# THE VISUAL MEDIATION OF A HISTORICAL INNOVATION

Lyubov V. Dimova, Dominik Lengyel

Brandenburg University of Technology Cottbus-Senftenberg, Platz der Deutschen Einheit 1, Cottbus 03046, Germany

**Abstract**

*This paper aims to show how a historical innovative engineering achievement can be mediated visually without having to study the underlying mathematics. The current dissertation examines the history and construction of the four crossing towers that Cologne Cathedral has had in the course of its history. Although depicted in numerous illustrations of the past centuries, their concrete appearance remains largely hidden. Documents from the cathedral archives allow us to reconstruct both its construction and its appearance. In the process, discrepancies between construction planning and execution as well as between execution and seemingly detailed visual reproduction for the public come to light. Here, however, we are concerned with its penultimate and final version, built between 1848 and 1880 and then slightly altered after the destruction of the Second World War. This raises the question of whether its mid-twentieth-century form does not require a revision to its late-nineteenth-century completion in order not to resurrect the original appearance, a twelfth-century design after all, as the completion of this already infinite building site. An important argument is precisely that engineering innovation which made the form planned in the Middle Ages possible under the demands of the 20th century.*

**Keywords:** *historical innovation, crossing tower of Cologne Cathedral, 3D computer reconstruction, visualization, verifying of model*

## 1. INTRODUCTION

The humanities and cultural studies disciplines of architectural history, architectural theory and monument preservation are concerned with the study, understanding and, in the case of monument preservation, the protection of architectural records of human life and activity from the first known buildings around 8000-9000 BC to the present day. From Vitruvius (1st century BCE) to modern times, the methods used to study architectural heritage have changed dramatically, especially since the advent of computer technology in the 20th century. Whereas in the beginning one relied on careful observation and precise reproduction (Schmidt 2008) of what one saw on parchment, and in the 19th century on photographic images, today there are 3D scanners, satellite imagery, 3D modeling and visualization program, as well as VR (Virtual Reality) and AR (Augmented Reality), with use of holograms in the near future. However, all these technologies may be insufficient for the proper reconstruction of a monument that has been partially or completely destroyed by construction defects, natural disasters or war. And even if not every building or structure from our distant or recent past needs to be reconstructed in some way and preserved for the future, there are buildings – historical innovations – that are so significant in terms of architectural style, form, material, construction or method of construction that they have to be passed on to future generations. (Schmidt 2008)

When 3D-reconstructing such a historical monument, the following should be taken into account :

– Which phase of construction is the subject of the reconstruction? Significant buildings usually undergo many changes over the centuries due to changes in religion, government, use of the building or sudden demolition;

– The available sources of information – written descriptions, drawings, photographs, 3D scans, etc. Here the reliability of the source is of great importance, not only in terms of the author, but also whether they are original drawings or copies (e.g. traced or printed from a plate), and the scale of the plans (1:1, 1:50, 1:100...) and whether they are dimensioned (in what unit of measurement –

metres, feet.... – including particularly the conversion from ancient to modern units, as the size of a foot varies according to the year and country in which it was used);

– The level of detail and the level of abstraction respectivly depend mainly on the quantity and quality of the sources as well as on the purpose of the reconstruction to give a general overview of the historic building or to provide detailed information about the construction, materials used, etc. No matter how detailed the reconstruction is, it can never be identical to the original, as changes are always made to the plans during the construction process. The only exception, at least visually, would be a full 3D scan of the original building; (Lengyel&Toulouse 2016)

– Visualization of the three-dimensional reconstruction – here there is a risk of falsificating the object – especially when using textures that represent the material from which the historical building was built. Things to consider apart from the building itself are the light – natural or artificial – and the building's context, i. e. surrounding buildings, but also landscape, vegetation etc. (Lengyel&Toulouse 2016)

There will always be an objective gap in knowledge, namely that of the actual appearance of the historical condition of a building that is only fragmentarily preserved. In this case, it will never be possible to find out down to the smallest detail, including all the merely visual characteristics, what an object was like, even if it is only the individual stone in a partially destroyed or restored masonry. In contrast, the architectural structure can be determined with some certainty. Obvious gaps in a masonry structure, for example, were almost certainly homogeneously completed and correspondingly consistently embedded in their context.

