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Building the Knowledge Base for Cultural Heritage Risk Assessment: The Case of the Arian Baptistry, Ravenna (Italy)

Sara Fiorentino *, Anna Casarotto, Ilenia Falbo and Mariangela Vandini

Department of Cultural Heritage, University of Bologna—Ravenna Campus, Via degli Ariani 1, 48121 Ravenna, Italy; anna.casarotto3@unibo.it (A.C.); ilenia.falbo@unibo.it (I.F.); mariangela.vandini@unibo.it (M.V.)

* Correspondence: sara.fiorentino2@unibo.it

Abstract

Disaster Risk Management (DRM) for cultural heritage is increasingly recognized as a global priority, yet methodological harmonization and conceptual inconsistencies continue to hinder its effective implementation. This study develops and tests an integrated framework for Disaster Risk Assessment (DRA) applied to the Arian Baptistery of Ravenna—part of the UNESCO World Heritage property Early Christian Monuments of Ravenna since 1996. By combining elements from the ICCROM ABC Method, the IPCC/UNDRR conceptual models, and the QuiskScan model associated with the Nara Grid for value assessment, the research identifies the essential data, definitions, and conditions required to prepare a coherent risk knowledge base. The workflow includes five main steps: context analysis, stakeholder mapping, value assessment, terminological alignment, and risk components systematization. Results demonstrate that effective DRA depends not only on technical assessment of hazards but also on the integration of social, institutional, and governance factors that shape vulnerability. The study also proposes a hybrid hazard framework combining ICCROM's Ten Agents of Deterioration with the UNDRR 2025 List of Hazards, expanding the concept of "dissociation" to include governance failures and socio-political risks. The Arian Baptistery thus serves as both a case study and a methodological laboratory, offering a replicable model for organizing knowledge, harmonizing terminology, and bridging disciplinary divides in cultural heritage risk management.

Keywords: disaster risk assessment; cultural heritage vulnerability and exposure; value assessment; ICCROM ABC Method; UNDRR; Nara Grid; QuiskScan; preventive conservation; World Heritage

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1. Introduction

The protection of cultural heritage from natural and anthropogenic risks has increasingly emerged as a global priority, as underscored by international frameworks such as the Sendai Framework for Disaster Risk Reduction 2015–2030 [1], the UNESCO Strategy for Reducing Risks to Cultural Heritage [2], and the guidelines developed by ICCROM and ICOMOS. Together, these initiatives have consolidated Disaster Risk Management (DRM) as a central component of heritage conservation.

Despite this growing attention, DRM for cultural heritage remains a developing and heterogeneous field, characterized by methodological diversity, disciplinary siloing, and operational challenges. Practitioners and institutions face a wide range of available tools—such as the ABC Method [3], RE-ORG [4], the FAR Program [5], and

QuiskScan [6]—each offering distinct perspectives, terminologies, and implementation requirements. The question is therefore not simply which tool to adopt, but how to establish the necessary conditions for their effective application: what information must be collected, which actors should be involved, and how to integrate data that are often scattered across disciplinary and institutional domains [7].

In many practical contexts, the main barrier to Disaster Risk Assessment is not the lack of methodological tools, but the fragmentation of the knowledge required to apply them. Information relevant to hazards, vulnerabilities, values, and management conditions is frequently dispersed across institutions, datasets, and disciplinary domains, limiting its effective use for decision-making. While existing studies largely focus on assessment models, less attention has been paid to the preparatory phase needed to organize, verify, and structure the knowledge base on which risk analysis depends. In addition, a strong geographic bias persists, with over seventy percent of case studies concentrated in Europe and North America [8]. Conceptual inconsistencies further undermine coherence across the field: divergent definitions of hazards, vulnerability, exposure, and risk coexist, and more than thirty percent of published frameworks misapply the conceptual models of the IPCC and UNDRR [9–11]. Moreover, stakeholder participation remains limited, with community engagement reported in fewer than twenty percent of studies, while most rely exclusively on professional experts [8].

Practical and institutional barriers exacerbate these issues. Fragmented, case-specific methodologies hinder comparability across contexts [8], and integration with global DRR instruments remains weak: financial and organizational constraints, coupled with siloed practices between heritage, climate, and urban planning sectors, further limit the scalability of existing models [12]. These combined gaps call for standardized, multi-hazard, and participatory frameworks, supported by open-access data infrastructures and sustained capacity building at the local level.

Risk management thinking has progressively evolved from reactive, compliance-oriented responses toward preventive and resilience-based approaches that emphasize uncertainty management, learning processes, and socio-ecological adaptation (Figure 1) [13–15]. These perspectives highlight the importance of integrating scientific knowledge, institutional coordination, and community engagement as key conditions for effective risk reduction.

Figure 1. Innovation curve—from destructive to regenerative approaches [13].

European initiatives such as PROCULTHER [14] and ICCROM's FAR Program [15] exemplify this transition, demonstrating how cross-sectoral collaboration and capacity building can support more proactive and coordinated approaches to risk management. The shift illustrated in Figure 1 reflects an increased awareness of uncertainty and the need to move from reactive responses toward predictive and organizational strategies.

The Arian Baptistery in Ravenna offers a paradigmatic context in which to explore these challenges. Constructed in the late fifth century and decorated with a remarkable

mosaic program depicting the Baptism of Christ, the monument forms part of the UNESCO World Heritage property Early Christian Monuments of Ravenna. Despite its outstanding universal value, the Baptistery faces multiple risks, including structural vulnerabilities, environmental stresses, and urban pressures. Numerous studies have addressed its historical development, materials, and conservation [16,17]; however, no comprehensive DRM framework has been established, and existing information remains dispersed across institutions, databases, and management practices.

This study revisits and connects previous research to identify what must be known and organized before applying structured DRM tools such as the ICCROM ABC Method [3]. By cross-referencing heterogeneous data sources, mapping stakeholders, and employing instruments such as the Nara Grid and QuiskScan for value assessment [6,18,19], the paper defines the essential data, conditions, and organizational steps required for hazards identification and systematization.

The Arian Baptistery therefore serves both as a case study and as a methodological laboratory to test how dispersed archival, technical, and experiential information can be transformed into a structured and operational knowledge system. The study focuses on the preparatory phase of Disaster Risk Assessment, producing operational outputs that support hazard systematization, value–vulnerability analysis, and the identification of priority information gaps. Beyond its local relevance, the proposed approach contributes to the broader debate on DRM for cultural heritage by providing a procedural and transferable framework for World Heritage properties facing similar challenges of data fragmentation, stakeholder coordination, and value-based decision-making. Ultimately, effective DRM is not only a matter of applying technical tools, but of organizing knowledge and strengthening connections between disciplines, institutions, and communities to support informed and resilient heritage management.

2. Materials and Methods

This study develops and tests an integrated framework for Disaster Risk Assessment (DRA) in the context of cultural heritage, combining conceptual refinement with site-specific application. The approach was designed to identify operational gaps in existing methodologies, refine the definitions of key components—hazard, vulnerability, and exposure—and apply an adapted assessment model to the Arian Baptistery in Ravenna, Italy.

2.1. Case Study

The selected case study is the Arian Baptistery, an architectural context recognized as a UNESCO World Heritage site, which by its nature differs from the museum collection case studies typically addressed by the ICCROM risk management methodology [3]. The choice of this monument is not solely related to the availability of long-term research activities carried out on the site, but rather to the opportunity it offers to critically explore how existing, heterogeneous datasets—produced through conservation, diagnostic, and monitoring studies—can be reinterpreted and systematized within a risk management framework. Building upon the extensive body of knowledge developed by the University of Bologna—Department of Cultural Heritage [16,20–23], the present study aims to assess which types of data can be effectively mobilized, adapted, or optimized for risk-based decision-making, and to identify gaps and critical issues that emerge when applying a collection-oriented methodology to a monumental architectural context.

2.2. Data Sources

Data collection was based on documentary, archival, and field information gathered at regional, local, and site-specific scales.

Documentary, archival resources and field information were analyzed to collect information on vulnerabilities—such as material properties, conservation history, and structural fragilities—as well as on exposure, including strategic geographical location, function, and cultural significance. Furthermore, territorial knowledge was fundamental to understanding the hazards and the exposures related present in and surrounding the study context. Numerous databases and sources were examined and cross-compared to obtain as comprehensive an overview as possible of the investigated site, while maintaining a holistic approach.

Further studies on the conservation condition, together with quantitative data derived from microclimatic monitoring or other physical parameters, would expand the existing body of collected information.

2.3. Methodological Framework

The initial framework adopted is the ICCROM Guide to Risk Management of Cultural Heritage, which incorporates the ABC Method and was developed based on the ISO 31000:2009 standard (ISO, 2009) [24]. The outline presented below follows the initial analytical phases established by the method; however, the framework has been updated and revised through the integration of additional tools better suited to describing the architectural context under investigation.

It proved necessary to supplement the published methodology with additional contributions, such as the hazard categories updated to 2025 issued by UNDRR [11] and the sub-classifications developed by the Canadian Conservation Institute for the ten agents of deterioration [3]. Another significant integration involved the use of the QuiskScan methodology [6], which, when combined with the preliminary completion of the Nara Grid [18,19], proved effective in articulating the value of the architectural context under study. Value estimation based solely on the methodologies proposed within the ABC method [3] was either overly complex or too simplistic; for this reason, this tool was implemented, while still grounded in the methodological principles of the approach developed by ICCROM.

a. Context analysis

Outlining the case study from socio-cultural, administrative, financial, and legal perspectives to identify contextual vulnerabilities.

Digitized databases consulted included:

- ICCD Catalogue of the Italian Ministry of Culture [25];
- Emilia-Romagna Cultural Heritage Web-GIS Portal [26];
- GeoNames [27].

Archival collections consulted included:

- Superintendency of Archaeology, Fine Arts and Landscape for the Provinces of Ravenna, Forlì-Cesena and Rimini (SBAPRa);
- Superintendency for Architectural and Landscape Heritage of Ravenna;
- Drawing Archive (SBAP, AD);
- Photographic Archive (SBAP, AF);
- Historical Archive (SBAP, AS);
- Archdiocesan Archive of Ravenna (AAR);
- State Archive of Ravenna (ASCRA);
- Ricci correspondence fund—Monumenti section, Biblioteca Classense (Ravenna).

b. Stakeholder mapping

Identifying the actors involved in site management and defining their respective spheres of influence.

This step was carried out through interviews with staff members of the National Museums and local shopkeepers operating in the square, as well as by consulting the

ICCD database of the Ministry of Culture [25] and the Emilia-Romagna Cultural Heritage Web-GIS Portal [26].

The interviews conducted with shopkeepers were anonymous. They aimed to understand the economic–commercial, relational, logistical–regulatory, and social impact profile of the relationship between the monuments located in Ariani's square and the existing commercial activities. The interviews with the staff and conservators of the Baptistery adopted a more technical focus, addressing maintenance-related aspects and the day-to-day management of the Baptistery.

c. Terminological alignment

Harmonizing definitions derived from the IPCC [28], UNDRR [29], and the ABC Method, in accordance with ISO 31000:2018 (ISO, 2018) [30].

