

# Digitization and Cultural Heritage Conservation: A BIM-Based Approach to Seismic Monitoring in the Basilica of Santa Maria degli Angeli

CLAUDIA CERBAI, FABIO BIANCONI, MARCO FILIPPUCCI and NICOLA CAVALAGLI,  
University of Perugia, Italy

---

To safeguard Italy's architectural and cultural heritage, particularly at risk given its seismic vulnerability, this research explores the integration of advanced digital technologies, including Building Information Modeling (BIM) and digital survey methodologies, to improve the knowledge, documentation, and conservation of historic sites. Using the Basilica of Santa Maria degli Angeli in Assisi as a case study, the research demonstrates how digitization processes applied to cultural heritage can support the protection and preservation of historic structures by incorporating intervention records and seismic monitoring data directly into the building's digital representation. Conducted by the University of Perugia's Department of Civil and Environmental Engineering in collaboration with the "Provveditorato Interregionale alle OO.PP. per la Toscana, le Marche e l'Umbria" (Interregional Directorate of Public Works for Tuscany, Marche, and Umbria), the study highlights the potential of BIM to serve as a comprehensive information-management tool for cultural heritage. The project aims to provide public administrations with enhanced capabilities for safeguarding and managing heritage assets.

---

## Keywords:

Digitization of the architectural heritage, cultural heritage protection, cultural heritage documentation, seismic vulnerability, BIM environment.

## SDH Reference:

Cerbai, Claudia, Fabio Bianconi, Marco Filippucci, and Nicola Cavalagli. 2025. "Digitization and Cultural Heritage Conservation: BIM-Based Approaches to Seismic Monitoring in the Basilica of Santa Maria Degli Angeli." *Studies in Digital Heritage* 9 (1): 129–146.

<https://doi.org/10.14434/sdh.v9i1.41856>

## 1. INTRODUCTION

The crucial challenge of protecting the architectural and cultural heritage, made even more urgent by the country's seismic vulnerability, finds in the Building Information Modelling (BIM) approach a new lever that supports knowledge, documentation and preservation of what needs to be managed by the public administration (Bianconi and Filippucci 2023). The digitization processes (Bianconi and Filippucci 2021) not only enhance the comprehension of historical structures (Dore and Murphy 2012) but also constitute indispensable prerequisites and tools for the continuous monitoring and planning

---

Author's address: Claudia Cerbai, Fabio Bianconi, Marco Filippucci and Nicola Cavalagli, Department of Civil and Environmental Engineering, University of Perugia, Piazza Università 1, 06123 Perugia, Italy; email: [claudia.cerbai@dottorandi.unipg.it](mailto:claudia.cerbai@dottorandi.unipg.it), [fabio.bianconi](mailto:fabio.bianconi), [marco.filippucci](mailto:marco.filippucci), [nicola.cavalagli@unipg.it](mailto:nicola.cavalagli@unipg.it)

© 2025 by the authors; licensee Studies in Digital Heritage, IU, Bloomington (IN), USA. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution License (CC BY-NC 4.0)

of conservation and restoration interventions case of unforeseen external catastrophes, such as earthquakes. This is evidenced by the damage caused to the Basilica of San Francesco in Assisi during the 1997 earthquake (Belardi et al. 2004), as well as the collapse of the central body of the Basilica of Santa Maria degli Angeli in Assisi in 1832 (Di Boveglio and D'Isola Maggiore 1834).

The present research is concerned with the case of Santa Maria degli Angeli, tracing its history up to the current restoration work. The objective is to define a new representation methodology, realized in a BIM environment, which will protect, safeguard and document the emblematic Franciscan architectural complex.

The study is part of a project carried out by the University of Perugia's Department of Civil and Environmental Engineering in collaboration with the "Provveditorato Interregionale alle OO.PP. per la Toscana, le Marche e l'Umbria" (Interregional Directorate of Public Works for Tuscany, Marche, and Umbria). It begins with an examination of the transition from digital survey to modelling (Bianconi et al. 2019) and aims to establish an effective methodology for the management of information in a BIM environment (Bianconi et al. 2023). This will facilitate the heritage management process in public administrations (Duni 2008, Martines 2018).

The aim of this study is to present a management model, which in this context will become an HBIM (Murphy et al. 2009), capable of integrating information. In this instance, the integrated digital survey assumes the form of object that interpret shapes and store multiple information. Particular attention is paid to the representation of information regarding the seismic deformations of the structure, taking to account the ongoing research activity on the property (Cavalagli et al. 2017) and the restoration needs in some areas of the Basilica. Indeed, the restoration work is currently underway with the reinforcement of the roofing in the apse area and the restoration of the correct structural behavior of the delicate drum-dome system.

Once these phases have been completed, work will move to the main front of the Basilica with the objective of restoring the necessary stability to such a grandiose element.

This research project is concerned with the study and representation of the Sanctuary's restoration work following the earthquakes of 1832 and 1997. It also considers the monitoring system that has been installed inside the Basilica to control its structural response to dynamic stresses. The aim is to create a global vision of the property, which is fundamental for the understanding and future management of the heritage by public administration (Bianconi et al. 2021).