Still, a 3D reconstruction and visualisation of a historical object is an important step for its immaterial preservation but also, if necessary, restoration in reality. Computer technology can be used to create multiple versions of a building that have been demolished today, allowing scientists to query their theories and come to a consensus on what it probably looked like or was at least intended to be structured in the past before heading for actual reconstruction. Furthermore, 3D reconstructions enable the detailed study of a building's construction methods and thus the study of technologies and ways of thinking of the original master builders that have been lost over the centuries. Last but not least, 3D visualisations enable the dissemination and easier understanding of architectural monuments among the general public in a way that is accessible to different age groups.

## 2. MATERIALS AND METHODS

### *2.1.Subject and Timeliness of the research work*

The subject of a three-dimensional reconstruction and visualization is the crossing tower of Cologne Cathedral in its third construction phase, which existed in its original form from 1860 until around 1961, when its decoration was replaced due to damage caused by bombing in the Second World War. The central tower was built during the time of the Industrial Revolution in Europe and its construction used filigree ironwork, a new design for the time. Although the material used, cast iron and wrought iron, and its properties had not been fully researched until then and were still quite rare for such a large and complex structure, its builders built a "very solid" structure (Der Köln – Lotse 2020) that had already survived 160 years and two world wars and was called the "iron crown of the cathedral" (Steuer 1980).

The reconstruction is part of the dissertation *"The crossing tower of Cologne Cathedral. Detailed investigation of the construction history and appearance of the crossing tower in the period from approx. 1332 to the present day and its visualization with the aid of new technologies"* and its deepening in the master's thesis *"The metal construction in the planning and execution of the crossing tower of Cologne Cathedral in the 19th century"*, written in the period April–September 2022 at the BTU Cottbus-Senftenberg, Germany.

*2.2.Materials*

The main source of information for the construction of a three-dimensional reconstruction of the central tower is the Cathedral Construction Archive in Cologne, as well as the dissertation by Thomas Schumacher "Großbaustelle Kölner Dom. Technik des 19.Jahrhunderts bei der Vollendung einer gotischen Kathedrale" from 1993, whose main source is again the Cathedral Construction Archives in Cologne.

Due to the replaced decoration of the tower in the 20th century, there are only a few photographs showing the tower planned and executed by Zwirner, with the help of Voigtel. The main sources of information are therefore the numerous plans, sketches and notes on individual details made during the design process, working drawings from the construction process, and views and sections of the completed tower, which were also published later. In addition, there is the textual description of the construction of the roof and crossing tower by Thomas Schumacher. His descriptions are based first on the study of numerous notes by those involved in the construction, then on the plans and drawings from the cathedral archives already mentioned, and finally on personal inspection of the components still preserved after the war. For the best possible understanding of the construction, especially of the roof and the lower part of the tower, which have been preserved in the original, additional contemporary photographs as well as the 360-degree panorama "Attic in Cologne Cathedral" were used.

Pictorial sources are divided as follows:

a Plans

aa Sketches, detail and working drawings

ab View and section of the completed crossing tower

ac Published plans

b Historical photographs (before the Second World War)

c Contemporary photographs (after the Second World War)

d 360-degree panorama

It is important to mention that during the 3D modelling process, discrepancies in the geometric reconstruction of some details in the published plans were found, most likely due to the transfer of the original plans to the printing plates. In addition, small differences were found between the individual sources caused by the scale of the plans, so during the 3D modelling the following scheme was used. The most reliable and detailed source for the exact dimensions of the 3D model are considered to be the dimensions and notes on the working and detail drawings, as well as the dimensions described by Schumacher from the correspondence of those involved in the construction. Next in importance are the working and detail drawings, whose information was constantly compared with the contemporary photographs of the surviving original components. The least reliable for the model are the published plans. They serve as a rough orientation for the dimensions and position of the individual elements from the other detailed plans. Since the historical photographs only show the upper part of the tower and their resolution is relatively low, they mainly serve to illustrate the external decoration of the tower. Here there is also a small discrepancy between them and the published plans. In the cover of the construction and the decoration of the tower, the 3D model probably deviates the most from the built crossing tower as the information is the least.