To enhance its relevance for climate change adaptation, several scholars have proposed embedding IPCC-style risk components [8,9] and UNDRR hazard definition and classification [31] into the ABC cycle, thereby developing a hybrid framework that combines ICCROM's procedural clarity and stakeholder focus with the conceptual rigor and climate specificity of IPCC and UNDRR contributes.

d. Value assessment

Developing a value diagram by combining internationally recognized methodologies, including the Nara Grid for assessing cultural heritage authenticity [18,19] and the QuiskScan method [6].

The construction of the Nara Grid—an internationally recognized framework—was supported by published literature addressing the monument's historical and artistic significance—particularly the research and valorisation program carried out by the University of Bologna [16]—as well as by the analysis of the archival sources mentioned above. Interviews with local institutional actors (the site manager and municipal staff), cultural experts and mediators, and stakeholders directly affected by the 2023 floods, alongside interviews with custodians, conservators, and shopkeepers active in Ariani Square, helped elucidate how different stakeholder groups perceive and ascribe value to the site.

The ABC method [3] proposes several ways of constructing the value pie for the context under investigation. Among the various options, it was necessary to consider the intrinsic value of the building itself, and the absence of a collection housed within it. Examples of value pie constructions that take the building into account include:

- The value pie that divides the building and collections into subcategories [3] (p. 47);
- The value pie that applies the four values proposed by English Heritage for architectural contexts—Evidential, Historical, Aesthetic, and Communal [3] (p. 52).

Other approaches to constructing the value pie are closely related to collection-based case studies and would have required substantial modifications to the given structure.

The first approach listed above was rejected because it is overly simplistic, as acknowledged by the authors themselves, since it considers the subcategories as having equal weight. The second approach was discarded because the value classes are based on a framework different from that of the Nara Grid and do not associate a quantitative measure (numerical or dimensional) with the predefined value classes, which QuiskScan does. Furthermore, QuiskScan adopts the same dimensions (artistic, historical, social, and scientific) as the Nara Grid, thereby aligning the two tools and making the process consistent and coherent.

It should be specified that the value pie is adapted according to the study context. In the case of Arian Baptistery, this approach was considered preferable to other existing options.

e. Hazard identification

Updating the ABC hazard classification by integrating subcategories from the CCI–ICCROM "Ten Agents of Deterioration" model and incorporating additional hazards identified in the classification proposed by Stevance and co-authors [31].

Web-GIS databases on territorial natural hazards were consulted, together with environmental parameters related to climate change [28], local press sources, and interviews conducted with site staff and shopkeepers in the square.

f. Exposure identification

The ABC Method classification [3] differentiates agents by their return period (rare, frequent, cumulative). Web-GIS platforms, municipal civil protection plans, and event databases (meteorological and seismic records) could be valuable exposure sources. Additional information can be found in published literature and archival documents reporting recurrent episodes over time, as well as testimonies provided by site management staff and individuals who experience the square daily.

g. Vulnerability identification

This section presents the continuation of the QuiskScan methodology [6], which supports the articulation of the vulnerability of the different components of the case study based on the value assessment previously carried out.

In the QuiskScan method [6], vulnerability is constructed as a comparative and matrix-based assessment of the intrinsic susceptibility of collection units to damage caused by agents of deterioration, without relying on risk scenarios or probabilistic estimates. It primarily concerns the tangible material susceptibility of objects or units to undergo physical or chemical change, while, where relevant, intangible factors of a political, social, economic, or reputational nature may also be considered. The assessment is not carried out at the level of individual objects but at the level of collection units defined during the collection anatomy phase, which should be internally homogeneous and clearly distinguished from one another on the basis of typology, materials, function, location, or curatorial classification.

In the case of the Arian Baptistery, the monument was subdivided according to the decorative features and architectural elements present (the mosaic dome, surviving fragments of wall paintings, windows, flooring, roof, and internal and external walls).

For each unit, vulnerability could be evaluated separately in relation to the ten agents of deterioration within the ABC/ICCROM framework, using a three-level qualitative scale (High, Medium, Low). The attribution is relative and comparative across units and is based on available knowledge, expert experience, and collegial discussion conducted under moderation and properly documented. Where internal heterogeneity exists, the modal or median level of vulnerability is adopted, while exceptions are recorded for potential later analysis; this highlights how the method accepts a degree of aggregation and simplification to ensure operational speed. The results are entered into a unit $\times$ agents' matrix that provides a structural mapping of heritage fragility, forming a preliminary knowledge base that remains distinct from the assessment of exposure or the estimation of risk.

Archival records, the literature on restoration interventions, and diagnostic diagnosis on the state of conservation and consultations with the personnel responsible for the monument's protection were the primary sources, supplemented by the full dataset collected throughout the preceding stages.

3. Results and Discussion

The following sections present the main operational outputs generated through the integrated framework, illustrating how the harmonization process supported the organization of knowledge and the identification of priority risk components.

3.1. Context Analysis

The present state of conservation and legibility of the Arian Baptistery reflects more than a century of restoration, neglect, and rediscovery (Figure 2). These successive interventions and periods of deterioration have produced cumulative material and structural transformations that directly influence the monument's current vulnerability profile.

Figure 2. The Arian Baptistry buffer zone and the ownership perimeters of the areas around the UNESCO monument. Image modified from [32]. Orange and light-blue colors are the same used in [26] for showing the different Italian Legal protection for the cultural heritage. On the left side of the image the view of the Arian Baptistry from the garden of the University of Bologna—Department of Cultural Heritage building (Ariani street, 1, Ravenna, Italy).

Since the nineteenth century, the monument has been affected by a sequence of restoration campaigns interspersed with periods of deterioration and neglect, each of which has left identifiable material and conservation-related traces on both the architectural fabric and the mosaic surfaces [33–42]. When the building, previously owned by the Lovatelli–Dal Corno families, was acquired by the Italian State in 1914, it was in severe disrepair [43–51]. Under the newly established Special Superintendence of Ravenna—the first of its kind in Italy, directed by Corrado Ricci—systematic restoration programs began, combining technical repair with documentation and study. Early twentieth-century restoration campaigns combined structural repair with systematic documentation, leaving extensive records that today support the reconstruction of past conditions and interventions [44,52–56].

During World War II, bombing in the surrounding area exposed the monument to significant stress. Although major collapse was avoided, vibrations caused damage to masonry and mosaic surfaces, leading to extensive post-war structural consolidation and roof reconstruction [48,57–63].

The recovery of the monument's decorative cycles continued throughout the twentieth century. In 1959, restoration of wall surfaces and mosaic fragments was completed, while subsequent campaigns in the 1970s addressed severe deterioration caused by water infiltration, leading to the detachment and reinstallation of the dome mosaic using the *strappo*

technique [46,58,62], a procedure that, while ensuring preservation, also introduced additional layers of material complexity and long-term conservation implications. Additional consolidation and maintenance work were undertaken between 1991 and 2005, including the repair of painted plaster imitating marble and the upgrading of lighting systems to improve visibility of the mosaics [16,49].

More recently, For the Arian Baptistery, a Level 1 (LV1) seismic vulnerability assessment was carried out a broader survey of historic buildings coordinated by the University of Parma (MADLab) on behalf of the Regional Superintendency of Emilia-Romagna. The analysis included a global seismic evaluation using the SIVARS procedure and linear kinematic analyses of local collapse mechanisms, providing comparable safety indices. This represents a rapid, screening-level assessment, useful for inter-building comparison and for establishing intervention priorities [64].

This assessment provides a preliminary comparative indicator of structural vulnerability and represents a key input for the integrated risk evaluation. As, in fact, Jigyasu and Chmutina [65] emphasize, increasing pressures on heritage in urban contexts—arising from geophysical factors, socio-economic change, and governance complexity—require a holistic diagnostic approach.

Overall, the conservation history of the Baptistery reveals a condition shaped by cumulative structural modifications, recurrent water-related deterioration, environmental exposure, and changing management frameworks. From a risk perspective, these layered transformations represent not only material fragilities but also systemic vulnerabilities linked to maintenance continuity, accessibility constraints, and governance complexity. The synthesis presented in Table 1 therefore supports the identification of cumulative risk factors, providing the contextual basis for the subsequent stages of the integrated Disaster Risk Assessment.

Table 1. Detailed explanation of the Arian Baptistry context. Conceptualization modified from the ABC Method [3].

Build Up the Context	Explanation
Name of the property	Battistero degli Ariani (Arian Baptistry) [Alternative names]: Oratorio di Santa Maria in Cosmedin
Type of asset	Individual asset; Baptistery; Religious building.
Geographical coordinates	WebGIS: Id. 9402; Coordinates GPS (lat/lon WGS84): 44°25′7.3819″–12°12′8.6025″ GeoNames: Id. 11951182; Italy IT, Emilia-Romagna 05, Province of Ravenna RA, Ravenna 039014
Date	Late 5th–early 6th century (c. 493–526 AD).
Description	Octagonal baptistery built under Theodoric for the Arian community, complementing the nearby cathedral (now Basilica of the Holy Spirit). Converted to orthodox use after the Byzantine conquest; state-owned since 1914. Structure in brick, with three apsidioles and large upper windows, about 2.5 m below street level. Originally surrounded by an ambulatory, now lost except for wall piers. Dome mosaics from the Gothic period preserved: central medallion of Christ's Baptism beneath the dove of the Holy Spirit; outer band with Apostles led by Peter and Paul towards the Etimasia throne. No wall mosaics survive; one apsidiole retains a fragmentary 17th-century fresco of a dove with intertwined serpents.

Table 1. *Cont.*

Build Up the Context	Explanation
Socio-cultural aspects	Inscribed (1996) in the UNESCO serial property Early Christian Monuments of Ravenna. Located in Piazzetta degli Ariani, within a historic urban complex including the Basilica of the Holy Spirit and remains of Droctulf's Lombard Wall. Fully accessible to visitors and wheelchair users. Open Mon–Thu 09:00–12:00; Fri–Sun 09:00–17:00. Ticketed entry on-site, online, or via associated museums. Vehicular access is regulated by municipal ordinances.
Administrative settings	Italy; State property; Ministry of Culture (MiC), Musei Nazionali di Ravenna. Listed as UNESCO World Heritage Site since 1996 (Early Christian Monuments of Ravenna)
Financial context	Managed by MiC—Musei Nazionali di Ravenna. Ticketing via on-site dispenser, partner museums, or Vivaticket. Reservations: prenotazioni@ravennantica.org.
Legal context	Governed by national cultural heritage law (Legislative Decree 42/2004) and MiC regulations (Decrees 14 Jul 1979; 30 Jun 2016) on access, supervision, and safety of state museums. Local regulations: Municipality of Ravenna, Council Res. 664/2016; Law 44/2017 (amending Law 77/2006 on intangible heritage).

3.2. Stakeholder Mapping

The stakeholder mapping conducted for the Arian Baptistery provided critical insights into the governance structure influencing the monument's management capacity and revealed structural conditions that directly affect risk preparedness and response. Following the visual model proposed by Tandon [66], stakeholders were represented as spheres—their size reflecting the level of influence, and their color distinguishing between direct (blue) and indirect (green) involvement under both ordinary and emergency conditions (Figure 3).

