

REDESIGNING BRAMANTE'S ROUNDED PERSPECTIVE: DIGITAL SPECULATIONS ON THE UNBUILT CLOISTER OF THE TEMPIETTO

REDISEÑO DE LA PERSPECTIVA REDONDEADA DE BRAMANTE: ESPECULACIONES DIGITALES SOBRE EL CLAUSTRO NO CONSTRUIDO DEL TEMPIETTO

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Highlights:

- Digital reconstructions offer insights into Renaissance architectural principles, exploring the potential structure and design choices of Bramante's unbuilt circular cloister.
- This study investigates the influence of classical Roman architecture on Bramante's design, highlighting the challenges and decisions in reconstructing historical spaces.
- Through 3D modelling, the paper reveals spatial and formal relationships within the cloister that reflect Bramante's innovative synthesis of classical and Renaissance architecture.

Abstract:

This study explores the speculative digital reconstruction of an unrealized circular cloister, designed by Donato Bramante as part of his project for the Tempietto of San Pietro, in Montorio, Rome, circa 1502–1510. By referencing Sebastiano Serlio's surviving drawing—the only contemporary representation of this project—and employing 3D digital modeling, the study examines two potential configurations for the cloister, shedding light on Bramante's integration of Vitruvian principles into Renaissance architectural theory. The research highlights the challenges posed by the Tempietto's unique spatial constraints; it also analyzes the role of classical architectural archetypes, particularly, the paradigm of the column and architrave in classical designs. Documenting the reconstruction process, this study applies digital reconstruction methodologies, including the Apollonio-Fallavollita-Foschi uncertainty scale, to explore the architectural and structural solutions, as well as the references Bramante might have considered. By addressing whether an architrave- or arch-based system might have been proposed, the research provides insights into Bramante's architectural intent. This analysis emphasizes the digital reconstructions potential when addressing historical designs characterized by high levels of uncertainty and interpreting lost architectural works. As part of the international CoVHer Project, this research demonstrates the value of digital tools in cultural heritage preservation and their potential to reinterpret lost or unrealized architectural works. These findings enrich the historiography of architecture, offering new approaches to verifying and reimagining historical designs. Future studies could extend these methodologies to explore other speculative reconstructions, bridging historical inquiry with contemporary visualization techniques.

Keywords: Renaissance architecture; digital reconstruction; heritage preservation; Bramante; architectural speculation; unbuilt architecture

Resumen:

Este estudio explora la reconstrucción digital especulativa de un claustro circular no realizado, diseñado por Donato Bramante como parte de su proyecto para el Tempietto de San Pietro in Montorio, Roma, hacia 1502–1510. Basándose en el dibujo conservado de Sebastiano Serlio —la única representación contemporánea de este proyecto— y empleando modelado digital en 3D, el estudio examina dos configuraciones potenciales del claustro, arrojando luz sobre la integración de los principios vitruvianos en la teoría arquitectónica renacentista por parte de Bramante. La investigación destaca los desafíos impuestos por las singulares restricciones espaciales del Tempietto; también se analiza el papel de los arquetipos arquitectónicos clásicos, en particular, el paradigma de la columna y el arquitecno en los diseños clásicos. Documentando el proceso de reconstrucción, este estudio aplica metodologías de reconstrucción digital, incluida la escala de incertidumbre de Apollonio-Fallavollita-Foschi, para explorar tanto las soluciones arquitectónicas y estructurales como las referencias que Bramante podría haber considerado. Al abordar si se podría haber propuesto un sistema basado en arquitecno o en arcos, la investigación ofrece perspectivas sobre la intención arquitectónica de Bramante. Este análisis enfatiza el potencial de las reconstrucciones digitales para abordar diseños históricos caracterizados por altos niveles de incertidumbre e interpretar obras arquitectónicas perdidas. Como parte del proyecto internacional CoVHer, esta investigación demuestra el valor de las herramientas digitales en la preservación del patrimonio cultural y su capacidad para reinterpretar obras arquitectónicas perdidas o no realizadas. Estos hallazgos

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enriquecen la historiografía de la arquitectura, ofreciendo nuevos enfoques para verificar y reimaginar diseños históricos. Investigaciones futuras podrían ampliar estas metodologías para explorar otras reconstrucciones especulativas, uniendo la indagación histórica con técnicas contemporáneas de visualización.

Palabras clave: arquitectura renacentista; reconstrucción digital; preservación del patrimonio; Bramante; especulación arquitectónica; arquitectura no construida

1. Introduction

Donato Bramante (1444-1514), a seminal figure in Italian Renaissance architecture, left an indelible mark on the field, even though some of his designs were never realized. One such unbuilt project is the cloister for the *Tempietto* of *San Pietro* in Montorio in Rome, which is the focus of this study. This article examines two possible configurations for the cloister, which, though never constructed, continue to fuel scholarly debate.

Born in Fermignano, Urbino, Bramante played a pivotal role in transforming Renaissance architecture, bridging medieval traditions and fully developing classicism. His work transcended a simple revival of classical forms, achieving an innovative synthesis of Renaissance ideals and the grandeur of Roman antiquity. As Vasari (1511-1574) notes in *Le vite dei più eccellenti pittori, scultori e architetti*, Bramante "[...] following in the footsteps of Filippo, paved a safe path for others in the

profession of architecture after him" (Vasari, 2012, p. 595). Vasari emphasizes Bramante's ability to advance Brunelleschi's legacy, mastering both theoretical and practical aspects of architecture. Vasari continues: "While the Greeks were the inventors of architecture and the Romans its imitators, Bramante not only emulated them with a new invention but also taught us, enhancing both the beauty and complexity of the art, which, thanks to him, we now see embellished" (Vasari, 2012, p. 595).

This article aims to explore Bramante's architectural vision for the cloister at San Pietro in Montorio by examining his sources of inspiration and Renaissance architectural principles (Fig. 1). Central to Bramante's work was the redefinition of architecture as a liberal art, elevating it from a mere *ars mechanica* to an intellectual discipline suited to 'free' men. This shift, along with its methodological implications, represented a new 'Brunelleschian' approach (Bruschi, 2003, p. 3) that Bramante masterfully adopted and expanded upon.

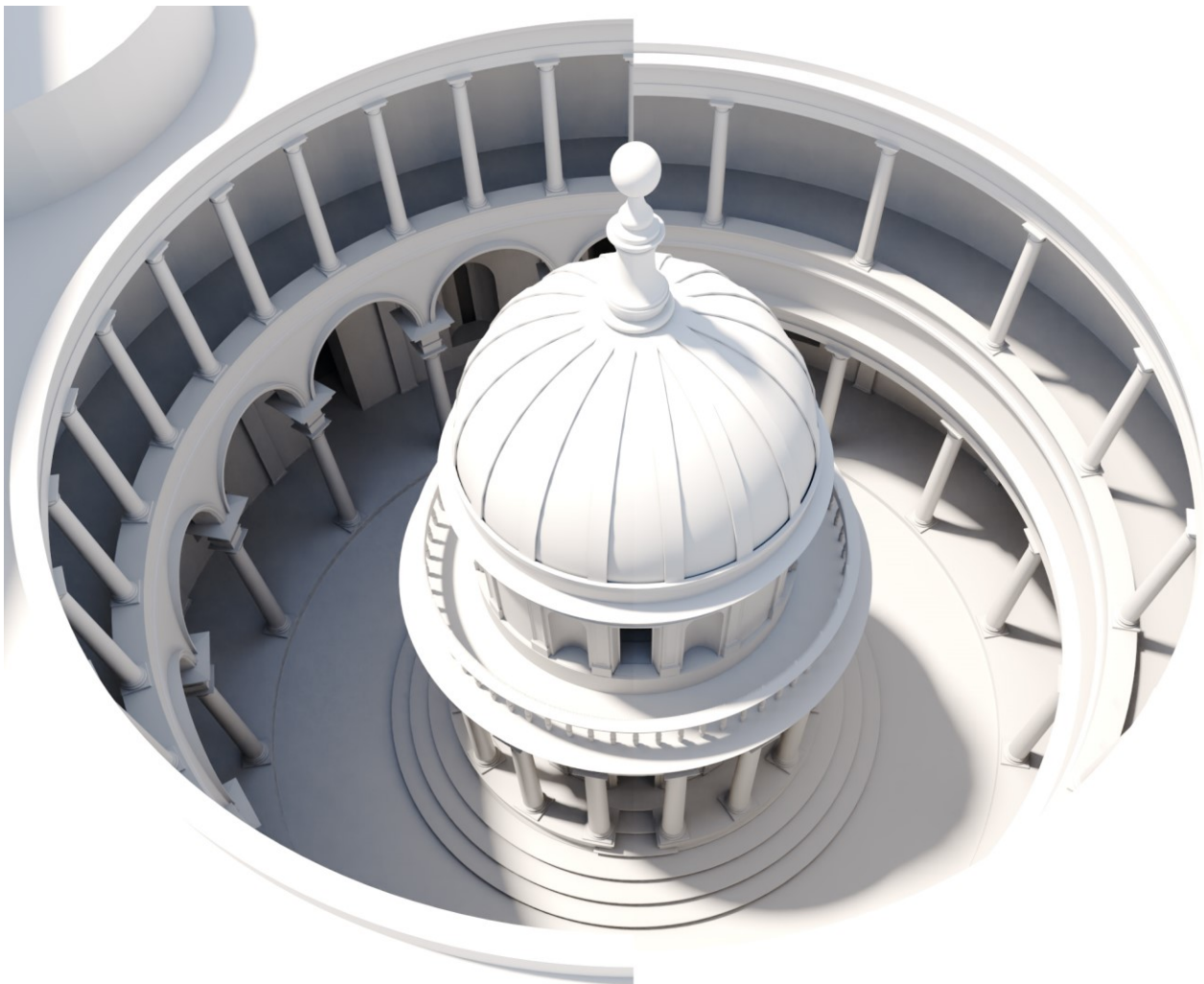


Figure 1: Composite image of the two reconstruction proposals studied in this paper.



Figure 2: Pages from the third book of Serlio's treatise dedicated to the representation of Bramante's *Tempietto*.