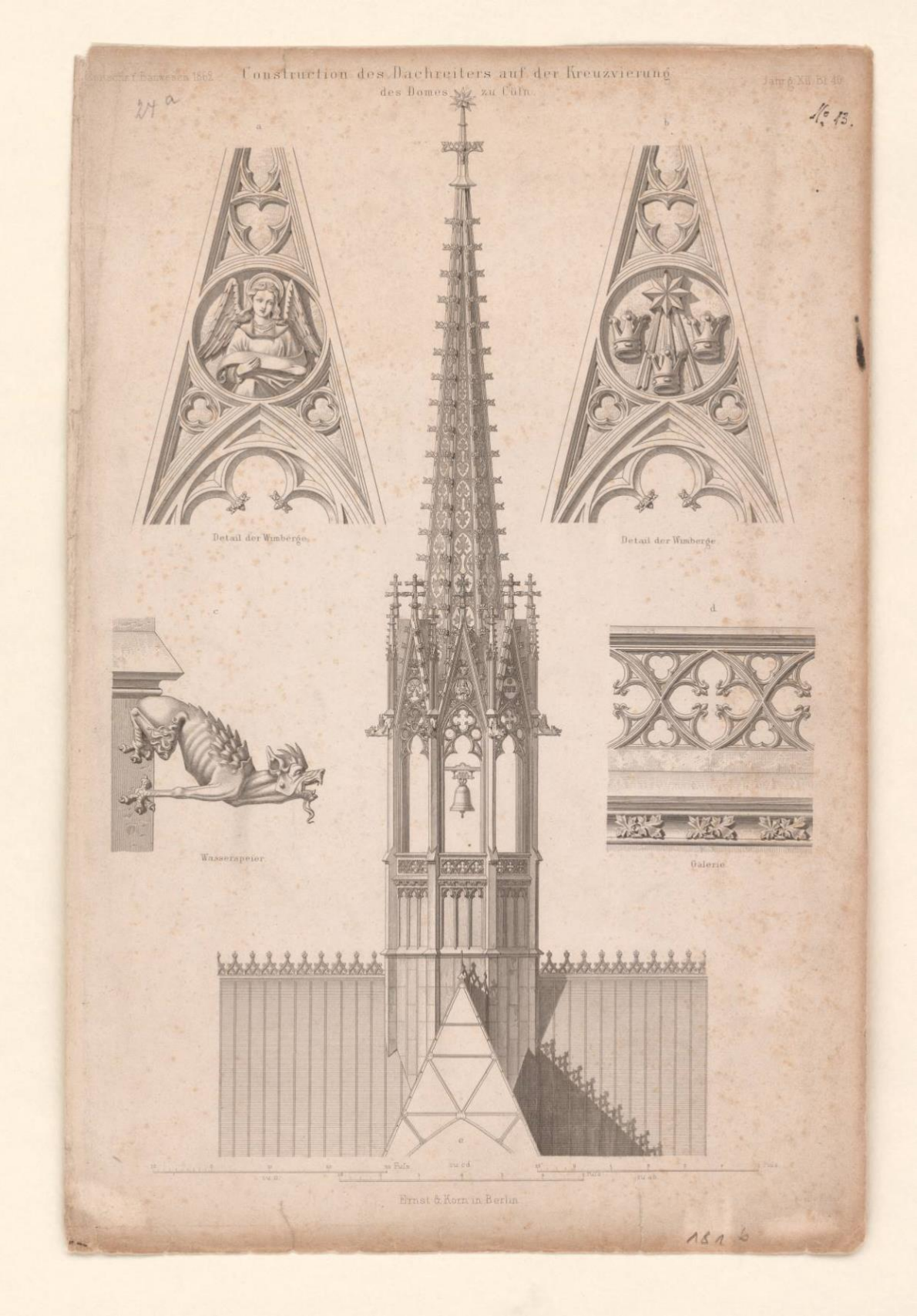


**Fig. 1.** Construction of the ridge turret on the cloister of the Cologne Cathedral. Journal Bauwesen 1862

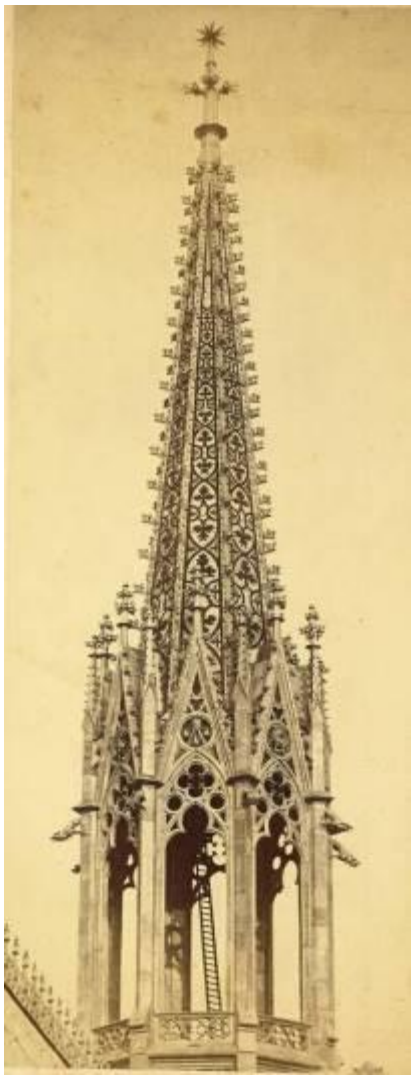

**Fig. 2.** Central tower of Cologne Cathedral. Cathedral building archive

*2.3. Procedure for the 3D reconstruction and visualization of a hitoric building*

The first step in creating a 3D reconstruction of the crossing tower of Cologne Cathedral from the 19th century was to collect as much and reliable data as possible about its construction and furnishings in the form of text and image sources, as described in detail in section *2.2. Materials.* Although the number and type of sources seemed very complete and extensive from the beginning, the quality of the plans and the possibility of using them completely could only be assessed after the computer work had begun.

As it was of great importance to the authors to create as detailed a model as possible at the beginning of the 3D modelling, and as there were numerous descriptions for the dimensions of the individual iron elements and for other technical drawings, the degree of abstraction was chosen as low as possible. As far as the elements with comprehensive information are concerned, the almost 1:1 scale model is practically identical to the original, i.e. apart from production-related deviations of elements considered to be identical and assembly-related deviations in the geometric disposition of the parts in space. For elements for which detailed information was not available, they were reproduced on a smaller scale, but then described and specially marked in the text section of the master's thesis in order to avoid distortions and the misleading of the viewer.

The reconstruction began with the most obvious elements, namely the columns of the substructure and their cast-iron "shoes" and "caps". In order to determine their exact dimensions, despite the dimension