## **2. THE CASE STUDY OF THE BASILICA OF SANTA MARIA DEGLI ANGELI**

The Basilica of Santa Maria degli Angeli dominates the area at the foot of Assisi to protect and exalt the holy places of St Francis's life, who chose the Chapel of the Porziuncola (Fig. 1), currently the heart of the Basilica, as the fixed point of the Order (Scotti 1989, Romanini 1989).



*Figure 1. The Basilica of Santa Maria degli Angeli and its heart, the Porziuncola.*

Indeed, Pope Pius V, responding to the ideologies born with the Trento's Council, which brought back the lives and acts of the Saints as exemplary models of Christian conduct, decided to build a reliquary architecture in honor of St. Francis's original place of devotion, protecting and exalting the Mother Church of the Franciscan Observance (Cerbai 2024).

In 1568, Galeazzo Alessi was charged with designing a basilica that had to be a central reference point in the territory, capable of guiding pilgrims to the holy place. The Alessian project made this requirement one of its fundamental principles, giving the Basilica a majestic verticality thanks to the dome, which towers over a unified body. In this way the Sanctuary became a tangible sign of the religious presence, confirming itself as a fundamental crossroads of the Umbrian territory.

Over the years, the Basilica has been subjected to numerous events that have disturbed its static stability. In addition to seismic events, the structure has always been affected by the subsidence of the foundations, which began in the earliest period of its life. The soil on which the foundations rest, although of good quality, has always had serious problems to cope with the considerable size of the Basilica due to its heterogeneity, causing differentiated and considerable subsidence; that was also aggravated by the long period of time that elapsed between the beginning of construction and its conclusion (which lasted more than a century). At present, the instabilities have long since subsided and the structure has stabilized through the redistribution of stresses (Capaldini 1999).

Also, because of this instability, the façade was identified as one of the critical points in the statics of the building since its construction. In fact, in 1674, when the sanctuary was still unfinished, the first signs of the main façade's settling began to appear. This, which was probably not built thick enough due to lack of finances, was leaning towards the square. It was decided to reinforce the lower order and demolish the second order to rebuild it, making it thicker.

Later it was partially affected by the collapse caused by the earthquake of 1832, after which it was rebuilt with features like the original façade.

However, the most drastic change to the main façade took place at the beginning of the 1900s, when, after the church's consecration as a patriarchal basilica, the friars felt the need to give Santa Maria

degli Angeli a new image, more majestic, to enhance the splendor of the architectural complex. In 1930 the work was carried out by Cesare Bazzani (Bartelli 1989) (Fig. 2), but this intervention did not help to improve the statics of the building, on the contrary, over time contributed to further inconveniences.



Figure 2: The evolution of the Basilica façade. From left: the original façade<sup>1</sup>, Luigi Poletti's intervention<sup>1</sup>, the new front by Cesare Bazzani.

### 3. EARTHQUAKES AND DAMAGE TO THE BASILICA OF SANTA MARIA DEGLI ANGELI OVER THE YEARS

Between the end of 1831 and the beginning of 1832, Santa Maria degli Angeli was struck by the violent earthquake that shook a large part of Umbria, causing numerous collapses inside the Basilica. The main damage was to the central body, with the collapse of the nave and the left aisle (Fig. 3).

The dome, despite the evident damage caused by the tremors, miraculously resisted structural collapse protecting the Porziuncola.

While no further collapses occurred after 1832, the Basilica has been subjected to subsequent seismic events, resulting in extensive structural damage. Following the 1997 earthquake, which affected the entire region, the necessity for new static and structural consolidation work became apparent.

#### 3.1 The restoration of the Basilica after the damage caused by the 1832 earthquake

After the collapse of the central body, the restoration work began with the consolidation of the remaining pillars and the construction of a protective structure around the Porziuncola, which was 'wrapped' in a wooden pyramid. In order to allow the devotees to use at least part of the Basilica, the remaining parts were immediately secured and protected from the rest of the collapsed complex (Vignoli 1989).

<sup>1</sup> Credit: L.F Gili. 1793. Breve ragionamento sopra il conduttore elettrico innalzato per ordine di Papa Pio VI sulla Basilica di Santa Maria degli Angeli di Assisi. Rome

<sup>1</sup> Credit: F. F. Mancini e A. Scotti (ed).1989. La Basilica di Santa Maria degli Angeli. Electa Editori Umbri Associati. Perugia. vol. 1

In 1836, Pope Gregory XVI named Cardinal Rivarola as apostolic commissioner for the restoration of the Basilica and he chose Luigi Poletti as engineer and director of works.

To reduce the weight of the roof over the vaults, Poletti eliminated further loads in the nave by adopting the concept of trusses. Since it was not possible to use a classical truss, due to roof's ridge would have been higher than the impost height of the dome windows, a special "lame truss"<sup>2</sup> was designed (Fig. 4). This structure, made of wooden beams and unusually shaped iron rods, wraps around the vault without touching it (Lunghi and Lunghi 1989).



Figure 3: The collapse of the Basilica's nave after the 1832 earthquake [3].



Figure 4: The central body of the Basilica of Santa Maria degli Angeli after Luigi Poletti's intervention<sup>3</sup>.

