The Enhancement of Cultural Heritage: from Documentation to Digital Simulation of MAC USP by Paulo Mendes da Rocha

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Abstract

The enhancement of the archival architectural heritage, in terms of preservation, has favored the documentation and investigation of projects and buildings. The significance of constructing 3D digital models in the domain of architecture is already a well-established idea. In addition, the digital reconstruction of hand-made drawings contributes to the deepening of the study of unbuilt. In this sense, the representation only by orthogonal projections is insufficient to perceive the spaces, on the other hand, animation allows us to include time by simulating the displacement of a virtual spectator. In the unbuilt project for the Museum of Contemporary Art at the University of São Paulo, MAC USP (1975), designed by architect Paulo Mendes da Rocha, the circulation system is organized by a set of ramps, footbridges, and stairs, which promotes the contemplation of the internal spaces. Using digital simulation, this article analyzes the temporal sequence of approach to this building, its accesses, penetration into interior spaces, and the multiple views from six paths resulted by animations. Rendering, animation, and axonometric resulting from 3D digital model, allowed us to analyze the circulation system, particularly the emphasis of the ramps in this project from the concept of promenade architecturale. The original contribution of this article is highlighting the singular circulation system adopted by the architect in this unbuilt project by digital simulations.

Keywords: unbuilt, promenade, circulation, animation, perception.

Introduction

The intensification of digital documentation of unbuilt projects, which took place in the last two decades, has become fundamental for the preservation of cultural and architectural heritage. Important researchers in different areas have used digital tools to investigate unbuilt or demolished projects. Martens and Peter (2010), in their research on virtual reconstruction of synagogues in the City of Vienna, emphasized the importance of 3D modeling to investigate the cultural heritage. Advanced technologies, using laser scanning or digital photogrammetry can quickly and accurately create a 3D survey [Wilson et al. 2018, p. 24]. In addition, 3D digital reconstruction of an archaeological site, using extensively the 3D documentation of the site is an efficient method to investigate cultural heritage [Guidi, Russo, Angheleddu 2013, p. 99].

Heritage architecture can be reconstructed with a range of digital technologies to record and remember buildings and sites. [Rushton, Schnabel 2020, p.193]. In XXI century, digital modernism heritage [Bartolomei, Ippolito, Vizioli 2022] has been a focus of researchers interested in digital reconstruction of the past or unbuilt. Studies on unbuilt architecture developed by Sdegno (2011); Foscari (2010); Harbison (1991); Galli and Mühlhoff (2000); Pfeiffer (1999); Larson (2000) demonstrate the importance of the theme in the last 40 years. Unbuilt projects are especially important due to the idea that they structure them, which, despite not

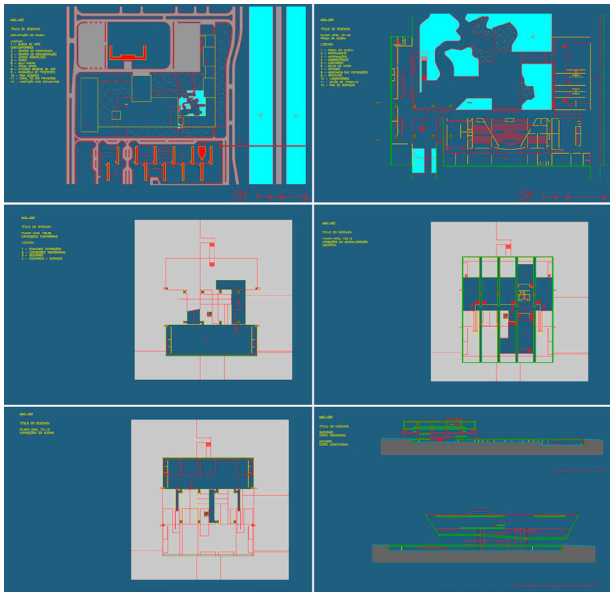


Fig. 1. Original drawings provided by Paulo Mendes da Rocha's office.