Notably, our understanding of this cloister comes primarily from Sebastiano Serlio's treatise, *Tutte l'opere d'architettura et prospetiva*, which provides the only account of Bramante's design (Fig. 2). As Serlio (1475–1554) noted, Bramante was the “inventor and light of good and true architecture” (Serlio, 1544). Through his reinterpretation of antiquity, Bramante applied an innovative lens, experimenting with space, form, and structure. His visionary approach continues to shape and influence modern architectural thought. Bramante's revolutionary approach stemmed from his direct study of ancient ruins and Vitruvius' writings. Patetta describes him as “one of the first to break free from medieval traditions to achieve a new architectural freedom grounded in classical antiquity” (Patetta, 2009, p. 9). This is particularly evident in his treatment of classical orders and his spatial compositions, which surpassed the limitations of earlier periods. Historians widely recognize Bramante as a pivotal figure in the transition from the empirical architecture of the 15th-century Renaissance to the full classicism of the 16th century, marking him as a true forerunner of design practices that would evolve throughout the entire century (Patetta, 2009, p. 12).

The *Tempietto*, erected on the site traditionally believed to be where Saint Peter was martyred¹, is celebrated for

¹ The site, traditionally believed to be where Saint Peter was crucified, was already mentioned in the first half of the 9th century as housing a monastery called *beati Petri quod vocatur ad laniculum*. Over the centuries, the complex,

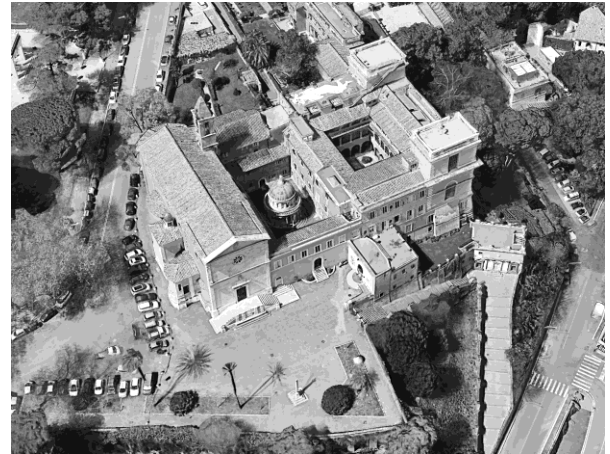


Figure 3: Aerial view of the San Pietro in Montorio complex, showing Bramante's *Tempietto* situated in the courtyard between the Church of San Pietro and the old cloister. Image from Google Earth.

its harmonious proportions and symbolic connection to Roman antiquity and Christian martyrdom. It was commissioned by the Spanish monarchs Ferdinand and Isabella between 1502 and 1510, it embodies both the grandeur of classical forms and the ideals of the Catholic Church. According to Freiberg, the *Tempietto* was a key element of the Spanish crown's cultural agenda in Rome, serving not only as a religious monument but also as a statement of political power (Freiberg, 2014, p. 38).

Situated within the courtyard of San Pietro in Montorio (Fig. 3), a church constructed between 1481 and 1500 that reflects the transition between the late Gothic and Roman Renaissance, the *Tempietto* is part of a complex steeped in architectural and historical significance. Adjacent to the *Tempietto*, the original cloister—described by Serlio as the *claustrum vecchio*²—aligns with the church's length and is separated from the *Tempietto*'s courtyard by a simple wall (Cantatore, 2017, p. 178). This wall likely functioned as both a structural boundary and a defining limit within Bramante's proposed design. The cloister visible today, however, was only completed in the late 16th century,

including a church and monastery, passed through various custodians—Benedictines, Celestines (under whom it became known as *Sancti Petri Montis Aurei* in 1320), Ambrosians, and Cistercian nuns. In 1472, the dilapidated structures and surrounding land were entrusted by Pope Sixtus IV to the Franciscan congregation of the Amadeiti, led by the Portuguese friar and reformer Amadeu de Menezes da Silva. This initiated the restoration and expansion of the monastery and the demolition of the old church to make way for the construction of a new one. This reconstruction was part of Sixtus IV's urban development program.

² The designation of the cloister as “*claustrum vecchio*” by Sebastiano Serlio suggests the intention of a new cloister in the vicinity. While this may or may not have been the envisioned circular cloister, the approximately equal distance between the Church of Saint Peter and the old Franciscan monastic structure from the fixed vertical axis provides credence to the notion that a cloister surrounding the *Tempietto* was always part of the plan. This spatial arrangement reinforces the hypothesis that Bramante's design aimed to harmonize the *Tempietto* within a coherent architectural framework.

after the monastery's construction, as attested by various records and surveys (Cantatore, 2017, p. 178).

In contrast, the current *Tempietto*'s courtyard arrangement —formalized in the 1830s— differs significantly from the Bramantian plan for a circular cloister, which remains the focus of this paper. Although Bramante's design was never realized, the 19th-century intervention sought to unify the space but ultimately diminished the architectural coherence of the *Tempietto* within its spatial context. (Cantatore, 2017, p. 172).

The design of the *Tempietto* marked a significant evolution in Renaissance architectural design, borrowing from ancient temple forms while imbuing them with new meaning. Unlike traditional religious spaces, the internal dimensions of the *Tempietto* are disproportionately small, suggesting that the primary function of the building was commemorative rather than liturgical (Bruschi, 2003, p. 190). The *cella* measures approximately 4.5 meters in diameter, with a substantial portion occupied by the altar, leaving minimal room for congregants. This shift from interior space to exterior visual emphasis likely reflects Bramante's intent to make the building an object of contemplation rather than a functional church. The smallness of the interior of the *Tempietto* and the 'necessity' of a controlled exterior space, or an 'interior' exterior, is exemplified by the courtyard, which likely functions as the nave.

Bramante demonstrated a pragmatic willingness to modify existing structures for his designs, as Egidio da Viterbo noted, "*Bramante non ebbe scrupoli perfino nel proporre a Giulio II di cambiare posizione alla tomba di Pietro nella basilica vaticana per esigenze progettuali*"³ (Cantatore, 2017, p. 178). This approach, evident in his willingness to manipulate preexisting elements into his designs, underscores his innovative use of classical elements extended beyond the structure's physicality to its experiential aspects. His use of perspective, which he had already explored in works like the illusionistic apse at *Santa Maria presso San Satiro* in Milan, plays a central role in the *Tempietto*. When viewed from the doorway, the altar, with its depiction of Saint Peter's crucifixion, aligns perfectly with the visual axis of the viewer (Fig. 4), creating a powerful connection between architecture and sacred narrative (Patetta, 2009, p. 33).

Using the singular surviving drawing in Serlio's architectural treatises, we employed 3D ArchiVHR (Architectural Virtual Hypothetical Reconstruction) to further investigate the unrealized cloister. By combining historical texts and architectural analysis with modern reconstruction methods, this study aims to shed new light on Bramante's vision and its implications for both historical and contemporary architectural practice. As Apollonio, Fallavollita, and Foschi argue, the significance of such digital reconstruction efforts "*is not in the methodology itself but in the clear identification of some concepts and classifications... that would help the scientific community to better share 3D models as scientific products*" (Apollonio, Fallavollita, & Foschi, 2023).

³ Bramante had no hesitation even in proposing to Julius II to change the position of Peter's tomb in the Vatican Basilica for design reasons

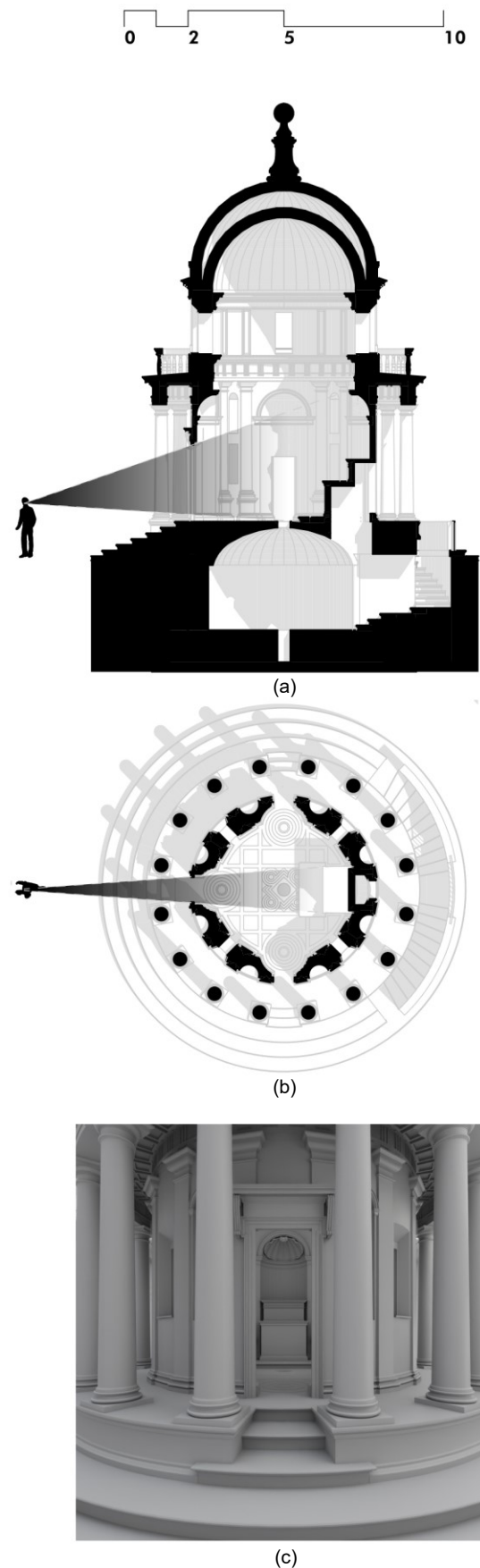


Figure 4: Demonstration of the analogical process through 2 images that convey the visual impact of the 3D model in a single moment: a) Transversal section; b) Plan; and c) 3D view of the entrance.

In keeping with this view, the current study not only reconstructs Bramante's unrealized architectural project but also reflects on the ongoing relevance of historical inquiry to modern architectural instruments, processes, and design practices.

2. State of the art

Despite Bramante's significant contributions to Renaissance architecture, his design for the circular cloister of the *Tempietto* has received relatively little scholarly attention. While the *Tempietto* itself is celebrated for blending classical elements with Renaissance innovation, the cloister—never built and documented only through a surviving drawing by Sebastiano Serlio—remains underexplored. This limited focus may stem from the greater historical significance of other unrealized projects by Bramante, such as his early design for St. Peter's Basilica, later completed by Michelangelo.

Serlio's drawing has undergone numerous reinterpretations in architectural history, with notable analyses by Giuseppe Marini (1810), Letarouilly (1840), and Bruschi (1973) (Bruschi, 2003; Letarouilly, 2016; Marini, 1810). Portoghesi's 1977 reconstruction renewed interest in the cloister, presenting perspective views that highlighted its role as a vital component encircling the *Tempietto* (Portoghesi, 1970). However, these studies largely emphasized geometric and structural elements without fully exploring Bramante's broader architectural intentions, notably highlighting that the limited discussion on the cloister consistently accepted the architrave solution without question.