<sup>2</sup> "capriata zoppa" Translated by the author

<sup>3</sup> Credit: "Prospettiva interna del tempio della Madonna degli Angeli presso Assisi secondo il suo risorgimento". Incision by P. Bertoni in S. Perelli. 1840. Relazione storica sul risorgimento della basilica degli Angeli presso Assisi. Tipografia dell'ospizio apostolico. Rome

The collapse of the nave also affected the façade, seriously damaging the second order, which was demolished. Poletti would have liked to change the original features, "his intention would have been to transform it into a monumental façade with a pronaos of eight columns at the front and two at the side, in the same Doric order as the rest of the building"<sup>4</sup> (Mancini 1989). Due to a lack of funds and Rivarola's opposition to the project, Poletti's idea was rejected and the façade was rebuilt according to Alessi's principles. The first order, which had not been destroyed, remained the original. In the second order, the large central window was replaced by a semicircular lunette, the volutes connected to the first order were raised and the original broken pediment was replaced by a complete triangular pediment. The façade was therefore higher than the original one, also due to the need to hide the excessive height resulting from the new roof structure of the naves, despite the technical precautions taken.

Finally, to deal with the dome damage, the structure was stiffened using three orders of steel rings.

However, these works did not fully protect the basilica, in fact, "after another strong earthquake in 1853, a general fortification of the church with iron chains was devised to prevent further collapses"<sup>5</sup>.

### 3.2 The Basilica from the 1997 restoration until today

Although there have been no other collapses in the Marian Sanctuary since the one in 1832, the structure has been subjected to numerous seismic events over the years, causing widespread instability and damage. For this reason, after the 1997 earthquake that shook the whole of Umbria, the Basilica underwent a new static and structural restoration.

After observing and verifying the structural behavior, the work identified three macro-areas on which intervention was required: the façade, the main body and the dome (Capaldini et al. 1999).

As mentioned in the previous paragraphs, the façade has always been a critical point of the structure, due to its composition, which is too high, too slender and lacks an effective anchorage to the central body, which has always given it a low rigidity and, consequently, an incorrect reaction to external stresses.

The structural deficiencies were exacerbated by the addition of the new façade, designed by Bazzani in 1930, which over time proved to be even more damaging to the structural problems of the Sanctuary. The new façade, characterized by low rigidity, not only failed to limit the deformations of the original structure, instead clung to it in the event of horizontal forces, increasing the overturning of the plane that already conditioned the statics of the element.

In addition, the almost complete absence of effective connections between the two facades and between the facades and the orthogonal masonry made the whole structure exposed to deformation during seismic events.

---

<sup>4</sup> "Nelle sue intenzioni, avrebbe voluto trasformarla in un prospetto monumentale con un pronao di otto colonne di fronte e due di fianco, della stessa ordinanza dorica che regna in tutta la fabbrica" Translated by the author.

<sup>5</sup> "per evitare nuovi crolli, dopo un ulteriore forte terremoto nel 1853, venne ideata una inchivatura generale della chiesa con catene di ferro" Translated by the author [19, p.204]

The works included a general reinforcement of the front by connecting the two façades to the central body and the stiffening of the twentieth-century extension, thanks to the addition of reinforced concrete box structures inside the central pillars, founded on micropiles and made integral with the masonry to which they are attached.

The central body of the basilica consists of three naves and five chapels on either side (Fig. 4).

When the analyses were conducted, the part of the building consisting of the main nave was marked by lesions, while diagonal lesions were found in the side aisles, especially in the left aisle (involved in the collapse of 1832).

In this case, the main cause of seismic deterioration, which can also lead to structural collapse, was attributed to the anomalous distribution of masses in relation to the structural rigidity of the central body: the vault of the central nave, which is more deformable and more massive than the side aisles, generates significant relative movements in the event of seismic stress, which also involve the vaults of the side aisles and the pillars. For this reason, the deformability of the central vault, in relation to the enormous stiffness of the lateral blocks, makes the greatest contribution to the vulnerability of the whole structure.

In the light of these considerations, the work carried out to restore the correct functioning of the structure was limited to compensating, as far as possible, the weaknesses of the structure, some of which could only be remedied by extremely invasive interventions that would distort the current structural and aesthetic scheme of the monument. The works therefore focused on a slight stiffening of the roof slopes and the reinforcement of the vaults, intervention that guaranteed an insignificant increase in the weight of the original structure (Fig. 5).

The work currently underway in the apsidal area, where a complete replacement of the roofing system is planned, is based on the same approach.