lines in feet, comparisons were constantly made between the detailed drawings and the more general plans/cuts, since these plans were, on the one hand, made by hand and, on the other, the dimensions in feet did not always correspond absolutely with the other drawings or textual information when converted into meters.

Once an element of the structure was completed, the link to other parts and their plans followed. In the case of the crossing tower, in order to find the corresponding drawing, as the documentation itself was not ordered and organised according to modern methods, contemporary and historical photographs were of great importance in order to be able to place the parts of the structure in the right place and to understand their function.

In addition to the tower itself, the iron roof structure surrounding it was also constructed in the 3D model, as both influence each other and a complete record of the supporting elements of the tower depends on those of the roof.

With the tower's and roof's supporting structure in 3D built, the next step was to verify the model by selecting perspectives that matched historical or contemporary photos. Overlaying the 3D reconstruction on the photos is the easiest way to see if the dimensions or position of an element in the plans was misinterpreted. If the reconstruction shows no deviations in several of the photos from different angles, one can proceed to the next step. In the case of the Cologne Cathedral, this was the construction, the covering of the roof with wooden slates and sheets of lead, and the external decoration of the tower with zinc sheets and ornaments. Here, in contrast to the supporting structure, the sources of information are not as detailed, that is, the degree of abstraction was higher and the elements were built only from drawings and photos, without dimension lines or text descriptions. Since the external decoration of the tower was destroyed during the Second World War and the historical photos showing the entire upper part of the tower are of very low resolution, it should be emphasized that this part of the 3D reconstruction is most likely to differ from the original, which is also expressly mentioned in the scientific work.

