: 0,10
max:0,25
gamma:0,45

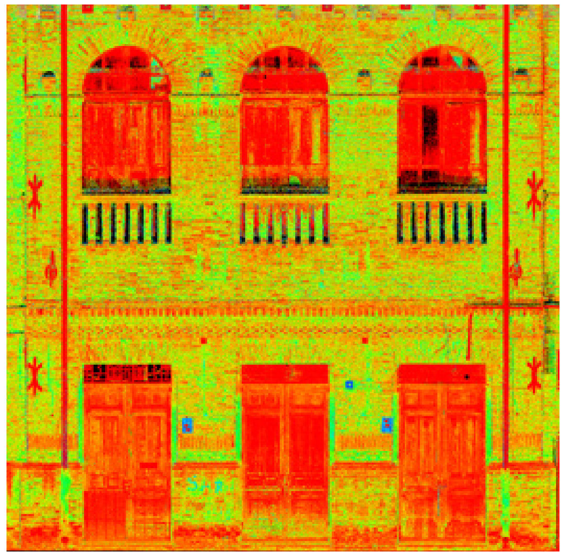
Fig. 98- 99- 100 Reflectance analysis of the hall. The northwest sector of the 3rd order of boxes. The interpretation of the data is described in paragraph 5.2.2.5. Developed by M.Suppa



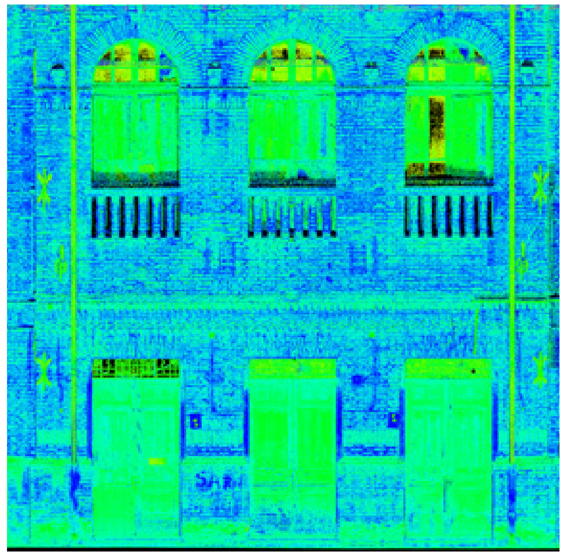
1
reflectance values
method colord from scanner: multi hue
min: 0,0010
max:0,99
gamma:0,45



2
reflectance values
method colord from scanner: multi hue
min: 0,10
max:0,99
gamma:0,45

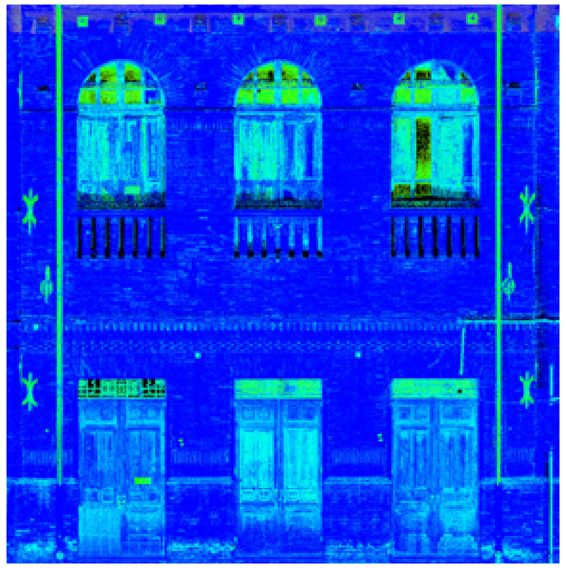


3
reflectance values
method colord from scanner: multi hue
min: 0,20
max:0,50
gamma:0,45



4
reflectance values
method colord from scanner: multi hue
min: 0,01
max:0,35
gamma:0,45

Fig. 101 Reflectance analysis of the east elevation via Dei Martiri della libertà. The interpretation of the data is described in the paragraph 5.2.2.5. Developed by M.Suppa



5
reflectance values
colord method from scanner: multi hue
min: 0,01
max:0,25
gamma:0,45

6
reflectance values
method colord from scanner: grayscale
min: 0,24
max:0,90
gamma:0,65

7
reflectance values
method colord from scanner: grayscale
min: 0,20
max:0,50
gamma:0,50

Fig. 101 Reflectance analysis of the east elevation via Dei Martiri della libertà. The interpretation of the data is described in the paragraph 5.2.2.5. Developed by M.Suppa

Map of degradation morphologies

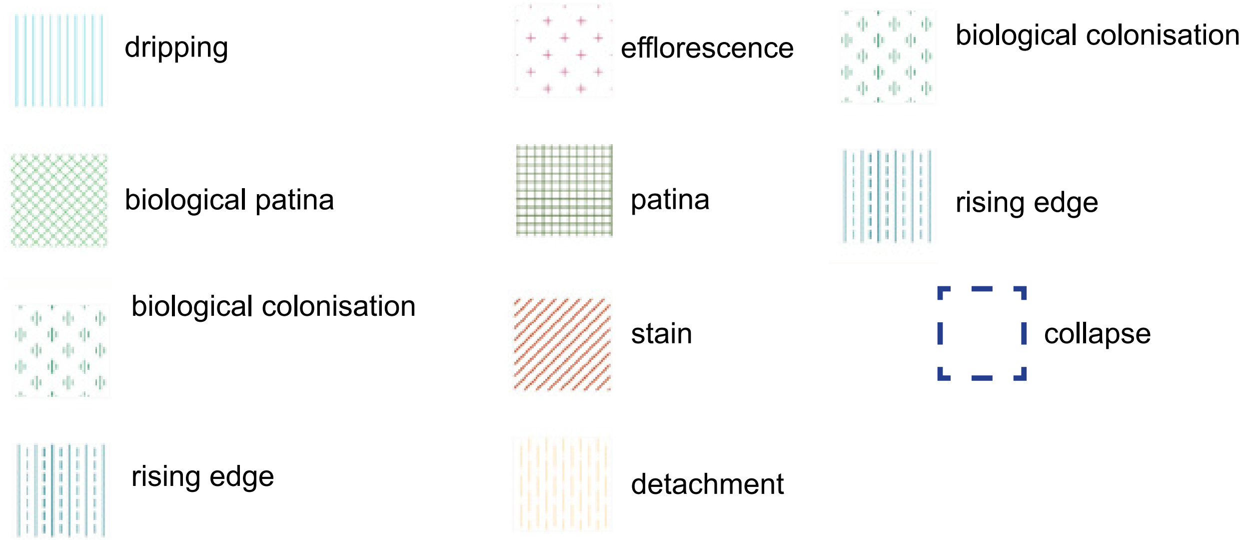


Fig. 102 Degradation morphologies of the external surfaces_East side of Viale Martiri della Libertà. The map is carried out using Standard UNI 11182 replaces the previous lexicon NORMA.L 1/88. Developed by M.Suppa

Fig. 103 Degradation morphologies of the external surfaces_East side of Viale Martiri della Libertà. Developed by M.Suppa

5.3 Setting up L3 - PLUS HBIM Level

5.3.1 HBIM implementation for seismic damage

BIM applied to the sector of the existing historical heritage represents a valuable tool for the documentation and preparation of actions for the conservation [R. Brumana et al.], maintenance and management of the asset or complex assets subject to interventions. The third level of the integrated procedural workflow for the damage survey - PLUS HBIM Level - provides a methodological approach to realizing three-dimensional models in a BIM environment supporting planned actions of management and mitigation of seismic risk about the specific architectural typology studied. More appropriately, the research addresses the issues of Heritage Building Modeling (HBIM) as it applies the BIM approach to the field of historical and architectural heritage. In this context, there are relevant differences between BIM and HBIM [M. Azenha et al., 2018] arising from the attributes of a historical building, not belonging to industrial construction, and for which the management strategies are aimed at analysis, conservation, and maintenance [R. Mora et al. 2021]

In the specific application context addressed by the research, the use of the HBIM model provides the opportunity to take advantage of a single environment "container" and "collector" of information derived from the application of the SD T, the geometric-dimensional data obtained through the integrated acquisition methods of survey (photogrammetry and terrestrial laser scanner - TLS) and subsequent predictive analysis. According to the Scan to BIM process, the historical theatres' BIM model, notably the Novi di Modena Theatre (pilot case application of the procedural workflow), is realized within the research path. This is part of the HBIM approach and consists in the realization of a parametric model from the survey data (TLS laser scanning, digital photogrammetry, etc..), aimed at creating a library of parametric objects, combined with information data to enrich the object in addition to the modelling phase [Apollonio et al., 2013].

The 3D digital acquisition using integrated digital techniques is widely used to acquire geometric/spatial data in the field of Cultural Heritage [Dore, Murphy, 2017; Bertocci, Bini, 2012] allowing to obtain, through optimization processes of data acquisition, morphometric models characterized by high accuracy, reliability (part 5.2).

In particular, the database of point clouds is a resource to represent the state of the art of framework of geometric variations that may affect the building about its entire life cycle, both for natural ageing of the asset and for the manifestation of imminent natural or anthropogenic risk situations.

In the passage scan to BIM of the data acquired during the 3D survey, considering the specific purpose of the research that aims to optimize the phases of survey, interpretation, and representation for historical theatres damage aimed at the mitigation of seismic risk, two aspects of parametric modelling should be considered. The first one concerns the geometric modelling of the existing architectural heritage characterized by very complex and irregular shapes.

Besides considering the articulated plano-volumetric organization of the typology of theatres, the aspects of geometric variation that the architectures have undergone due to seismic action must also be addressed in the scientific field of research.

We know that modelling the deformation framework and the misalignments resulting from the earthquake and the conservative state, from the reading studied, is a theme still open in the HBIM environment. Although supported by three-dimensional data characterized by the potential level of accuracy and precision of three-dimensional digital surveys [Di Luggo, Scandura, 2016], Parametric models implement a geometric simplification in the modelling process of the scanned data. However, the simplifying aspect of modelling does not belong only to parametric modelling. Still, it is inherent to the modelling process itself and whether it is automatic, such as mesh making, or of a manual nature. This last one in the applicative circle of the cultural assets could be an effective practice. However, there are issues about tolerance management because the model is susceptible to the operator's subjective interpretation. Therefore, it seems clear that in the modelling process, there remain problems of geometric representation in terms of adherence between the numerical model and its geometric abstraction, which could be substantially complex in the presence of

damaged architecture [Garozzo et al., 2019]. However, there is no shortage of experiments in geometric modelling of seismic damage [M. Artus, C. Koch, 2020-2021] that are being developed and verified.
The second aspect is related to the information attributes that the BiM environment can implement. Considering the traditional industrial BIM workflow, information is produced and entered during the design and construction phase within the PIM project information model, which is then transferred via an asset information model (AIM) to the owner at the end of the design phases for building maintenance [J. Hulan, I. J.Ewart, 2020]. Otherwise, it is the case for heritage design on existing heritage where information cannot be entered at the design stage but must be recorded through a retrospective collection of data and information about the asset. In the context of the existing historical building, the collection and digitization of databases, still very often in paper form, represent a crucial point; having in advance a homogeneous and hierarchical information corpus of historical documents, monitoring data, structural and technological information, etc., allows identifying sustainable intervention actions and targeted strategies of maintenance and planned management, especially about the context of damaged heritage or in a situation of risk.
The concept of HBIM is first introduced by Murphy et al. I [2013] as a methodology where the objects of a parametric model are not only represented in their geometric definition but also at specific
information attributes derived from a historical database.
Data enrichment (and related information management) is crucial in the HBIM model because it is intended more as a data collector than a geometric representation. [R. Quattrini et al. 2018].
In the BIM professional application procedure, the parametric model is defined by the LOD (development level), which represents not only the geometric detail but also the specific attributes of the asset as defined by the AIA[15], the LOI (information level) and LOG (geometric level).
The *Plus HBIM* level focuses on realising a parametric HBIM model of non-geometric data in the face of the limitations of geometric modelling of existing structural damage and degradation phenomena to support conservation actions.
Therefore, the research in this section intends to define specific LOI and Psets applicable to provide the picture of damage and deterioration conditions related to seismic damage. This methodological approach aims to have parametric models for damaged historical buildings with a LOD E[16] and/or F[17] populated by important information attributes that can be consulted, processed, and updated by the actors of the reconstruction process for optimized management - temporal and economic - of the whole process.
The intersectionality and multidisciplinarity of the investigation context to implement the current procedures present firstly on the regional scale and then on the national scale are aimed at facilitating the comparison between different competencies, at different scales at different moments of the life cycle of buildings [M. Medici 2015].
In the context of risk management, the interoperability of BIM provides tools for operational prevention. Furthermore, realising an interoperable parametric model enriched with information could be an essential tool in optimizing the management strategies of the existing historical heritage. Thanks to the possibility of cross-referencing and sharing data among all the subjects responsible for the reconstruction process, it is possible to plan and program strategies for conserving and managing the damaged heritage.
Therefore, the last level HBim model of the procedural workflow transposes and processes what has been collected in L1 and L2.. In the model should be integrated all the information that improve the documentation of the asset for damage analysis and the overall knowledge of the artefact: dating periods, historical information on building materials, historical changes to the building, such as consolidation or plant upgrades, restoration work carried out as a

15 https://www.aiacontracts.org/contract-documents/19016-project-bim-protocol

16 Standard 11337 part 4. LOD E: specific object

17 Standard 11337 Part 4. LOD F: executed object

result of previous earthquakes, external risk factors. Therefore, the HBIM model can be understood as supporting the work of professional engineers, local administrators (RUP), and especially the Joint Commission, which would optimize the phases of evaluation and validation of projects. The HBIM methodology, as highlighted by some researchers in recent years, could offer many advantages to the management of a historic built environment in the phases of exercise of Conservation, Repair and Maintenance (CRM) programming [L. J.N. Ostwegel et al. I,2022].
It should also be mentioned that the research path through the adoption of the parametric model identifies the possibility of overcoming the limitations of the scheduling system used in the visual survey of L1, whose limits were described in Ch.1. Optimizing the visible damage survey in the ordinary and the emergency phase is practical if the information deduced in the survey phase is referred to and linked directly to the shape. From this point of view, we support the importance of parametric modelling and its connection with semantic platforms that can amplify the informative detail of the damage associated with the models and, consequently, indicate a damage index more responsive to reality. This point, therefore, could be an advantage in setting available funds for primary tasks to be prepared. Moreover, this scenario could open the perspective to digital APPs dedicated to the survey of seismic damage connected to semantic platforms. The information database structured in L1 could support the surveyors allowing the optimization of the survey operations and, therefore, the recording of information related to the collapse mechanisms activated by the action of the earthquake and the morphologies of degradation closely associated with the damage directly on the model. Therefore, an improvement in monitoring, management, and maintenance in case of emergency or proactive conservation of cultural heritage would be implemented.