As Bruno Zevi emphasized in *Saper vedere l'architettura* (1948), architecture could only be represented by architecture itself, implying that the essence of architectural experience cannot be fully captured through traditional two-dimensional drawings or photographs (Zevi, 1948). This perspective is particularly relevant for unbuilt or lost works like Bramante's cloister, where traditional representational methods fall short. Digital 3D modelling and virtual reality (VR) provide a closer approximation to the architectural experience that Zevi envisioned, enabling a virtual embodiment of space, light, and perspective. Through VR, viewers can navigate these digital reconstructions interactively, approximating the spatial experience of a physical structure.

Recent advances in digital reconstruction have introduced methodological frameworks designed to support rigorous academic inquiry. Foundational guidelines like the Seville Principles in 2017 (ICOMOS 2017) and the earlier London Charter in 2009 ("Londoncharter," 2009), emphasize transparency and accuracy in virtual heritage documentation. However, these frameworks are sometimes limited in practical application, leading to further initiatives like the Inception Project ("INCEPTION", 2015) and the DFG Research Network's *Digital 3D Reconstructions as Tools of Architectural Historical Research* (2018). These initiatives seek to bridge the gap between theoretical guidelines and practical applications, advocating for transparency in projects where speculative interpretation is often required. Within this framework, reconstructions are approached as interpretative models that present plausible recreations rather than definitive representations (López-Menchero

Bendicho & Grande, 2011). The European CoVHer initiative extends this approach, emphasizing rigorous source identification and advocating for a philological approach to historical speculation.

The application of VR in architectural heritage has significantly impacted the study of unbuilt or lost structures. For instance, a study by Jiménez Fernández-Palacios, Morabito, and Remondino demonstrates how VR platforms can incorporate data from advanced scanning technologies, like LiDAR, to enable virtual walkthroughs of heritage sites, providing a spatial experience aligned with the original architectural intent (Jiménez Fernández-Palacios, Morabito, & Remondino, 2017). Similarly, projects such as the VR experience at the Balzi Rossi Museum leverage high-resolution photogrammetry to digitally capture historical sites and create immersive experiences, allowing visitors to explore the architecture of different historical periods interactively (Iacono et al., 2024). Furthermore, artificial intelligence (AI) is expanding the possibilities for architectural heritage visualization. Tools such as Generative Adversarial Networks (GANs) are being used to recreate lost architectural elements by learning from similar structures. The ARQGAN project applied GANs to restore incomplete features of ancient Greek temples, demonstrating how these technologies can enhance speculative reconstructions like Bramante's cloister (Delgado-Martos et al., 2024). By combining AI with traditional reconstruction techniques, digital models can offer more nuanced interpretations of unbuilt architecture, aligning with Zevi's vision for architectural representation through the architecture itself.

These advancements in digital reconstruction and VR underscore the importance of speculative models for understanding and preserving architectural heritage. For Bramante's cloister, digital tools provide a unique opportunity to explore the spatial qualities and design intentions that would otherwise remain speculative. As such, this study situates itself within a broader tradition of digitally reconstructing historical architecture, recognizing the potential of these technologies to not only represent but also bring to life architectural works that might otherwise be lost to history.

3. The success of the *Tempietto* and Serlio's drawings

The architectural debate surrounding Bramante's *Tempietto di San Pietro* in Montorio is significantly enriched by Sebastiano Serlio's depiction of the cloister plan in his treatises. This inclusion is notable, as Bramante is the only "modern" architect featured in Serlio's Third Book, which is otherwise dedicated to antiquities - a testament to the profound legacy of his work. Serlio's architectural writings are invaluable for understanding Bramante's intentions, as they offer the only surviving representation of the unrealized cloister design (Bruschi, 2003).

Though Serlio's work postdates Bramante by some decades, the proximity of their lifetimes and shared Renaissance ideals lend authority to his depictions. As Cantatore highlights, Serlio's drawings, although adapted for reuse by readers, provide a credible basis for understanding Bramante's intent to integrate a new structure with the pre-existing complex (Cantatore, 2017, p. 172). As both an architect and theoretician,

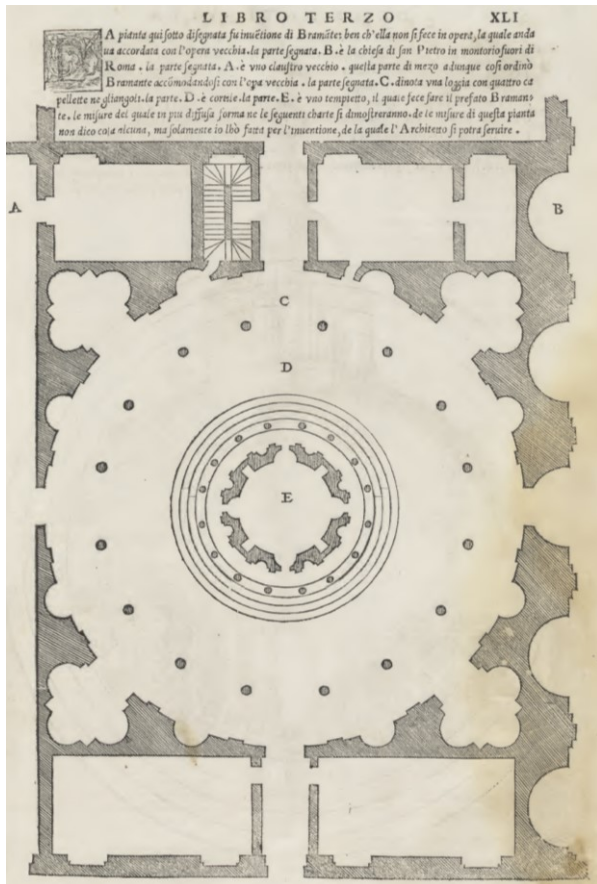


Figure 5: Plan of the cloister as envisioned by Bramante and drawn by Serlio in his Third Book.

The original text states as such: “La pianta qui sotto disegnata fu inuentione di Bramante, bench'ella non si fece in opera, la quale andava accordata con l'opera vecchia. La parte segnata B, è la chiesa di San Pietro in Montorio fuori di Roma. La parte segnata A, è un chiostro vecchio. La parte segnata C, dinota una loggia con quattro cappelle negli angoli. La parte D, è un cortile. La parte E è uno Tempietto, il quale fece fare il prefatto Bramante. Le misure del quale in più diffusa forma nelle seguenti carte li dimostreranno. Delle misure di questa pianta non dico cosa alcuna, ma solamente io l'ho fatta per l'inuentione, della quale l'architetto si potrà servire.”

Serlio's treatises systematically codified Renaissance architectural knowledge, providing a bridge between earlier architects like Bramante and later figures such as Palladio.⁴ His *Tutte l'opere d'architettura et prospetiva* was a crucial text in disseminating Renaissance architectural principles across Europe, influencing the trajectory of architecture for generations.

In Serlio's depiction, Bramante's circular *Tempietto* is placed at the centre of an equally circular courtyard (Fig.5), embodying a Renaissance reinterpretation of classical forms rather than mere replication. From antiquity to the Middle Ages and through to Neoplatonic Humanism, the circle has symbolized the world and

divine perfection. “This layout, as Palladio would say about the Pantheon, is a “figure of the world,” evoking the divine reality of the cosmos and serving as both a conceptual and visual expression of the “sacred,” linking architecture with spiritual ideals” (Bruschi, 2003, p. 190).

Serlio's description of the cloister's plan is precise and detailed, providing insights into Bramante's design (Serlio, 1540, p. XLI). He writes: “The plan drawn below was devised by Bramante, although it was not executed. It was intended to match with the existing structure. Section B marks the Church of San Pietro in Montorio outside of Rome. Section A indicates an old cloister. Section C denotes a loggia with four small chapels at the corners. Section D is a courtyard. Section E is a small temple, which was commissioned by Bramante. The measurements of this temple will be described in more detail in the following pages. I will not discuss the measurements of this plan here, but I inserted it for the idea [“invention”], which architect may find useful”.

While some measurements of the *Tempietto* are noted⁵, Serlio emphasizes that most of the building can be measured due to its modularity, demonstrating Bramante's mastery of proportion and geometry —key elements of Renaissance architecture.

However, there has been scholarly debate regarding the accuracy of Serlio's depiction. Some researchers suggest that he may have idealized or altered certain aspects of the design for pedagogical purposes (Bruschi, 2003, p. 202). For example, the depiction of the four chapels at the corners of the loggia is problematic, as the presence of the church's apse would have made it impossible to construct all four. In reality, only three could have been built. This discrepancy suggests that Serlio's plan may have been a more diagrammatic representation of an idea rather than an exact blueprint. It also raises the possibility that during Bramante's planning of the cloister, the configuration of the church itself may have been different, potentially allowing for a layout that accommodated the four chapels. The use of the term “invention” by Serlio indicates his awareness of this, framing the design as conceptual rather than strictly practical. Despite these concerns, Serlio's representation remains a critical source for understanding the *Tempietto's* cloister and its broader significance in Renaissance architecture.

⁵ The pages that Serlio dedicates to the description of the *Tempietto* include the following:

“In the previous page, I mentioned that I would describe Bramante's *Tempietto* in more detail, which is not very large but was built solely to commemorate the Apostle Saint Peter, as it is said that he was crucified on this very spot. The temple is measured using the ancient Roman foot, which consists of sixteen digits. [...] The diameter of the temple is twenty-five feet and twenty-two minutes, and the width of the portico around the temple is seven feet. The thickness of the columns is one foot and twenty-five minutes, and the width of the door is three and a half feet. Those small squares with circles inside them, which are around the portico, denote the coffers above the columns. The thickness of the wall is five feet. The remaining measurements can be understood from the initial ones”.

⁴ It is no coincidence that in one of Andrea Palladio's most famous buildings, one of the main features—the system of windows with a double entablature framing a central arch—is named the *Serliana*.



Figure 6: Renaissance-era representations of the Tempietto: a) "The Marriage of the Virgin", Raphael Sanzio, 1504; b) "Alexander the Great Kneeling Before the High Priest of Ammon", Francesco Salviati, c. 1545; c) "Massacre of Coligny and the Huguenots on Saint Bartholomew's Day", Giorgio Vasari, 1572; d) "The Flight of Helen from Troy", Federico Barocci, 1598–1602.

Another key consideration when studying the *Tempietto* is the impact it had on the imagination of its contemporaries. As mentioned earlier, the inclusion of the *Tempietto* in Serlio's treatise is significant. However, even more telling is its frequent appearance in various pictorial representations of the time.