At the center of this network, the Arian Baptistery is state-owned and managed by the Italian Ministry of Culture through the *Musei Nazionali di Ravenna*, in coordination with the Superintendency of Archaeology, Fine Arts and Landscape—Architectural Heritage Division. These two institutions form the core operational nucleus. During emergencies, they coordinate with the Fire Department, the Civil Protection Agency, and the Carabinieri Command for the Protection of Cultural Heritage (TPC), occasionally supported by specialized volunteer groups trained in heritage rescue and recovery.

The mapping, however, highlights fragmentation in the distribution of competences. While the Ministry retains ownership and formal responsibility for conservation, the Municipality of Ravenna—whose mayor also has the leadership of the local Civil Protection in case of emergency—plays an informal but pivotal coordinating role during emergencies and in urban risk policies. This duality mirrors a recurrent tension in Italian heritage governance, where national-level mandates and local operational needs often intersect without fully aligning [16]. From a risk perspective, this institutional duality represents a governance vulnerability, as decision-making authority, operational coordination, and emergency responsibilities are distributed across different administrative levels without fully integrated procedures.

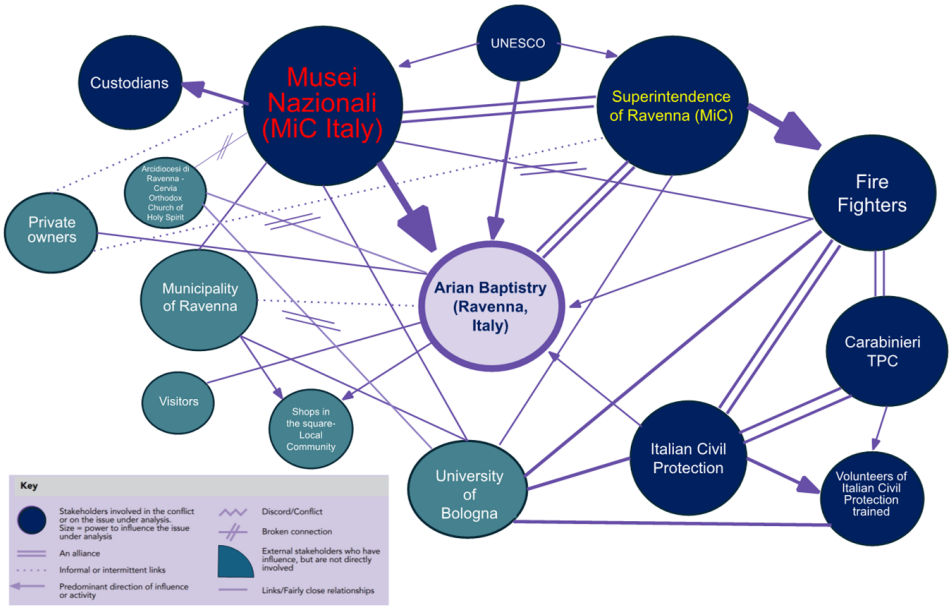

Figure 3. The stakeholders map for the Arian Baptistry. In red, the ownership of the site (National Museums of the Ministry of Culture (MiC), state property) is highlighted, while in yellow the institution (the Superintendency, Architectural Heritage Division) responsible for the protection, conservation, and enhancement of cultural and landscape heritage is indicated. This body carries out activities such as verifying and declaring the cultural significance of assets, managing their cataloging, authorizing interventions, and promoting studies and research aimed at their understanding and valorization. The legend explains the colors used and the meaning of each connector. Map conceptualization modified from [66].

At the international level, the UNESCO World Heritage Centre and its regional offices oversee the conservation of the Outstanding Universal Value (OUV) for which the Early Christian Monuments of Ravenna were inscribed in 1996. Oversight is exercised through Periodic Reporting, Reactive Monitoring, and Advisory Monitoring mechanisms [67]. Yet, these controls—though essential for accountability—remain largely external to the site's daily management, generating limited feedback loops between local implementation and global monitoring frameworks. This separation limits the integration between international monitoring requirements and local risk management practices, reducing the effectiveness of feedback mechanisms for preventive action.

The outer, green spheres of the mapping represent actors exerting indirect but strategic influence. The University of Bologna, through its long-term involvement in projects such as SIRIUS [21], RESTART [22], and CHANGES [23], acts as an intermediary between scientific research, institutional stakeholders, and civil protection agencies. This bridging role has been crucial for knowledge transfer and for promoting shared methodologies in preventive conservation. Similarly, the Municipality of Ravenna maintains active partnerships with cultural and academic institutions, demonstrating how local governance can catalyze intersectoral collaboration and community awareness around heritage risks.

Despite these positive connections, the analysis also reveals critical boundary conditions that undermine the coherence of site management. The privately-owned residence adjoining the Baptistery's western side remains a long-standing issue: the absence of agreement on its potential expropriation restricts full public accessibility and limits the feasibility of conservation interventions. These ownership constraints represent a critical exposure factor, as they directly affect physical accessibility for maintenance and emergency operations.

Likewise, the Wall of Droctulf—another monument within Piazzetta degli Ariani—is under private ownership and currently being verified by the ministry [26]. Religious

institutions add an additional layer of complexity. The Archdiocese of Ravenna–Cervia maintains minimal interaction with municipal and ministerial authorities. This functional separation further contributes to the fragmentation of management responsibilities within the site's historical ensemble.

Beyond the institutional dimension, the mapping also reflects the socio-economic dynamics surrounding the monument. Since the *ArianInPiazza* project [20], commercial and hospitality activities have adapted to the Baptistery's presence, increasing pedestrian flow and contributing to the revitalization of the square—previously used as a parking area. While this regeneration has fostered a stronger community connection to heritage, it has also introduced new challenges related to visitor management, crowding, and surface deterioration. The increase in pedestrian flows therefore represents an emerging pressure factor that may amplify surface wear and complicate emergency evacuation or site protection procedures.

Overall, the stakeholder analysis reveals a governance system characterized by strong institutional presence but high structural fragmentation. From a Disaster Risk perspective, this condition constitutes a significant dissociation risk, as ownership, operational management, emergency coordination, and spatial control are distributed among multiple actors without fully integrated decision-making mechanisms. At the same time, the presence of academic institutions and collaborative projects demonstrates a potential bridging capacity that can support knowledge integration and inter-institutional coordination. These analytical findings informed the subsequent phases of the research, contributing to the identification of governance-related vulnerabilities within the integrated risk framework. The find also demonstrates significant potential for collaboration, especially through academic mediation and participatory approaches developed under projects like SIRIUS [21] and CHANGES [23].

3.3. Terminological Alignment

Before proceeding with the systematization of different risk components—hazards, exposures, and vulnerabilities—it was necessary to establish a shared conceptual and terminological foundation. This step was required to ensure that key risk-related concepts, often defined and operationalized differently across disciplinary domains and research phases, could be consistently understood and applied within a unified Disaster Risk Assessment (DRA) framework. Terminological alignment therefore represents an intermediate but crucial phase in the DRA process. In the context of the Arian Baptistery, it enabled terminology adopted in previous conservation, diagnostic, and monitoring projects to be harmonized and coherently interpreted. This step was not merely theoretical, but explicitly pragmatic: by providing a common conceptual lens, it allowed heterogeneous datasets to be reinterpreted, compared, and integrated in support of risk-based management strategies.

The comparison of definitions among the IPCC [10], UNDRR [11], and ICCROM's ABC Method [3] (Table 2) revealed both terminological convergence and disciplinary divergence among climate science, disaster risk reduction, and cultural heritage conservation. While all three frameworks share a foundational understanding of risk as the interaction between hazard, vulnerability (or susceptibility), and exposure, the way these components are defined and operationalized varies according to disciplinary priorities and underlying values.

While IPCC and UNDRR primarily frame risk in terms of impacts on human, ecological, and infrastructural systems [9,31], the ABC Method translates risk into the expected loss of cultural value [3]. This value-based perspective allows environmental and social pressures to be interpreted within the specific priorities of heritage conservation.

Table 2. Definitions for risk components from the Intergovernmental Panel for Climate Change (IPCC) [10], the UN Disaster Risk Reduction (UNDRR) [11], and from the ABC Method [3].

Definition	IPCC Glossary AR6	UNDRR Components of Risk	ABC Method
Disaster risk	The likelihood over a specified period of severe alterations in the normal functioning of a community or a society due to hazardous physical events interacting with vulnerable social conditions, leading to widespread adverse human, material, economic, or environmental effects that require immediate emergency response to satisfy critical human needs and that may require external support for recovery.	Disaster risk is expressed as the likelihood of loss of life, injury or destruction and damage from a disaster in a given period of time.	/
Risk	The potential for adverse consequences for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of *climate change*, risks can arise from potential *impacts* of climate change as well as human responses to climate change. Relevant adverse consequences include those on lives, *livelihoods*, health and *well-being*, economic, social and cultural assets and investments, infrastructure, services (including *ecosystem services*), *ecosystems* and species.	/	*General definition:* The possibility of a loss of value to the heritage asset. *Measurement definition*: "The expected fractional loss of value to the heritage asset per unit time (e.g., 1% loss of value per century). In the ABC method, this is converted into a 15-point logarithmic scale called the Magnitude of Risk (MR), where MR 15 = 100% loss per year, MR 14 = 10% loss per year, etc."
Hazard	The potential occurrence of a natural or human-induced physical event or trend that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems and environmental resources.	A hazard is 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. Hazards may be natural, anthropogenic, or socio-natural in origin.	"Agent" and "Threat" are synonyms for hazard. Something that has the potential to cause damage or loss of value to the heritage asset.

Table 2. *Cont.*

Definition	IPCC Glossary AR6	UNDRR Components of Risk	ABC Method
Vulnerability	The propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements, including sensitivity or susceptibility to harm and lack of capacity to cope and adapt.	Vulnerability is the human dimension of disasters and is the result of the range of economic, social, cultural, institutional, political, and psychological factors that shape people's lives and the environment that they live in.	The manual does not use the word "vulnerability" as a standalone glossary term, but it explains the concept as susceptibility: "Susceptible parts of the heritage asset" are those inherently sensitive to a given *hazard* (e.g., textiles susceptible to moths, or wood susceptible to humidity fluctuations). Susceptibility alone does not create risk—*exposure* is also needed.
Exposure	The presence of people; livelihoods; species or ecosystems; environmental functions, services, and resources; infrastructure; or economic, social, or cultural assets in places and settings that could be adversely affected.	The situation of people, infrastructure, housing, production capacities, and other tangible human assets located in hazard-prone areas.	Defined through models of events and cumulative processes: For events: "Exposure" is the probability chain of conditions that allow the hazard to reach and affect the asset. For cumulative processes: exposure is "the flux or dose of the agent (e.g., light, pollutants, moisture, pests) reaching the asset." In practice: "Where items are both susceptible to an agent and exposed to that agent, we have that part of the asset at risk (the part that will be affected)."