being implemented, are present in the architect's work as a whole.
The redrawing (2D) and digital models (3D) of these unbuilt projects enabled the visualization and analysis of buildings for years imagined by the architect and that so far remained unknown. Renderings, animations and perspective vertical sections were produced from the digital models, which enabled a better understanding of spaces in their three-dimensionality. In addition, the great advantage of creating a 3D digital geometric model is being able to generate virtual paths through such spaces.
In this research, the graphic analysis by animations and axonometry of MAC USP allows us to appreciate, synchronously, various formal and spatial aspects, leading us to understand the environments designed by the architect, gradually, through the virtual displacement of the observer.
The main methodological procedures and stages of the research: 1) Survey and digitization of information at the architect's office; 2) Identification of design concepts, and strategies in his projects; 3) Three-dimensional modeling of the building; 4) Study of the circulation system and routes; 5) Graphical analysis through renderings and animations; 6) Production of axonometrics and perspective sections; 7) Analysis of the path of the sun and shadows projected inside the building; 8) Discussion of the results obtained. As a result, we identified eight concepts in his unbuilt project.

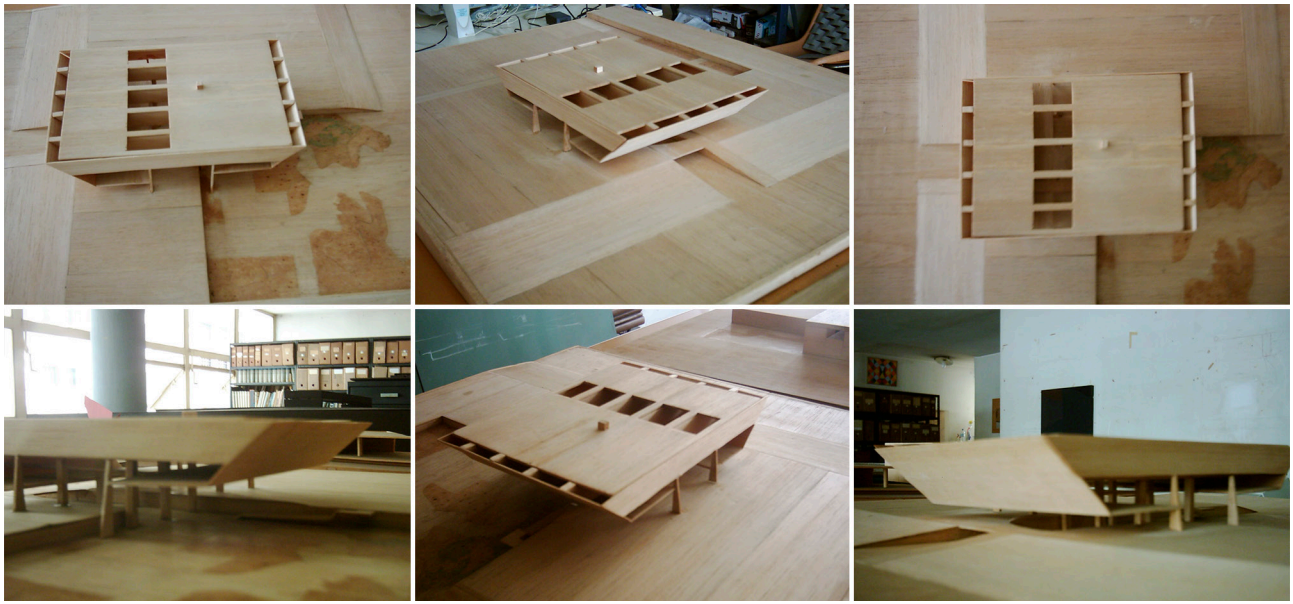
Precedents and historical context

Paulo Mendes da Rocha (1928-2021) was an important modern architect. He was awarded, including the Pritzker Prize (2006). Three themes that underlie his architecture: territory, technique, and the contemporary city [Artigas 2007, p. 7]. The drawings of the vertical sections are the starting point of the design process [Solot 2020, pp.35-37]. The architect Catherine Otondo [Otondo 2013, p. 14], who worked with the architect, states that the Mendes da Rocha design reveals, as a particular characteristic: the desire for movement.
From the 1950s, mainly due to the work of Vilanova Artigas (1907-1985), the reinforced concrete (brut) served as a way of giving a meaning of constructive 'truth'. But there is another important fact: the prominence of architect Oscar Niemeyer's ideas.
Oscar Niemeyer (1905-2012) emerges as a great modern architect from the 1940s onwards in Brazil. His ideas and concepts had repercussions on São Paulo architects from 1950 onwards, among them Paulo Mendes da Rocha. It is possible to establish a reinterpretation of the inverted pyramid of the Museum of Modern Art of Caracas (1954), by architect Oscar Niemeyer, in the MAC USP project. The idea of a large pyramidal volume also appears in the design for the Georges Pompidou Cultural Center Competition (1971). Therefore, there are strong indications that the innovative character of PMR architecture has its origins in the work of Oscar Niemeyer and Vilanova Artigas.