A clear example is Raphael's "The Marriage of the Virgin" (1504), where a centrally planned building serves as the backdrop to the religious event. Perhaps due to the contemporaneity of the painting with the construction of the temple, the structures differ. Nevertheless, the relationship becomes evident when Bramante's sketch and Raphael's painting are compared. Far more literal reproductions are seen in "Alexander the Great Kneeling Before the High Priest of Ammon" (1545), "The Massacre of Coligny and the Huguenots on Saint Bartholomew's Day" by Giorgio Vasari (1572), and "The Flight of Helen from Troy" by Federico Barocci (1598–1602) (Fig. 6). The observation of these reproductions, where the temple is decontextualized and placed as the backdrop for an imagined classical scene, highlights a clear issue: the building is designed to be observed from the outside, a perspective machine that attracts the viewer and presents itself in its perfect and graceful form, isolated as the focal point of attention and magnificence.

Ultimately, interpreting the *Tempietto* di *San Pietro* in Montorio through Serlio's plan is key to understanding its place within Renaissance architecture. The plan represents the synthesis of ancient and modern architectural thought, exemplifying Bramante's ability to engage in a dialogue between past traditions and contemporary innovations. Serlio's inclusion of Bramante in a volume dedicated to antiquity affirms the enduring influence of his work and solidifies his position as a central figure in the evolution of Renaissance architecture: "Deemed worthy, by Serlio and Palladio, to stand alongside the prestigious works of the ancients, as an example of the 'good and beautiful architecture' first brought to light by Bramante himself" (Bruschi, 2003, p. 185).

4. Methodology

The methodology for this study involved the use of three-dimensional modelling to comprehensively analyse Bramante's unrealized cloister project for the *Tempietto* of *San Pietro* in Montorio. A critical aspect of this approach was the integration of both horizontal and vertical representations of the architecture, which were primary elements under scrutiny. While Digitisation methodologies, such as the CoVHer approach, typically rely on analogical graphical sources for three-dimensional reconstructions, this was not feasible in the case of the *Tempietto* due to the lack of sufficient detailed plans. The most authoritative source available was a singular plan from Sebastiano Serlio's collection (Serlio, 1540, p. XLI), underscoring the necessity of studying additional influences - whether written, constructed, or derived directly from Bramante's own designs.

Serlio's documentation suggests that the design of the *Tempietto* was highly modular, implying that similar modularity could be expected in the cloister. Understanding the structure of the *Tempietto* itself was fundamental to this study. To ensure accuracy, we began by referencing the surveys published by Paul Letarouilly in his seminal work *Edifices de Rome Moderne*, first released in the 1840s (Letarouilly, 2016, pp. 103–105, 322–323). Although Letarouilly's drawings idealize the *Tempietto* to some extent, they remain the most comprehensive surveys available and thus were critical in forming the basis of our analysis.

Formal analysis of the existing structure and its limitations revealed overlooked relationships in prior studies of the floor plans and sections. The goal of this exploratory investigation was to elucidate the relationships between different architectural elements and justify the rationale behind the original design.

Bramante's mastery of perspective manipulation is well-documented, and the *Tempietto* exemplifies this skill. One prominent example is the way the altar is framed by the entrance door. This observation, though potentially derivable from plan studies, became immediately apparent through the pragmatic exploration of the model (Fig. 4). Such use of perspective in the *Tempietto* led us to hypothesize that the remaining design elements would likely adhere to similar principles, in line with Renaissance aesthetic preferences.

In our research, we experimented with modelling two distinct options for the cloister, both based on the

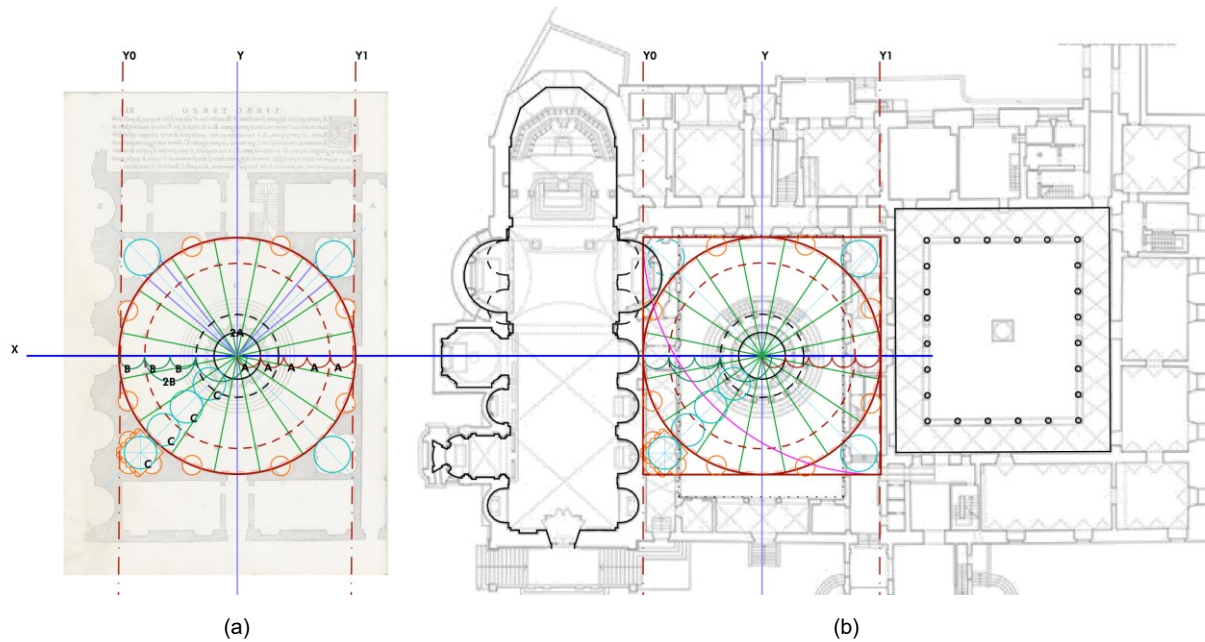


Figure 7: Vector-based modular redrawing of Serlio's schematic, overlaid onto two different contexts: a) Serlio's original drawing; and b) the same reconstruction applied to a contemporary survey of the complex. Notably, the depiction of the San Pietro in Montorio church in Serlio's drawing is mirrored compared to its actual layout. While Serlio's drawing shows five chapels (with a subtle indication of continuation), our reconstruction demonstrates that six chapels fit perfectly within the space. This alignment is consistent with Francesco di Giorgio Martini's scheme for religious buildings with a single hall, reinforcing the hypothesis of an earlier church configuration that accommodated this arrangement.

foundational element of the Doric column, which Serlio described as measuring one and a twenty-fifth Roman feet (Serlio, 1540, p. XLII). The aim was to test various configurations and understand how the design might have functioned in relation to the *Tempietto*. In both modelled scenarios, the visual effect of the *Tempietto* from the cloister entrance revealed that the temple's figure is abruptly truncated, fully revealing itself only when one steps out from under the portico into the courtyard (Fig. 9, Fig. 11).

This practical experimentation made possible through digital modelling, allowed us to identify previously overlooked aspects of the design, particularly regarding visual experience and spatial dynamics. Moreover, the simplicity and flexibility of the model helped streamline the analysis without losing critical architectural detail.

The 3D modelling of the cloister began with a proportional analysis of the drawing found in the third book of Serlio, aiming to critically obtain a vector-based plan of the intended cloister (Fig. 7). Given the lack of additional drawings and the absence of specific measurements from Serlio, a deductive approach was used to uncover the underlying relationships between the architectural elements. This method relies on the modularity that characterizes many of Bramante's designs, as well as the compositional principles of the Renaissance.

As a comparison system, we decided to use three additional drawings: two 19th-century interpretations and one modern reconstruction. Specifically, these were the plans by G. Marini (1810), P. Letarouilly (1840), and a reconstruction attributed to R. Lauri and transmitted by A. Bruschi.

An important ratio that emerged from studying Serlio's plan is the relationship between the covered portico area and the open space leading to the *Tempietto*, which is approximately 1:2. Additionally, the ratio between the internal radius of the *Tempietto* and the radius of the circle inscribed within the pilasters is about 1:5. This ratio places the circumference corresponding to the intercolumniation of the portico columns at one-fifth of the entire cloister's radius. Considering the internal diameter of the *sacello* to be 4.44 meters, a measurement confirmed by contemporary surveys, such as that of Arq. Almagro Gorbea (2023) in the archives of the Royal Academy of Spain, we extrapolated this value using the module of 15 Roman feet (a unit employed in the *Tempietto* according to Serlio). Based on this, we determined that the cloister would have had a radius of approximately 11.10 meters (equivalent to 5 modules), resulting in a total diameter of 75 Roman feet or 300 Roman palms. To test this dimension, we drew a circle with the defined radius centred on the *Tempietto* over a modern survey of the *San Pietro in Montorio* complex.

This approach contrasts with that of Cantatore (2017), who focused on aligning dimensional references between Serlio's plan and existing structures by assigning predefined measurements to elements like the church chapels or the courtyard. This method required scaling Serlio's drawing to fit specific measurements, often resulting in distortions or discrepancies with the real context. As Cantatore herself acknowledges, "in this way, the sixteenth-century drawing is excessively reduced and appears out of scale with the actual context" (Cantatore, 2017, p. 175), highlighting the inherent limitations of using Serlio's drawing as a rigorous dimensional base rather than as a proportional guide.