The ABC Method further operationalizes risk through the Magnitude of Risk (MR) scale, enabling transparent prioritization of interventions. In addition, the ABC framework expands the concept of hazard to include agents of deterioration (e.g., humidity, pollutants, biological activity), which are rarely considered in disaster frameworks but are critical for material conservation [3,68]. This disciplinary shift demonstrates how the translation of terminology adapts risk concepts to the specific vulnerabilities of material culture, enriching rather than replacing broader DRR models.

A key insight from this comparative analysis concerns the treatment of vulnerability.

Although the term "vulnerability" is not explicitly used in the ABC glossary, it is operationally represented through susceptibility. This semantic adaptation highlights the need for interdisciplinary alignment to ensure consistent interpretation across conservation and disaster risk frameworks.

While central to IPCC and UNDRR models, the term does not explicitly appear in the ABC Method. Instead, it is implicitly represented by notions such as susceptibility and sensitivity. Rather than reflecting a conceptual gap, this variation signals a process of semantic adaptation, through which shared principles are recalibrated to fit different dis-

ciplinary languages. This underscores the necessity of interdisciplinary literacy in cultural heritage risk management: conceptual clarity is a precondition for operational coherence.

Integrating these perspectives allows the global consistency of climate-risk frameworks to be combined with the operational precision of conservation-based assessment. In the specific case of the Arian Baptistery, the alignment had immediate operational implications. By translating the concepts of hazard, vulnerability, and exposure into a common structure, existing datasets from SIRIUS [21] and CHANGES [23] were reinterpreted according to standardized definitions. This process made it possible to identify available information (e.g., conservation history, environmental trends, maintenance data) and to highlight critical gaps, particularly regarding exposure metrics and susceptibility to hydrogeological hazards.

Overall, the terminological alignment enabled heterogeneous information from different projects and institutional sources to be integrated into a coherent analytical structure. This operational harmonization supported the subsequent systematization of hazards, exposure, and vulnerability (Sections 3.5–3.7) and ensured that risk components were interpreted consistently within the integrated Disaster Risk Assessment framework.

3.4. Value Assessment

The assessment of heritage values represents a fundamental step in the Disaster Risk Assessment (DRA) process, as it defines the parameters through which potential losses are identified, measured, and prioritized. In the framework of the Arian Baptistry study, value assessment served not only to outline the monument's intrinsic cultural significance but also to interpret its relational and functional role within the wider urban and social fabric of Ravenna.

In accordance with the ABC Method [3,68], "value" was approached as a multidimensional construct encompassing tangible, intangible, and contextual attributes. As carried out in the case study presented in Casarotto and colleagues [69], the Nara Grid—developed from the Nara Document on Authenticity and published by ICOMOS [18,19,70–72]—was employed. This tool offers a structured approach to assessing authenticity across several key dimensions: Form and Design, Material and Substance, Use and Function, Traditions and Techniques, Location and Setting, and Spirit and Feeling. The information summarized in Table A1, Appendix A, is the result of historical-artistic, conservation, and historiographical research described in Section 3.1.

Moreover, the interviews conducted by the research team, together with Shoo's study on perceptions of the significance of Ravenna's UNESCO sites during the 2023 flooding events [73], constitute an important contribution to understanding the social perception of the Arian Baptistery. The Shoo's study draws on ten semi-structured interviews (Oct–Dec 2023), selected through purposive and snowball sampling, involving UNESCO and local institutional actors (site manager, municipal staff), cultural experts/mediators, and stakeholders directly affected by the flood, including representatives from the agricultural sector. The interviews reveal how UNESCO-related discourse and the prioritization of the historic center shape both risk governance and public narratives, potentially contributing to a redistribution of flood risk towards peripheral areas.

To complement Shoo's investigation, interviews were conducted with Baptistry's conservators, custodians, and shopkeepers who experience the Ariani square daily.

Subsequently, it was decided to use the QuiskScan methodology developed by Brokerhof and Bülow [6]. The QuiskScan [6] is a rapid, qualitative risk assessment tool developed to provide heritage institutions with an integrated overview of collection value, vulnerability, and potential risks within a limited timeframe. It was conceived as a pragmatic response to the recognized effectiveness—but practical complexity—of established

collection of risk assessment methodologies, particularly those developed by Stefan Michalski and Jean-Louis Pedersoli [3] within the ABC method.

Within the QuiskScan methodology, the estimation of value is a central analytical step that provides the reference framework for identifying potential losses to a collection. Value is assessed at the level of defined collection units and is expressed in relative, qualitative terms (high, medium, low), rather than as an absolute or monetary measure. This approach acknowledges the multidimensional nature of cultural value and builds on established collection valuation frameworks by integrating cultural-historical, social, and use-related criteria, while also considering attributes such as condition, completeness, provenance, and rarity.

To better contextualize the value estimation criteria, set out in the method, it was decided to compile Nara's Table A1 in Appendix A as a first step, implementing this phase in the workflow suggested by the Brokerhof and Bülow method [6].

The emphasis on relative ranking allows interdisciplinary teams to reach a shared judgment on significance within a clearly defined institutional and contextual scope. By avoiding precise quantification, the QuiskScan reduces methodological complexity while maintaining conceptual consistency with risk-based decision-making models, ensuring that value assessment remains sufficiently robust to support the identification of "vulnerable value" and the prioritization of subsequent risk analysis.

The method was designed for museum collections, which is why the "quantity" section indicates the number of objects present in the identified subcategory of the entire collection considered. In the context explored in this research, almost all of the works are architectural decorations, such as mosaic vaults and fragments of frescoes, while the only semi-mobile element of historical and artistic value is a medium-sized decorated stone baptismal font. For this reason, it had been agreed to express the quantity in square meters of surface area for decorations and architectural elements and a number for the mobile-semi-mobile objects present, accompanied by the dimensional measurements of the object. These dimensional data for movable objects were included from the outset to provide guidance on how they should be packaged and, if required, transported during an emergency away from their conservation setting.

Table 3 shows the estimated value associated with each architectural and movable element into which the monument has been divided. Due to the complexity of the elements present with different quantitative scales (square meters and number of objects), it was not possible to proceed with the graphical visualization of the value diagram and the weighted value diagram as proposed by Brokehof and Bülow [6]. However, Table 3 remains valid and easily understandable.

By analyzing each dimension (artistic, historical, social, and scientific) in all its aspects (Form and Design, Material and Substance, Use and Function, Traditional Techniques and Workmanship, Location and Settings, and Spirit and Feelings), a qualitative value (high, medium, low) was assigned to each part of the building based on the findings set out in the Nara grid.

The Baptistery has undisputed historical and artistic value thanks to the presence of 5th-century mosaics depicting the Baptism of Christ, an exceptional testimony to Arian theology and its political symbolism in Late Antiquity.

The historical and artistic dimensions are closely linked to the monument's identity value, as one of the few surviving expressions of Western Arian Christianity. At the same time, the site possesses strong social and educational values, reinforced through recent participatory initiatives such as *ArianInPiazza* [20], SIRIUS projects [21,23], reframing the Baptistery as an active space for civic awareness, demonstrating that resilience is cultural as much as physical.

Table 3. Assessing the value of the single portions of the Arian Baptistry using the Nara grid aspects and dimensions.

Arian Baptistry							
Portions of the Building	**** Quantity**	**Artistic Value**	**Historic Value**	**Social Value**	**Scientific Value**	*** Current Value**	**Weighting**
Ceiling mosaic	≈80 m^2	H	H	H	H	H	10
Fresco fragments	≈2 m^2	H	H	M	H	H	10
Column with basin	1 element (W *** ++, 1 m H ****, 0.4 m D ***** basin, 0.15 m D column)	M	M	M	M	M	1
Interior brick walls	≈400 m^2	L	M	M	M	M	1
Windows	8 ≈ 16 m^2	L	M	L	L	L	0.1
Door	1 ≈ 5 m^2	L	L	L	L	L	0.1
Pavement	≈120 m^2	L	H	L	H	M	1
Exterior brick walls	≈400 m^2	L	H	M	H	M	1
Tiled roof	≈80 m^2	L	M	L	L	L	0.1

* Current value assessment: 4/4 and 3/4 H = High; 2/4 H, 4/4 M, 3/4 M = Medium; 2/4 M, 4/4 L and 3/4 L = Low. ** Total square meters of the Arian Baptistry (interior and exterior) = (80 m^2 × 2) + (400 m^2 × 2) = 960 m^2. For the mobile objects inside the Baptistry, the number of items is indicated. *** W = weight (qualitatively expressed (1 to 5 +), = ++ heavy). **** H = height (meters). ***** D = diameter (meters).

The numerous modifications that the Baptistery has undergone externally over time have transformed its structure and volume [47–49], which is why the external brick walls have been given a lower quality score than the architectural decorations such as the mosaic in the dome and the fragments of frescoes—signs of the structure's continuous use over the centuries.

The pavement is of recent construction [47], created after numerous archeological excavations carried out in the 20th century to understand the stratigraphy and elevation of the building [47,55,56]. The doors and windows are also from the 20th century, the result of renovations carried out to turn the site into a museum [47]. The roof with internal trusses supporting the mosaic vault has been modified several times over the centuries following water infiltration that was irreversibly compromising the mosaic, using modern manufactured materials such as reinforced concrete [47–49].

Overall, the contextual value further extends beyond the monument's architectural boundaries. Situated in the Piazzetta degli Ariani, the Baptistery contributes to the vitality of an urban area shaped by historical stratification and contemporary practices. Its conservation thus depends not only on material maintenance but also on the sustainability of its surrounding social and economic networks.

It can be stated that the value assessment functioned as a diagnostic and interpretive tool—a bridge between cultural significance and risk prioritization. By quantifying and contextualizing what is most valuable about the Arian Baptistery, it provided the conceptual and operational foundation for the subsequent stages of hazards and exposure systematization, ensuring that disaster-risk management for cultural heritage is guided not merely by technical protection, but by the safeguarding of meanings, functions, and community connections.

3.5. Hazards Identification

This phase of the methodological process involved the systematization of hazards affecting the Arian Baptistery and its surrounding context. This step aimed to translate the conceptual and terminological framework previously defined into an operational structure capable of supporting observation, comparison, and decision-making. The process focused not only on cataloging potential hazards but also on organizing the diverse sources of knowledge that inform risk understanding across scales—from regional statistics to site-specific data.

To this end, the research team updated the Stages of Control proposed by Michalski and Pedersoli [3], integrating them with the Levels of Enclosure developed within ICCROM's FAR Program [5]. The resulting framework (Figure 4) provides a multi-scale grid that links regional, local, and site-specific observations, thereby enabling a contextual reading of risks and enhancing comparability across heritage sites.