5.3.2 Requirements of the federated model “Theaters”

Cultural heritage modelling cannot be limited to dimensional geometric aspects but must represent historical, material, technological-constructive characteristics [P. Maiezza, 2019] belongs to the entire life cycle of historical assets. The grammatical and syntax meanings of a historical asset, tangible and intangible, flow within the modelling based on the critical process of direct or indirect analysis, which in the research proposal is represented by L1 and L2. In this sense, the parametric model must meet the criteria of transparency and reliability. The first criterion, closely related to the critical representation interpretation phase [Brusaporci, 2017], has been widely addressed in the archaeological field[18]. The digital reconstruction of the artefacts in their ancient configuration is primarily based on indirect information critical-comparative analysis and interpretative hypotheses. Regarding reliability, it should be understood about the morphometric model, accuracy and precision of the measurement [Apollonio et al. 2013; Quattrini et al. 2016], and other information such as construction technologies [Brusaporci et al. 2018].
These premises have been essential for defining the parametric modelling methodology described for the historic theatres of the Emilia-Romagna region falling within the 2012 earthquake crater area. The basic concept of BIM design is remembered that modelling in the BIM environment does the possibility of contextually governing the seven dimensions of the project, with specific reference to aspects related to three-dimensional modelling (3D), time (4D), costs (5D), management (6D) and sustainability (7D) [COMMITTE, 2017]. In the specific field of research, historical study and specialised investigations represent necessary features that must be included in parametric modelling to support integrated documentation, preservation, and preventive and planned management, of existing historic heritage assets. In this sense, the parametric model realized in the BIM environment can offer the cultural heritage sector new tools to support the activities of management, maintenance, documentation, and conservation through digital collaboration

18 The London Charter (2009) is the essential reference for the definition and understanding of transparency is. It defines “Intellectual transparency” as: “The provision of information, presented in any medium or format, to allow users to understand the nature and scope of “knowledge claim” made by a computer-based visualization outcome” (p.12).

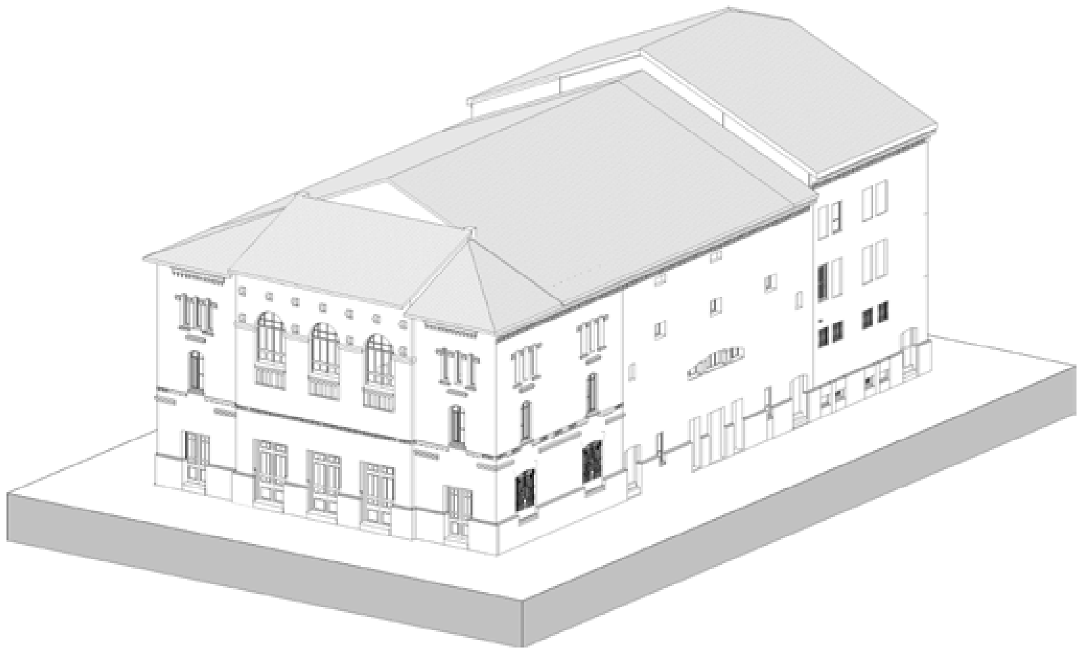


Fig. 104 - Parametric modelling of the theatre - north-east view. The processing was performed during the research. Developed by M.Suppa

and efficient information management. The 3D (geometry) and 4D (time-based) modelling of BIM technology can be helpful for heritage interpretation, presentation, and simulation applications." [Historic England 2017]. Because of these characteristics, the research path has focused on implementing parametric modelling to study the damaged theatres of 2012. It provides multiple levels of design, allowing coordination between different actors working in cultural heritage protection. In this context, in a particular way comes the 4D modelling acquires a key role because it will enable the analysis of historical theatres in their historical development and then about seismic events or interventions unrelated to the risk that have involved the building in its life cycle. In this sense than the three-dimensional models of theatres belonging to L3 incorporate the body of data and information - historical, legacy data, geospatial data, technical drawings, images, remote sensing data, predictive diagnostic analysis, intangible information, coming from the application tools of L1 and L2 (meta form SD T and SD DAP). The parametric models of the theatres, in particular the one of the pilot case of the Social Theater of Novi in Modena, must represent and describe the meanings and the inherent values. These significances are associated with specific spatial components declined according to dedicated properties, properly verticalized to the damage analysis and the revealed conservative state.
Several elaborations were carried out for the BIM model of the Social Theatre of Novi. During the research, one modelling was carried out to define the coding and the property sets; the students carried out the others. Some students' illustrations developed within "the techniques and representation of architecture course" at the University of Ferrara are shown in this chapter. The students were provided with the point cloud acquired in the survey campaign, the CAD drawings made to represent the 2D data and the photographic report (Appendix A).
The research, therefore, proposes the parametric modelling of cultural heritage, starting from the specific field of investigation, trying to guide and define good practices to optimize the decision-making and management process of reconstruction and maintenance of cultural heritage. Furthermore, the interoperability and data sharing inherent in the BIM flow allow, in fact, the interaction of multidisciplinary teams, as well as the possibility of interface with other tools such as GIS.
The federated model of the Theatre of Novi responds to BIM Level 2. Level 2 "refers to a collaborative process of producing discipline-specific federated models that consist of 3D data, geometric and non-graphical data, and associated documentation. Information

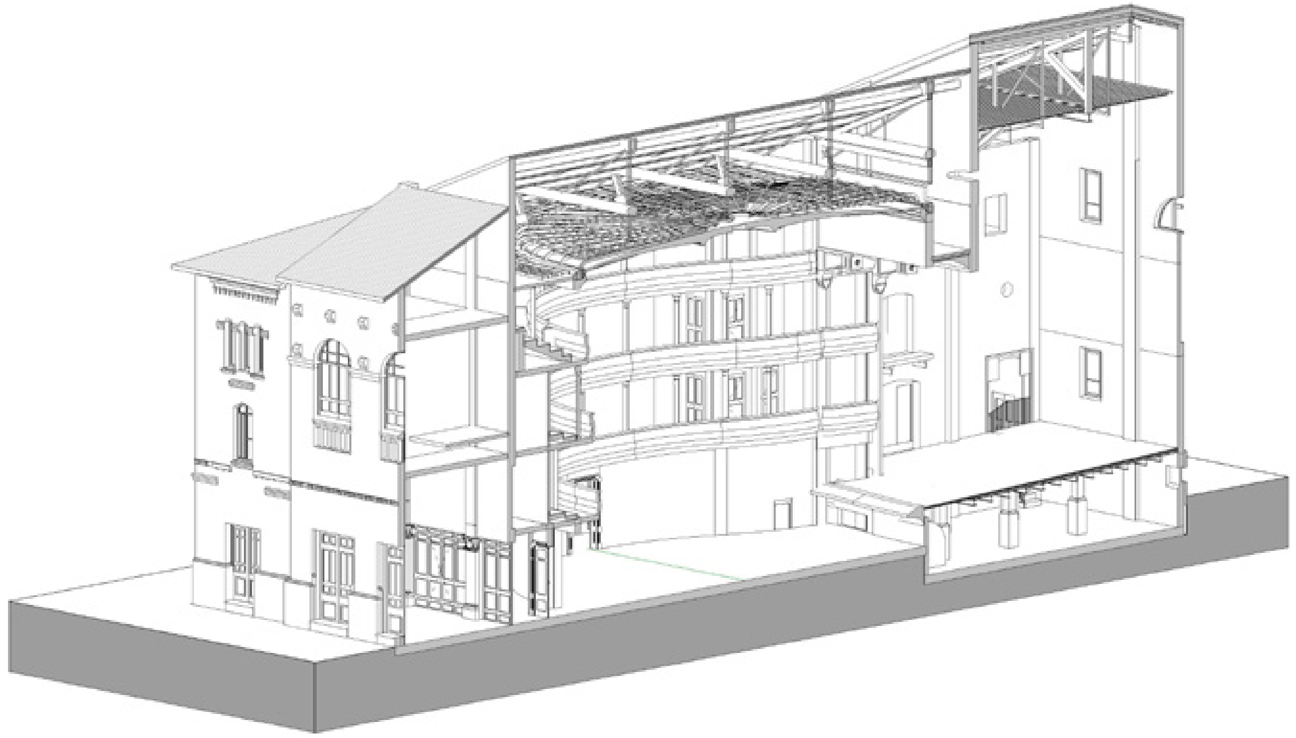


Fig. 105 - Theater axonometric cross-section Parametric modelling of the theatre processing performed during the research. Developed by M.Suppa

is exchanged using non-proprietary formats, such as industry foundation class (IFC) and building operation information exchange. Level 2 BIM requires all project and asset information documentation and data to be electronic and managed within a CDE [Historic England 2017 BIM for Heritage: Developing a Historic Building Information Model p.7]. To proceed to the characterization of models, valid for this research, to ensure interoperability and data sharing with other software should be done in the open format IFC (Industry Foundation Classes-ISO 16739:2013) organized by BuildingSMAR). Interoperability is an essential factor since it guarantees the possibility to interact on a shared model in an interdisciplinary way. It is, in fact, well established that CDE environments, systematized datasets, and conventional nomenclature are a tool to support decision-making and management to define strategies and actions on heritage [Hull and Ewart 2020].
The IFC standard allows operating according to the Open BIM approach. Therefore, the data can be shared between different software, reducing the loss of data included in the model. In addition, the IFC format allows for object-based model views, including 3D (and 2D) geometry, properties, and interrelationships between objects [P. Bonsma et al. 2018].
The most up-to-date IFC4 ADD2 TC1 version is defined in ISO 16739-1:2018, but the pilot application case model is developed by setting the IFC2x3 software certification program since it is not yet certified. This is tested for Coordination View Certification 2.0 (CV 2.0) to export and import IFC2x3 files.
The export of IFC2x3 files verifies the following exchange requirements:
- Architectural model
- Structural model
- Construction Services Engineering Model - Import

All three exchange requirements must be supported in the export while the import application manages the model according to its purpose and functionality. [19]
Data sharing can be supported by an IDM (Information Delivery Manual) and then by filtering parts of the IFC schema producing an MVD (Model View Definition). The standard sharing format is STEP/EXPRESS, which has limited support of serialisation so that in recent years other types of serialisations have been defined, such as ifcXML and ifcOWL. The ifcOWL

19 *https://www.buildingsmartitalia.org/compliance/certificazione-del-software/*

turns out to be compatible with the Semantic Web standards RDF, RDFS, and OWL2.
The model of the Theatre of Novi, modelled with Revit software by AutoDesk, has been realized concerning the indications provided by the Italian standard UNI 11137, the English system (PAS 1192-2 of 2013), and the American system (BIMForum). The standard defines the subdivision of LODs represented based on both the development levels of graphic attributes LOG (geometric details) and LOI (information attributes) [P. Maiezza, 2019].
Referring to 11337, the parametric model of the Novi Theatre was developed with a specific LOD AND objected according to which: "entities are graphically virtualized as a specific geometric system. Therefore, the quantitative and qualitative characteristics (performance, size, shape, location, orientation, and cost) are specific to a single production system related to a defined product"[20].
As described in the previous paragraph, the study path for research and the limits of graphical modelling of deformation variations, the crack framework, and the relative state of preservation focus on the LOI definition appropriate to the documentation, management, and monitoring of seismic damage. Therefore, rules and specific sets have been defined to define the particular attributes that the models must contain in this context.