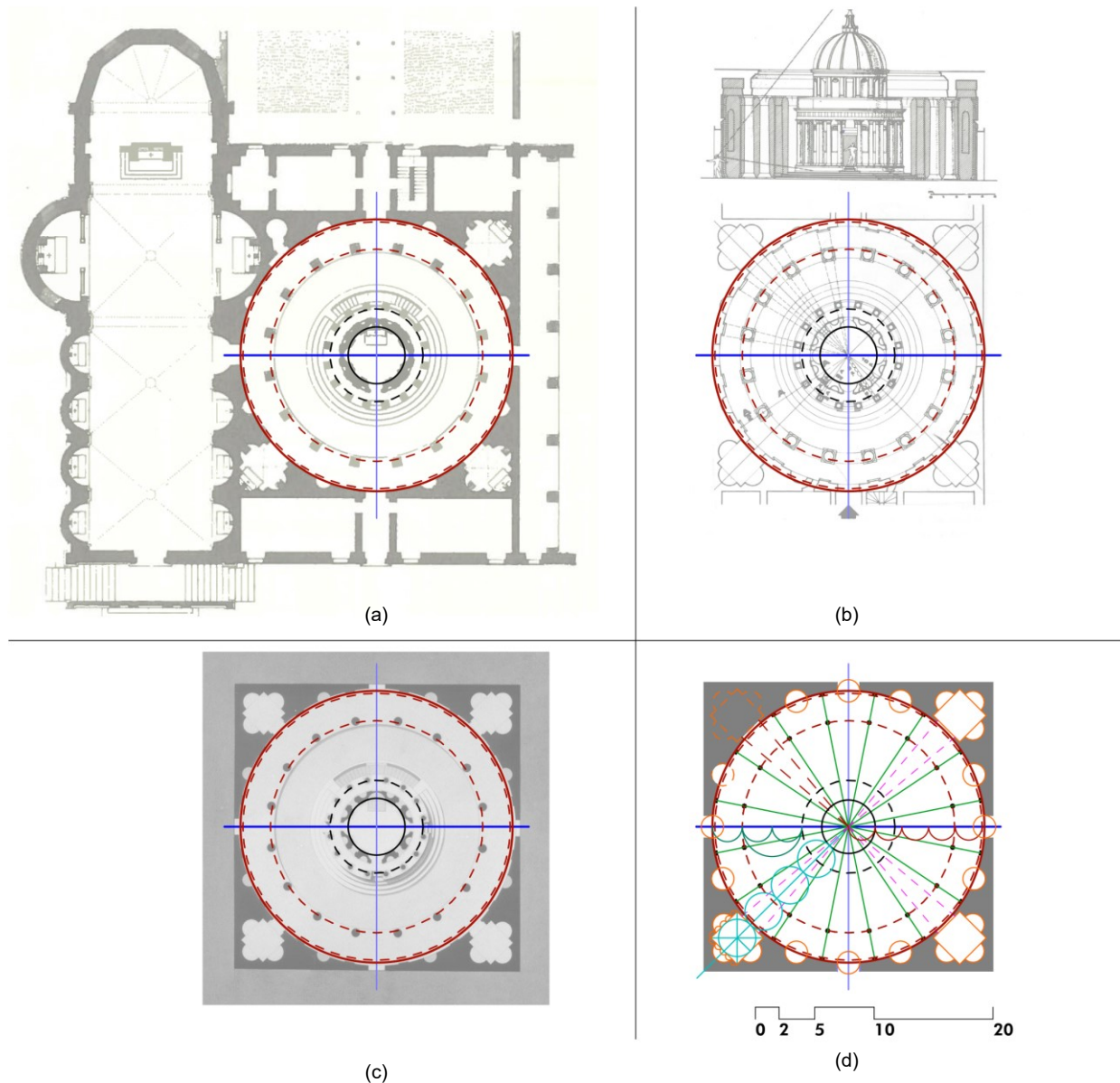


Figure 8: Comparison of the construction geometry across various subsequent reconstructions: a) Paul Letarouilly in the third volume of *Édifices de Rome Moderne*, 1840; b) R. Lauri, 1973, based on indications from Arnaldo Bruschi; c) G. Marini, 1810; and d) authors' own geometry.

Our methodology prioritizes modularity over fixed dimensions, interpreting Serlio's drawing as an indication of proportions and relationships rather than a literal measurement template. By anchoring our analysis to the fixed elements built by Bramante and extrapolating outward using modular units, we avoid imposing arbitrary measurements onto the plan. Instead, we focus on the coherence and proportional logic intrinsic to Bramante's design. This approach better aligns with Serlio's depiction, treating the plan as a conceptual tool while respecting the spatial relationships evident in the surviving-built elements.

To validate our findings, we compared the derived circumference with the aforementioned plans, scaling each plan to a 4.44-meter internal circumference for the *Tempietto* (Fig. 8). The closest matches were the 19th-century interpretations, with Marini's plan showing a slight deviation of -0.179 meters and Letarouilly's plan aligning almost perfectly.

To determine the proportions of the four corner chapels, we observed a consistent relationship between the Tempietto, cloister walls, and chapel depth, following a 2:1 ratio. Similarly, the round niches were proportioned to align with the spatial rhythm of the cloister walls and interior windows.

The discussions surrounding the four corner chapels, which Letarouilly resolves by removing one of them, led us to explore the possibility that the apses of the church were a later addition. Interestingly, by continuing the series of present side niches within the church, the space is evenly filled, suggesting that the design Serlio presented not only could be plausible but could also serve as a confirmation of a previous configuration of the Church of Saint Peter. By extending the lines of the outer walls, we further confirmed that the cloister's circumference was defined by subtracting volume from the boundary walls of both the old cloister and the church. This supports the notion that the square in

which the circle was inscribed was meant to be adapted in wall thickness to the existing structures.

With the exact dimensions of the *Tempietto* known and the available space for the circular cloister defined, we were able to make some preliminary deductions. The placement of the *Tempietto* precisely at the centre between the church of *San Pietro* in Montorio and the external wall of the old cloister aligns with Bramante's intended spatial organization.

The modelling process utilized Archicad 25 to construct and analyse Bramante's unrealized cloister project efficiently. Once a vector-based plan for the base was produced from Serlio's drawings, the next step involved creating a series of elements or profiles that could be extruded and revolved to build the full model of the cloister. This approach was particularly advantageous, as it allowed for rapid adjustments and the exploration of multiple design options.

This workflow was specifically chosen to accommodate the need for flexibility in the model, enabling us to test various configurations without the need to redraw each element from scratch. For example, using ArchiCAD's parametric tools for elements like beams, columns, and handrails allowed us to modify dimensions and proportions on the fly. With parametrized profiles, we could easily adjust individual components or the entire

structure to reflect new hypotheses or explore alternative architectural scenarios. This adaptability was invaluable, as it permitted efficient iteration across different configurations of the cloister's structural system—whether architrave-supported or arch-based—while retaining consistency in the overall design framework.

By using ArchiCAD 25's parametrical capabilities, each component of the cloister could be accurately represented, making the model both a practical tool for visualization and a dynamic framework for speculative reconstruction. This software choice thus supported a comprehensive digital investigation into Bramante's architectural intentions, providing a robust platform for examining spatial relationships, proportions, and the visual impact of the cloister within its historical context.

By employing this digital tool, we were able to visualize and test different architectural hypotheses in ways that traditional two-dimensional methods could not achieve, providing deeper insights into spatial relationships and design intent.

5. The problem of the cloister

"The Bramantean cloister therefore appears to be very constrained within the available space, but not impossible to construct" (Cantatore, 2017, p. 175).

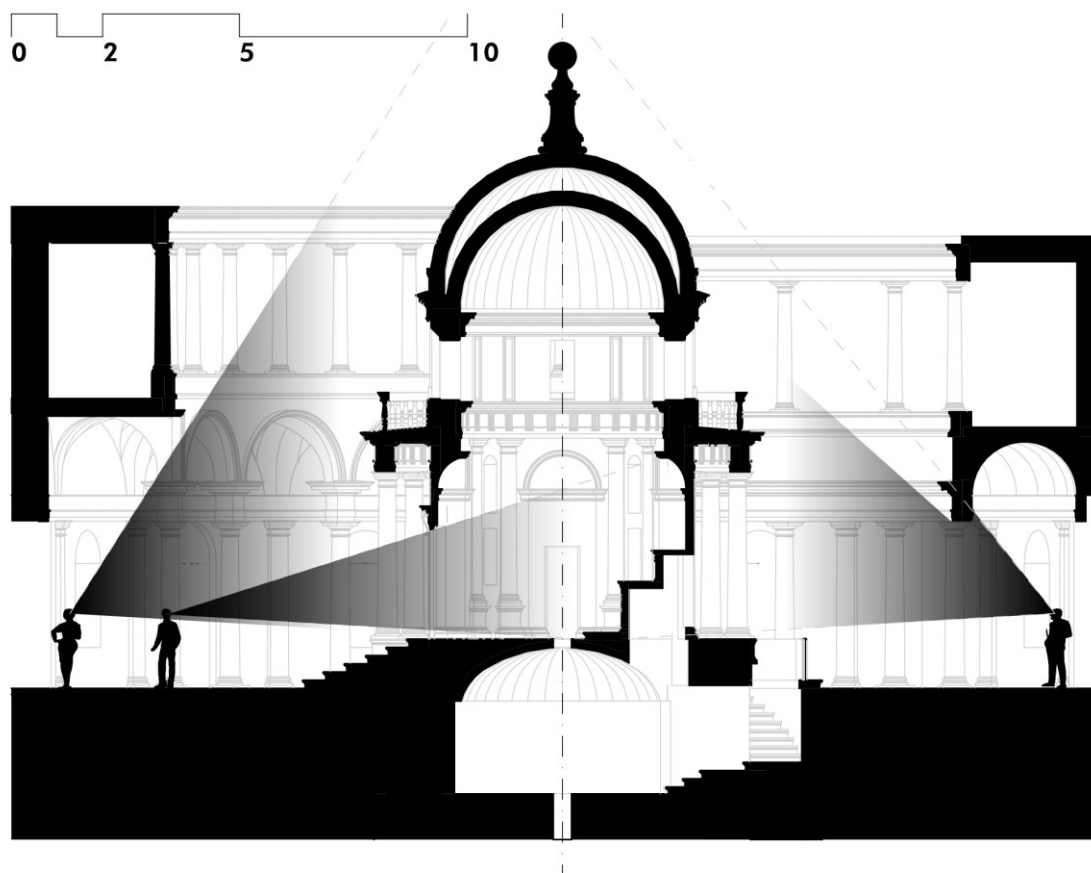


Figure 9: The architrave version appears on the right, while the arch version is on the left. The ideal observer is positioned along the line of columns at the courtyard threshold, with the drawing illustrating the distinct visual cones experienced from the portico in each configuration.

The primary issue with the original cloister design lies in its schematic representation, preserved through Sebastiano Serlio. As previously noted, Serlio idealized the plan, omitting crucial details about how the cloister would integrate with the existing structures —the old cloister and the adjacent church. While Serlio provides useful information, such as the number of columns (sixteen, just like the *Tempietto*), the courtyard size, and the portico dimensions, he overlooks the spatial constraints imposed by the surrounding buildings. Notably, the church and the old cloister are mirrored, and the church's transept apse is entirely omitted from the drawing. This lack of contextual detail leaves significant questions about Bramante's original intentions unresolved.