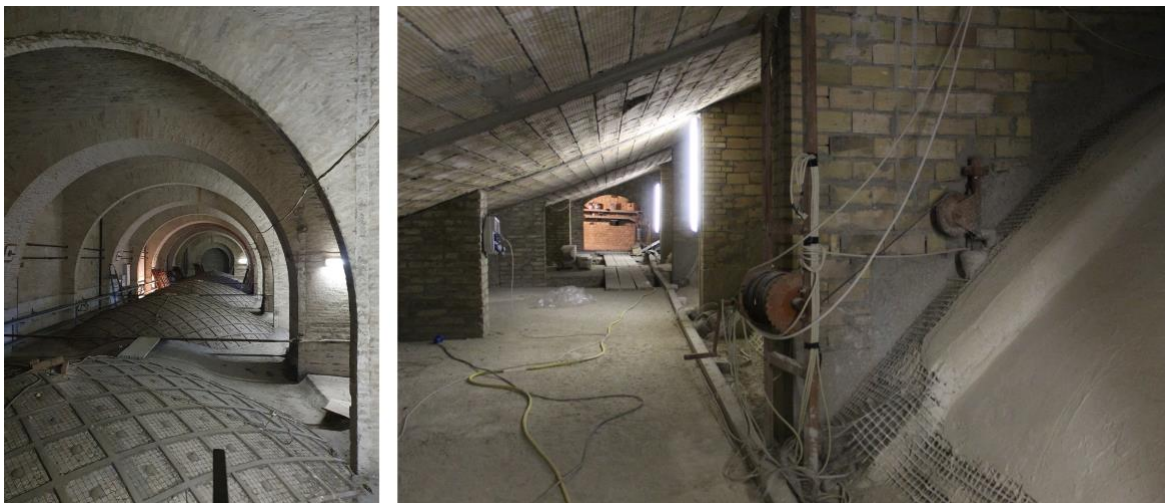


Figure 5: (left) Work on the vaults of the aisles and (right) support structure for the roof of the apsidal area.

Since it has never been seriously affected by seismic damage mechanisms, the roof of the apsidal area is still constructed with walls bearing on the vault of the choir and apse (Fig. 5). The current work has focused on the reinforcement of the vault, using the technology described above, and then continued with the complete removal of the current roof to replace it with the nave's lamellar truss system.

### 3.2.1 The dome

Back to one of the main concepts of the original design of the Basilica, a monumental verticality to stand out in the skyline of the valley of Santa Maria degli Angeli, let's focus on the peculiar composition of the dome system.

To meet this requirement, it was necessary to increase the height of the drum. As a result, the dome no longer conforms to the proportional characteristics that architecture assigns to these structures (Gusella et al. 2012).

The higher elevation of the drum, combined with the reduced structure's thickness of the entire dome, creates a fascinating architectural element, but also a very slender drum-dome system that requires adequate analysis to verify its structural safety.

The structural organism of the dome, including the drum, the arches and the four pillars that support it, forms a masonry organism that is almost completely independent by the rest of the building. In fact, the adjacent structures, such as the choir, transepts and nave, have an autonomous vertical support. Numerous studies have shown that under dynamic stress, the dome structure, which is higher and heavier than the adjacent structures, has a longer period of vibration and greater oscillations than the lower structures. The braking action of the dome body by the surrounding masonry organisms causes damage both to the organisms themselves and to the drum, but thanks to the interference, there is still a dissipation of energy and a limitation of the oscillation amplitude that the dome would assume if it were completely free to move.

The interventions carried out after the 1997 earthquake were aimed at strengthening the dome to enable it to absorb dynamic stresses without suffering damage or failure, by adding external rings to the impost of the spherical part and to the base of the drum.

Over the years, numerous studies have been carried out on the structural response of this part of the architectural complex (Cavalagli and Gusella 2015), which have produced heterogeneous data with varying levels of technicality.

So far, the restoration work currently underway in the Basilica has focused on restoring the proper structural functioning of the drum-dome system and the introduction of new monitoring sensors.



Figure 6: The dome as a landmark of the Porziuncola, graphic reworking by the author.

#### 4. THE SHM STRUCTURAL MONITORING

The Basilica, like many significant architectural heritage complexes, in the last years has been object of structural monitoring activities. SHM (Structural Health Monitoring) systems provide information that can lead to the detection of anomalies in the structural behaviour, thus helping to activate proper interventions before collapse. The main objective is therefore prevention.

The results of the data processing phase are a valuable decision-making tool for those involved in heritage conservation. However, there is currently a lack of communication between those who monitor and those who intervene. The integration of monitoring data, even in real time, in a single digital environment leads to a global view of the architectural complex. Integrating data collection and processing in a BIM environment will lead to more efficient heritage management.

Inside the Basilica, since 2017, there are both static and dynamic sensors, which are continuously recording data of displacements across cracks and vibrations of specific points of the structure.

The static monitoring system is constituted by 6 displacement sensors, 3 LVDTs and 1 laser sensor installed on specific parts of the structure, in particular corresponding to the presence of past damages and on the double façade system (Fig. 7).

The dynamic monitoring system only consisted of 2 piezoelectric accelerometers installed on the base of the dome (Fig. 8).

The vibration data were recorded continuously under operating conditions using a multi-channel system and stored in 30-minute time series (Cavalagli et al. 2016).

The dynamic monitoring system was installed with the aim of studying the evolution of the structure's natural frequencies over time, in order to have an effective system for early damage detection. To achieve this, it is necessary to process the data acquired from the monitoring and to obtain various outputs, either technical, with graphs showing the acceleration data sets, or representative, such as numerical FE models, which allow the actual behaviour of the structure under stress to be visualised and hypothesized.

As part of the ongoing restoration work, it is planned to upgrade the monitoring systems within the drum-dome system with the installation of strain gauge sensors on Diwidag reinforcement bars inserted into the drum masonry and fibre optic sensors in the proximity of the composite material rings. Both new technologies will be linked to the instruments already installed in the Basilica to improve the monitoring system.