5.3.2.1 HBIM model coding for historic theatres

In this paragraph are defined the rules of the data property sets of the model aimed at the research purposes. The rule set is applied to the pilot case of the Social Theater of Novi di Modena (fig. 104-105), whose model has been realized in AutoDesk Revit, supporting the point cloud acquired through the techniques described in the paragraph (5.2.2 of this chapter). The cloud was imported into Revit software following the export of the same in the open format E.57, which, as defined by the ASTM Committee, was developed to ensure data interoperability between 3D imaging hardware and software systems, therefore suitable for data storage in different application domains.
The methodology of LOI development reported below applied to the pilot case but referred to the historic theatres of the Emilia-Romagna region. However, attributable to a limited scale factor of the national and international territory, it can be considered applicable also on geographical scales different from the regional one. In fact, except for some parameterizations, such as materials and construction techniques, the analysis structure, then taken up in the parametric modelling in the face of the morpho-typological study (Ch. 3) of the historical Italian theatres, can be considered applicable and valid. Therefore, the effort that we tried to make was to overcome the logic of case by case, which characterizes the richness of cultural heritage, and define based on morpho-typological criteria standard parameters, classes, and families of objects necessary to document the state of damage.
The structure of the methodology is declined on the architectural typology Theaters. As follows from the comparative analysis, each theatre is divided into six structural subunits - UST, each of which are defined categories of elements about which are defined specific Pset. The model is developed on the discipline Architecture and Structure. In the particular case of the Theater of Novi being the structure in load-bearing masonry, the model is set on the discipline Architecture.
According to the morpho-typological criterion, the federated model of the historical Theatres presents a Coding system through which easy accessibility to the information and the workflow is assured. In respect of this, every model and relative connected elaborates to it, follow the coding system under indicated:
1. ID of the theatre defined by the database of the SD T;
2. The National Unique Code (NCT), where present;
3. Code of the Emilia-Romagna Cultural Heritage WebGispatrimonio culturale
4. the model level (Model levels follow the terminology defined in paragraph 5.1)
5. Code of discipline of the model
6. alphanumeric code relative to the phase of the project of reference and the project

20 UNI 11337-4-2017

IFC mapping LOI

Theatre	ifcSite
Structural Units	ifcBuilding
Macroelement	ifcBuildingElement

OBJECT TYPE	DATA	PROPERTY TYPE	Pset CODE
Object name referred to by Pset.	Fixed text		
Theatre	Data	Anagraphical	TheatreAnagraphicalData
Theatre	Data	Qualitative	TheatreQualitativeData
Theatre	Data	Quantitative	TheatreQuantitativeData
Theatre	Data	Documents	TheatreDocuments
UST	Data	Anagraphical	USTAnagraphicalData
UST	Data	Qualitative	TheatreQualitativeData
UST	Data	Quantitative	TheatreQuantitativeData
UST	Data	Documents	TheatreDocuments
Element	Data	Anagraphical	ElementnagraphicalData
Element	Data	Documents	ElementDocuments
Element	Data	Qualitative	ElementQualitativeData
Element	Data	Quantitative	ElementQuantitativeData
Element	Data	Seismic Damage	ElementSeismicDamageData
Element		Conditions	ElementAssesmentConditions
Element		CodingData	ElementCoding

Tab a/b The IFC coding has defined each object type: Theater; UST, macro-elements. Developed by M.Suppa

elaborates. About these, the code is composed of six alphanumeric characters.
The IFC coding has defined each object type (Theater; UST, macro-elements), presented in tables n.(a,b)
For each UST, the rooms identified as IfcSpatialZone (para 5.1, Tab. c) have been mapped through the identification code used in the 2D representation proposed for the Novi Theatre. In particular, it is specified that the documents that will integrate the model's informative content will have to respect the following requirements. The documentation is admitted formats. Bcf *.docx *.docm *.pptx *.pptm *.txt *.xls *.xlsx *.pdf; i formati delle immagini sono *.bmp *.jpg *.jpeg *.png *.tiff *.pcx *.gif *.tga, mentre glie elaborati tecnici sono ammessi il formato *.dxf e *.dwg.
The codification of the elements[21] is concerned, it has been implemented applying a univocal coding methodology to describe functions and characteristics of each component (Tab d); thus, a typing has been set up, allowing the element to be associated with the related UST. Therefore, it has been offered an identification code and an IFC class for each component and its type code marked by three characters. Since it was necessary to set rules for the specific typology of historical theatres, it is essential to identify 11 families - a) Footing, b) Walls, c) Slab, d) Beams, e)Columns, f) Structural reinforcement elements, 8) Covering, 9) Windows, 10) Doors have been typified to include specific parameters that were valid for the

21 In the HBIM model, the elements correspond to the macro-elements of the Directive 2011, with appropriate declinations for identifying structural, technological systems (e.g., beams and trusses elements) to make the model a tool for the precise individualization of seismic damage.

ad hoc "IfcPropertySet" set on Historic Theatre - Ifc.Site

IFC mapping	ADM	PropertySet	Property	Type	U.M	Description	List	Values List
IfcSite.Theatre.AnagraphicData.Name	Theatre	AnagraphicDataTheatre	Name	IfcText	N.A	Name		
IfcSite.Theatre.AnagraphicData.HistoricName	Theatre	AnagraphicDataTheatre	Historic Name	IfcText	N.A	Historic name		
IfcSite.Theatre.AnagraphicData.Owner	Theatre	AnagraphicDataTheatre	Owner	IfcText	N.A	Owner		
IfcSite.Theatre.AnagraphicData.AssetCode	Theatre	AnagraphicDataTheatre	Asset Code	IfcText	N.A	Asset Code		
IfcSite.Theatre.AnagraphicData.Region	Theatre	AnagraphicDataTheatre	Region	IfcText	N.A	Region		
IfcSite.Theatre.AnagraphicData.Province	Theatre	AnagraphicDataTheatre	Province	IfcText	N.A	Province		
IfcSite.Theatre.AnagraphicData.Municipality	Theatre	AnagraphicDataTheatre	Municipality	IfcText	N.A	Municipality		
IfcSite.Theatre.AnagraphicData.LegalStatus	Theatre	AnagraphicDataTheatre	LegalStatus	IfcText	N.A	LegalStatus		
IfcSite.Theatre.AnagraphicData.Adress	Theatre	AnagraphicDataTheatre	Adress	IfcText	N.A	Adress		
IfcSite.Theatre.AnagraphicData.Latitude	Theatre	AnagraphicDataTheatre	Latitude	IfcText	N.A	Latitude		
IfcSite.Theatre.AnagraphicData.Longitude	Theatre	AnagraphicDataTheatre	Longitude	IfcText	N.A	Longitude		
IfcSite.Theatre.AnagraphicData.CadastralID	Theatre	AnagraphicDataTheatre	CadastralID	IfcText	N.A	CadastralID		
IfcSite.Theatre.AnagraphicData.CadastralSheet	Theatre	AnagraphicDataTheatre	Sheet	IfcText	N.A	Sheet		
IfcSite.Theatre.AnagraphicData.Cadastral Parcels	Theatre	AnagraphicDataTheatre	Parcels	IfcText	N.A	Parcels		
IfcSite.Theatre.AnagraphicData.CadastralSub	Theatre	AnagraphicDataTheatre	Sub	IfcText	N.A	Sub		
IfcSite.Theatre.AnagraphicData.HistoricalUse	Theatre	AnagraphicDataTheatre	HistoricalUse	IfcText	N.A	HistoricalUse		
IfcSite.Theatre.AnagraphicData.StartDate	Theatre	AnagraphicDataTheatre	StartDate	IfcText	N.A	StartDate		
IfcSite.Theatre.AnagraphicData.EndDate	Theatre	AnagraphicDataTheatre	EndDate	IfcText	N.A	EndDate		
IfcSite.Theatre.AnagraphicData.SeismicZone	Theatre	AnagraphicQualitativeData	SeismicZone	IfcText	N.A	SeismicZone		
IfcSite.Theatre.AnagraphicData.Lastearthquake	Theatre	AnagraphicDataTheatre	Lastearthquake	IfcText	N.A	Lastearthquake		
IfcSite.Theatre.AnagraphicData.SeismicDamage	Theatre	AnagraphicDataTheatre	SeismicDamage	IfcBoolean	N.A	SeismicDamage		
IfcSite.Theatre.AnagraphicData.DamageFormMIC	Theatre	AnagraphicDataTheatre	DamageFormMIC	IfcText	N.A	DamageForm		
IfcSite.Theatre.AnagraphicData.GlobalDamageLevel	Theatre	AnagraphicQualitativeData	DamageLevel	IfcText	N.A	DamageLevel	List	1 No damage; 2 Minor damage; 3 Medium damage; 4 Severe damage; 5 Destructive damage; 6 Total Damage
IfcSite.Theatre. AnagraphicData.ExternalRisks	Theatre	AnagraphicQualitativeData	ExternalRisks	IfcText	N.A	ExternalRisks	List	landslide risk flood risk industrial risk other natural risk anthropic risk
IfcSite.Theatre. AnagraphicData.Accessibility	Theatre	AnagraphicQualitativeData	Accessibility	IfcText	N.A	Accessibility		accessible partially accessible not accessible
IfcSite.Theatre. AnagraphicData.StructuralSafety	Theatre	TheatreQuantitativeData	StructuralSafety	IfcText	N.A	StructuralSafety		
IfcSite.Theatre.QuantitativeData.MediumWidth	Theatre	TheatreQuantitativeData	MediumWidth	IfcReal	ml	MediumWidth		
IfcSite.Theatre.QuantitativeData.MediumLength	Theatre	TheatreQualityData	MediumLength	IfcReal	ml	MediumLength		
Ifc.Site.Theatre.AnagraphicData.MediumHeight	Theatre	TheatreQualityData	MediumHeight	IfcReal	ml	MediumHeight		
Ifc.Site.Theatre.AnagraphicData.MediumArea	Theatre	TheatreQualityData	MediumArea	IfcReal	mq	Medium Area		
Ifc.Site.Theatre.AnagraphicData.LastSurveyDate	Theatre	TheatreQualityData	LastSurveyDate	IfcText	N.A	LastSurveyDate		
Ifc.Site.Theatre.AnagraphicData.SurveyFirm	Theatre	TheatreQualityData	SurveyFirm	IfcText	N.A	SurveyFirm		
Ifc.Site.Theatre.AnagraphicData.SurveyTeam	Theatre	TheatreQualityData	SurveyTeam	IfcText	N.A	SurveyTeam		
Ifc.Site.Theatre.AnagraphicData.DataOwener	Theatre	AnagraphicQualitativeData	SurveyTeam	IfcMiltiText	N.A	SurveyTeam		
Ifc.Site.Theatre.AnagraphicData.Datamanager	Theatre	AnagraphicQualitativeData	SurveyTeam	IfcMiltiText	N.A	SurveyTeam		
Ifc.Site.Theatre.AnagraphicData.DataPurpose	Theatre	AnagraphicQualitativeData	SurveyTeam	IfcMiltiText	N.A	SurveyTeam		

Tab c The IFC coding concerning the Theater. Developed by M.Suppa

ad hoc "IfcPropertySet" set on Historic Theatre - Ifc.UST

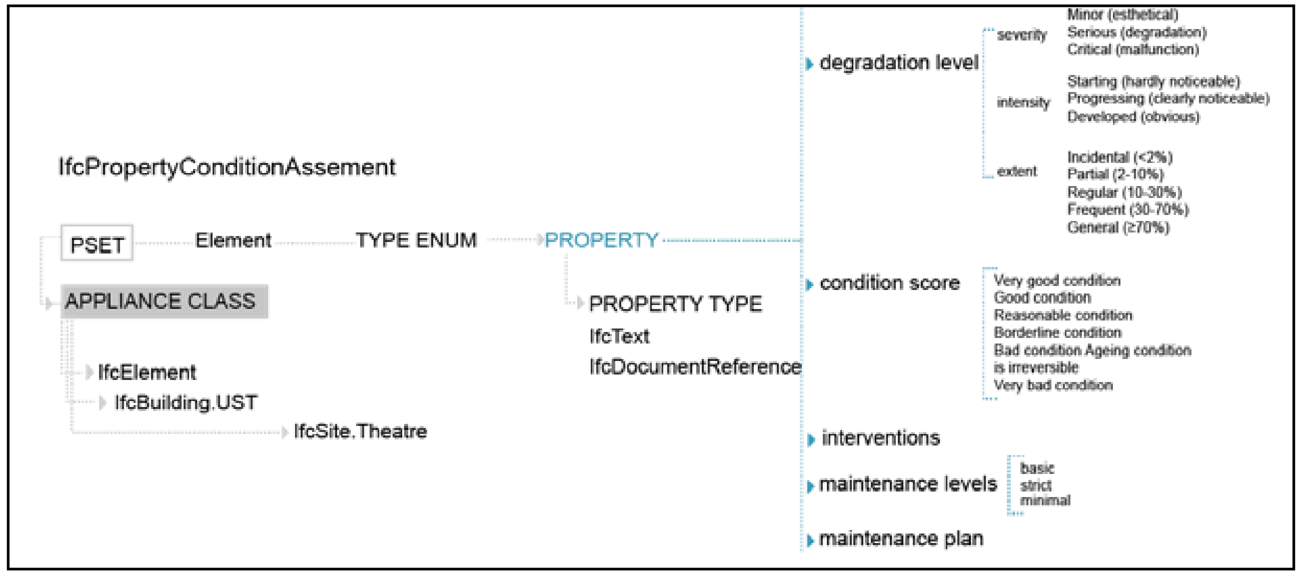
IFC mapping	ADM	PropertySet	Property	Type	U.M	Description	List	Values List
IfcBuilding.UST.AnagraphicData.Name	UST	USTAnagraphicData	Name	IfcText	N.A	Name	List	1 forepart/foyer 2 hall/cavea 3 proscenium arch 4 stage and backstage 5 facilities block 6 foundations
IfcBuilding.UST.QuantitativeData.MediumWidth	UST	USTQuantitativeData	MediumWidth	IfcReal	ml	MediumWidth		
IfcBuilding.UST.QuantitativeData.MediumLength	UST	USTQualityData	MediumLength	IfcReal	ml	MediumLength		
IfcBuilding.UST.AnagraphicData.MediumHeight	UST	USTQualityData	MediumHeight	IfcReal	ml	MediumHeight		
IfcBuilding.UST.AnagraphicData.MediumArea	UST	USTQualityData	MediumArea	IfcReal	mq	Medium Area		
IfcBuilding.UST.AnagraphicData.BasementFloors	UST	USTQualityData	BasementFloors	IfcInteger	N.A	Number of basement floors	List	LG
IfcBuilding.UST.AnagraphicData.Floors	UST	USTQualityData	Floors	IfcInteger	N.A	Number of floors out ground	List	GF 01 M1 02 M2 03 M3 04 Gallery
IfcBuilding.UST.AnagraphicData.SeismicDamage	UST	USTAnagraphicData	SeismicDamage	IfcBoolean	N.A	SeismicDamage		
IfcBuilding.UST.AnagraphicData.USTDamageLevel	UST	USTQualityData	SeismicDamage	IfcText	N.A	DamageLevel	List	1 No damage; 2 Minor damage; 3 Medium damage; 4 Severe damage; 5 Destructive damage; 6 Total Damage
IfcUST.AnagraphicData.Accessibility	UST	USTQualitativeData	Accessibility	IfcText	N.A	Accessibility	List	accessible partially accessible not accessible
IfcUST.AnagraphicData.StructuralSafety	UST	USTQualitativeData	StructuralSafety	IfcBoolean	N.A	StructuralSafety		