However, there is a fourth architect who inspired Mendes da Rocha: Affonso Reidy (1909-1964). Reidy carried out innovative and outstanding projects in Rio de Janeiro, such as the Museum of Modern Art in Rio de Janeiro. MAM is a building characterized by the large main monoblock, made of exposed reinforced concrete, suspended by a robust and daring set of porticos that characterize its structure as unique.

Circulation in Architecture: space time and movement

Historically, circulation in architecture has been explored by architects as one of the main design premises. From the concept of *parcours*, in the Beaux-Arts course, to the concept of the *promenade architecturale*, formulated by Le Corbusier, circulation has increasingly become one of the aspects explored for the experience through space.
In general, modern architects operate with at least three fundamental notions: space, time, and movement. Free movement through spaces, over time, has become one of the aspects widely explored by modern architects. The space-time notion was debated in modern architecture. The so-called "fourth dimension" [Zevi 1994], "time", has been fully introduced in modern architecture.
In the 1920s, Le Corbusier said: "Architecture is circulation". The architect points out the "rule of walking", writing that: "Good architecture is walked and traversed inside and outside. It is living architecture" [Le Corbusier 1961, p. 43]
There are intimate relationships between space, time and movement. The displacement through space, over time, implies different directions of gaze. Our vision is attracted to certain focal points or points of interest, above all caused by contrasts. It is concluded that the architecture is dependent on the circulation system.
The concept Le Corbusier's *promenade architecturale*, the user's experience in space is defined: "In [the Villa Savoye] we are presented with a real *architecturale promenade* […] It is by moving about […] that one can see the orders of architecture developing" [Le Corbusier, Boesiger 1936, p. 24]. Therefore, the promenade can be understood as a path, a route that promotes an experience of space, especially the visual fields and focal points for walking.
The multisensory experience that involves several elements that make up the space and form, such as light and materials, impact the user's perception in their journey through spaces. Naturally, elements with ramps and stairs are important in this process, as they are part of the planning and promote the route. But there is also the ritual of appreciation, as Philip Johnson (1965) said: "Architecture is surely not the design of space, certainly not the massing or organizing of volumes. These are auxiliary to the main

Fig. 2. Photos of the model obtained during a visit to Paulo Mendes da Rocha's office.



point which is the organization of procession. Architecture exists only in time" [Johnson 1965, p. 184].
The 'procession' that Johnson refers to is the trajectory prepared by the architect to enjoy the spatiality intended for the project. It is a ritual of appreciating the beauty of the building as we move through it. In this sense, the promenade is directly related to the circulation system and its elements but is not restricted to them. Material and immaterial elements make up the experience of space.