After completing the 3D modeling of the object, its visualization follows. The main aspects of this part of the work are as follows:

– the way of presentation – line drawing, near to photorealistic renderings;

– visualization of building materials and textures;

– camera position - pedestrian perspectives, bird's eye view, axonometry, 3D slice, etc.;

– type and direction of light;

– presentation of the surrounding elements - neighboring buildings, trees, people.

Two types of representation were used to visualize the crossing tower – a line drawing to explain the individual structural elements and near to photo-realistic black and white renderings so that the viewer can get an also emotional impression of the historical place. The reason for the black and white imagery – simulating physical space’s photographies – is to avoid adulteration of the building materials, which would lead to a distrust of the whole 3D model. The building materials are not presented in detail, only some of their qualities are used, such as the stronger glare of metal elements compared to wood or stone elements.

The position of the virtual camera is on the one hand a pedestrian perspective (1.70 m above the ground), with which the viewer can trustfully perceive space as if being in the tower, on the other hand perspectives with a focus on individual elements of the building, as the understanding and getting to know the tower and the roof from a static point of view is the main task of this 3D reconstruction. This is also the reason why neighboring elements or people are not shown. Both the visualization of the exterior of the cathedral and the roof, as well as the construction, used natural light, which, although understandable for the external representations, raises some questions for the supporting structure, which in reality could only be illuminated by artificial light. However, as the focus of this work is on technological innovation, the surroundings of the tower or cathedral are omitted, and the geometry, although projected naturally, is only illuminated to highlight its spatial features.