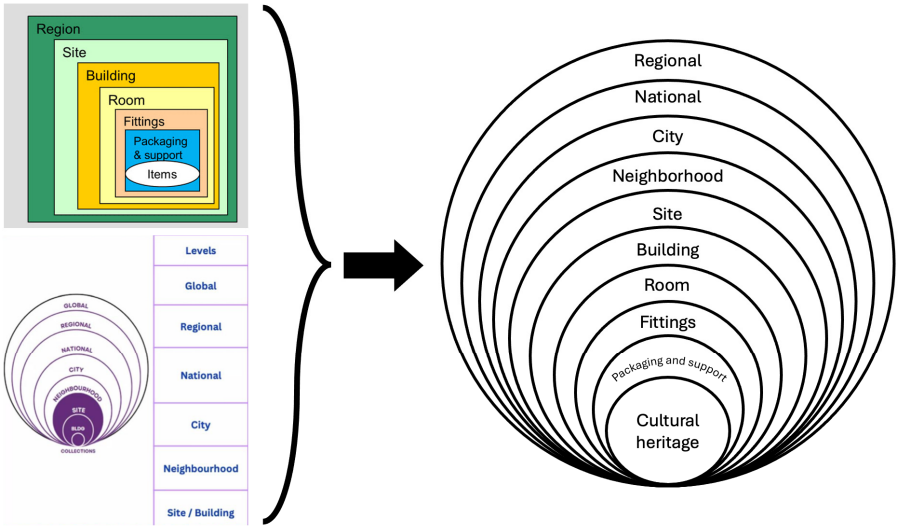

Figure 4. Levels of enclosure. Source: Revised from READY track 1 course material by FAR program ICCROM [5] and stages of enclosure from [3].

Table 4 summarizes the three main categories of knowledge sources employed in this study:

1. Regional statistical data, derived from meteorological and civil-protection databases, providing macro-level information on climatic trends, hydrological events, and urban exposure;
2. Scientific and technical data, including conservation reports, diagnostic analyses, and environmental monitoring outputs related to the Baptistery's materials and structure;
3. Local and experiential knowledge, encompassing the insights of site managers, technicians, and community stakeholders engaged in heritage and emergency management.

For each category, the table defines its relevance for Disaster Risk Assessment (DRA), its level of applicability according to the Levels of Enclosure, and examples of corresponding tools and datasets. This classification supports a structured approach to data collection, allowing the integration of heterogeneous information into a coherent interpretive model.

Table 4. The sources of knowledge for risk assessment. Modified from [3].

	Regional Statistic	Scientific and Technical Knowledge	Local Knowledge
Definition	Statistical data form the fundamental basis for understanding catastrophic risks. Numerous organizations worldwide have developed extensive resources, including online tools, to help non-specialists estimate and anticipate these risks.	The CCI webpage on agents of deterioration [74] offers an introductory overview of the key characteristics of each agent. For a more comprehensive understanding, further reading or consultation with experts—such as those at the institutes responsible for this manual—is recommended.	This type of knowledge requires direct engagement, including meeting with people, conducting discussions and interviews, and carrying out surveys of facilities, collections, and sites. It is important to neither overvalue nor undervalue this source in comparison with the other two. It also encompasses the practical judgment and intuition of the operators.
Use for disaster risk assessment	This is the primary source of information regarding the occurrence and magnitude of rare events.	This source typically provides insights into the vulnerability of heritage assets to cumulative processes and underpins most theoretical frameworks used for risk analysis.	This source typically provides information on the occurrence of common events and the severity of cumulative hazards. It also serves as the primary reference for understanding all five stages of risk control [3] and the assessment of local layers.
Level of applicability	Regional National City Neighborhood (rarely available)	Site Building Room Fittings Packaging and support Material of the cultural heritage	Neighborhood Site Building Room Fittings Packaging and support
Examples	Geographic Information Systems (GIS) Climate data tables Statistical data on natural disasters Government-generated statistics Shared datasets among heritage organizations	Scholarly and technical literature Engineering and architectural design documents Consultations with scientific and technical experts	Facility surveys Documentation of buildings Institutional memory Staff expertise Local residents' recollections Observations of prior damage

The detailed hazards' subcategories—presented in Appendix B, Table A2—is structured according to the Ten Agents of Deterioration framework, developed by the Canadian Conservation Institute (CCI) [74] and adapted to include the most recent Stevance and co-authors [26], list of Hazards and materials from ICCROM's FAR READY Track 1 course [31].

This list does not seek to be exhaustive but to serve as an evolving reference for researchers and practitioners conducting heritage-focused DRA.

Table A3 in Appendix B repeats the subdivision created in Table A2, Appendix B, and associates it with the levels of enclosure—a scale of observation ranging from the general context (the European context) to the furniture within the context under investigation. This

table helps to keep track of the level of involvement and action of the authorities responsible for the hazards identified, thus defining a targeted scale of action and involvement.

A key innovation of this study lies in the expansion and reinterpretation of several agents of deterioration to better capture governance, social, and geopolitical dimensions of risk.

The agent "dissociation" was broadened to encompass human-induced processes linked to political, economic, and socio-cultural factors. These include mismanagement, institutional discontinuity, and decision-making failures that, while not immediately visible, have profound long-term effects on conservation and preparedness. Two specific subcategories were introduced: risks related to management responsibility and risks related to emergency response capacity. Both proved crucial in interpreting the site's response to the 2023 floods in Emilia-Romagna, which exposed significant gaps in coordination and accountability.

The agent "thieves and vandals" was extended to include acts of war and armed conflict. This addition reflects the evolving threat landscape identified by UNESCO and ICCROM, acknowledging that monuments of Outstanding Universal Value (OUV) like the Arian Baptistery may become symbolic or strategic targets.

For the agent "pests", the classification was refined following Caneva [75] to distinguish between microorganisms, insects and rodents, and birds and domestic animals. This broader taxonomy accounts for the hybrid exposure conditions of urban heritage sites, which combine outdoor and enclosed environments and thus face diverse biological pressures not addressed in traditional museum-based models.

A particularly significant reinterpretation concerned the agent "water", traditionally subdivided into natural, technological-mechanical, and accidental events in the original ABC Method. The present study adopts a more reflective approach, informed by the discourse promoted by UNDRR [76] on the semantic pitfalls of the term "natural disaster."

While floods, storms, or earthquakes may originate from natural processes, their destructive impact is largely determined by human vulnerability, poor planning, and insufficient preventive measures. As UNDRR's "Demystifying the Semantic Issue of Natural Disasters" highlights, labeling such phenomena as "natural" risks concealing structural negligence and erasing human responsibility. For the Arian Baptistery, this reframing is especially relevant: the floods of 2023 and 2024 [77–79] demonstrated that the monument's exposure was less a consequence of uncontrollable natural forces than of systemic fragilities in territorial planning and drainage management.

Recognizing this interplay between environmental and human factors repositions risk assessment as both a technical and an ethical exercise—one that demands accountability and proactive governance rather than reactive conservation.

The systematization of risks achieved three major outcomes:

1. A unified multi-hazard framework harmonizing ICCROM, CCI, and UNDRR classifications, ensuring consistency across disciplines and scales by integrating standard tools;
2. An integrated data structure connecting archival, climatic, and observational information specific to the Arian Baptistery, identifying critical vulnerabilities such as hydrogeological exposure, material decay, and institutional fragmentation;
3. A transferable analytical model capable of informing comparative studies and guiding preventive strategies in other World Heritage contexts.

Ultimately, this phase demonstrates that effective risk management begins with the organization of knowledge. By consolidating dispersed data into an interoperable framework, the systematization process not only clarifies the current risk landscape of the Arian Baptis-

tery but also establishes a replicable model for strengthening cultural heritage resilience through informed, evidence-based decision-making.

Table 5 presents the hazards identified for the Arian Baptistery case study, using the tables and research guidance outlined in this chapter. The bibliography provides references to the databases, documents, reports, and sources consulted for each hazard identified. These bibliographies may serve as a starting point for application in other contexts, particularly within the European territory and, more specifically, in Italy.

Table 5. Single hazards identified and the bibliography correlated.

10 Agents	Subcategories	Exposure Rate of the Baptistry for Single Hazards Identified
Physical forces	Catastrophic forces (low incidence, high intensity)	Earthquake risk [80,81]
		Structural vulnerability [82]
	Working forces (high incidence, moderate to high intensity)	Car and vans traffic (from interviews to shopkeepers)
		Restorations [45–49]
		Archeological excavations of the basement [45–50]
		Accidental hurts related to tourists' access (interviews)
	Cumulative forces (high incidence, low intensity)	Natural and anthropogenic subsidence [83–87]
	Low-level forces (variable incidence, low intensity)	Wind erosion [28,88]
Thieves and vandals	Linked to vandalism	Graffiti on the Holy Spirit Church in the square [89,90]
		Neglect of the square [91–95]
	Linked to security systems	Robberies in the square [96,97]
		Absence of Blue shield sign
		Wooden entrance door
		Malfunction of security camera system
	Linked to armed conflict	Symbolic attack as an UNESCO site
		Proximity to the train station (military target)
Fire	/	Wildfire risk (especially during summer period) [98–101]
		Proximity to green areas [102–104]
		Proximity to the church of Holy Spirit which have a high percentage of wooden structural material and liturgical furnishings
		Heating systems of private houses near the Baptistry
		Gas heating system for outdoor café used in winter
		Short circuit of technological furniture
		Presence or IR lamp as indoor heating system in the Baptistry

Table 5. *Cont.*

10 Agents	Subcategories	Exposure Rate of the Baptistry for Single Hazards Identified
Water	Natural—Climate change and human induced	Land use [83]
		Tsunami risk [101,105]
		Riverine flood [77–79,101,106–111]
		Rainfall flood [77–79,101,106–111]
		Ground-water flood [77–79,101,106–111]
		Consecutive dry days [28,111–114]
		Snowfalls [28,111–114]
		Heavy rainfalls [28,111–114]
	Technological/mechanical	Municipal sewer pipe clogged for heavy rains
		Municipal sewer pipe clogged for lack of maintenance
		Water leaks in the roof [45–49]
	Accidents	Use of fire extinguisher into the Baptistry and fire fighter water pumps
Pests	Microorganism	Indoor algae and cyanobacteria in proximity to floor led lights
		Outdoor algae and bryophytes on the basement
		Dust
	Insects and rodents	Following exceptional flooding events, rodents will be seen emerging from sewer pipes (interviews to shopkeepers)
		Spider nets on the mosaic ceiling
		Organic sediment between tiles causing moss and grass growth on the roof
	Birds, bats and domestic animals	Pigeons on the pontoon holes
Pollutants	Airborne pollutants: atmospheric source and emissive products	Air pollutants [83,115]
		Relevant incident risk [101,113]
	Pollutants transferred by contact	Salt impregnation due to direct contact of the bricks to the soil moisture
	Intrinsic pollutants	Metal corrosion of external pipes
Light, UV, IR	/	Daily exposure on sunlight [102]
Incorrect temperature	Temperature too high	Hot consecutive days [28,111–114]
		Tropical nights [28,111–114]
		Difficulties on maintaining indoor microclimate standards
	Temperature too low	Frost days [28,111–114]
		Snowfalls [28,111–114]
		Difficulties on maintaining indoor microclimate standards [116–122]
	Temperature fluctuation	Difficulties on maintaining indoor microclimate standards [116–122]