One significant issue is the absence of any elevations of the cloister. Without elevations, we cannot fully understand the design direction Bramante intended to take. Serlio's depiction, which shows a regular and symmetrical portico, also introduces inaccuracies, such as the inclusion of a fourth chapel in the northwest corner —an addition that would have been impossible to realize due to the presence of the church's apse. In this regard, Paul Letarouilly's 1840 reconstruction of the plan seems to offer a more credible interpretation of Bramante's original vision (Fig. 8).

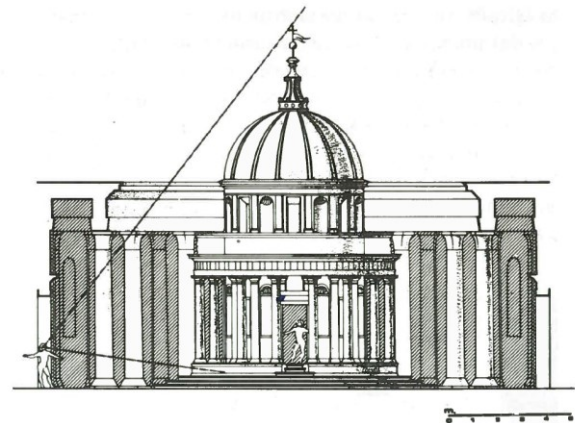
A fundamental question regarding the cloister's design is the structural system Bramante intended for the portico: whether it was to be supported by an architrave (trabeated) system or by arches. Classical reconstructions tend to favour the architrave solution. Notable examples include interpretations by Paolo Portoghesi (Portoghesi, 1970, p. 53), and R. Lauri (Bruschi, 2003, p. 209) (Fig. 10A, 10B), along with several anonymous authors. However, these reconstructions often show a degree of bias, using exaggerated perspectives or manipulated sections that prioritize a clear view of the *Tempietto* at the expense of spatial coherence.

To gain insight into Bramante's design logic, it is essential to place his work within the context of Renaissance architectural theory, particularly that of Vitruvius. Vitruvius' writings, republished in 1486, were considered the foremost authority on ancient architecture during the Renaissance. Bramante's work closely aligns with Vitruvian principles, especially in his use of modular proportions.

A key element to consider is the significance of the number sixteen. This number plays an important role in Bramante's works, appearing in the *Tempietto*, its cloister, and in his first Roman project, the cloister of *Santa Maria della Pace* (1501). According to Vitruvius, sixteen is a "perfect number", a combination of ten and six, symbolizing balance and harmony

Vitruvius explains: "*But later, observing that six and ten were both perfect numbers, they combined the two and thus made the most perfect number, sixteen. They found their authority for this in the foot. For if we take two palms from the cubit, there remains the foot of four palms; but the palm contains four fingers. Hence, the foot contains sixteen fingers*" (Vitruvius Pollio, 1914, p. 74).

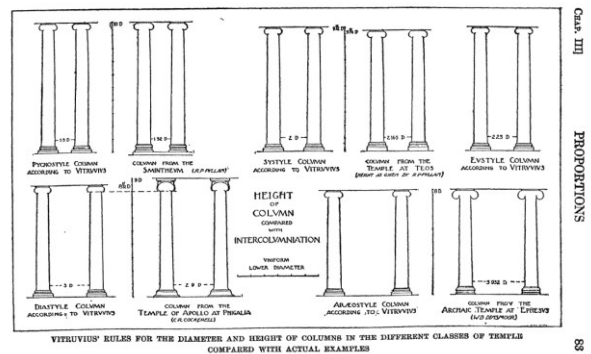
Vitruvius highlights the number sixteen as fundamental to achieving ideal architectural proportions. Bramante's choice of 16 columns, the application of the monopteros



(a)



(b)



(c)

Figure 10: a) Reconstruction by R. Lauri with enlarged order, b) Portoghesi's exaggerated perspective allowing the *Tempietto* to be framed despite the entablature; c) Excerpt from Morris Hicky Morgan's 1914 translation of Vitruvius, illustrating the proportions of the classical orders according to Vitruvius.

typology for the temple, and the use of the Doric order in the *Tempietto* - extensively described by Vitruvius - suggest that Bramante may have adhered to similar principles in his design for the cloister at *San Pietro in Montorio*.

However, while the *Tempietto* itself seems to be a near-perfect translation of Vitruvian principles through a Renaissance lens, applying these same principles to the cloister proves more challenging. Specifically, issues arise when we examine the spacing between the

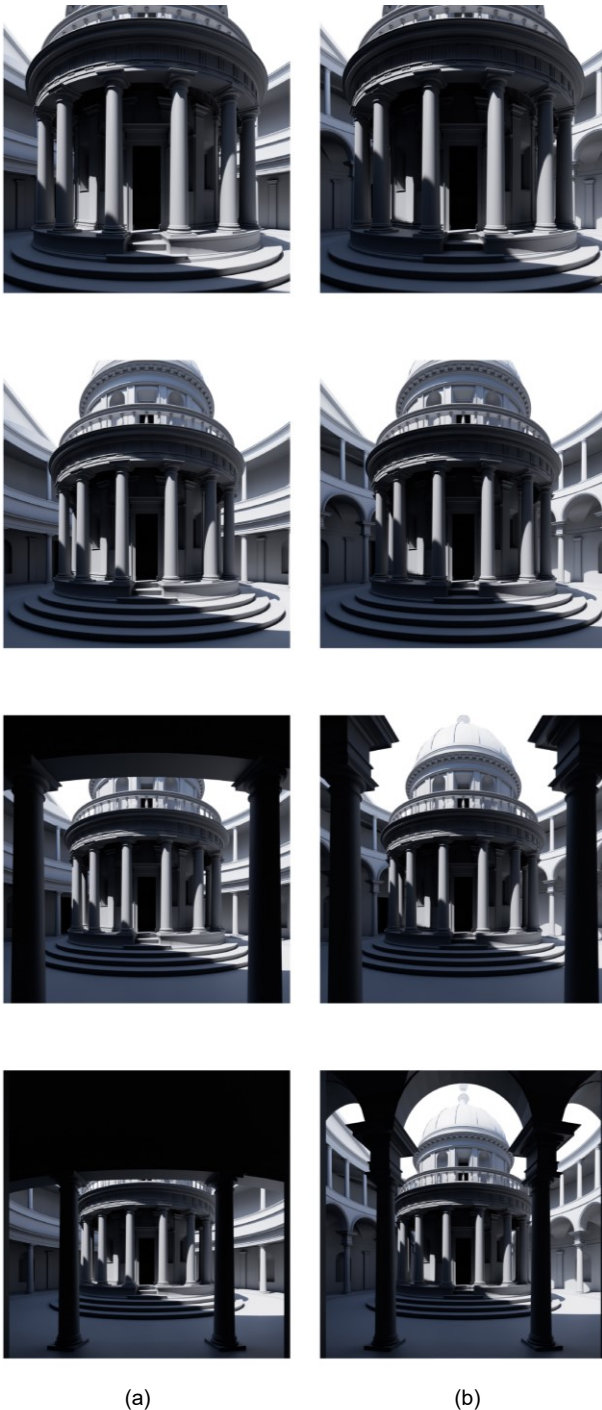


Figure 11: Sequence of images showing the framing of the Tempietto in two configurations: column a) Architrave-supported configuration; and column b) Arch-supported configuration.

columns (*intercolumnia*). In the *Tempietto*, Bramante followed Vitruvius' recommendation for "*eustyle*" spacing—two and a half column diameters—which Vitruvius considered the most graceful and proportionate.

In contrast, Serlio's plan for the cloister shows columns spaced much farther apart, exceeding even the "*areostyle*" (wide spacing) described by Vitruvius. This deviation would not only violate classical proportional standards but also pose significant structural challenges (Fig. 10C).

Vitruvius explains: "*In araeostyles, we cannot employ stone or marble for the architraves but must have a series of wooden beams laid upon the columns. And moreover, in appearance, these temples are clumsy-roofed, low, broad, and their pediments are adorned in the Tuscan fashion with statues of terra-cotta or gilt bronze*" (Vitruvius Pollio, 1914, p. 80).

It raises the question of whether Bramante intended such an exaggerated intercolumniation, or if this was Serlio's interpretation of the design. One explanation is that Serlio, in his schematic representation, was more focused on conveying a conceptual idea of Bramante's design rather than ensuring architectural accuracy. His use of the term "*inventione*" suggests that the plan should be seen as a creative exercise rather than a faithful reproduction of the intended structure. Still, it's not unlikely that Bramante intended to use 16 columns for the outer portico, considering that he insisted on using 16 pilasters on the exterior wall of the *cella*—an innovative solution. Due to the limited linear space, this resulted in a very dense surface where the openings appear excessively elongated.

A possible solution to the issue of wide intercolumniation would be to thicken the columns. Lauri's reconstruction, for instance, proposes that the columns of the portico were sized by projecting their diameter radially from the centre of the *Tempietto*. However, this approach would result in a "giant order", which would dwarf the scale of the *Tempietto*, reducing it to a decorative element beneath the imposing portico. Such disproportion would disrupt the harmony of the design, further suggesting that Bramante did not intend to apply classical orders literally in this context.

In essence, the problem of the cloister underscores the challenges in interpreting Bramante's unrealized design. Serlio's schematic plan offers only a partial and idealized view, leaving critical questions unresolved regarding the portico's structure, the use of classical orders, and column spacing. While a definitive reconstruction of the cloister remains speculative, an analysis of Vitruvian principles and a close comparison with Bramante's other works provide valuable insights into the architect's likely approach. However, as is often the case in Renaissance architectural studies, we must navigate the fine line between documented evidence and speculative reconstruction.

6. In favour of the arch

A key focus of this discussion is the empirical evidence suggesting that Bramante may have departed from the classical canon of architectural orders, which traditionally feature columns always surmounted by architraves. As Cantatore notes, "*In the rectangular free area, Bramante would have drawn a square cloister with a circle inside, that is, an annular portico around the Tempietto, with columns almost certainly architraved, of greater diameter than those of the chapel and therefore presumably taller than the latter*"⁶

⁶ "*Nell'area libera rettangolare Bramante avrebbe tracciato un chiostro quadrato con inscritto un cerchio, ovvero un porticato anulare intorno al Tempietto, con colonne quasi certamente architravate, di diametro maggiore di quelle del sacello e dunque presumibilmente più alte di queste ultime*". (Cantatore, 2017, p. 174)

(Cantatore, 2017, p. 174). However, the hypothesis of an architrave-supported portico must be contextualized within Bramante's broader design tendencies, particularly his innovative handling of architectural space systems.