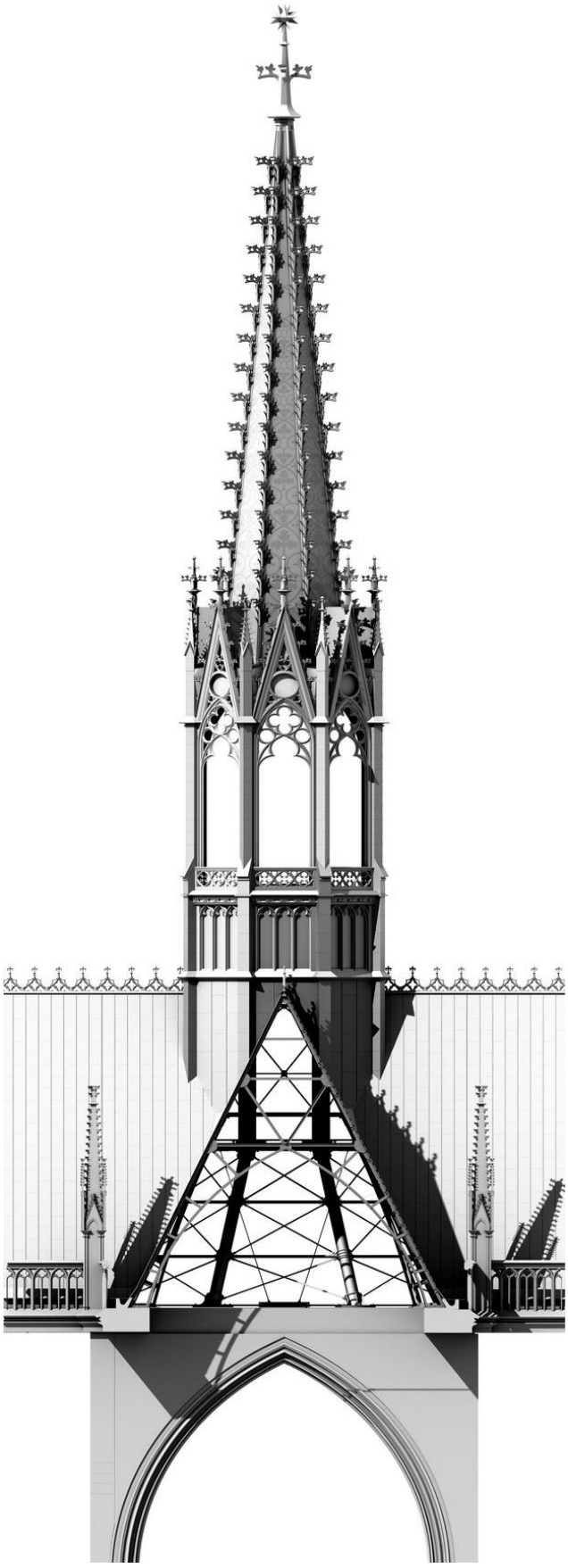

**Fig. 3.** 3D reconstruction of the crossing tower of Cologne Cathedral. Lyubov Dimova

## 3. RESULTS

The result of the 3D reconstruction and visualization of the Cologne transcept tower is a complete axonometric representation of the structure of the tower and its surrounding roof in the form of a line drawing, which allows the study and understanding of the metal elements used. From this drawing, all the individual elements can be specified in detail, right down to how they are fastened with bolts or rivets, their dimensions and their position. The 3D model itself can be used for engineering calculations of the forces acting through the structure and weak points, thereby facilitating repair work on the structure.

In addition to the purely constructive result of the 3D reconstruction, there are numerous "photographs" that give every viewer an idea of almost what the tower looked like in the 19th century. As with further work with the model, in addition to the 2D rendering itself, VR and AR can also be combined, in which the viewer not only sees the tower, but can also "experience" it.

Part of the project so far is also a 3D-printed model of the 3D reconstruction, which is about 1 m tall and allows a physical spatial investigation with eyes and hands.