MAC USP, 1975, São Paulo

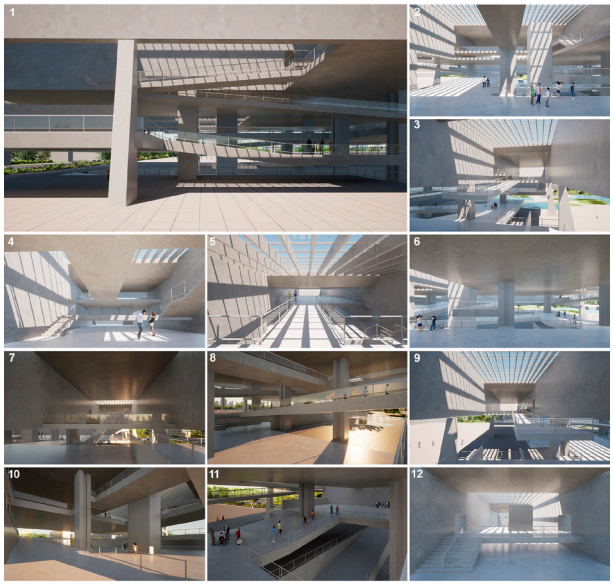
The Museum of Contemporary Art of the University of São Paulo –MAC-USP (1975)– is one of the unbuilt projects of great importance and architectural oeuvre by the architect Paulo Mendes da Rocha.
The architectural parti was defined by a spatial distribution of the architectural program in 5 floors above ground and a semi-underground floor, connected by a set of 6 ramps, two stairs and a large central elevator of 4 x 4 meters. The ordering of the space is given by the axes of the eight internal pillars. Embedded in the pillars, the ramps define inclined planes. The large wall without openings, facing east and west, contrast with the two side faces, facing North and South, with large areas of natural lighting and ventilation.
The project has a visual apprehension fluidity, since the large internal 'voids' allow an immediate understanding of the constituent elements of the Museum's sections.
The present study was developed from the original project, a preliminary study (fig. 1). The photos of the physical model, obtained during one of the visits to the architect's office, allowed the complementary interpretation of some of the formal and spatial characteristics of the building project (fig. 2).
For the construction of the 3D digital model, drawings provided by the architect's own office were used. However, due to the fact that the drawings related to the preliminary study do not have detailed technical specifications, it was decided to analyze similar two projects by the architect: Museum of Sculpture (MUBE) (1988) and the Georges Pompidou Cultural Center (1971). For the modeling of the glass roof, an idea was used similar to the proposal used by the architect for the Pinacoteca do Estado (1993). In this way, it was possible to interpret the language and similar decisions present in other projects and works.
Similar projects designed by Paulo Mendes da Rocha and the architects who inspired him, such as Oscar Niemeyer and Affonso Eduardo Reidy, were analyzed, as well as interviews with professionals who worked with the Mendes da Rocha, in order to obtain additional information. It is worth mentioning the contribution of the testimony of the architect Roberto Leme Ferreira [1], who worked on this project in the 1970s.
The unbuilt MAC USP spaces were simulated both through renderings (static simulations) and animations (dynamic simulations), in order to highlight the quality of the internal spaces.
During the modeling, we realized that the implantation of the MAC on the topography of the site allowed the use of the semi-underground floor which would take in the installation of support activities.
There are 5 ramps connecting the 5 floors of the main volume and 2 ramps in the semi-underground volume. The width of the ramps varies between 2.5 and 11 meters wide, with slopes between 6.4% and 13%.
Figure 3 shows the accesses to the building, the suspended volume and the semi-underground volume, and the prominence of collective spaces on the ground floor. With the design of the Square (fig. 3.1), the architect established the horizontal plane as a divider of the Museum's functional program: a semi-underground one, where the restaurant, the central reception, the administration, the laboratories, the auditoriums, the support areas, and the internal square are located; and the other suspended, where the exhibition, library and scientific management areas are located. At the top of the suspended block, the exhibition halls are separated by voids, which generate variations in ceiling heights (double or triple), but which are connected by a set of ramps that create a spiral path around a large void center on the first and second floors.
The building is marked by the suspended block, whose regularity and simplicity of the external form contrasts with the dynamics of the internal spaces, with alternating ceilings, diagonal ramps, and atriums. From the reception, on the ground floor, it is possible to identify almost all the floors of the building.
The central idea of MAC's ground floor is to make the open space, a place for staying in, and contemplating views. The digital simulations confirm the idea that the semi-underground area of the MAC (figg. 3.7-3.11) would also serve as 'large terraces' for exposure and contemplation of the surroundings. The landscaping project is noted as an integral

Fig. 3. The MAC, the Square, and the ground and semi-underground spaces as terraces for contemplation and living.

Fig. 4. Axonometrics of the MAC USP floors.

Fig. 5. Sections and plans of the perspective floors, and the MAC structural system.