Bramante's approach was deeply informed by a profound understanding of the methodologies of Alberti and Brunelleschi. As Bruschi observes, "*Bramante, with a profound understanding of the design methods not only of Alberti but also of Brunelleschi, adopted in his work both of these approaches to correlation—on the plane and in the third dimension—of two or more systems: order + arch of different sizes*" (Bruschi, 2003, p. 44). This layered approach to design, integrating both planar and volumetric systems, suggests that Bramante might have favoured an arched colonnade rather than a purely architrave-based solution, aligning more cohesively with his architectural language and Renaissance aesthetic preferences.

When considering the architectural precedents that would have informed Bramante's thinking, it becomes clear that he had access to numerous examples of colonnaded rotundas, many of which deviated from the classical canon in innovative ways. These precedents include the Maritime Theatre at Hadrian's Villa (118-125 AD), Santo Stefano Rotondo (circa 468-483 AD), and the Mausoleum of Santa Costanza (circa 337-351 AD) in Rome (Fig. 12). Among these, the Maritime Theatre is the only example featuring a circular portico, offering a compelling point of reference for Bramante's potential experimentation.

A critical observation emerges here: all these buildings, which Bramante likely studied, employed a greater number of columns than the sixteen envisioned in Bramante's design. As a result, the intercolumniation (the spacing between columns) in these precedents is narrower than what we observe in Bramante's plan (Table 1). While the diameters of these ancient rotundas differ from that of Bramante's proposed cloister, a comparison remains insightful.

Table 1: Comparative Dimensions and Intercolumniation Ratios of Bramante's Cloister and Classical Circular Structures.

	Diameter in meters	Columns	Intercolumniation in meters	Intercolumniation in column diameters
Bramante's Cloister	18	16	2.6	4
Maritime Theatre at Hadrian's Villa	35.5	40	2	2.75
Santo Stefano Rotondo	25.5	22	3	2.5
Santa Costanza	13	12 (double, 24 total)	2.35	3

These proportions become even more informative when expressed in terms of column diameters, following Vitruvian principles. For example, the Maritime Theatre features an intercolumniation of approximately 2.75 column diameters, *Santo Stefano Rotondo* approximately 2.5, and *Santa Costanza*, despite its use of double columns, approximately 3 column diameters at its narrowest point. In contrast, Paul Letarouilly's reconstructed plan for Bramante's cloister suggests an intercolumniation of approximately 4 diameters, a significant deviation from classical precedents. This discrepancy raises doubts about the viability of a traditional architrave (trabeated) solution for the cloister.

However, hybrid solutions can be found in these historical examples. For instance, Santo Stefano Rotondo incorporates niches and arcades along its outer perimeter, effectively addressing the challenge of widely spaced columns. Similarly, Santa Costanza

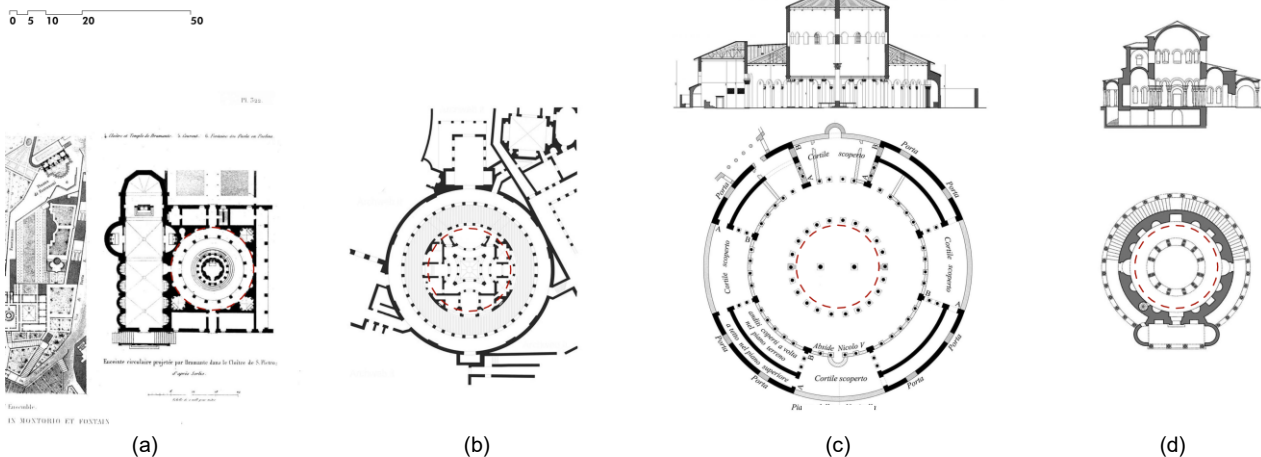


Figure 12: Comparison of circular floor plans: a) Bramante's Cloister as drawn by Letarouilly, b) Maritime Theater at Hadrian's Villa, c) *Santo Stefano Rotondo* in Rome, and d) Mausoleum of *Santa Costanza* in Rome. The red circle represents the largest diameter of Bramante's circular portico.

utilizes vaults and arches above the central row of columns. The most classical example, and the only one to feature an architrave, is the Maritime Theatre, which remains an outlier in Roman architecture.

Further, Hadrian's Villa provides additional examples of experimentation, particularly in the colonnade at the Nymphaeum. Here, we observe a clear instance of arches on columns—a less canonical, yet plausible solution. Another classical precedent for the arch-and-column system can be found in the Basilica of *San Pietro* in *Vincoli* (5th century, rebuilt between 1471 and 1503), a structure dedicated to the same saint as Bramante's *Tempietto*.

The Renaissance period itself was marked by a revival and reinterpretation of ancient architectural principles, particularly those of classical orders and spatial composition. Architects like Filippo Brunelleschi explored similar ideas, notably in his design for *Santo Spirito* in Florence, where he integrated classical orders with arches and introduced the "Brunelleschian dado" (*pulvino*) above the columns. This combination exemplified how Renaissance architects reconciled classical orders with innovative structural elements such as arches.

Given these precedents, it is reasonable to consider that Bramante may have embraced the arch as a viable solution for the cloister. Bramante's works provide clear examples of the arch-on-column system. The first is the crossing tower (*tiburio*) of *Santa Maria delle Grazie* in Milan, still reflecting medieval traditions. A more refined example can be found in the Doric cloister of Sant'Ambrogio, also in Milan, where arches harmoniously integrate with the classical order. Lastly, the small cloister of *Santa Maria della Pace* in Rome effectively manages its limited space by employing arches, albeit placed on pilasters rather than columns.

To summarize, while a definitive reconstruction of Bramante's cloister remains elusive, it is plausible that Bramante intended to deviate from a purely classical architrave system in favour of an arch-based structural

solution. The numerous precedents available to him, both ancient and contemporary, suggest that such an approach would not have been unusual within the broader context of Renaissance architectural experimentation. The interplay between classical principles and innovative design solutions lies at the heart of Bramante's architectural legacy, reflecting the Renaissance spirit of reimagining antiquity through the lens of modernity.

7. The scale of uncertainty

The speculative nature of reconstructing unbuilt or lost architectural projects, such as Bramante's cloister at the *Tempietto*, necessitates a clear framework for addressing the uncertainties inherent in the process. As discussed earlier, this study employs the Apollonio-Fallavollita-Foschi uncertainty scale to measure the confidence levels associated with different design elements based on source reliability.

Digital reconstruction initiatives have increasingly emphasized the importance of transparency, particularly in how speculative elements are documented and visualized. As Kuroczyński et al. highlights, the Scientific Reference Model (SRM) is "a documented and published basic model" that allows other scholars to trace the decision-making process, identify sources, and understand the reasoning behind each aspect of the reconstruction (Kuroczyński, Apollonio, Bajena, & Cazzaro, 2023). This traceability is critical in speculative reconstructions, where limited primary sources lead to varied interpretations. As part of the CoVHer project, we adopted the uncertainty visualization framework developed by Apollonio-Fallavollita-Foschi, which systematically classifies levels of uncertainty according to the reliability of the sources that underpin the reconstruction process (Apollonio, 2016; Apollonio, Fallavollita, & Foschi, 2021). While this system offers a nuanced breakdown of uncertainty and criteria for assigning levels, it presented practical challenges in our specific study of Bramante's cloister.

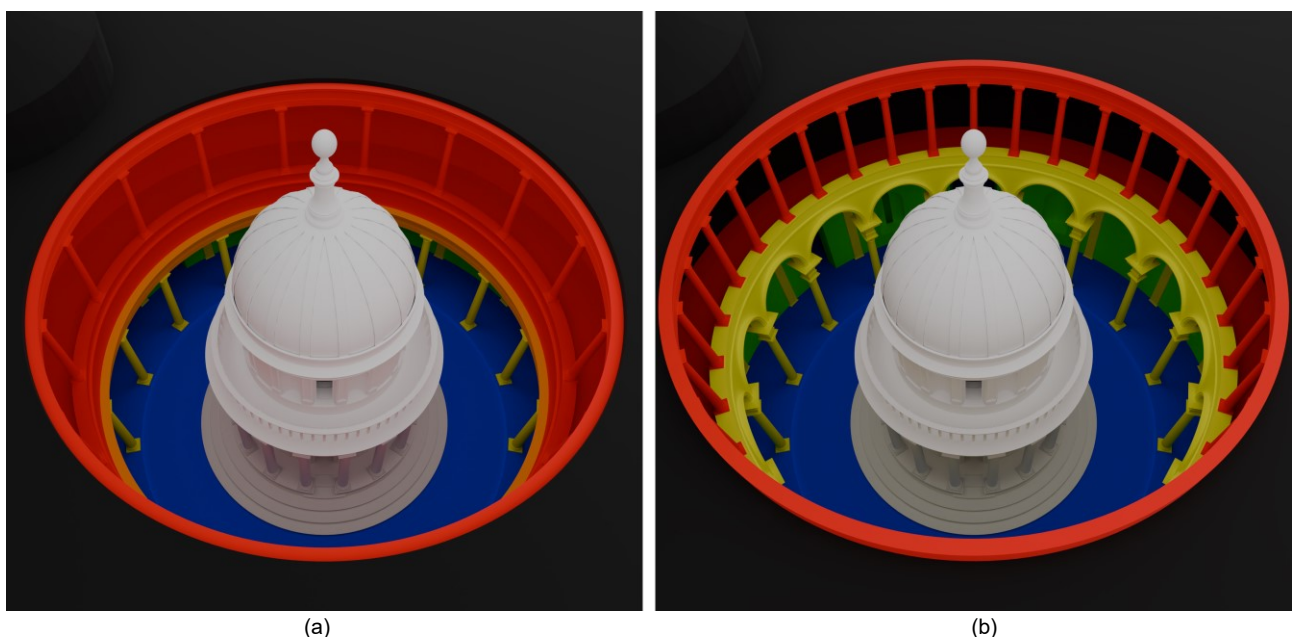


Figure 13: Visualisation of the uncertainty scale for the two reconstructions: a) Architrave, and b) Arches, with average values of 75.97% and 72.90%, respectively.