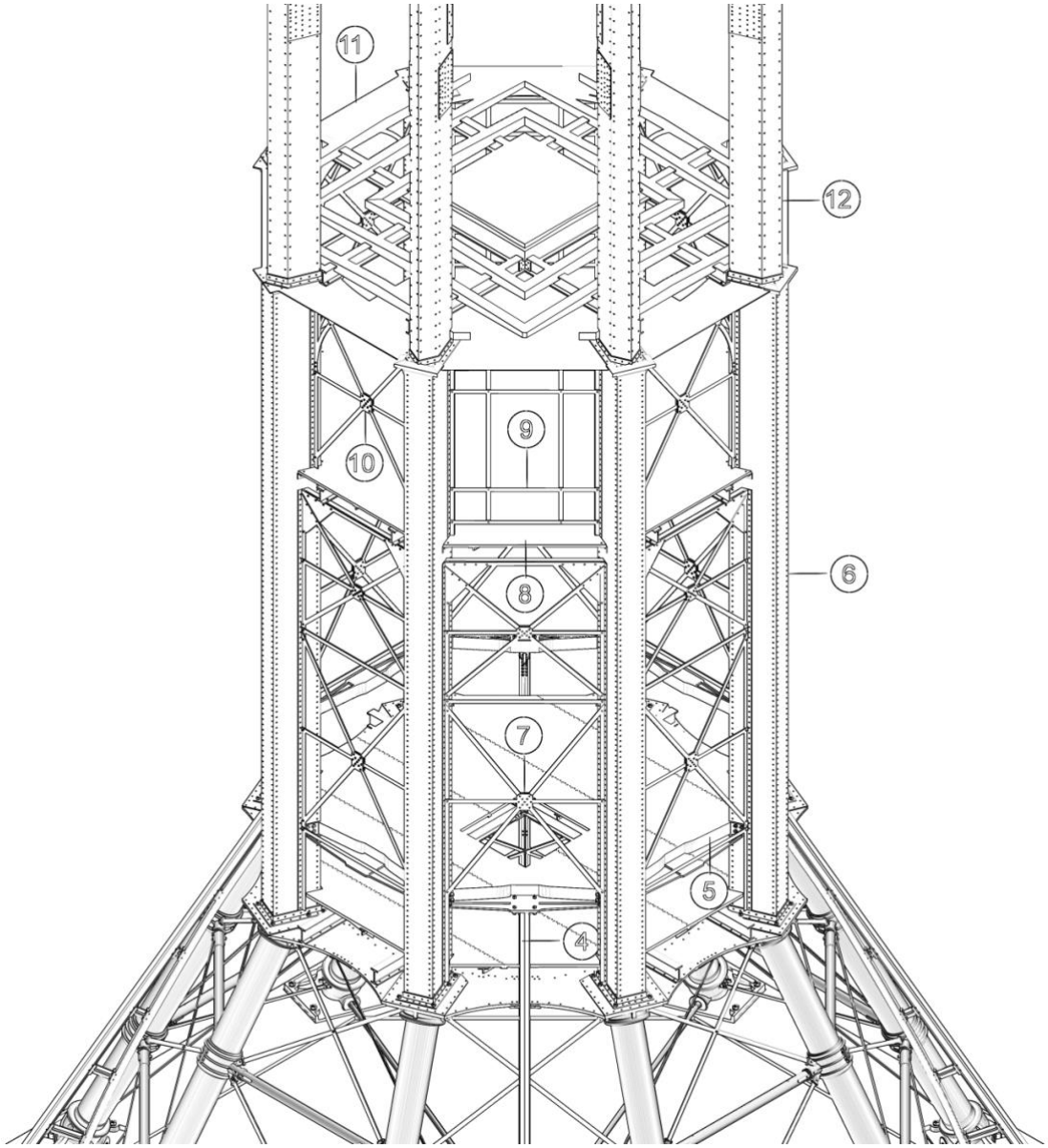


**Fig. 4.** Axonometry of tambour of crossing tower. Lyubov Dimova

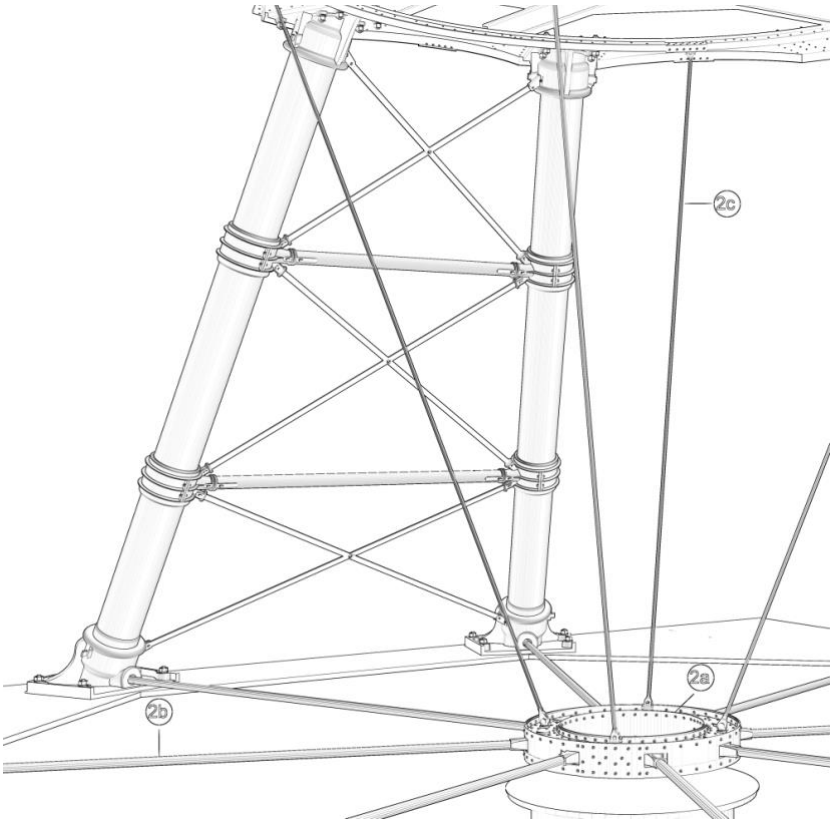


**Fig. 5.** Detail of tension ring of crossing tower. Lyubov Dimova

**Fig. 6.** Renderings of tension ring of crossing tower. Lyubov Dimova

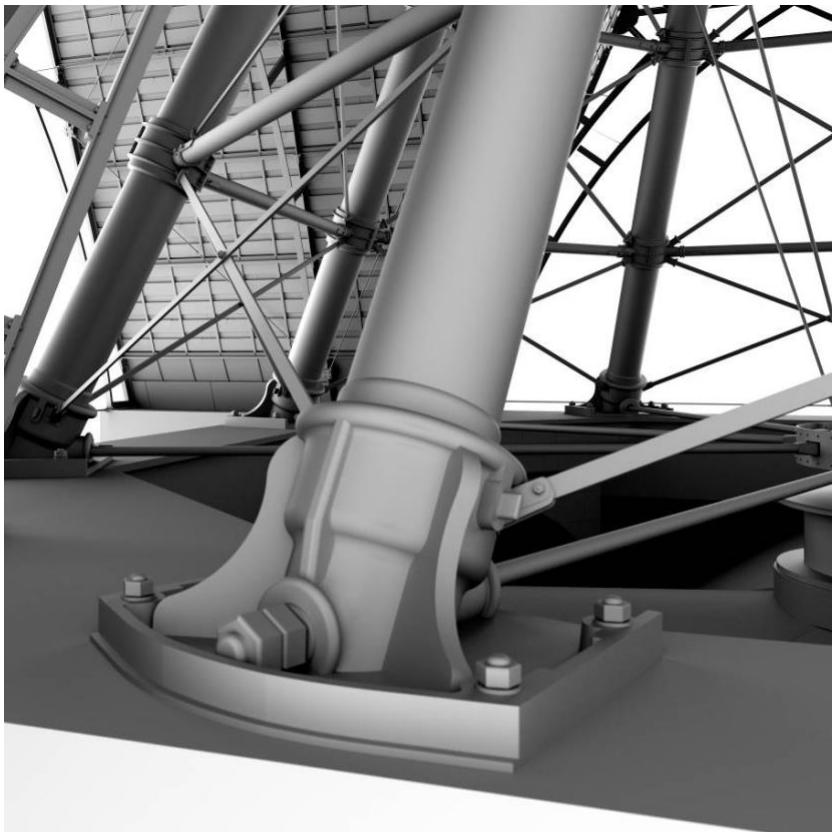

**Fig. 7.** Renderings of shoe of crossing tower. Lyubov Dimova

**Fig. 8.** Renderings of node of the crossing tower roof structure. Lyubov Dimova

**Fig. 9.** Renderings of the substructure of the crossing tower. Lyubov Dimova

**Fig. 10.** Renderings of tambour of crossing tower. Lyubov Dimova

## 4. DISCUSSION

After completing the study of the monument, building the three-dimensional computer model and its visualization, the author is faced with the challenge of proving the veracity of the model in order to defend his scientific work. The main question remains where are the limits and possibilities of verifying a model built based only on two-dimensional plans and photographs of a historic facility whose present-day view differs from the original one.

In the case of the example of the crossing tower of Cologne Cathedral considered here, the main supporting structure has been preserved in its original form, and if desired this part of the model can be examined in detail by comparing the dimensions and position of each individual element with the actual structure, which would be an extremely laborious and time-consuming work to perform.

Another possibility for proving veracity is understanding how a metal structure functions. By studying the materials used, as well as the technical capabilities of the time of its building, the author can verify that the model he has built could be constructed and withstand the various forces of impact using structural and static principles. Even if a complete and accurate proving of the location and size of the elements cannot be achieved by this method, it can generally verify whether or not such a structure could function properly.

Verification the external decoration of the tower is even more difficult to achieve. Of course, there remains the possibility of researching preserved fragments of the decoration after its removal in the archives of the cathedral, or else in samples used at that time in other similar facilities, but the probability of concrete success is too small and it would rather be again a very general and vague validation of the model.

## 5. CONCLUSIONS

In addition to the benefits of making a three-dimensional model in the study and work of historical innovation so far indicated, it can be added that the overall model, among other things, also has an evaluative role in mediating the intersection in terms of sources. Through it, various historical condition questions can be answered simply by reconciling all historical and current information.

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