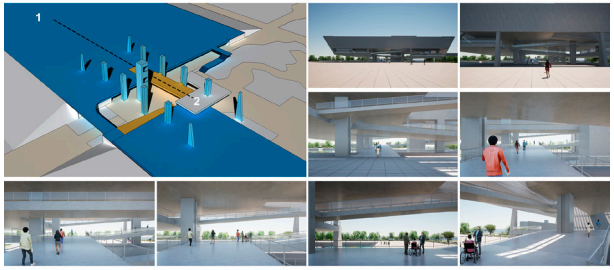
Fig. 6. Emphasis on the circulation system: MAC ramps, walkways, and stairs.



part of the landscape design. This public space would be the link between the landscape, the building, and the city.
The building is 75 meters wide, 95 meters long and 18.60 meters high in relation to the level of the raised square. The courageous structure, consisting of 8 square pillars (2.10 x 2.10 m), spaced by 25 x 15 meters from axis to axis, with cantilevered volumes 23.4 meters at both ends towards the longitudinally, and only two trapezoidal pillars on each side of the building, support the building. In addition, there is a set of 4 large internal longitudinal beams, in the suspended volume, that embrace the pillars, two by two.
The construction of the 3D digital model allowed an accurate understanding of the building's structural system. Figure 4 shows the axonometrics of the MAC floors. Figure 4, shows the large semi-underground support area, the living space, and its proximity to the proposed landscaping. The perspective sections allow us to understand the structural system (fig. 5).
The explanation of Le Corbusier's promenade for Villa La Roche is timely to explain the spatiality of the MAC project: "[the Maisons La Roche-Jeanneret] will be rather like an architectural promenade. You enter: the architectural spectacle at once offers itself to the eye. You follow an itinerary and the perspectives develop with great variety, developing a play of light on the walls or making pools of shadow" [Le Corbusier, Boesiger 1936, p. 60].
The images rendered (fig. 6) show the emphasis on the circulation system and the different paths through the 5 floors of the high volume. The ramps cross the wide spaces, at different heights, creating diagonals that dynamize the space. On the other hand, the walkways connect spaces on the same plane, but cross the space in order to provide the enjoyment of wide internal views. The stairs, in turn, are introduced at the end of a path or on the sides of walkways. This circulation system is entirely interconnected, allowing the user to freely access the building on one side and exit on the other.
It is possible to establish some relationships between the MAC USP project with other projects by the architect, as well as by Oscar Niemeyer. The first feature is the division of the functional program between the suspended part and the underground part of the building, separated by a large free ground floor. The idea of creating a public square on the ground floor is present in all PMR Museum projects.
The suspended part of the building mainly comprises large exhibition and administrative rooms, while in the underground part, auditoriums, laboratories, workshops, technical support, warehouses, and parking. At MAC, the large areas for exhibitions are flexible and adaptable to various types of exhibitions.

Dynamic Simulations - Animations

In the dynamic simulation of a virtual observer, the camera follows a pre-established trajectory. This process is called 'walkthrough', that is, walking through space. Animations are made up of hundreds of frames, which, when displayed sequentially, allow us to create the illusion of movement. Furthermore, this process is important to understand the so-called fourth dimension, time. This virtual 'walk' is of great importance for the investigation of unbuilt spaces, in order to examine the perception of spaces.
Twelve animations were produced. These simulations made it possible to analyze sensations promoted by the displacement of the virtual observer in the architectural space, bringing the idea of the 'architectural walk' or *promenade*. Human-scale animations were generated, as well as aerial walks, inside and outside the building. However, in this article, only 6 routes were selected.
Route 1 (fig. 7, above) starts at the Square (viewpoint 1) in a straight line until accessing the building via the ramp that leads to the 1st floor. On this path, the focal point are the ramps that intersect on the upper floors. The wide permeable ground floor spaces and the wide internal visual fields stand out. Walking along the ramp, one can discover the lateral transparency of the building and the surrounding landscape. The human scale of the people walking around helps to notice the proportions and scale of the building.
Route 2 (fig. 7, below) starts on the 1st floor (viewpoint 2) with a ramp leading to the 2nd floor. During the walk along the ramp (between viewpoints 2 and 3) you can see the large atrium on the right and the surrounding landscape on the left, both with wide open spaces. The focus of attention is the play of light and shadow and the large spaces destined for temporary exhibitions. When going through the 2nd floor, from points 3 to 4, the magnitude of the spaces can be noticed. At the end of route 2 (viewpoint 5) you come across the 3rd. ramp, which gives access to the 4th floor. From this point of view, the walkway on the 5th floor stands out, which crosses the space transversally, flanked by the large beams that rest on the large square pillars, and the large zenith lighting.