Table 2: Scale of uncertainty according to Apollonio-Fallavollita-Foschi (Apollonio et al., 2021).

		Description
■	1	~0-14% Reliable assumption derived from reality-based data
■	2	~14-28%~14-28% Reliable conjecture based on clear and accurate direct/ primary sources
■	3	~28-43% Conjecture based on stylistic/ structural references by SAME AUTHORS
■	4	~43-57% Conjecture based on stylistic/ structural references by DIFFERENT AUTHORS
■	5	~57-71% Conjecture based on stylistic/ structural references by SAME AUTHORS when direct/ primary sources are not available
■	6	~71-86% Conjecture based on stylistic/ structural references by DIFFERENT AUTHORS when direct/ primary sources are not available.
■	7	~86-100% Conjecture based on personal knowledge due to missing or unreferenced sources

The particular context of Bramante's cloister —where only one typological plan by Serlio is available as a contemporary source— results in a high baseline level of uncertainty (Fig. 13). This makes our reconstruction process more speculative from the outset, posing unique challenges in applying the Apollonio-Fallavollita-Foschi scale effectively. As noted by Apollonio *et al.*, this classification system is well-suited to cases where a variety of sources, such as architectural remains and diverse documents, support a more granular breakdown of certainty (Apollonio, 2016). However, with limited primary documentation for the cloister, applying the scale in a way that supports detailed comparative

analysis becomes difficult. Although visually compelling, the scale may misleadingly suggest that distinct reconstructions are directly comparable when, in fact, they may rest on entirely different evidential foundations.

Furthermore, the distinction between levels is skewed towards exact sources, which favours cases with incomplete but specific documentation. This framework lends itself well to archaeology, where the goal often involves reconstructing plausible versions based on a mix of conjecture and evidence. However, for the cloister's plan, the scale becomes less balanced, as the reliance on a single source limits the depth of comparative speculation. Apollonio's Critical Digital Model approach, which emphasizes traceability, the quality of historical reconstruction, and visualization, aligns with these observations. It suggests that the scale could be adapted to better account for projects reliant on minimal documentation by allowing flexibility in visualizing speculative elements with greater clarity (Apollonio et al., 2021).

While the Apollonio-Fallavollita-Foschi scale is invaluable for documenting projects with diverse sources and measurable gaps, our application revealed its limitations when applied to reconstructions that involve high levels of speculation, such as Bramante's cloister. Ultimately, this chapter underscores the need for adaptable uncertainty scales that can support reconstructions based on minimal documentation, allowing both experts and audiences to navigate the balance between documental evidence and informed speculation.

8. Discussion

At this juncture, it is pertinent to reflect on the insights gained from studying and modelling Bramante's *Tempietto* and the unrealized cloister. As reiterated throughout this paper, there is no definitive resolution to the dilemma between an architrave and arch-based

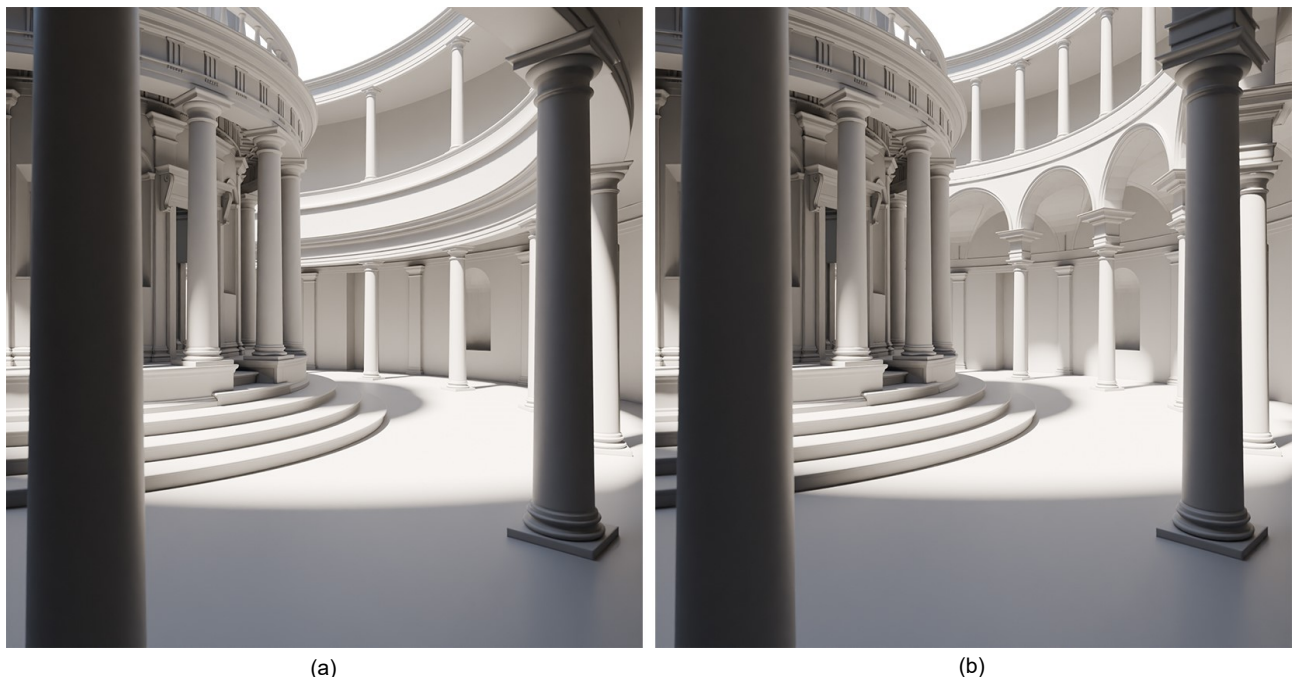


Figure 14: Comparative view of the two options at the portico level: a) Architrave; and b) Arches, suggesting the movement of those circulating, surpassing static and axial perspectives.

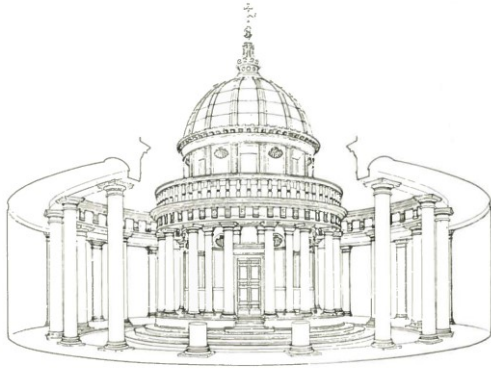


Figure 15: Portoghesi's reconstruction highlighting the issue of the portico and *Tempietto* coexistence, resolved through sectional views.

structural solution for the cloister (Fig. 14). It is intriguing to note how varying interpretations of this issue result in diverse outcomes.

On one hand, we have speculative reconstructions, such as those by Paolo Portoghesi (Portoghesi, 1970, p. 54) (Fig. 15), which canonize a solution that may not entirely reflect a realistic representation. It is worth considering that, had digital modelling tools been available to Portoghesi, his conclusions could have shifted, allowing for a deeper exploration of the structure's complexities.

Moreover, while Bramante's cloister project was never realized, it is clear that his conceptual approach had a lasting influence on subsequent architectural works. The "*inventione*" preserved in Sebastiano Serlio's treatise, for instance, appears to have inspired other significant projects, which materialized spatial interpretations of Bramante's ideas. Notable examples include the Circular Patio of the Palace of Charles V in Granada (1527-1568) and the Plan of the Monastic Complex of *Serra do Pilar* in Porto (construction began in 1537, completed in the 17th century) (Fig. 16). Both structures, while grounded in classical architectural principles, offer solutions to the same problem of a colonnaded rotunda, yet with markedly different column arrangements.

The number of columns in both the Circular Patio and *Serra do Pilar* is significantly greater than what Bramante envisioned. The Palace of Charles V features 32 columns, while *Serra do Pilar* employs 36 columns, in contrast to the 16 columns proposed by Bramante. It is compelling to consider that these designs may have drawn inspiration from Bramante's unrealized cloister. In the case of the Palace of Charles V, the doubling of the number of columns and the experimentation with the circle inscribed within a square recalls Bramante's innovative spatial composition. Similarly, the design of the four lateral chapels in *Serra do Pilar* reflects elements of Bramante's vision, as presented by Serlio, even though constructing all four chapels would have been structurally unfeasible in the case of the *Tempietto*'s cloister.

This influence demonstrates the profound impact of a single diagrammatic plan, published in 1540 in Serlio's treatise, which crossed territorial boundaries and inspired architects in other countries. If such a conceptual drawing could inspire architectural works



(a)



(b)

Figure 16: Built circular courtyards: a) View of the Palace of Charles V in Granada; and b) View of the Serra do Pilar in Porto.

beyond Italy, it underscores the importance of reconstructing and communicating Bramante's spatial vision. By reconstructing Bramante's unrealized designs, we not only preserve historical architectural thought but also allow it to inform and inspire contemporary architectural discourse.

The ambition of this study, therefore, is threefold: to understand, disseminate, and inspire. Understanding Bramante's design process offers invaluable insights into Renaissance architectural experimentation. Disseminating these findings through digital models and academic study ensures that the knowledge extends beyond historical inquiry into active architectural practice. Finally, by bringing Bramante's unrealized vision to life, even in a speculative form, we aim to inspire future generations of architects and scholars, offering them a spatial and intellectual framework with which to engage.

Looking ahead, the next phase of this research could explore alternative structural solutions for Bramante's cloister. In this study, we concentrated on a design where the columns match the size of those in the *Tempietto*, testing various scenarios for both architrave and arch-based systems. However, an intriguing direction for further investigation would be to examine the feasibility of larger columns capable of supporting the wider intercolumniation required for a classical architrave or increasing the number of columns to achieve an ideal Vitruvian proportion. This approach would necessitate recalculating column dimensions in relation to the structure's load-bearing requirements, potentially offering insights into how Bramante might

have balanced his pursuit of classical proportions with practical structural considerations.

This work contributes to Renaissance architectural discourse and underscores the relevance of speculative digital reconstruction in architectural history. Bramante's ideas, though incomplete or unrealized, continue to resonate, reminding us that architecture is not merely the art of building but also the art of imagining.

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Author Contributions

All authors have contributed equally to the paper.

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