Tab d the IFC coding concerning the UST. Developed by M.Suppa

Element coding

FUNCTION CODE	TYPE CATEGORY	IFC CLASS	FUNCTION CODE SUBTYPE	SUBCATEGORY	IFC TYPE ENUM
FOT	Footing	IfcFooting			
FOT	Footing		PLT	Footing plinth	Footing plinth
FOT	Footing		MAT	Footing mat	Footing mat
WLL	Wall	IfcWall			
WLL	Wall		BRN	External WallSurface	External WallSurface
WLL	Wall		BRN	Internal Wall	Internal Wall
WLL	Wall		PRT	Partion	Partion
SLB	Slab	IfcSlab			
SLB	Slab		BRN	Bearing wall	Bearing wall
SLB	Slab		VLT	Vault	Vault
SLB	Slab		PLF	Plafond	Plafond
SLB	Slab		CRV	Crossvault	Crossvault
SLB	Slab		RBV	Ribbed Vault	Ribbed Vault
SLB	Slab		ARL	Arelle	Arelle
ROF	Roff	IfcRoff			
ROF	Roff		PRF	Pent roof	Pent roof
ROF	Roff		GRF	Gable roof	Gable roof
ROF	Roff		TSR	Trussed roof	Trussed roof
ROF	Roff		MLL	Mullion	Mullion
ROF	Roff		RFT	Rafter	Rafter
ROF	Roff		STR	Strut	Strut
BEM	Beam	IfcBeam			
BEM	Beam		PLD	Plafond	Plafond
BEM	Beam		JST	Joist	Joist
BEM	Beam		STG	Straining Beam	Straining Beam
BEM	Beam		LNT	Lintel	Lintel
BEM	Beam		TBM	T Beam	T Beam
BEM	Beam		IBM	I Beam	I Beam
BEM	Beam		HBM	HE Beam	HE Beam
ELR	Reinforcing Element	IfcReinforcingMesh	RMH	Reinforcing Mesh	Reinforcing Mesh
ELR	Reinforcing Element	IfcTendon	TND	Tendon	Tendon
ELR	Reinforcing Element	IfcCamorcanna	CMR	Camorcanna	Camorcanna
STR	Stair	IfcStair			
STR			STT	Straight	
STR			CRV	Curved	
STR			WDR	Winder	
CLN	Column	IfcColumn			
CVG	Covering	IfcCovering			
CVG	Covering		CLG	Ceiling	Ceiling
CVG	Covering		VEL	Velarium	Velarium
CVG	Covering		FLR	Floring	Floring
CVG	Covering		CLD	Cladding	Cladding
WNW	Window	IfcWindow			
WNW	Window		SPL	SinglePanel	SinglePanel
WNW	Window		DPL	DoublePanelVertical	
WNW	Window		UDF	UserDefined	UserDefined
DOR	Door	IfcDoor			
DOR	Door		SSW	Single Swing	Single Swing
DOR	Door		DSW	Double Swing	Double Swing
DOR	Door		FIX	Fixed	Fixed

Tab e shows the identification code and an IFC class for each component and its type code for each of the 11 families - a) Footings, b) Walls, c) Slab, d) Beams, e) Columns, f) Structural reinforcement elements, 8) Roofing, 9) Windows, 10) Doors. Developed by M.Suppa



Tab f shows the identification Pset - IfcPropertyDamageAssessment sittin up. Developed by M.Suppa

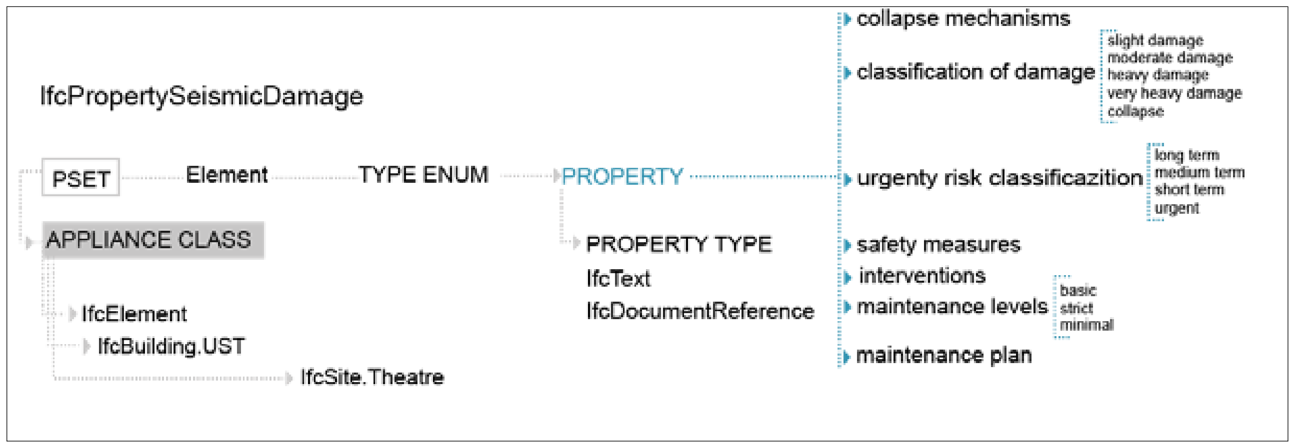
morpho-typological confirmation of historic theatres. (Tab e)

For each element, it is appropriate to define the material characterization, for which it is restricted for a specific classification. Therefore, they are characterized by a set of properties. The variety of materials is taken what is described in INCEPTION [E. Piaia and t al, 2020] that decline in IfcMaterial single material, IfcMaterialList - multiple, unstructured materials) or IfcMaterialSet (multiple-layered materials). The materials themselves can be formatted as a free string or by a string containing a material code according to the CI/SfB standard. Materials characterization is relevant to documenting damage and condition of the earthquake-affected theatre for building assessment using nondestructive procedures. Therefore, once the materials are classified, they can be associated with assessing seismic damage expressed through collapse mechanisms and the particular conditions of degradation of the asset following the earthquake.

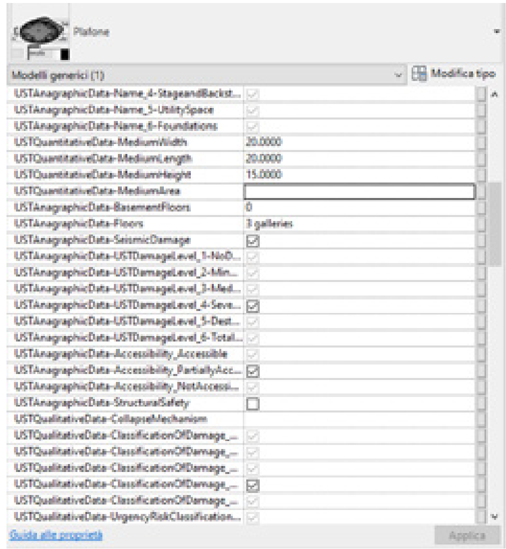
The information related to the damage and the state of preservation are classified according to the Pset - IfcPropertyDamageAssessment (Tab f); IfcPropertyConditionAssessment (tab g)- defined per instance.

For the IfcPropertyDamageAssessment, we referred to the Directive 2011. For the IfcPropertyConditionAssessment, we referred to the CEN (European Committee for Standardization) standard SIST-TS CEN/TS 17385:2020 “Method for condition assessment of immovable constructed assets.”

The following are presented some extractions of the HBIM model of the parametric model of Novi di Modena and, in particular, the Plafond system (fig. 106; 107).



Tab g shows the identification Pset - Method for condition assessment of immovable constructed assets sitting up. Developed by M.Suppa



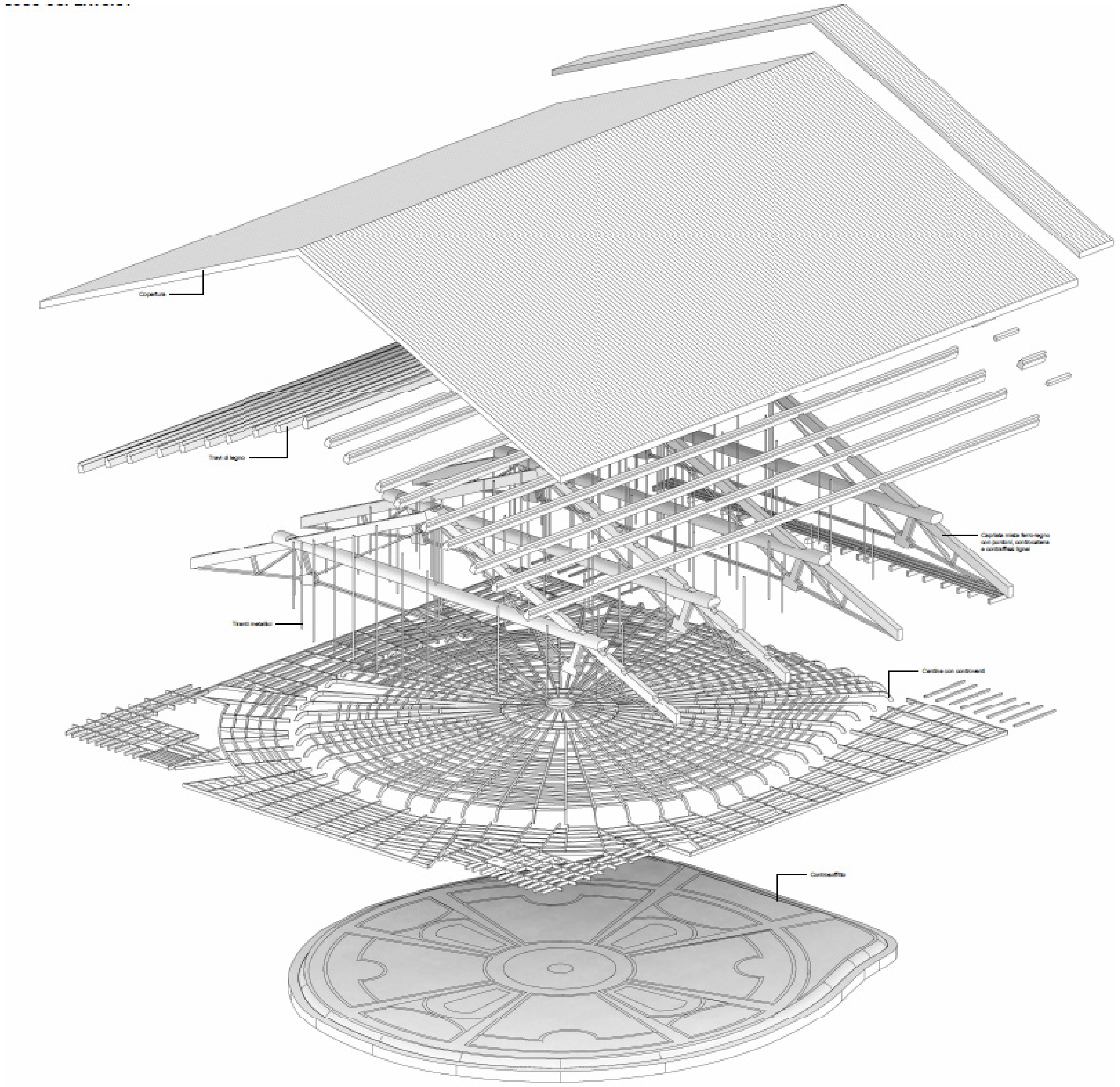


Fig. 106 -107 shows the identification Pset - IfcPropertyDamageAssessment sitting up in Revit and the plafond analysis. Developed by M.Suppa Above: Bim model was developed during the research. Down: model Developed I. Bardelli, G.Formentin, I.Franchin, F. Fregapane.

CHAPTER 6

Sixth Section: Towards Semantic Database of Emilia-Romagna Theatres

Abstract

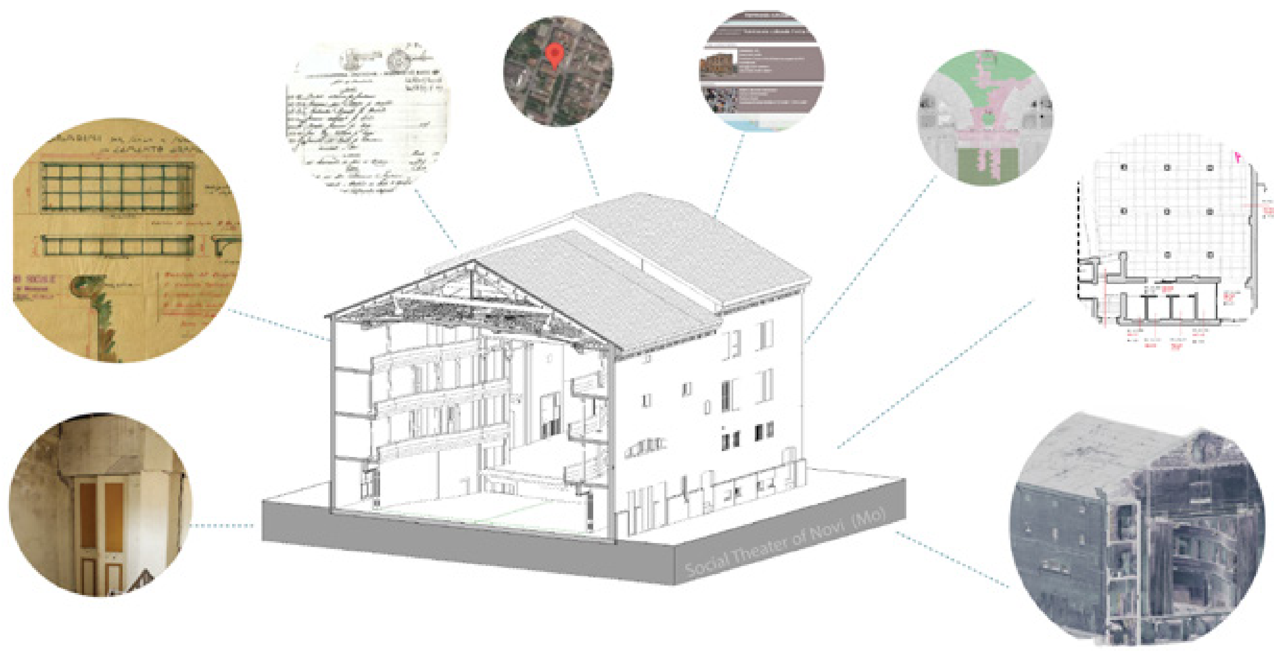
In the application context of the research, the use of semantically classified three-dimensional models has the specificity of supporting actions aimed at the conservation, management, and proactive maintenance of damaged assets and the specific survey sample. Integrating the three procedural levels is crucial in presenting the workflow of integrated procedures in earthquake damage surveys.

The importance of having a single, standardised database of identification data and captured 3D data that inform the parametric model becomes apparent. Furthermore, a semantic web of the BIM model implementation is needed to ensure accessibility, visualisation, and data manipulation for various users' documentation, preservation, and management purposes.

Among different platforms, the research, an overview of which is in chapter six (CINTOO; FLYVast etc.), proposes using the interoperable platform INCEPTION to optimise the phases and actions in a single collaborative environment of management and monitoring among the different actors in the reconstruction process.