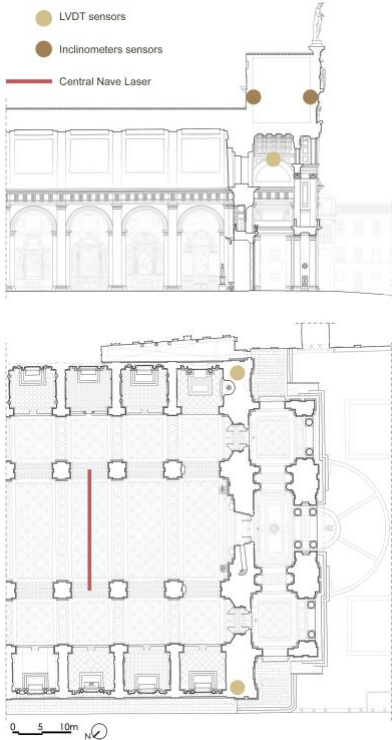


Figure 7: Static monitoring system.

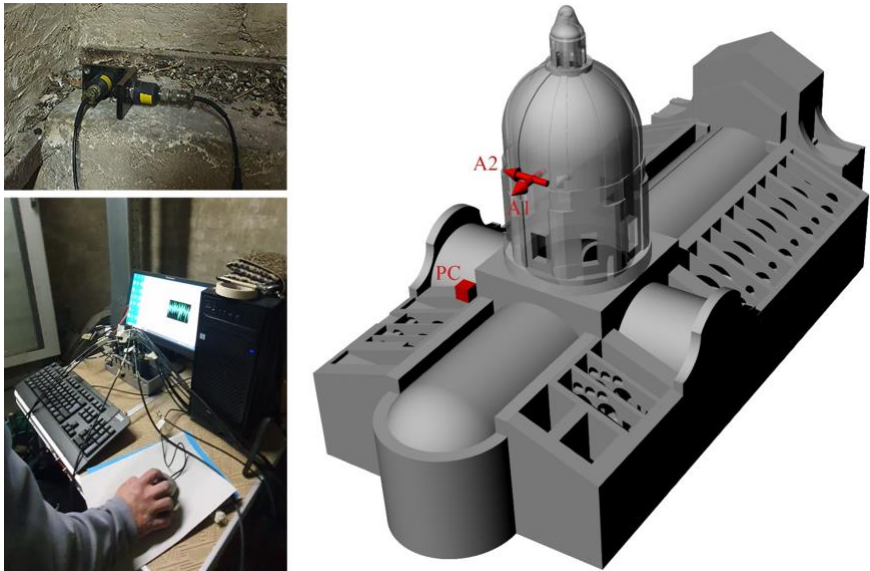


Figure 8: Dynamic monitoring system since 2017.

## 5. PERSPECTIVES FOR THE DOCUMENTATION OF THE ARCHITECTURAL HERITAGE OF PUBLIC ADMINISTRATIONS

The research, carried out by the University of Perugia's Department of Civil and Environmental Engineering in collaboration with the Provveditorato Interregionale alle OO.PP. per la Toscana, le Marche e l'Umbria, addresses the challenge of digitising the architectural heritage in order to improve its protection, but above all to improve the management of the vast and heterogeneous information that surrounds these complex architectural monuments. The Basilica of Santa Maria degli Angeli, selected as a representative example of the architectural heritage managed by the Provveditorato, is characterised by the presence of a vast amount of information, as are other buildings of historical importance. From historical-archival data, which is essential for understanding the evolution of the structure over time, to technical details from structural analyses and seismic monitoring activities. In particular, the restoration works and analyses mentioned above have produced a substantial corpus of technical documentation, including the results of investigations into the structural behaviour of the building during seismic events. In the case of assets managed by public administrations, it is crucial to ensure not only the protection of a vulnerable heritage, but also the immediate accessibility and understanding of information related to the building's state of preservation and seismic safety, using digitisation tools and continuous monitoring.

To deal with this, the research is divided into three main phases. The first is the transition from the two-dimensional survey, which is exhaustive and detailed in the case of the Basilica (Cerbai 2023), to the digital model. In this way, a global and exhaustive representation of the spatiality of the architecture is obtained.

Contextually, following an initial phase of data collection and organization, the incorporation of information within the model will facilitate the transition from a digital product to an information management model, thereby completing the BIM environment.

For this purpose, the use of a document management system has been foreseen, which centralizes all the documentation related to the asset. The implementation of this system will result in the automation of different document management processes and an improvement in the speed of text search, which will facilitate daily use.

The most complex data to handle are those derived from structural monitoring, both in terms of defining an appropriate methodology for incorporating them into the model, and in terms of readability and comprehensibility. The results of this analysis can be presented in the form of a graph that numerically lists the information, or they can be interpreted by means of models that simulate the recorded structural responses. For the first category, it is necessary to discuss about the representation of information that is not immediately comprehensible in figures that are not adequately trained. Experiments are currently underway to incorporate graphics into the BIM environment, but this will need to be further developed when dealing with real-time data.

In the second case the challenge is to be able to bring the simulation models into the BIM model to satisfy the need to have all the information in a single environment. Currently, these are carried out with external programs, so defining a methodology to integrate them into the BIM environment would lead to obtaining a complete digital twin, with the possibility of displaying all the information

in real time, running simulations and setting a threshold above which an alert mechanism is activated in case of malfunctioning of the structure.