Table 5. *Cont.*

10 Agents	Subcategories	Exposure Rate of the Baptistry for Single Hazards Identified
Incorrect RH	Damp, over 75%	Disaggregation of mortar with organic and/or gypsum compounds [45–49]
		Corrosion processes in oxidizable metal elements and swelling of the masonry and plaster beneath the mosaic [45–49]
	RH above or below a critical value for the object materials	Difficulties on maintaining indoor microclimate standards [116–122]
	RH above 0%	
	RH fluctuations	Difficulties on maintaining indoor microclimate standards [116–122]
Dissociation	Related to institutional and political context	Management fragmentation [67]
	Related to economic context	Insufficient budget [67,123]
	Related to social and cultural context	Difficulty accessing archives by both internal staff and external scholars' documents relating to the Baptistry [67,73]
		Lack of valorization of the entire context of the square [16,67,124,125]
	Related to the object/building/site	Security cameras deface the monument [126,127]
		Loss of the metal cross affixed to the top of the roof [16]
		Failure to modernize non-renewable energy sources [67]
	Related to elements next to the object/buildings/site	The Baptistry is not fully accessible on all sides from the outside due to superimpositions (gates, private house next to the Baptistry wall) [16,67]
		Restaurants put outside tables too near the Baptistry (interview to custodians)
		Uncertainty property for the Droctulf wall [26]
	Related to staff care	Lack of personnel causes limited openings hours [128]
	Due to action	Low stakeholder involvement (like world heritage managers, local and municipal authorities, local community, researchers, tourism industry, local business and industry and NGO's) [67]
	Management of the responsibility	Management fragmentation [67]
		Management of routine maintenance through fixed-terms contracts [67]
	Related to emergency response of the cultural site	Ambulance had difficulty passing through the narrow street close to the square due to outside tables put in the corner of the street (interviews to shopkeepers)
		Due to failure to update the plan a safety and emergency plan for the architectural asset, interventions during the emergency phase will be delayed as a result of the lack of predefined action plans and designated responsible parties [67]

Additional sources, not available within the scope of the present study but certainly valuable for a deeper understanding of the monument, include microclimatic monitoring aimed at assessing fluctuations in the measured parameters (temperature, relative humidity, illuminance, and concentration of airborne pollutants), as well as the use of diagnostic instrumentation to carry out micro-destructive or non-invasive analyses in order to investigate the constituent materials and the related deterioration phenomena. This approach allows for a more comprehensive assessment of the conservation condition of the object under study, supported by quantitative data in addition to direct visual examination and prior knowledge.

3.6. Exposure Identification

The comparative analysis of the IPCC, UNDRR and the ABC Method (ICCROM) frameworks (see Section 3.3) shows that the concept of *exposure* constitutes a structurally shared component in risk definitions, although it undergoes a significant semantic and operational recalibration when transferred from the domain of Disaster Risk Reduction (DRR) to that of cultural heritage conservation.

Within the IPCC and UNDRR models, exposure is defined as the presence of people, livelihoods, ecosystems, infrastructure, or economic, social, and cultural assets located in hazard-prone areas and therefore potentially subject to adverse impacts. In this perspective, exposure has a predominantly spatial and territorial dimension: it describes the location of human and environmental systems in relation to the distribution of hazards, thus representing a geographical condition of potential interaction between vulnerable elements and damaging phenomena.

In the ABC Method developed by ICCROM, the same concept is reformulated from a conservation and material standpoint. In the case of events, exposure is understood as the chain of conditions that allows the hazard to reach the cultural asset; for cumulative processes, it corresponds to the flux or dose of the deterioration agent (such as light, humidity, pollutants, or biological agents) that effectively affects the asset. In this context, exposure does not merely coincide with the presence of the asset in a risk-prone area, but rather with the degree of physical contact between the damaging agent and the material fabric of the cultural heritage object.

The convergence between these two interpretations occurs through a shift in analytical scale and object of reference. In DRR models, cultural heritage is considered among the exposed "assets" within a broader territorial system, with primary attention given to the socio-economic and functional impacts of damage. In the ABC Method, by contrast, the cultural asset becomes the central system of reference, and exposure is translated into measurable physical parameters, such as light dose, relative humidity fluctuations, pollutant concentrations, or surface wetting time. Through this operational translation, the general concept of exposure used by IPCC and UNDRR becomes applicable at the monumental and material scale: exposure is transformed into a quantifiable variable linked to the processes of interaction between risk agents and matter, and is therefore directly integrable into diagnostic, monitoring, and conservation planning protocols. In this way, conceptual continuity is established between global risk frameworks and conservation practice, not through mere terminological transfer, but through a process of semantic adaptation that preserves the logical structure of risk—namely, that risk cannot exist without exposure—while adapting it to the specific nature of cultural heritage.

This interpretation represents an operational translation developed for the purposes of this study. While alternative readings of the concept of exposure may be adopted within different disciplinary frameworks, the approach proposed here is intended to support its practical application at the monumental and material scale and is therefore presented as a

methodological option open to discussion within the field. Valuable sources of information for assessing exposure rates may be territorial in nature, particularly for certain types of hazards such as floods or earthquakes, or may derive from measurable data obtained through monitoring processes or archival data retrieval. Hazard maps, whether digitized or available through web-GIS platforms, such as those referenced in Table 5, provide information on return periods associated with hazard zonation and therefore contribute to defining exposure conditions. The identification of events that have occurred recurrently over time through archival sources represents another category of exposure-related data. Similarly, the collection of datasets documenting persistent or recurring critical conditions, such as systematic peaks in temperature and relative humidity, accumulated light dose, or the sustained growth of biodeteriogens, provides evidence of continuous or repeated exposure to deterioration agents.

Together, these sources make it possible to characterize exposure not only as a spatial condition, but also as a temporal and process-based phenomenon, thereby strengthening the quantitative basis for risk assessment in cultural heritage contexts.

3.7. Vulnerability Identification

The QuiskScan method [6] can be applied to obtain a qualitative overview of the vulnerability of the individual components of the Arian Baptistery to the main agents of deterioration. Although not formally required within the ABC methodology [3], this step may be included to support a more explicit and structured interpretation of component-level vulnerability and to complement the information derived from the previous analytical phases.

Within this framework, each building component vulnerability could be assessed against the ten main agents of deterioration using a three-level qualitative scale (High, Medium, Low). Values can be estimated using a semiquantitative approach based on available documentation, direct observation, and expert judgment. The results may be recorded in a matrix structure, allowing a comparative reading across components and agents.

The value assessment presented in Table 3 can be integrated with the vulnerability scores in a combined matrix (Table 6), enabling a Value × Vulnerability reading for each component. For clarity, hazards associated with each risk agent may be grouped at the macro-agent level.

The QuiskScan color-coding system [6] translates the Value × Vulnerability combination into a visual hierarchy. This visual scheme is intended as a decision-support tool: it allows for the rapid identification of those parts of the building where high cultural significance coincides with high susceptibility to damage. The matrix should therefore be understood as a methodological device—illustrating how value and vulnerability can be cross-read—rather than as a quantitative risk calculation. It supports subsequent phases of prioritization and targeted investigation without replacing detailed analytical assessments where required.

The integrated Value–Vulnerability reading may highlight a hierarchy of potentially critical components. In the case of the Arian Baptistery, the ceiling mosaic and the wall painting fragments could emerge as the most sensitive elements, since their high cultural value coincides with comparatively high susceptibility to several agents of deterioration, particularly water, relative humidity fluctuations, and environmental pollutants.

Conversely, architectural components such as exterior walls, pavement, and roof—although exposed to environmental stressors—may show a lower relative criticality due to their medium or low cultural weighting and greater material robustness.

Table 6. The vulnerability assessment of the Arian Baptistry portions. Scheme modified from [6]. I Physical forces, II Thieves and vandals, III Fire, IV Water, V Pests, VI Pollutants, VII Light-UV-IR, VIII Incorrect temperature, IX Incorrect relative humidity, X Dissociation. Total square meters of the Arian Baptistry (interior and exterior) = (80 m^2 × 2) + (400 m^2 × 2) = 960 m^2.

Arian Baptistry		Value Assessment		Vulnerability to Agent of Deterioration									
Portions of the Building	**Quantity**	**Current Value ***	**Weighting**	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**
Ceiling mosaic	≈80 m^2	H	10										
Fresco fragments	≈2 m^2	H	10										
Column with basin	1 element (W ** ++, 1 m H ***, 0.4 m D **** basin, 0.15 m D column)	M	1										
Interior brick walls	≈400 m^2	M	1										
Windows	8 windows ≈ 16 m^2	L	0.1										
Door	1 door ≈ 5 m^2	L	0.1										
Pavement	≈120 m^2	M	1										
Exterior brick walls	≈400 m^2	M	1										
Tiled roof	≈80 m^2	L	0.1										

* Current value assessment: H = High; M = Medium; L = Low. For the mobile objects inside the Baptistry, the number of items is indicated. ** W = weight (qualitatively expressed (1 to 5 +), = ++ heavy). *** H = height (meters). **** D = diameter (meters).

This integrated reading illustrates how prioritization can shift when value and vulnerability are considered jointly rather than separately. The framework helps redirect attention from the overall building envelope to limited but highly significant decorative surfaces, suggesting where preventive conservation measures and emergency planning efforts could be concentrated.

Furthermore, high vulnerability levels associated with the dissociation category suggest that organizational and management conditions—already identified in the stakeholder analysis—should be considered as a substantial component of the overall risk profile. The framework therefore supports a systemic interpretation of risk, in which material fragility and governance conditions jointly define priority areas for intervention.

4. Conclusions

This study set out to build the knowledge base required to undertake Disaster Risk Assessment (DRA) for the Arian Baptistery in Ravenna. By integrating archival, technical, and experiential sources, dispersed information was organized into a coherent operational structure through five complementary steps: context analysis, stakeholder mapping, terminological alignment, value assessment, and risk components identification.

A first key outcome concerns value assessment, which clarifies what is at stake—historical-artistic and spiritual significance alongside contextual and social functions—ensuring that risk prioritization is anchored in the attributes that the community and the World Heritage designation aim to safeguard.

A second outcome is the systematization of hazards through the integration of ICCROM/CCI heritage-focused categories with the UNDRR multi-hazard perspective.

This process resulted in an interoperable classification framework that supports observation, comparison, and decision-making across institutional and disciplinary domains.

Three main contributions emerge from the study. First, the research demonstrates that effective DRA for cultural heritage begins with knowledge organization. The consolidated baseline—represented by the tables, figures, and updated taxonomies presented in the paper—translates heterogeneous records (historic interventions, diagnostic data, environmental information, and governance conditions) into comparable units across scales. In particular, the Value–Vulnerability matrix (Table 6) provides a concrete operational output, enabling the identification of priority components where high value coincides with high susceptibility. In the Arian Baptistery case, this analysis highlighted the ceiling mosaic and the fresco fragments as the most critical elements, indicating the need to concentrate preventive conservation measures and emergency preparedness on these limited but highly significant surfaces.