In the specific field of research, the choice of the Inception platform is related to the developed HBIM ontology that allows associating all I1 and L2 information to the parametric model (L3) according to the proposed segmentation of the model into objects and families of elements. Therefore, to document seismic damage, it is possible to use theatre models and query the model by filtering the hierarchical information present within the DS T.

This aspect is significant in that it ensures 360-degree documentation of the historical theatres of Emilia.



Cover Image - Chapter 6 - Outline of the INCEPTION methodology, based applied to the pilot case of the Social Theater of Novi di Modena: from holistic documentation and data capture to semantically enriched 3D models. Developed by M.Suppa

6. Existing web platform analysis

The importance of data sharing in the documentation of Cultural Heritage is a central theme of the same code of Cultural Heritage and Landscape [DL 42/2004]. All 'art. 17 are defined procedures and methods of cataloguing, the methodologies for the definition of collection, processing, exchange and accessibility of data and their integration into the network of state, regional and local databases. Such indications resumed in the Code of the digital Administration [D.L. 82/2005] are related to articles 3 and 6 of the DL 42/2004:

Art. 3 [1]
1. The guardianship consists in the exercise of the functions and the discipline of the direct activities,
based on an adequate cognitive activity to identify the assets constituting the cultural heritage and guarantee its protection and conservation for purposes of public fruition.
2. The exercise of the functions of protection is also expressed through measures aimed at conform and regulate rights and behaviours inherent in the cultural heritage.

Art. 6[2]
1. The valorisation consists of the functions' exercise and the activities' discipline to promote the cultural heritage knowledge and ensure the best conditions for the public use and fruition of the heritage itself, including by people with disabilities, to promote the cultural heritage development. It also includes the promotion and support of interventions to conserve cultural heritage.
Cultural heritage. Concerning the landscape, the enhancement also includes the rehabilitation of buildings and areas subject to protection compromised or degraded or the creation of new coherent and integrated landscape values.
2. The valorisation is implemented in forms compatible with the protection and not prejudice its needs.
3. The Republic favours and supports the participation of private subjects, single or associated, to enhance cultural heritage.

The digital documentation of cultural heritage has implemented a "democratisation [Maietti et al., 2019], which opens up new forms of access and new technological systems for inclusive knowledge, protection, valorisation, and fruition of cultural heritage. In this sense, digital documentation represents a fundamental aspect as it opens the path of shared preservation and management and inclusive participation of the heritage itself [Brunelli, 2014; Luigini and Panciroli, 2018].

1 Art. 3
1. La tutela consiste nell'esercizio delle funzioni e nella disciplina delle attività dirette, sulla base di un'adeguata attività conoscitiva, ad individuare i beni costituenti il patrimonio culturale ed a garantirne la protezione e la conservazione per fini di pubblica fruizione.
2. L'esercizio delle funzioni di tutela si esplica anche attraverso provvedimenti volti a conformare e regolare diritti e comportamenti inerenti al patrimonio culturale.

2 Art. 6.
1. La valorizzazione consiste nell'esercizio delle funzioni e nella disciplina delle attivitàdirette a promuovere la conoscenza del patrimonio culturale e ad assicurare le migliori condizioni di utilizzazione e fruizione pubblica del patrimonio stesso, anche da parte delle persone diversamente abili, al fine di promuovere lo sviluppo della cultura. Essa comprende anche la promozione ed il sostegno degli interventi di conservazione del patrimonio culturale. In riferimento al paesaggio, la valorizzazione comprende altresila riqualificazione degli immobili e delle aree sottoposti a tutela compromessi o degradati, ovvero la realizzazione di nuovi valori paesaggistici coerenti ed integrati.
2. La valorizzazione è attuata in forme compatibili con la tutela e tali da non pregiudicarne le esigenze.
3. La Repubblica favorisce e sostiene la partecipazione dei soggetti privati, singoli o associati, alla valorizzazione del patrimonio culturale.

The use of ICT applied to cultural heritage has generated an evolution of cataloguing systems. Thanks to the use of Linked Data and Semantic Web, platforms have been developed and implemented that facilitate the exchange and sharing of data between different actors in the sector and the broad public of users.
Several kinds of research have been oriented to developing semantic platforms during the last years.

On an international scale, the best-known platform is Europeana. The portal was created in 2008 by an initiative of the European Union. Today it is a federated platform that is widely interoperable, collecting multiple metadata associated with millions of objects and encompassing several cultural organisations. The semantic Web of Europeana is based on the methodology of federated search, where starting from a search query to local databases, the results are combined and made available to the user.
Europeana has its RDF-based metadata standard known as EDM (European Data Model) that replaces the 2010 Europeana Semantic Elements (ESE) standard, which had several limitations in the interoperability of resources[3]. The EDM standard does not have a fixed schema. Instead, it is an ontology that allows distinguishing the object from the metadata and has datasets containing many images, theses, and audiovisual content accessible in XML and RDF format.
Another international experience is represented by the Rijksmuseum in Amsterdam that in 2013 realised a digital catalogue of images made accessible by an API (Application Programming Interface) dedicated website Rijksstudio. The catalogue images are free and are available as Linked Open Data (LOD) on platforms such as ARTstore and Wikimedia Commons.
The digital cataloguing portal SIGECweb (Information System General Catalogue) developed by ICCD is worth mentioning in the Italian context. As described by ICCD, it is a web-based platform aimed at "managing the entire flow of cataloguing, from the production and dissemination of cataloguing standards to the assignment of unique catalogue codes, to the cataloguing of goods (archaeological, architectural and landscape, ethno-anthropological, photographic, musical, naturalistic, numismatic, scientific and technological, historical and artistic), to the publication of catalogue cards for use on the site of the general catalogue of cultural heritage".
It is essential to invest in interoperable environments capable of exchanging information and data between software platforms and applications with different functions in this context. In proprietary or non-proprietary formats, data exchange is part of the BIM methodology, whose use favours the possibility of operating in a shared environment. It seems clear that the challenge is to create a workflow standardised by codes and rules that ensure the integration and exchange of data without taking information to take advantage of the benefits of the collaborative environment [Bruno, 2018].
The first experiments towards developing semantic platforms using three-dimensional models date back to the late 1990s and early 2000s. Early research focused on hierarchising levels of documentation from a semantic subdivision and organisation of elements and forms, according to the "grammar of form" of Stiny and Mitchell (1978) and Stiny (1975, 1980). In 1985 Quintrand presented the first semantic classification applied to three-dimensional modelling. The topic of classification used in morphometric models has been extensively addressed by Gaiani (1999) and then by Meyer (2007) in GIS systems. In the early 2000s, Just Meyer developed a GIS application to manage data types related to Luxembourg's National Service Sites and Monuments. The application was based on a web server, characterised by intuitive accessibility.
In these years developed ShapeAnnotator, a modular system to load 3D triangular meshes, select the most suitable primitives to approximate sets of triangles in clusters that define the parts of the shape that constitute the whole model [Attene et al.,2007].
During the last few years, several types of research have been oriented towards the development of semantic platforms taking advantage of the application of BIM methodology

3 According to the ESE standard, metadata was in text format, not URI.

to optimise the flow of documentation [Rizvic, Okanovic, & Sadzak, 2015], conservation aimed at restoration, management and interactive use of cultural heritage [Potenziani et al., 2015; Potenziani, 2016].
The 3DHOP software - 3D Heritage Online Presenter [Potenziani et al., 2015; Potenziani, 2016] - is developed to promote sharing, dissemination, and fruition on the Web of three-dimensional content related to cultural heritage. It is an open-source platform that integrates 3D models within a modular scheme of WEB pages to meet the different needs of the cultural heritage sector. The platform also performs the dual function of viewer and inter-connector of 3D content thanks to additional components and features; the platform can ensure interaction with 3D content.
In this context, it should also be mentioned the research experience of the WEBBIM project called BIM3DSG developed by the research team of the Milan Polytechnic [F. Fassi, C. Achille, A. Mandelli, F. Rechichi, S. Parri, 2015] applied then on the case study of the Milan Cathedral. The developed WEBBUM system aims at visualising complex 3D models on the Web [F. Fassi et al. 2015], sharing and exchanging data and information of different types (geo-referenced point cloud, ortho-imaging polygonal models, photos, documentary and technical information.
The functionalities and the interface of the platform ensure interoperability. The system is articulated on three levels of use, a first part dedicated to professionals who can interact directly with the modelling software making changes to three-dimensional models. A second level is devoted to the majority of users who can enjoy the visualisation of the model according to different levels of detail. The platform is designed to be accessible and navigable on other digital devices for this type of user. The third level of use provides a central database in which the models and related information and data are collected. The database is designed to share and exchange data in real-time and installed remotely on the cloud. The central database contains models realised in JONSON format, directly usable on the Web, the Text information associated with them and the data and documents necessary to implement the knowledge of the building.
The central database system is developed in PostgreSQL for Linux but is adaptable to Microsoft SQL Server or Oracle Database.
Despite the cases examined above, the following are innovative platforms developed for cloud point management, visualisation, and manipulation in the survey sector.
These platforms work with cloud technology ensuring sharing of data and a collaborative way of working. In addition, these platforms are accessible to teams of specialists, clients, and contractors, implementing visualisation and manipulating the new one without using specific hardware.

1. EUCLIDEON UNLIMITED 3D enables large 3D geospatial datasets visualisation and management at high speed. It integrates with geospatial visualisation software such as Euclideon idStream and udSDK, Ersi and Censium etc.

2. CENSIUM was developed in 2011 as an application for visualising objects in space. It is currently an open, interoperable platform. It includes a suite of tools to build 3D geospatial applications.

3. The VERCATOR platform allows cloud registration from different acquisition systems. In addition, it is possible to convert data into other formats through this platform.

4. FLYVAST, on the other hand, is a webGL solution to process, manage, publish and share 3D scan data autonomously. The platform uses Potree's advanced technology to view new data immediately without waiting for loading time. It handles large clouds that are rendered in a short amount of time without compromising the detail of the information being stored. Specific tools are available for automatic segmentation to extract sections and metric reports within the cloud. (fig. 108)

5. EDUserNET Empowering the 3D word allows storing and visualising data from any source - point clouds, textured meshes, H.D. images, 360° panoramas, ortho, models, maps and documents - all in one environment. In this sense, it is a valuable platform for surveying and monitoring and design, planning and asset management actions.

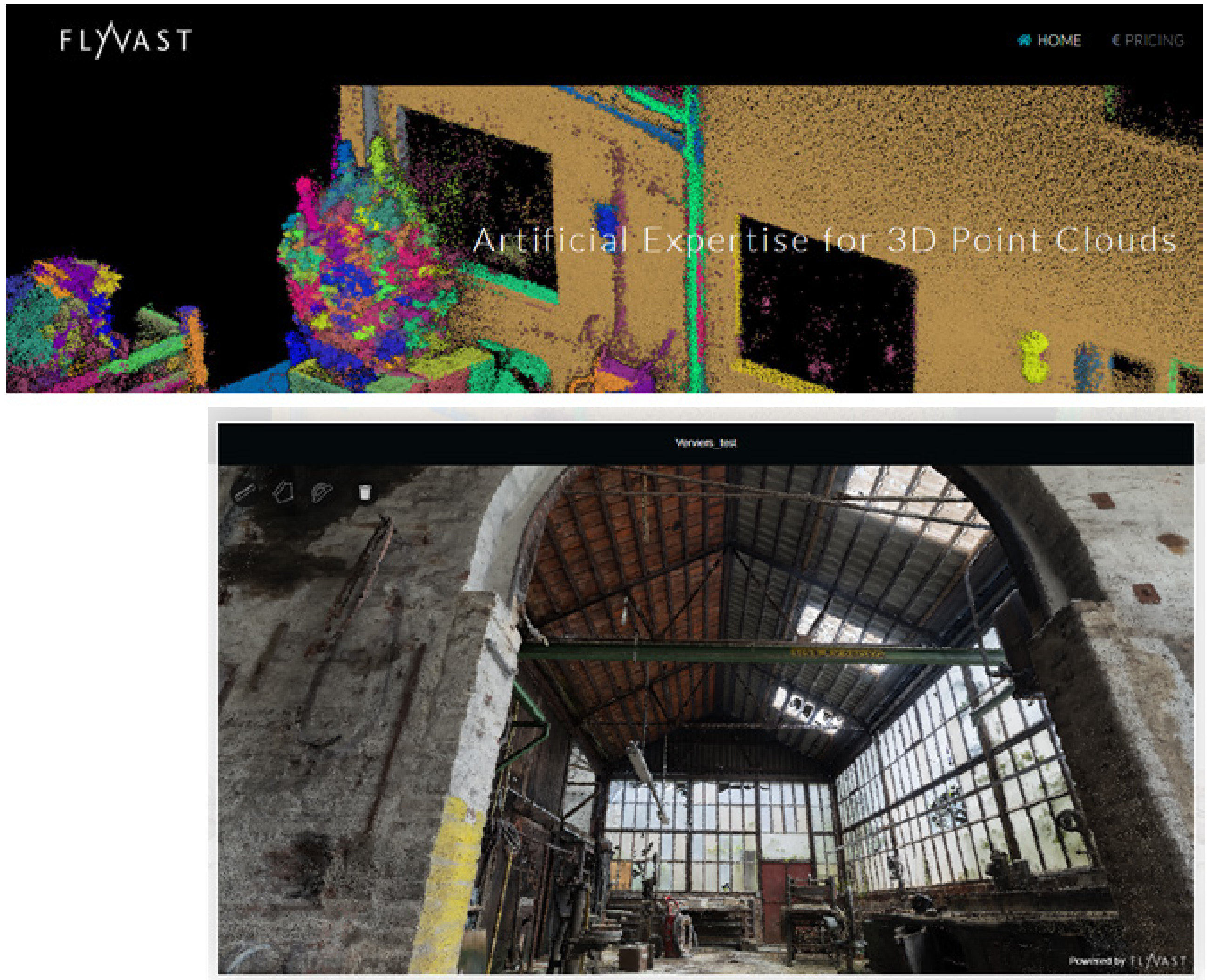


Fig. 108 FLYVAST, platform, to process, manage, publish and share 3D scan data autonomously. Image from https://flyvast.com/

6. The last platform presented is CINTOO. Through it, you can transform massive laser scanning data into a format compatible with both the cloud and BIM. The data can be shared, visualised, measured or used in Scan to BIM workflows. CINTOO has strong interoperability with BIM 360. REVIT, NWD, 3D, DWG, J.T., and IFC models can be used from BIM 360 to the Cintoo cloud. In this sense, the platform allows comparing scan data with parametric models so that when the analysis is performed in Cinto cloud, it can be used in BIM 360 for project coordination.(fig.109)