## 5.1 First research results

The available information about the Basilica of Santa Maria degli Angeli is extensive, fragmented across numerous archives and comprising a diverse range of materials. These include historical records, technical data from surveys and projects, and other documents pertaining to the basilica's construction and maintenance. In the initial phase of the research, the available data were catalogued and organized in the Document Management system. The information was structured with a thematic subdivision of the archival material and photographic documentation and in a chronological format for dimensional and photogrammetric data of the survey campaigns, as well as restoration work related to both ordinary maintenance and seismic damage. Information on the restoration work in progress is being collected through regular on-site surveys, thanks to this a history of the work carried out can be set up and compared with data on previous and future work. This phase, together with the collection of monitoring data, will continue throughout the research period, also in relation to the interventions that will affect the façade, scheduled to begin in 2027.

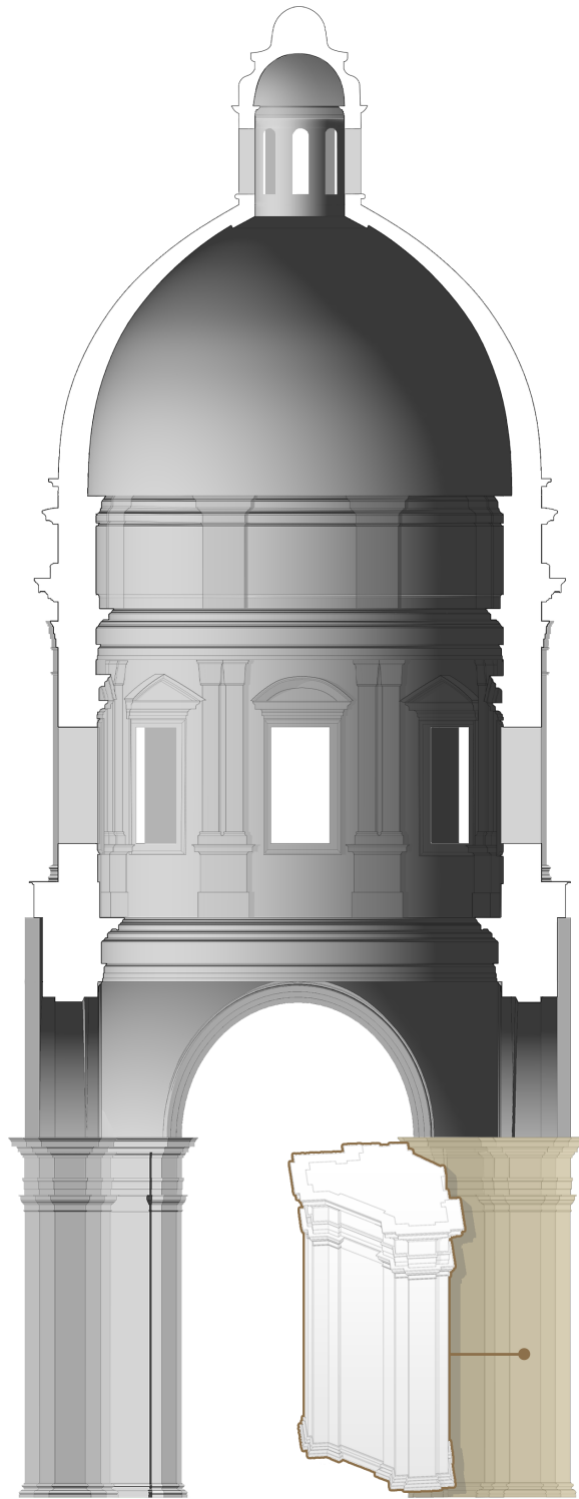
Particular attention was paid to the cataloguing of the decorative apparatus, to facilitate the transition to the digital model.

Following an initial experimental modelling phase, which was limited to a small part of the architectural complex in order to test the analysis and extraction of information from the model, the process was then extended to a larger scale, with an in-depth analysis of modelling strategies.

The highest level of detail was concentrated in the dome area, exploiting the data and events related to this area, with the aim of developing a methodology that could be replicated over the entire architectural complex. The initial step was to establish the level of detail to be applied, balancing geometric precision with the complexity of the decorative system (Bianconi et al. 2024). In this preliminary phase, it was decided to reduce the complexity of the decorative apparatus's modelling, limiting it to the most significant and representative components of the Basilica. This approach was taken in order to guarantee a faithful representation of both the structural and artistic elements, defining a systematic methodology that takes into account the static and dynamic characteristics of the building, as previously analyzed. This methodology ensures an accurate and functional representation.

Once a satisfying model has been produced, the level of detail can be gradually increased, incorporating decorative elements that were initially excluded or providing more detail for those that were simplified.

To model the dome, a methodological approach was adopted, beginning with the establishment of a structural model composed of three principal macro-areas: the core structure, the drum and the dome. Within these areas, the level of detail was gradually increased, the elements were divided into parameterized families and subjected to varying degrees of modelling in accordance with aesthetic and functional requirements.



*Figure 9: The dome's model.*

The modelling process began with the four main pillars, which constitute the load-bearing elements of the structure. These pillars were modelled through the use of parameterised families, thus ensuring their correct classification within the model in both a geometrical and an informative sense. In this case, the decorations were added subsequently due to their close relationship with the supporting structure itself. The modelling of the connection structure between the pillars and the drum was particularly challenging due to the articulated geometry of the surfaces, which exhibited multiple curvatures. In this context, the decorative apparatus was deliberately simplified to emphasize the primary role of the supporting structure, as the decorations were not functional to the structural behavior.