Second, the alignment of key terms (hazard, vulnerability/susceptibility, exposure, and risk) between IPCC/UNDRR frameworks and the ABC Method establishes a shared vocabulary that preserves conservation specificity while remaining compatible with climate and disaster risk reduction planning. This alignment proved operationally relevant for reinterpreting existing datasets (e.g., SIRIUS) and for preparing the application of quantitative risk metrics such as the Magnitude of Risk.

Third, the expanded categorization of agents—particularly the reframing of dissociation to include governance and responsibility issues, the inclusion of conflict within the thieves/vandals category, the refined taxonomy of pests, and the critical reinterpretation of water hazards—captures institutional and socio-environmental drivers that strongly influence risk conditions at UNESCO urban sites. In the case study, this expanded interpretation made it possible to identify governance fragmentation, ownership constraints, and limited coordination among institutional actors as significant components of the dissociation risk, demonstrating that organizational conditions represent a major driver of overall vulnerability.

Overall, the application of the integrated framework produced a shift in risk interpretation. Rather than identifying only material fragilities, the analysis revealed a systemic risk configuration in which highly valuable decorative elements coexist with governance fragmentation, accessibility constraints, and environmental pressures. This combined reading would not have emerged from separate value, hazard, or vulnerability assessments, and provides a more operational basis for defining priorities and intervention strategies.

The knowledge structure developed in this study is intended to support the subsequent phases of the Disaster Risk Management (DRM) process, including the formulation and quantification of risk scenarios within the ABC methodology. Without this preparatory structuring, risk statements may remain incomplete or inconsistent, as hazard, vulnerability, and exposure information may be fragmented or misinterpreted.

The analysis also highlights key gaps to be addressed prior to full DRA/DRM implementation:

- Data and monitoring: continuous site-specific environmental and structural monitoring (microclimate, moisture pathways, vibration), standardized exposure metrics, and shared data registers;
- Governance and preparedness: a coordinated emergency plan with clear responsibilities and integration with municipal risk scenarios and exercises;
- Methodological adoption: testing a hybrid ABC–IPCC/UNDRR workflow for quantified risk (including uncertainty handling), with periodic updates linked to maintenance cycles and resource planning.

Two limitations should be acknowledged. The present phase relies primarily on existing documentation, and quantitative risk estimation has been scoped but not yet implemented. Moreover, although the framework is designed to be transferable, its parameters should be calibrated for other assets and institutional contexts before broader urban-scale application.

By focusing on what needs to be known, verified, and connected before modeling, the study identifies knowledge organization as a prerequisite for credible and operational Disaster Risk Assessment. The Arian Baptistery case demonstrates that this preparatory phase enables the identification of priority components, governance-related vulnerabilities, and system-level risk drivers, representing the essential first step toward evidence-based, coordinated, and actionable Disaster Risk Management in World Heritage urban contexts.

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Abbreviations

The following abbreviations are used in this manuscript:

AAR	Archivio Arcivescovile di Ravenna
ARPAE	Regional Agency for Prevention, Environment and Energy of Emilia–Romagna
$ASCR_A$, *Atti Com.*	Archivio di Stato di Ravenna, *Atti Comunali*
ASR_A, *Prefettura*, A.G.	Archivio di Stato di Ravenna, fondo *Prefettura*, Archivio generale
BCR, *CRM*	Biblioteca Classense di Ravenna, fondo *Carteggio Ricci-Monumenti*
CCI	Canadian Conservation Institute
CO_2	Carbon Dioxide
DRA	Disaster Risk Assessment
DRR	Disaster Risk Reduction
DRM	Disaster Risk Management
HR	Relative Humidity
ICCD	Central Institute for Cataloguing and Documenting Cultural Heritage
ICCROM	International Centre for the Study of the Preservation and Restoration of Cultural Property
ICOMOS	International Council on Monuments and Sites
INGV	Italian National Institute of Geophysics and Volcanology

IPCC	Intergovernmental Panel on Climate Change
IR	Infrared Radiations
ISO	International Standard Operation
MR	Magnitude Risk
OUV	Outstanding Universal Value
PM	Particulate Matter
SDG	Sustainable Development Goals
SBAP, *AD*	Soprintendenza per i Beni Architettonici e Paesaggistici di Ravenna, Archivio Disegni
SBAP, *AF*	Soprintendenza per i Beni Architettonici e Paesaggistici di Ravenna, Archivio Fotografico
SBAP, *AS*	Soprintendenza per i Beni Architettonici e Paesaggistici di Ravenna, Archivio Storico
SBAPRa	Soprintendenza Archeologia, Belle Arti e Paesaggio per le province di Ravenna, Forlì-Cesena e Rimini
UNDRR	United Nation Office for Disaster Risk Reduction
UNESCO	United Nations Educational, Scientific and Cultural organization
UV	Ultraviolet Radiations

Appendix A

This section shows the Nara grid [18,19] compiled with information found in the literature and through interviews with various stakeholders (from staff responsible for the conservation and maintenance of the site to shopkeepers operating their businesses in the square).

Table A1. The Nara Grid [18,19] for the Arian Baptistry.

Dimension -> Aspects	Artistic	Historic	Social	Scientific
Form and Design	Octagonal baptistery with apses and arched windows; dome mosaics depict Christ's Baptism, the Holy Spirit, John the Baptist, and Apostles around a gemmed throne; north apse fresco with dove, serpents, grotesques, putti, lobster, and lizard [34–37].	Late 5th–early 6th c. (493–526 AD) baptistery, only extant example built for Arian worship under Theodoric [34–37,40–44]. Severe modification had been made over the decades, alternating the conjuctions with the other monuments of the square [16,50].	Arian-period monument reflecting Theodoric's architectural and iconographic models; parallels with Neonian and Roman-Mediterranean traditions [40–44,51].	Coherent late antique baptistery preserving Arian iconography despite later functional changes and restorations [129–138]. Scientific studies had tried to establish the original asset of the Baptistry in conjuction with the Holy Spiriti Church and the wall of Droctulf [16,20,50].
Material and Substance	Brick structure with reused materials; dome mosaics executed with period-typical tesserae [45–49]. During the restoration carried out by Felice Kiebel [45–49], two of the apostles' figures were almost entirely reconstructed, and several existing lacunae were filled.	Materials consistent with 5th–6th-century building and decorative practice [45–50]. Extensive restorations done modified the bedding mortars and tesserae originally used [45–49]. The external appearance of the Baptistry severely change during the 20th century [139–151].	In the early twentieth century, Superintendent Corrado Ricci promoted an extensive restoration campaign aimed at removing post–Late Antique accretions from Ravenna's principal monuments, thereby contributing to the construction and enhancement of the city's image as an emblematic center of Byzantine mosaic art [52–54].	Archival and analytical studies confirm 5th–6th-century materials, distinct from later additions [152–154].

Table A1. *Cont.*

Dimension -> Aspects	Artistic	Historic	Social	Scientific
Use and Function	Built for Arian baptism under Theodoric; converted to Orthodox rite (557–570 AD) as Santa Maria in Cosmedin; later used by Theatine clerics and the Confraternity of the Cross; state property since 1914 [25,26,32]; UNESCO inscription 1996 [124,125].	Same functional evolution from Arian to Orthodox use; later ecclesiastical reuses and state ownership [40–44,50].	State and UNESCO property open to the public (Mon–Thu 09:00–12:00; Fri–Sun 09:00–17:00) [32]. The Baptistry is currently visited by visitors from all over the world [123].	Original baptismal use inferred from layout, dome mosaics, and sources; now a protected cultural asset [50,51,82,83].
Tradition, Technics, and Workmanship	Traditional Arian-era construction and mosaic techniques; octagonal plan and gold-background mosaics with concentric apostolic bands reflect Arian liturgy and Ravenna–Milan typology [40–44].	Techniques and execution consistent with late-5th/early-6th-century practices [34–37]. Large modifications and restorations had been executed internally and externally [45–49]	Craftsmanship and decoration correspond to intended function and patronage. Severe modification had been made over the decades, alternating the conjunctions with the other monuments of the square [16,50,151,152]	Documentary evidence confirms 5th–6th-century methods, distinct from modern restorations [16,45–49].
Location and Setting	Situated in the Arian square, Ravenna, near the Church of the Holy Spirit and the Wall of Droctulf; partially enclosed by modern buildings (Palazzo Strocchi and private residence), affecting original spatial context [26,67].	Lost visual and functional connection with adjacent Church of the Holy Spirit and Wall of Droctulf [50].	Enhances the surrounding monumental complex, attracting visitors and supporting local cultural activity; studied in the 2013 *ArianInPiazza* exhibition [16,20].	Spatial relations with adjacent monuments analyzed (2013–2015) to inform conservation and access policies [16].
Spirit and Feelings	Sole surviving baptistery of Arian worship; plain exterior contrasts with richly decorated dome.	Key monument shaping Ravenna's cultural identity and artistic experimentation in mosaic art.	Reflects its original role as an Arian baptismal space, later reinterpreted as civic heritage. A monument of strong identity significance for the citizens of Ravenna [73] and a symbol of national identity.	Urban regeneration and enhancement projects transformed the Arian square into a vital cultural and touristic area [16,84].

Appendix B

This section presents a detailed exploration of the sub-classification system developed from the framework initially proposed by Michalski and Pedersoli [74].

The following work results from the integration of the updated list of hazards classified by UNDRR [11] and Stevance and colleagues [31], combined with insights drawn from the READY Track 1 course organized by the FAR project of ICCROM, as well as the bibliography produced by Tandon [5].

The proposed Table A2 does not claim to be exhaustive; rather, it aims to provide guidance and support for those undertaking Disaster Risk Assessments (DRA) for cultural heritage, by encouraging critical reflection on the proposed and expanded categories.

Table A3 repeats the hazard classification created in Table A2 and combines the levels of enclosure proposed in Section 3.5 to investigate the monument on different scales, from the macro-territorial level down to the plant engineering level.

Table A2. Subcategories renovation of the ABC agents of deterioration [74].