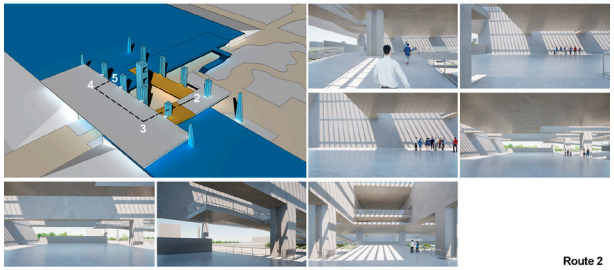
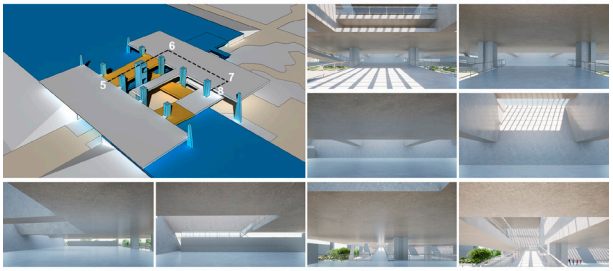
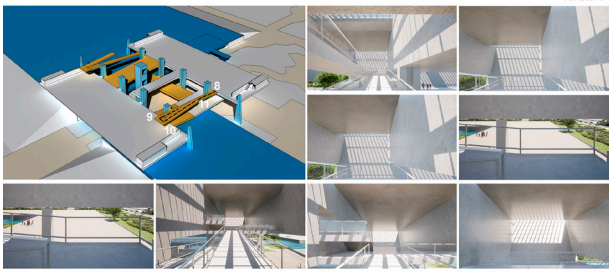


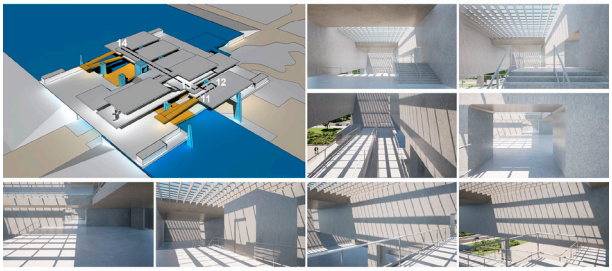
Fig. 7. Route 1: from the Square to 1st floor; Route 2: from 1st to 2nd floor.

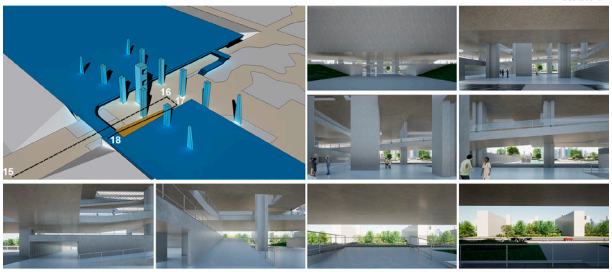
Fig. 8. Route 3: from the 2nd to 3rd floor; Route 4: from 3rd to 4th floor.

Fig. 9. Route 5: from 4th to 5th floor; Route 6: from 5th floor to mezzanines.