The drum was modelled in three sections, with the central band hosting the large windows that provide illumination to the area below. In this phase, the level of detail of the decorative apparatus was increased to enhance the aesthetic value of the element and to ensure that the stylistic characteristics of the dome under study were recognizable in comparison to other similar structures.

The final and most complex phase was the modelling of the actual dome, including the additional portion of the roof lantern. Since the model is based on a detailed and accurate survey, the geometry of the dome result not perfectly circular, increasing the complexity of the modelling. To address these difficulties, two separate local models were developed: one for the dome and one for the roof lantern. This subdivision made it possible to obtain a representation more faithful to the real conformation of the structure.

## 6. CONCLUSIONS

The research represents a significant first step towards the digitisation of the architectural heritage, with a particular focus on the conservation and advanced management of the important cultural assets.

The study demonstrates that an in-depth knowledge of a historic building is a fundamental step in establishing an effective conservation and preservation program for the architectural heritage. An asset of such complexity, which has undergone various transformations over the centuries, due to natural causes, human wishes, but also to critically planned interventions, requires a thorough understanding of its evolution and current conformation before undertaking any future intervention. This is essential in order to plan actions that are truly beneficial and not harmful.

This is the context of the proposed research, which aims to create a digital archive structured in BIM environments. This will ensure that all future interveners have access to an organised and reliable database.

Once a functional procedure has been identified for the proper management of the sanctuary's part under study, it can be replicated both inside the architectural complex itself, e.g. on the façade to prepare for future restoration work, and, in particular, on case studies with different characteristics and needs to verify the actual effectiveness of the methodology.

In this way, public administrations will be actively supported in the critical decision-making phase, thanks to a comprehensive framework of easily accessible and adequately understandable information. This will encourage maintenance planning aimed at avoiding extraordinary interventions where they are not necessary and at making interventions more timely where they are really needed.

## REFERENCES

- Bartelli, Carla. 1989. "La nuova facciata. Il progetto di Dante Viviani (1913) e gli interventi di Cesare Bazzani (1925–30)." In *La Basilica di Santa Maria degli Angeli*, edited by Francesco Federico Mancini and Aurora Scotti, vol. 1, 207–232. Perugia: Electa Editori Umbri Associati.
- Belardi, Paolo, Fabio Bianconi, Alessia Bonci, and Paolo Verducci. 2004. "Emergenza, verifica, ricerca. Il terremoto del 1997 in Umbria." *Parametro* 251: 74–77.
- Bianconi, Fabio, and Marco Filippucci. 2021. *Digital Draw Connections. Representing Complexity and Contradiction in Landscape*. Lecture Notes in Civil Engineering, vol. 107. Cham: Springer International Publishing.
- . 2023. *La rivoluzione BIM per la pubblica amministrazione. Sperimentazione nel territorio di Città di Castello*. Edited by Filippo Cornacchini. Perugia: Maggioli Editore.
- Bianconi, Fabio, Marco Filippucci, Giuseppe Amoroso, and Mattia Bertinelli. 2019. "From the Integrated Survey of Historic Settlements to the Pattern Book within the BIM." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XLII-2/W9*: 135–142. <https://doi.org/10.5194/isprs-archives-XLII-2-W9-135-2019>.
- Bianconi, Fabio, Marco Filippucci, Sabrina Battaglini, and Francesco Cappilli. 2023. "Historic Building Information Modeling (HBIM) and Common Data Environment: The Case Study of Palazzo Vitelli in San Giacomo in Città di Castello." In *New Advances in Building Information Modeling and Engineering Management. Digital Innovations in Architecture, Engineering and Construction*, edited by María De Las Nieves González García, Fernanda Rodrigues, and João Santos Baptista. Cham: Springer. [https://doi.org/10.1007/978-3-031-30247-3\\_4](https://doi.org/10.1007/978-3-031-30247-3_4).
- Bianconi, Fabio, Marco Filippucci, Michela Meschini, Claudia Fabiani, and Marco Ceccobelli. 2024. "BIM for Post Modern Lexicon. The Representative Question of Architectonic Language from America to Italian Local Replications." In *Contemporary Heritage Lexicon*, edited by Cristiana Bartolomei, Alfonso Ippolito, and Simone Helena Tanoue Vizioli. *Springer Tracts in Civil Engineering*. Cham: Springer. [https://doi.org/10.1007/978-3-031-61245-9\\_15](https://doi.org/10.1007/978-3-031-61245-9_15).
- Bianconi, Fabio, Marco Filippucci, Andrea Parisi, and Sabrina Battaglini. 2021. "HBIM per la gestione della pubblica amministrazione. Il caso studio di Palazzo Vitelli alla Cannoniera." *DN9*: 22–33. Roma: DEI Tipografia del Genio Civile.
- Capaldini, Paolo, Daria Ripa di Meana, and Bruno Salvatici. 1999. "Basilica patriarcale della 'Porziuncola': progetto di ripristino statico e funzionale a seguito degli eventi sismici del 26.09.1997 e successivi." *Ingegneria Sismica. Quadrimestrale tecnico-scientifico* 2 (May–August): 5. Bologna: Patron Editore.
- Cavalagli, Nicola, Luca Botticelli, Vittorio Gusella, and Filippo Ubertini. 2017. "Dynamic Monitoring and Nonlinear Analysis of the Dome of the Basilica of S. Maria degli Angeli in Assisi." In *COMPdyn 2017. 6th ECCOMAS Thematic Conference on Computational Methods in Structural*