In the application context of the research, the use of three-dimensional models classified semantically has the specificity to support actions aimed at conservation, management and proactive maintenance of damaged assets and the specific sample of investigation. In presenting the workflow of procedures integrated into the survey of seismic damage (ch. 5), the integration between the three procedural levels is fundamental. If L1 provides the information database in which the theatre is collected and hierarchised master data, quantitative and qualifying identification, the L2 offers the three-dimensional database of the object for analytical knowledge dimensional, metric and geometric. This level also allows performing the first diagnostic analysis about the state of damage and degradation

conditions of the theatre through non-destructive procedures constituting the basis for subsequent investigation and targeted specialised inspections. The first two levels represent the basis for the HBIM model. As described in Chapter 5 at para(s)1;3, the BIM modelling of a historical asset is subject to several simplifications of a geometric nature, dictated by the interpretive capacity of the operator in the modelling process. Therefore, it was deemed appropriate to focus on model informational characterisation due to the research specifics to document, detect, and represent damage. Although the BIM has been made possible as a first informative characterisation associated with the segmentation and categorisation of the object in technological elements, it is necessary to make an HBIM model for exhaustive documentation of the theatres. This implies an enrichment of data to thoroughly understand the asset, i.e. its material and immaterial meanings.
In perspective, therefore, to provide an HBIM model is to employ the interoperable and implementable platform of INCEPTION, where you can proceed to populate data, metadata, multimedia elements, semantic classifications, hyperlinks that allow you to achieve the necessary enrichment degree to document the objects thoroughly studied. The operation that the BIM environment does not succeed to manage if not in a limited way, because it is a local model that even if realised in an open format, IFC in the export phase does not succeed to preserve all the information.
In order to the forehead of the importance to have an only database standardised of the identifying data and of the acquired 3D data that inform the parametric model, it is necessary a semantic implementation web for the BIM model that guarantees the accessibility, the visualisation and the manipulation of the data to documentative scopes, conservatives and management for various types of users. The opportunity to operate on the interoperable platform INCEPTION allows optimising the collaborative workflow between the different subjects of the reconstruction process. It also represents an opportunity for knowledge and valorisation for the general public, which is given the possibility to navigate in the 3D models of the theatres, accessing at the same time all information contents connected to it. The valorisation and inclusive use represent a crucial aspect after the restoration phase of the theatre because they affect the management and active monitoring of the theatre.

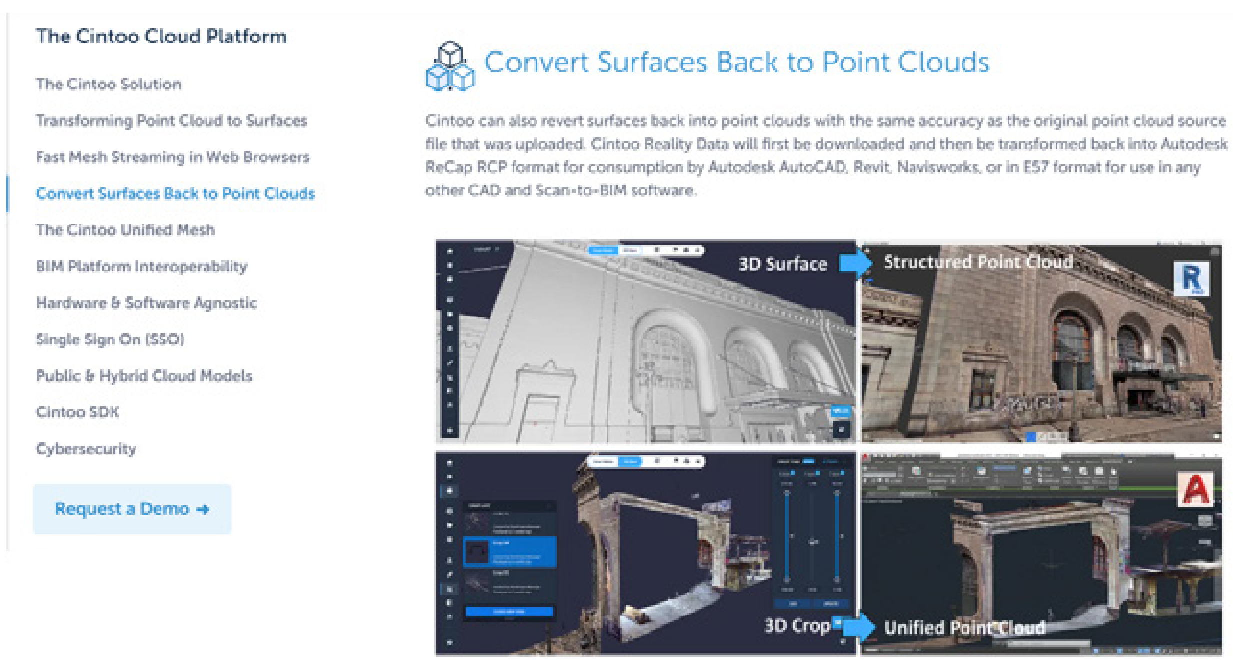


Fig. 109 - CINTOO platform transforms massive laser scanning data into a format compatible with the cloud and BIM. The data can be shared, visualised, measured or used in Scan to BIM workflows. Image from https://cintoo.com/

6.1 HBIM platform selection: INCEPTION

Inception's semantic web platform is an innovative cloud-based tool to make cultural heritage accessible and understandable through enriched 3D models. The platform is developed within the Inception project - Inclusive Cultural Heritage in Europe through 3D semantic modelling- funded by the European Commission within the Horizon 2020, Call Reflective-7-2014, Advanced 3D modelling for accessing and understanding European cultural assets.
In the historical architectural and archaeological heritage field, due to the limitations of geometric modelling that simplifies object interpretation related to the accuracy and precision of modelling object detail or model segmentation, data enrichment becomes a key aspect in documenting cultural heritage. The need to overcome gaps has led to the search for a new tool that takes advantage of existing semantic technologies and develops others specifically for the INCEPTION project have led to the platform's development.
The need that moves the development of the platform is to give continuity between the process of data acquisition and HBIM modelling, for which, as mentioned in Chapter 5. para 5.3.1, is necessary and indispensable enrichment of data.
In this direction, the project has identified the principal goals carried to the elaboration INCEPTION DAP (Data acquisition protocol). The setting on the specificities of the damage in the ch. 5. para 5.2.2 is introduced, arriving at the documentation and data collection connected to the semantic modelling to aggregate the data effectively, adopting the BIM methodology.
As described in chapter 5 para 5.3.1, it uses the Scan to Bim process for the parametric modelling of the theatre. Many uninterpreted, unsegmented data represent the morphometric. BIM succeeds in importing this quantity of data, but modelling and segmentation (Apollonio, Gaiani, & Sun, 2017) is a lengthy process and subject to operator interpretation. Understanding

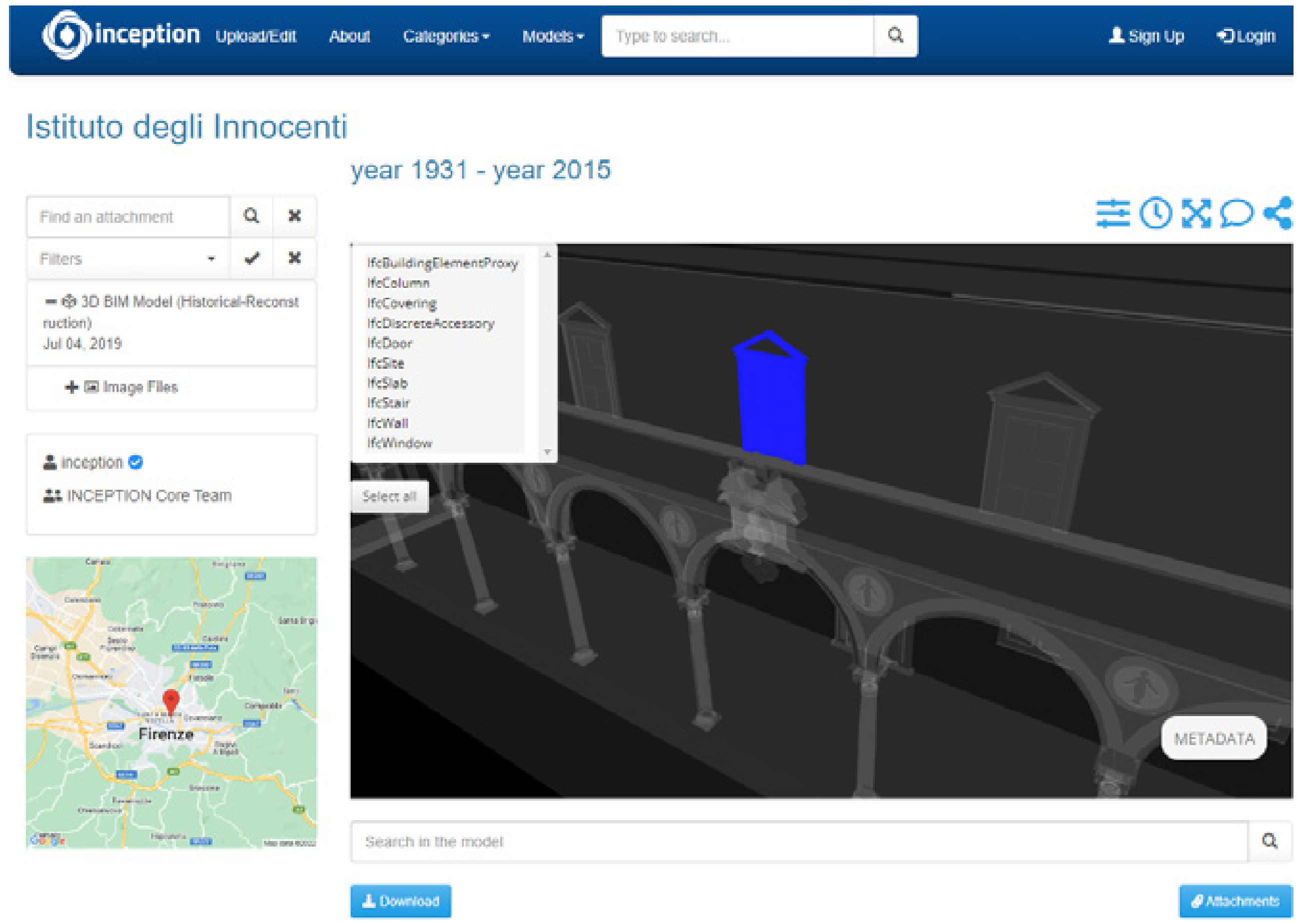


Fig. 110 - the semantic HBim platform Inception was developed with funding from the European Union's Research and Innovation Horizon 2020 of the European Union under grant agreement No. 665220 Developed by INCEPTION team

which objects to model represents a foundational aspect related to the purpose of the model. Therefore, in modelling an object, it is necessary to achieve a geometric or detail LOD that allows for a degree of geometric accuracy and object granularity level that allows for object segmentation. These operations can be performed in BIM, but for a parametric model to be identified as HBIM, it requires an integrated level of knowledge.
The adoption of the HBIM layered semantic ontology stems from the awareness of the limitations of the BIM methodology, which, while managing to ensure the characterisation of the model and its technological elements and a level of knowledge, fails to include all the information that requires external resources. In fact, in passing from a BIM model to an HBIM one, the IFC format can preserve the information related to the components. Still, the photo knowledge information links to historical or iconographic sources are lost. To solve this problem, INCEPTION has not limited itself to developing a static digital archive database but as a working environment in which the existing natural capabilities of the IFC standard are extended.
All the information that needs external information cannot be integrated into the logic of a model IFC of BIM. Therefore, this awareness led to the need to design a new tool, a layered and interoperable ontology, to collect and store further heritage information in the BIM model by matching correct architectural elements to each structural or decorative part of the building [Iadanza et al., 2019].
The INCEPTION platform used the HBIM ontology to associate the segmented parametric BIM model with data and information from external resources such as metadata, multimedia elements, hyperlinks, documentary, iconographic, and photographic sources contained in digital archives, offline and online, such as the Getty AAT (The Getty Art & Architecture Thesaurus), Europeana, Wikipedia, etc. Within the project, starting from the models of the 9 case studies, the architectural characterisation of the model was partially remapped with the BiM open standard for semantic modelling IfcOWL.
The platform consists of a three-dimensional viewer that allows appreciating BIM modelling and surface characterisation and an interface that will enable the exploration of information