10 Agents	Subcategories	Single Agents
Physical forces	Catastrophic forces (low incidence, high intensity)	Earthquake War and vandalism (breakage) Shipment disaster Extreme handling hazards Floor collapse Roof collapse
	Working forces (high incidence, moderate to high intensity)	Handling (for photo shoot, installation, crating. . .) Transit (in-house) Shipment (loading, unloading, cargo transfer) Gravitational loads (distortions compressing) Construction vibrations Excavation
	Cumulative forces (high incidence, low intensity)	Shipping Gravity (improperly designed supports or lead to distortion or breakage or objects) Subsidence
	Low-level forces (variable incidence, low intensity)	Building vibration (occupant activities, mechanical equipment, road traffic) Construction vibration (controlled blasting, pile driving. . .) Acoustic sources (audible and sub-audible, air-borne) Vibration (loud music)
Thieves and vandals	Linked to vandalism	Theft Vandalism Civil Unrest Neglect of heritage Security threat
	Linked to security systems	Absence of signs (prohibitions) Absence of camera (CCTV-Closed-circuit television cameras) Hedges not taller than 0.4 m Trees not taller than 6 m Presence of security lighting Presence of security at the entrance Presence of guardians (night) Presence of custodians (day) Presence of security lightning enclosed in vandal-proof casing Absence of screen or steel bars on windows/doors Roof opening not locked and alarmed Fragile material of the entrance (wood) Record keeping of staff access during and after opening hours/sign-in sheet/electronic tracking system Barriers (plastic/glass) against attack (shoots, dirt. . .) Psychological barriers for exhibition (cord, signs, raised platforms. . .) or PIR system (infrared motion detectors) Absence of non-removable, tamper-proof security screws, locks, brackets and hanging devices that can only be loosened or removed by using customized implement Loading bay (shipping/receiving), offices, labs, studios, server room, depos, storages, security control room. Controlled and restricted area

Table A2. *Cont.*

10 Agents	Subcategories	Single Agents
Thieves and vandals	Linked to armed conflict	Armed conflict Warfare, drone/missile attacks Air/land attacks Landmines Unexploded ordnance Incidental fire Looting International targeting Terror attack Shooting Bombing Cyberattacks Operational disruption Spread misinformation Data breach Compromised security systems Fire and arson Symbolic attack Neglect of heritage
Fire		Lightning Wildfires Accidental fire Fire due to relevant incidence (linked to factories) Proximity to forest Bush or grass fires Exposure to adjacent burning buildings Trash containers Electrical sources (overloaded wiring, electrical panels, electric equipment and appliances and HVAC system (heating/ventilation/air conditioning) systems Proximity of combustible materials to heat source as portable heaters Open flames (such as candles and food warmers used during catered events) Construction and renovation activities such as work (welding, paint removal, cutting. . .) the use of casting materials that heat Improper use, storage, and/or disposal of flammable liquids such as thinners Smoking materials Gas leaks Arson Building material (non-fire resistive) Older heating system and electric wiring Large open staircase that allows fire and smoke to spread Concealed voids above ceilings, below floors and behind walls Basement and attics non compartmented Openings around installed or removed ductwork; electrical pipes not fire resistive Material where the penetrations pass through floors, ceilings and walls Cleaning supplies, solvents, paints, waxes inappropriately stored

Table A2. *Cont.*

10 Agents	Subcategories	Single Agents
Water	Natural—Climate change and human induced	Flood Flash flood Slow rising flood Rainstorm Windstorm Hurricane Sleet and ice storm Avalanche/glacier burst High water table Tsunami Spring melt or run-off Ice jam Located by or close to a body of water Water scarcity Droughts
	Technological/mechanical	Sewer failure/back up Sprinkler system malfunction Broken water line (freezing or construction) Leaking roof Leak from heating system, Ventilation system or air conditioning system Overflowing sinks (toilets, drains) Blocked eaves Careless use of water during special events, social function Use of water during construction and renovation/maintenance/restoration Poorly/improperly insulate building Storm drains/sewer (unable to cope)
	Accidents	Water used in cleaning up chemical spills Water damage due to fire (sprinkler system discharge or/and fire hoses)
Pests	Microorganism	Fungi Mold Bacteria (heterotrophic and autotrophic) Algae and cyanobacteria Lichens Bryophytes Vascular plants
	Insects and rodents	Insects (specify types) Arthropods (specify types) Rodents
	Birds, bats and domestic animals	Birds (specify which type) Nest of birds Bird guano deposits Absence of barriers protective clothing for birds Bats Dejections of domestic animals Human dejections

Table A2. *Cont.*

10 Agents	Subcategories	Single Agents
Pollutants	Airborne pollutants: atmospheric source and emissive products	Ozone Hydrogen sulphide Carbonyl sulphide Sulphur dioxide Nitrogen dioxide Particles (soot, salts) PM 2.5 PM 10 Sulphur-based gases Organic acid (carboxylic acids) Relevant incidence (linked to factories) Release of toxic chemicals Smoke (from a fire) Health hazards Power outages
	Pollutants transferred by contact	Plasticizer form PVC (polyvinyl chloride) Sulphur compounds from natural rubber Staining materials from wood (knots) Viscous compounds from old polyurethane foams Paper clips on paper Adhesives on object Oily material from leather Acids from some mineral specimens Fatty acids from people or from greasy objects like skin/leather Salts impregnation during burial or immersion in seawater Impregnation of residue of cleaning agents Impregnation of salt from brick or stone floor of foundation
	Intrinsic pollutants	Composite object having harmful compounds (alum, iron, gall ink, corrosion copper in contact with leather, adhesive tape 'original') Composite objects made of sulphur-based compounds and metals Acetic acid Nitrogen oxide compounds from hydrolysis of cellulose acetate and cellulose nitrate
Light, UV, IR		Fading by natural light (all spectrum) Fading by artificial lights (UV, IR and VIS compound of the spectrum) UV (natural and artificial) which caused yellowing, chalking, weakening, disintegration of materials IR heats the surface (linked to incorrect temperature)
Incorrect temperature	Temperature too high	Increasing of number of hot days and cumulative exposure which cause physical damage (brittle) Heatwave Cumulative chemical damage from all exposures to temperature that is high enough to cause rapid decay Physical damage during events when the temperature is too high Biological damage during events when temperature is high enough for growth
	Temperature too low	Temperature too low to cause physical damage (brittle)
	Temperature fluctuation	Direct physical effect of temperature fluctuations (expansion, shrinkage, fatigue, cracking and conservation of materials)

Table A2. *Cont.*

10 Agents	Subcategories	Single Agents
Incorrect RH	Damp, over 75%	Damp which causes mold Damp which causes mechanical damage Damp which causes colorants bleed
	RH above or below a critical value for the object materials	Critical RH which causes corrosion of material Critical RH which causes glass crizzling and weeping Critical RH which causes minerals to crimple, weep
	RH above 0%	RH above 0% which causes internal chemical disintegration (hydrolysis, dye instability, residual chemicals)
	RH fluctuations	RH fluctuations +/− 40% RH fluctuations +/− 20% RH fluctuations +/− 10% RH fluctuations +/− 5% RH fluctuations which cause flat sheets of paper, film, tape, with an image or data layer may delaminate, fracture or distort permanently RH fluctuations which cause wood or wood assemblies may crack, split, delaminate or distort permanently RH fluctuations which cause paintings or paint layers may crack, delaminate or flake RH fluctuations which cause damages to other organic objects
Dissociation	Related to institutional and political context	The site does not have appropriate conditions for opening to the public. The management of the site is a secondary or tertiary responsibility of the staff. There is a coordination protocol between public institutions designated to protect cultural heritage. The protection institution receives technical guidelines and financial support from the government to reduce risks related to heritage. The territory suffers from political instability, weak governance, or conflicts There are shortages of funds, personnel, emergency personnel, lack of communication between departments, unclear rules, decisions made from above, lack of political will, overlapping unclear rules/methodologies Regular monitoring of the state of conservation is not carried out There is no staff dedicated solely to the maintenance of equipment (lighting, pumps, etc.)
	Related to economic context	The site generates income for surrounding businesses. There are no programs to generate additional revenue. There are no subsidies from the community or private individuals to support the archeological site. In emergency situations, there is a fund that is accessible, flexible, and easy to use.
	Related to social and cultural context	Failure to promote the site Cultural heritage is a potential target for warfare (even in the past) The relationship with the community surrounding the site is weak

Table A2. *Cont.*

10 Agents	Subcategories	Single Agents
Dissociation	Related to the object/building/site	Illegally acquired object Small object size (difficult to label) Fragile object (difficult to label) High cultural value Unresolved copyright or ownership issues Object currently not "fashionable" Object valued for uses not common to bulk of collection Object for destructive sampling or destructive research Large numbers of objects High diversity of objects Collection/site/building data from many sources Collection/site/building data digitalized in obsolescence repository Tradition of illegal object acquisition Tradition of illegal object acquisition Overall poor condition of collection Digital media susceptible to obsolescence
	Related to elements next to the object/buildings/site	Other professionals do not understand the value of the cultural context. There are unsafe/abandoned/dilapidated buildings near the archeological site. There are difficulties in accessing the site with emergency vehicles (architectural barriers, narrow roads, etc.).
	Related to staff care	Unregulated or unrestricted access to collection area building sites Staff not aware of legal issues Choice of unstable products or poor systems for catalogs and labels Incomplete or inadequate record keeping Staff not adequately aware of storage organization Poor organization of the collection area building site Other professional's sense of collection values and issue not comprehended Cultural value not understood or appreciated by custodians Unstrained volunteers (staff not aware of correct procedures
	Due to action	Misplacing objects Removing identifying labels or tags from object Recording object and collection data in an illegible manner Recording object and collection data in non-permanent manners Errors in transcription
	Due failure to act	Legal requirements to continue ownership Electronic records not transcribed or migrated to ensure continued accessibility Object identification is not permanent Object non adequately identified to prevent discarding Object not tracked closely enough to prevent their loss Activities of maintenance staff not proscribed enough
	Management of the responsibility	Collection on held in dedicated spaces Collection care is secondary or tertiary responsibility of staff Insufficient part-time staff Staff not trained in collection management Priority for due diligence much lower than priority for product delivery Failure to foster appreciation values

Table A2. *Cont.*

10 Agents	Subcategories	Single Agents
Dissociation	Related to emergency response of the cultural site	There is no written emergency protocol for cultural heritage for specific risks. No drills are carried out to test procedures for securing cultural heritage. There is no list of priorities for the most significant evidence. there are no means/tools owned by the protection agency to deal with emergencies There is no designated place to store assets removed from the cultural context The roof has not been reinforced to withstand major weather events

Table A3. The diagram used to track and record data relating to the various hazard agents shown in Table A2 is displayed according to the level of enclosure affecting the context examined. This subdivision helps to keep track of the level of territorial incidence of the various risk agents.

Levels of Enclosure -> 10 Agents	Subcategories	Europe-Italy	Emilia-Romagna	Ravenna	Arian Square	Baptistry	Furniture in the Baptistry
Physical forces	Catastrophic forces (low incidence, high intensity) Working forces (high incidence, moderate to high intensity) Cumulative forces (high incidence, low intensity) Low-level forces (variable incidence, low intensity)						
Thieves and vandals	Linked to vandalism Linked to security systems Linked to armed conflict						
Fire	/						
Water	Natural—Climate change and human induced Technological/mechanical Accidents						
Pests	Microorganism Insects and rodents Birds, bats and domestic animals						
Pollutants	Airborne pollutants: atmospheric source and emissive products Pollutants transferred by contact Intrinsic pollutants						
Light, UV, IR	/						
Incorrect T	Temperature too high Temperature too low Temperature fluctuation						
Incorrect RH	Damp, over 75% RH above or below a critical value for the object materials RH above 0% RH fluctuations						

Table A3. *Cont.*

Levels of Enclosure -> 10 Agents	Subcategories	Europe-Italy	Emilia-Romagna	Ravenna	Arian Square	Baptistry	Furniture in the Baptistry
Dissociation	Related to institutional and political context Related to economic context Related to social and cultural context Related to the object/building/site Related to elements next to the object/buildings/site Related to staff care Due to action Due to failure to act Management of the responsibility Related to emergency response of the cultural site						

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