- Dynamics and Earthquake Engineering*, edited by Manolis Papadrakakis and Michalis Fragiadakis, 2542–2553. Rhodes Island, Greece.
- Cavalagli, Nicola, Gabriele Comanducci, Vittorio Gusella, and Filippo Ubertini. 2016. "First Results of the Vibration-Based Structural Health Monitoring of a Masonry Dome." In *ECCOMAS Congress 2016. VII European Congress on Computational Methods in Applied Sciences and Engineering*, edited by Manolis Papadrakakis, Vissarion Papadopoulos, George Stefanou, and Vagelis Plevris, 5366. Crete Island, Greece.
- Cavalagli, Nicola, and Vittorio Gusella. 2015. "Dome of the Basilica of Santa Maria degli Angeli in Assisi: Static and Dynamic Assessment." *International Journal of Architectural Heritage* 9: 157–175.
- Cerbai, Claudia. 2023. *Rilievo per l'interpretazione della Basilica di Santa Maria degli Angeli. Dalla Porziuncola di San Francesco alla Basilica-reliquiario di Galeazzo Alessi*. Unpublished dissertation. Firenze: Università degli Studi di Firenze.
- . 2024. "Digital Survey for the Interpretation of the Basilica of Santa Maria degli Angeli in Assisi. From the Porziuncola of Saint Francis to the Basilica-Reliquary of Galeazzo Alessi." In *Franciscan Landscapes: Conservation, Protection and Use of Religious Cultural Heritage in the Digital Era*, edited by Stefano Bertocci and Federico Cioli, vol. 1, 195–206. Firenze: Didapress.
- Di Boveglio, Benvenuto, and Mariano D'Isola Maggiore. 1834. *Compendio storico del Perdono di Assisi e della chiesa detta Porziuncola*. Assisi: Tipografia Sgariglia.
- Dore, Conor, and Maurice Murphy. 2012. "Integration of Historic Building Information Modeling (HBIM) and 3D GIS for Recording and Managing Cultural Heritage Sites." In *18th International Conference on Virtual Systems and Multimedia*, Milan, 369–376. <https://doi.org/10.1109/VSM2012.6365947>.
- Duni, Giovanni. 2008. *L'amministrazione digitale: il diritto amministrativo nella evoluzione telematica*. Milano: Giuffrè Editore.
- Gusella, Vittorio, Paolo Belardi, Fabio Bianconi, Marco Armeni, Nicola Cavalagli, and Luca Martini. 2012. "The Domed Skyscraper of Galeazzo Alessi. The Geometric and Structural Ambiguities of the Dome of the Saint Mary of the Angels Basilica." In *Domes in the World. Cultural Identity and Symbolism. Geometric and Formal Genesis. Construction, Identification, Conservation*, edited by Gennaro Tampone, Roberto Corazzi, and Emma Mandelli. Florence: Nardini Editore.
- Lunghi, Antonio, and Elvio Lunghi. 1989. "Il terremoto del 1832 e la ricostruzione di Luigi Poletti." In *La Basilica di Santa Maria degli Angeli*, edited by Francesco Federico Mancini and Aurora Scotti, vol. 1, 189–206. Perugia: Electa Editori Umbri Associati.
- Mancini, Francesco Federico. 1989. "Presentazione." In *La Basilica di Santa Maria degli Angeli*, edited by Francesco Federico Mancini and Aurora Scotti, vol. 1, 13–16. Perugia: Electa Editori Umbri Associati.
- Martines, Francesco. 2018. "La digitalizzazione della pubblica amministrazione." *Rivista di diritto dei media. MediaLaws*. Milano.
- Murphy, Maurice, Eugene McGovern, and Sara Pavia. 2009. "Historic Building Information Modelling (HBIM)." *Structural Survey* 27 (4): 311–327. <https://doi.org/10.1108/02630800910985108>.
- Romanini, Angiola Maria. 1989. "'Reliquiae' e documenti: i luoghi del culto francescano nella Basilica di Santa Maria degli Angeli presso Assisi." In *La Basilica di Santa Maria degli Angeli*, edited by

- Francesco Federico Mancini and Aurora Scotti, vol. 1, 53–88. Perugia: Electa Editori Umbri Associati.
- Scotti, Aurora. 1989. "Da eremo a santuario." In *La Basilica di Santa Maria degli Angeli*, edited by Francesco Federico Mancini and Aurora Scotti, vol. 1, 17–34. Perugia: Electa Editori Umbri Associati.
- Vignoli, Francesca. 1989. "La fabbrica alessiana e il cantiere di Santa Maria degli Angeli dal XVI al XIX secolo." In *La Basilica di Santa Maria degli Angeli*, edited by Francesco Federico Mancini and Aurora Scotti, vol. 1, 97–160. Perugia: Electa Editori Umbri Associati.

Received June 2025; revised June 2025; accepted July 2025.