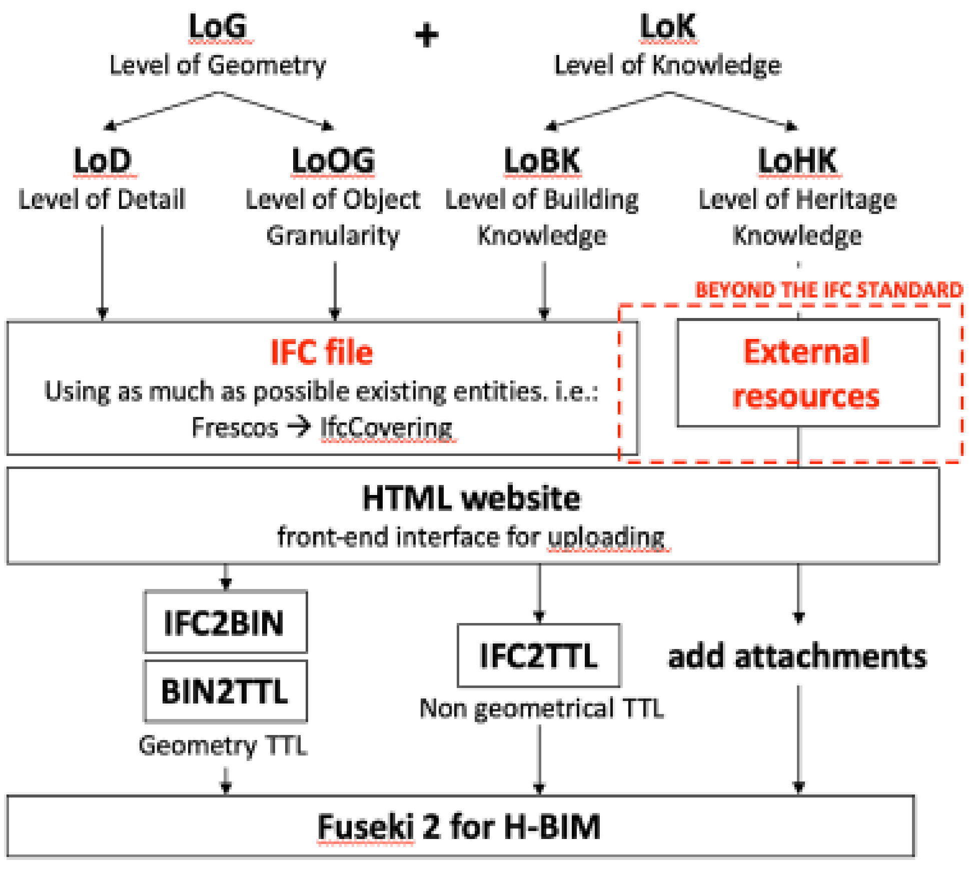


Fig. 111 - Data aggregation on Incepiton's HBIM platform. Developed by INCEPTION team

related to the model and objects, whether semantic or numerical, which can also be reused to provide the model viewer with added value.
The interface ontology allows to
Correctly define the structural and decorative architectural features of the 3D model, focusing on the Cultural Heritage domain.
- Link them to related external vocabularies and ontologies, being W3C standards a common language in research and sharing heritage data.
- Easily link valid documents to deepen knowledge about any part of the building, regardless of their file format, with excellent granularity.
- Filters information by User Profile and Scope to enable personalised and user-friendly navigation for tourists, professionals, heritage experts and administrators.
- Develop a standard API for querying data and properties to connect and share knowledge embedded in the 3D model hosted on the INCEPTION platform, allowing third parties to develop tools based on available, self-explanatory data.
- Add layers of knowledge by linking other specific ontologies suitable for specialised projects on specific domains. [Maietti et.all 2019].
INCEPTION Platform as a way to unite 3D representation and the world of Linked Open Data.
Models are stored in categorisations within the platform that can be declined. However, not being a simple archive or database, it follows the logic of the BIM collaborative environment, so the models are contained within a single place, which houses different models, made by other authors depending on the purpose for which the model was created. In this space dedicated to the models, it is possible to explore the model according to the logic of BIM discretisation, visualising the technological components, filtering the categories. Moreover, it is possible to visualise the same model superimposing to the IF model one DAE that can be put in the relation among them.
The transition from one model to another can be done dynamically while maintaining the

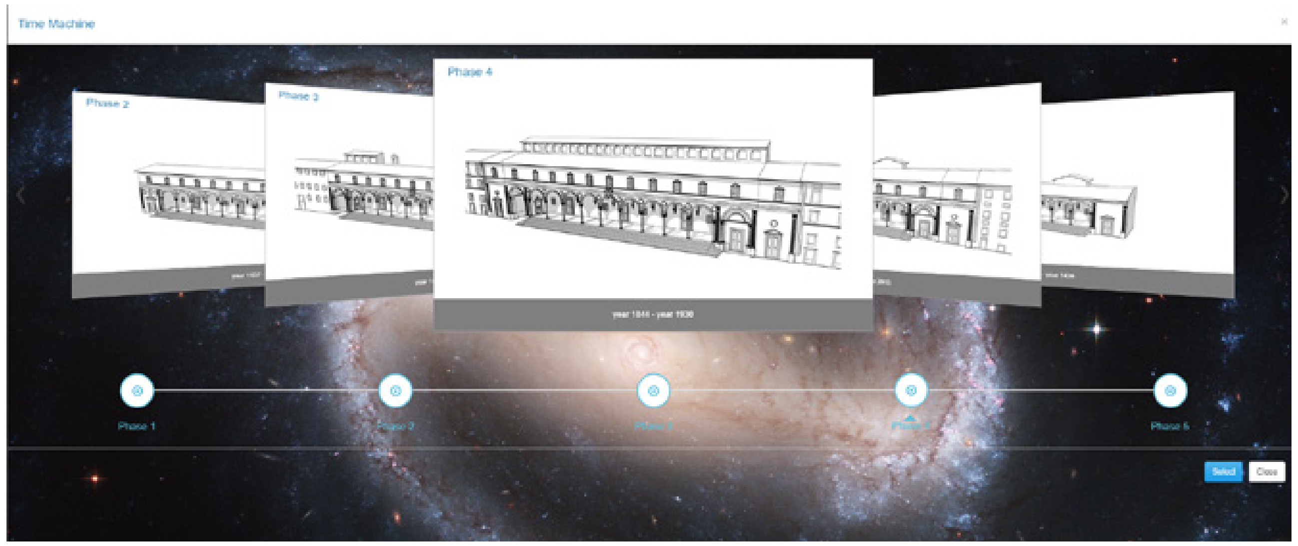


Fig. 112 - The image shows the time machine function of inception that allows visualisation of the model by historical steps. Developed by INCEPTION team http://www.inceptionhbim.eu/platform.

same point of view. An HTML interface uses semantic web technologies to assign a URI to each modelled geometry [Idanza, 2020]. Therefore, each object is associated with a URI (Unique Reference Identifier). Using the URI code, it is possible to enrich data from external resources. The association of a URI to each element is also helpful in the interrogation phase of the model. Having each three-dimensional object connected to information associated with that specific element goes to identify each object uniquely. Data and files can be attached accordingly to each element using this URI. Integrating the use of the platform into the data aggregation process has further extended the use of the IFC standard during modelling. [Maietti et al.] The developed H-BIM ontology then transforms the geometric (LOG) and knowledge (LOI) data of the IFC model, including all characterisations and properties, into

semantic triples. When new IFC properties are included or specially created in the IFC file, they are directly handled and interpreted into semantic triples. This aspect applied to a model that is born locally allows different interrogations on the Web. Each object is characterised by an OWL ontology, consisting of element definitions and single components belonging to the building.
The very high LoOG (level of Objects) guarantees the adoption of the unique code URI consent to have an ontology as an individual, an aspect that ensures [Maietti et al. 2019], by the possibility of enriching each component with complex information (fig.110)
Through the URI, the model components hierarchisation of the individual parts of the building and vice versa is maintained. Definition this hierarchical correlation to each element or object it is possible to link external content.
In the specific field of research, this aspect of the HBIM ontology of INCEPTION is highly advantageous for several factors. The platform adoption could allow associating all the I1 and L2 information to the parametric model (L3) according to the proposed segmentation of the model in object and families of elements. Therefore, in order to document the seismic damage, it is possible to use the models of the theatres and to query the model filtering the hierarchical information inside the DS T, composed by descriptive, technical and graphic annexes acquired pre, during and post-seismic, and associate them to the thematic mappings and tables related to the damage and the state of preservation of the theatre elaborated in the L2. For each UST segmented in the IFC model and its component, having the sets defined in L3 is a possible way of exploiting the ontology Inception, a classified and hierarchical registry related to each object of the theatre.
This aspect is significant since it guarantees 360 documentation of the Emilian historic theatres. Therefore, the different users following opportune profiling could interact and interoperate inside the model in this optics. The Inception platform having to answer the fundamental requirement of the HBIM of interoperability allows operating in the home. Within the forum, using the properties of the IFC and BFC model, modifications and implementations of the model can be made without the support of external plugins. Even if, at the moment, this

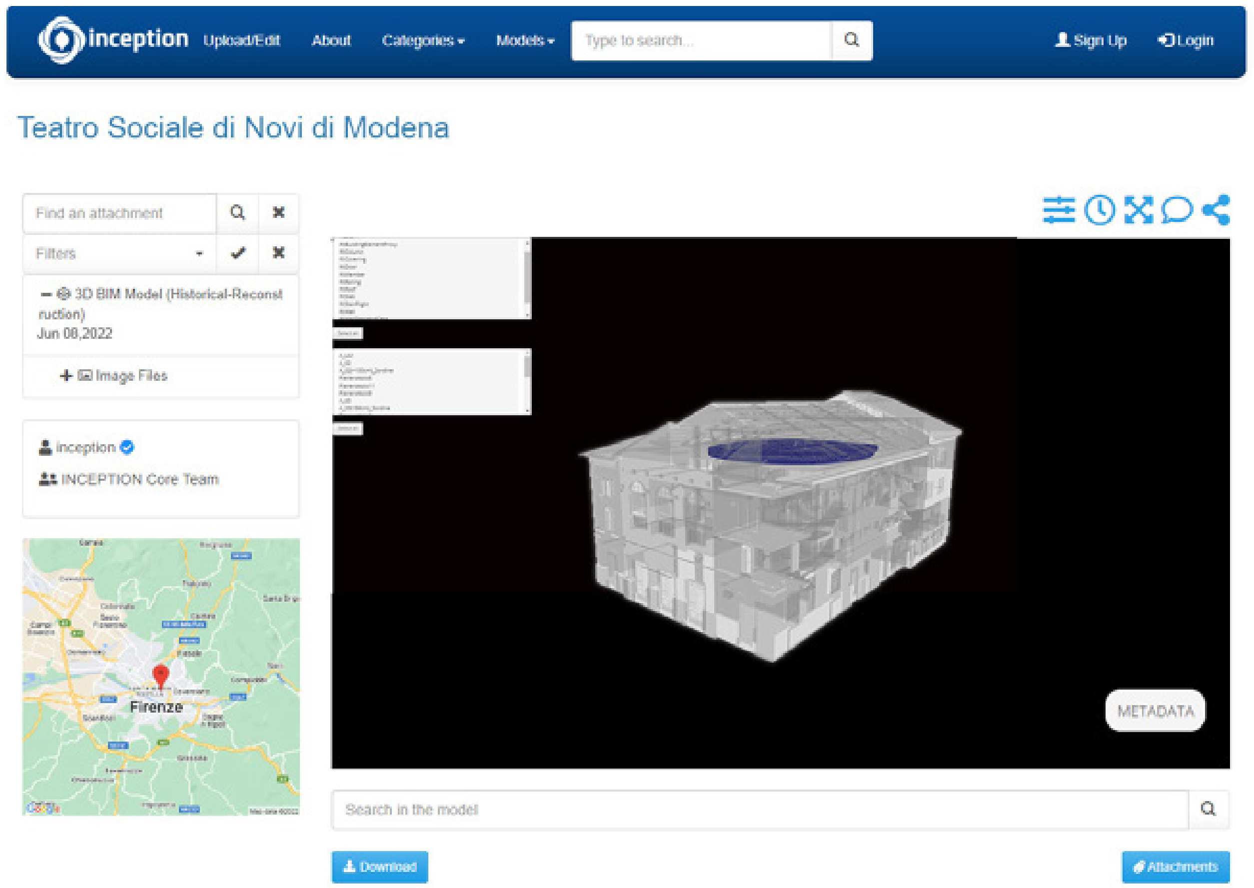


Fig. 113- the image shows the test of the Novi Theater model uploaded to the Inception platform. Developed by M.Suppa

function is still in the setting phase, the platform can guarantee the collaborative space of HBIM. The owner author of the model can modify the models to define, for example, a new specific sett. At the same time, the possibility of interaction of external users is foreseen, who are not allowed to modify the objects directly but to leave feedback to indicate the modification to be made. The developed ontology also allows filtering the model about the left feedback. Exploiting this latter aspect could optimise the workflow between the various professionals; they interface in the project of restoring the theatre and could affect the optimisation of the decision-making process of the Joint Commission that could then interact directly with the designers.
Another valuable aspect of integrated documentation of historical theatres is the Time Maschine (fig.111) function of the platform. It automatically creates a time scale and generates dynamic views in real-time, displaying only the geometric elements corresponding to the selected period or dates, allowing everyone spatial and multi-temporal fruition of the architectural complex. Typically, web viewers of 3D models allow point views linked to x,y,x coordinates. In Inception, on the other hand, using BIM data, it is possible to obtain a three-dimensional reconstruction of the object assigned to it through a query of information linked to the phase or period. This functionality is potentially advantageous because it should allow for inspiring information about previous interventions on historic earthquake-related or non-earthquake-related theatre and provide a visual timeline of earthquakes that have affected the architectural asset, thus optimising proactive planned investment management and maintenance at decision-making stages.
According to the ontology logic, the information related to the object can be grouped about phase and dating. This aspect would then allow associating to each object of the theatre specific information coming from the SIGECweb and PATER archives, containing information about pictorial decorations, historical news, news surveyed by the IBC in 1982.
Finally, the integration functions with GIS systems must be considered. A relevant aspect for ARRER, since as described in ch. two2 during the emergency has used the webGIS is to feel the damaged cultural heritage buildings. Because the geometric level and the knowledge level are not separated, keeping the interconnection data and the conversion to HBIM and GEOM ontologies, it is possible to convert IFC files with a minimum loss of data into GIS-related content [Maietti et al. 2019].
Due to these aspects, the research has indicated the ontology developed by INCEPTION as a solution to rejoin the integrated documentation of damaged Historical Theatres or slopes in risk situations, optimising time and workflow of the decision process and identifying strategies for the maintenance and programme management of the same.
In order to conclude, wanting to touch only tangentially, the theme of enhancement and inclusive use, it should be recalled that during the development of the platform, have been tested different ways of using the multiple outcomes and results of the process of digitisation and semantic organisation of data within the platform, to validate the methodology of documentation, tested tools, uses and exploitation [Iadanza 2020]. V.R. and A.R. applications capable of interacting with the 3D models of the platform are developed for tourism and educational purposes. The platform allows static or dynamic experimentation of the models available through APPs for mobile uniforms or headsets.
In this sense, the platform's use could implement the fruition and accessibility of theatres according to the scope of the valorisation path.

CONCLUSIONS

Proposals and potential integrated surveying procedures for seismic damage documentation and management

The research path through the workflow of the survey process of historic theatres in Emilia-Romagna highlighted the importance of integrated documentation applied to the cultural heritage sector to develop strategies for proactive maintenance and management of cultural heritage. While focusing on the specific field of research, the importance of systematically collecting data and information describing the characteristics and meanings of the typology studied was defined to obtain knowledge of the building throughout its life cycle and prevent damage to the building in risky situations. Information such as historical evolution, morpho-typological, structural, and technological characteristics, geospatial data, state of preservation, and documentation of previous interventions the building has undergone provide the basis for defining preventive maintenance and management actions.

In this sense, the research has taken up the “Principles for the Recording of Monuments, Groups of Buildings and Sites” defined by ICOMOS, according to which holistic documentation must integrate all the information necessary to describe the attributes proper to a historic building (Ch 4 para 4.3). Following these guidelines, the contribution of integrated digital documentation is clear and fundamental. Through digital systems of survey and documentation, it is possible to respond to the needs of all the actors involved in the preservation and protection of the CH to define targeted actions for managing cultural heritage. Chapters 3 and 4 described the problems, and critical issues arising in the post-earthquake emergency phase for the survey of seismic damage to theatres encountered by the MIC teams tasked with conducting the initial surveys to gather, within the tight timeframe of the emergency, the basic information useful for the documentation and survey of theatres: location, ownership, legal status, historical records, geometric records, diagnostic records, and pre-earthquake conservation interventions data.

In addition to the difficulty of finding the necessary documentation to know the damaged theatres, there is the critical issue of not having ad hoc seismic damage survey sheets for theatres. These issues in 2012 were a reason for slowing down the timely choices for securing damaged buildings. Therefore, based on these considerations, a holistic approach was adopted for imprinting extensive methodology and thus procedural workflow development. The ‘interdisciplinary approach, first, aimed to improve the historical-architectural and technological-structural knowledge of the specific attributes of the Historic Theater to have a comprehensive cognitive framework that optimises the stages of damage survey and active monitoring of preventive risk situations. This aspect was the subject of the double level of investigation of the critical comparative analysis (chapter 4) and the morpho-typological study (chapter 3).

Successively, the research focused on improving the workflow of the damage survey phases that underlie the actions of the design and decision-making process of post-earthquake reconstruction. Based on the standardised documentation protocols (Ch. 4, Sec. 4.3), an integrated procedural flow was therefore developed, organised into three levels of damage documentation (Ch. 5): Screening Level (L1), Survey Level (L2) and HBIM (L3). Following the extensive methodology, some phases of the meta protocol, particularly L1, were tested outside the 2012 Emilia crater area on the specific case study of the Masini Theater in Faenza. The theatre selection was performed about the Romagnola geographic area, classified in seismic macro zonation 2. In addition, the methodological approach was extended to an international scale, particularly in the Croatian site for the Croatian National Theater in Split, which was also surveyed according to L1 criteria. The Croatian theatres were selected depending on the collaboration ARRER has with Croatia within the FIRESPILL project and the morpho-typological characterisation resembling the theatres studied during the research.

Regarding the integrated workflow levels, the first level through the DS T application tool, the digital meta-form of symbolic damage survey of theatres, has been defined to regulate the phases of visual inspection during an emergency and proactive monitoring of the health status of regional theatres. The screening level (L1) aims to develop a digital database containing valuable information for the knowledge of the 106 historic regional theatres linked to data on seismic damage and the theatres' preservation condition. DS T's application uses information from surveys conducted in the ordinary or emergency phase to be systematised for each surveyed theatre. The database was developed with Microsoft Access to facilitate collaboration and integration with the Emilia Romagna cultural heritage GIS websites and regional GIS portals.

The current visual inspection procedures (Form A - DC and B-DP of MIC) govern the methodology of surveying seismic damage by identifying the collapse mechanisms activated on the macro-elements of the building and then expressing the damage index on a global scale. In this regard, DS T, to effectively document the damage and state of preservation, introduces macrostructural subdivision into USTs (structural subunits). Their identification is derived from the results of the comparative analysis of the inspection sample (Ch. 4 Sec. 4.1.2;4.2). In fact, from the study of specialised surveys, optical professionals to achieve LC3 (Accurate Knowledge Level) proposed damage analysis using the identification of structural macro-areas. The valuable aspect of surveying and studying the post-earthquake deformation and damage frameworks was also helpful in managing the construction phases. Therefore, DS T takes up this methodological aspect of monitoring damage surveys in the emergency phase and monitoring routine visual inspections to estimate the damage index. The DS T, consisting of 13 categories, collects the helpful information to draw an identity card of the theatre. Against the essential information found in the first five categories of the meta-form, the T06 category analyses the UST, representing the characterising macro-elements. The damage survey identifying the collapse mechanisms activated for each UST during the earthquake is recorded in T09. Through this procedure for each UST, against the specific characterisations defined in T06, the local damage index of each UST is estimated, which will then determine the global damage estimate. In addition to assessing the damage index for the survey, this aspect was intended as a qualifying element to optimise the subsequent stages of specialised investigation and immediately identify the most damaged areas needing securing interventions. Therefore, based on the information gathered during the application of DS T (L1), we proceed to the 'application of DAP DS (Ch. 5 para. 5.2), which indicates the use of integrated digital survey methods and tools for detailed analysis of geometric variations and the lesion framework.

DAP DS follows the workflow defined by DAP INCEPTION. Through the 8 steps (Ch. 5, Sec. 5.2), an optimised procedure is described for data acquisition through 3D acquisition tools, point cloud classification aimed at understanding the theatre, processing and graphical building representation of the damage found. The DAP DS aims to provide standardised guidelines to organise the workflow of special survey procedures to document a damaged theatre's geometric and dimensional aspects and to guide data discretisation through point cloud classification for seismic damage representation. In addition, in the specific field of damaged cultural property, the data acquisition protocol is used to define the survey category to document seismic damage. To achieve an accurate, reliable, and optimised investigation of seismic damage, achieving the A and A++ categories defined by DAP Inception is necessary.

The workflow for data acquisition and processing ensures not only the uniformity of the 3D digital survey [Maietti et al. 2019], but at the same time, it turns out to be a fundamental requirement for HBIM modelling of theatres. Morphometric databases nowadays in the cultural heritage sector are indispensable tools for documenting the architectural characteristics of assets; therefore, they support parametric modelling defined in the last level of Plus HBIM (L3).

Therefore, within L3, data and information collected in the previous levees flow together and are linked via p-sets to the parametric model processed by the 3D data acquisition model. As described in Ch. 1 Sec. 1.5, one of the limitations of the DS T about the damage survey

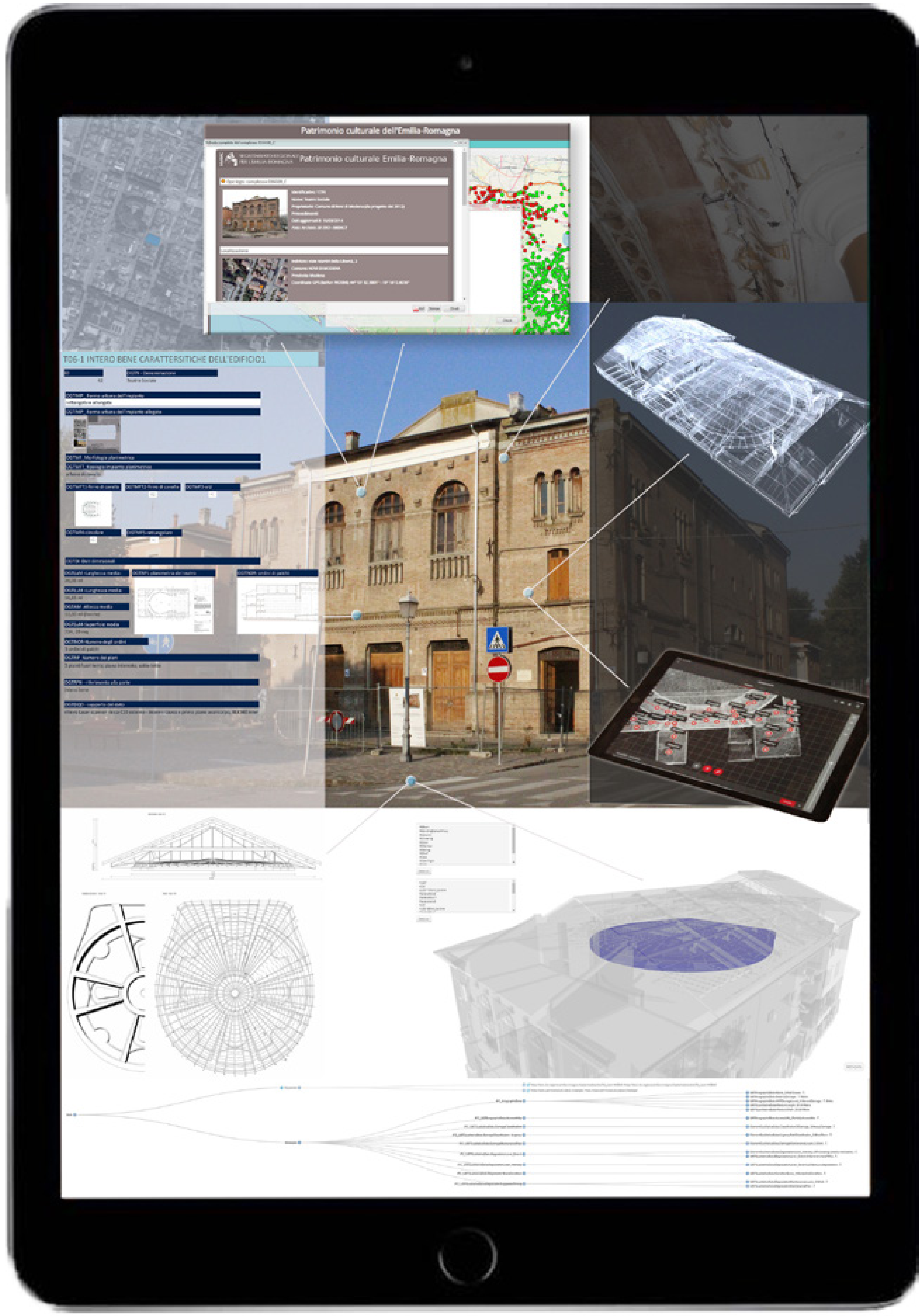


Fig. 114 the image shows tThe possibility of developing a single app that can connect to regional databases and Inception's HBIM platform to control the three layers of the integrated workflow. Developed by M.Suppa is that it cannot accurately track the collapse mechanisms detected directly on the damaged element. Therefore, the purpose of L3 is to assign the damage information inferred from the visual survey (L1) to each geometric element and then systematically survey and analytically process it in L2.

This aspect represents an element of future development of the present research work, thus suggesting the use of digital morphometric models and BIM methodology. The Inception HBIM platform could play a pivotal role in supporting the development of this approach, whereby the digital database and the parametric model would be integrated. The use of the platform is beneficial for the overall knowledge and documentation of the asset and for optimising the collaborative and interdisciplinary workflow among the different actors in cultural heritage reconstruction and decision making. Chapter 6.2 described how the platform represents a data enrichment tool in which all knowledge layer information can be integrated into the IFC file and then linked and associated with the parametric model through the developed ontology. This aspect makes it possible that all the data collected in the DS T, including photographic, historical and state-of-fact documentation, damage maps, and building conditions processed in L2, can be associated with another documentary, archival, and iconographic information contained in external resources.

The first step of development could be identified using dedicated Apps, through which to proceed during the visual survey (L1) to the digital recording of data in real-time. This aspect should be developed following the preestablishment of a digital database, as indicated for theatres, containing the archival data of each individual surveyed asset. The application to be developed would be linked to morphometric model management software. In recent months, Leica has been experimenting with the cyclon 3DR touch version software with the Ministry of the Interior apparatuses, responsible for ensuring the public rescue and prevention service, surveying and control of structures, directly on in situ point cloud models. Such devices would bridge the gap between visual surveying and the subsequent stages of surveying and diagnostic investigation.

On the other hand, the second step is transferring the visual and 3d digital survey data to the parametric model appropriately and then processing it to be managed on the interoperable HBIM platform. This operation aims to optimise the flow of monitoring and management of all actors, administrative, technical, and experts active in the damage mitigation and reconstruction process. The development of an application that can facilitate the transfer and analysis of damaged information and data directly on the objects of the inspectable model on the platform is a first step toward optimising the phases of surveying during emergencies and monitoring and managing the asset during routine inspections. Therefore, the research introduces this possible future scenario to provide an effective integrated documentation tool for the addressed case study of historic theatres. The integration of documentation tools makes it possible to initiate strategies and practices for Preservation-Monitoring-Diagnosis-Intervention Planning-Management from the individual building to the entire system of regional historic theatres.

Testing of an initial application could be done in connection with the app that ARRER is developing as part of the FIRESPILL project for seismic damage survey. Part of the research results could converge and be tested both on the of the theatres analysed in this contribution and later tested both on one of the Croatian case studies to standardise the integrated procedural flow on an international scale of the specific typology studied.

A tangential aspect to the specific issues addressed is that of heritage enhancement after the reconstruction process. This aspect could not be considered in the typology analysed since theatres, as described in Chapter 3, represent a space of cultural production and fruition.

In this sense, a possible future development on the use of HBIM models addressed to both conservation and inclusive enhancement and fruition issues is represented by Resolution No. 869 of 30/95/22 of the RER Council. This act promotes submitting projects for the performing arts sector for restoration and rehabilitation interventions aimed at conservation

and technological innovation projects aimed at enhancement.

During the historical investigation, it was noted that over time these spaces have gone through moments of crisis due to changes in society, compounded by the recent crisis in the theatre sector following the Covid Sar 19 pandemic.

Therefore, posing the question of how Emilia's theatres that have been restored or are being restored can once again become active spaces of social, urban, and cultural regeneration is an issue that the research, while not analysing, kept in mind in its concluding remarks. In particular, integrated digital documentation and HBIM models can be inspected and used through Inception's interoperable platform. They could be exploited not only for conservation or monitoring purposes but also as a support for cultural operators in setting up the stage space or experimenting with new ways of staging theatrical performances. Or, as covid's experience has shown, allowing spectators to witness actual virtual performances. On the other hand, using the HBIM platform could enable an inclusive enjoyment of the theatre space, allowing access to historical information about each theatre's specific attributes or creating ad hoc narrative paths.

Appendix A_0A_ Photographic survey
Apprendix B_ Damage survey
Apprendix C_Degradetion survey

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Developed by M.Suppa

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Developed by M.Suppa

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Developed by M.Suppa

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API: Application Programming Interface

AR: Augmented Reality

ARRER: Agency for the Reconstruction of the Emilia Romagna Region

BIM: Building Information Model

CAD: Computer-Aided Design

CMO: Concept Modelling Ontology, open standard on top of Semantic Web

CMO with Extensions: Open standard for developed within Proficient

E57: ASTM E2807 standard for point-cloud data

FEM: Finite Element Model

IFC: Industry Foundation Classes (ISO 16739:2013) open standard organized by BuildingSMART

HBIM: Heritage Building Information Modelling System

MiC: Ministero della Cultura

REVIT: Relational database system for the BIM AutoDesk system (from the producers of the system: Revit Technology Corporation)

SfM: Structure from Motion Photogrammetry / data aquisition

URI: Uniform Resource Identifier, a string of characters used to identify a resource

VR: Virtual Reality

W3C: World Wide Web Consortium, the main international standards organization for the World Wide Web

WebGL: Web Graphics Library, a JavaScript API for rendering interactive 3D computer graphics and 2D graphics within any compatible web browser without the use of plug-ins

2D: Two dimensional

3D: Three dimensional