In both routes, the alternation of heights, the amplitude of the internal visual fields, and the magnitude of the spaces, whether for exhibitions or for circulation, draw attention.
During route 3 (fig. 8, above), between viewpoints 5 and 6, it can be seen how the 11-meter-wide ramp intersperses two large spaces: on the right, the elevator volume stands out; on the left is the large void with access from the square. The sensation of walking along the smooth ramp, released in space, is one of freedom and pleasure when walking. In point of view 6, the projection of shadows caused by the zenith lighting on the inclined blind gable stands out. The large beams modulate the space of the permanent exhibition hall so as to contribute to the perception of smaller spaces within the overall magnitude. Between points 6 and 7, the alternating ceiling height of the mezzanine above, on the 5th floor, and the voids interspersed by the large beams stand out. At the end of this route, from point of view 8, you can see the ramp leading to the 4th and 5th floors.
Located in the highest area of the building, route 4 (fig. 8, below) takes the user through a 2.5-meter-wide ramp. In this section, the large atrium below can be seen on the right; the great beam above; and the great zenith lighting. The sensation is of bodily crossing the space, close to its constructive elements, whose rite of appreciation is the enjoyment of the innovative beauty of the building as we move through its interior.
On both routes, from an elevated point of view, you can enjoy the wide views of the interior of the building. Noteworthy are the internal voids, interspersed with ramps, walkways and beams, as well as the impact of the large, glazed areas that make up the zenith lighting.
Route 5 (fig. 9, above) allows you to appreciate the spaces on the 4th and 5th floors. The walkway crosses the beams, leading the user through the various elevated 'galleries' of the permanent exhibition areas, located on the mezzanines above the exhibition areas located on the 2nd and 3rd floors. During the walk along the footbridge, with a lower ceiling, the exhibition areas can be observed, modulated by the beams, with zenith lighting that penetrates the interior of the building.
The main access, at street level, occurs during route 6 (fig. 9, below). Between viewpoints 15 and 16, one enters the building between two slopes, until reaching the reception of the Museum. The 4 x 4 m elevator, next to the reception, would take the user to all floors of the building. The images show the large public space, permeable to conviviality. From point 16, you can appreciate the large atrium above, the restaurant on the left, the large outdoor area treated with a landscaped design in front, and the circulation on the right, next to the auditoriums on the semi-underground floor. From viewpoint 17, you can go up the ramp that gives access to the raised ground floor, next to the square. This section invites the user to appreciate the USP student housing, located in front of the Museum.
Therefore, it can be concluded that the temporal sequence of displacements through routes 1 to 6 allows the user to enjoy multiple views. It is the spatial richness, resulting from the alternation of ceiling heights, full and empty spaces, light, and shadow, and the circulation system that generate a ceremonial of appreciation of the beauty of the building as we move through its interior.
One of the outstanding features of the building is the zenith lighting. The animation of the penetration of solar rays inside the MAC (fig. 10) made it possible to verify the effect caused by the penetration of light during the 1st of January on the perception of spaces. The main frames of this animation during the day and night of January 1st, contribute to the appreciation of the intensity of the light and the play of light and shadow. The sloping walls and large beams reflect the dramatic incident light into the building (fig. 10.3-10.17), particularly onto the exhibition halls. Interestingly, it was noted that the simulation carried out during the night (fig. 10.19-10.27) allowed the visualization of the light emitted by the moon (fig.10.24-10.27) during a January summer night.
The perception of the built environment depends as much on shapes and spaces as on light and materials, which make up the sensory experience of the architectural tour. The phenomenological appreciation, through computational resources, allows the analysis of this sensorial experience. The textures and other properties of the materials, the penetration of direct light, the distribution of indirect light in environments awaken different interpretations and provide different sensations, captured by our senses.
It is through a leisurely walk on foot that one can appreciate the spatial characteristics and phenomena of an architectural work: shapes, spaces, light and shadow.

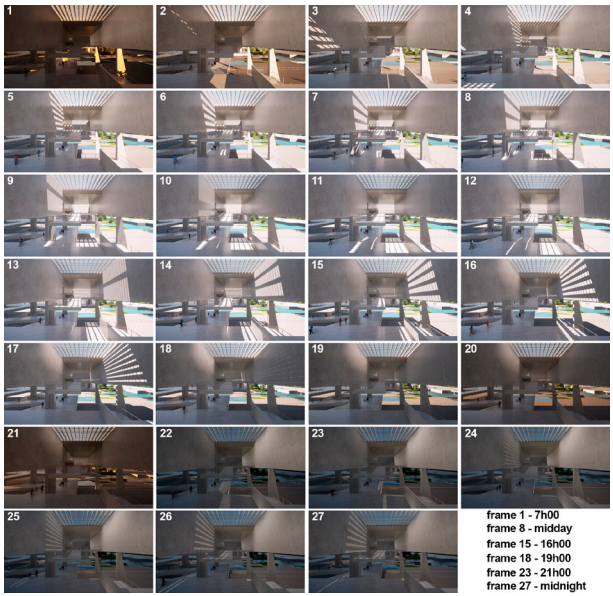
Discussion and conclusions

The 3D digital model made it possible to generate two- and three-dimensional drawings. But it was the static simulations –renderings, and the dynamic ones– animations that favored the perception of spaces more acutely. As defined by Docci

et al: "Procedendo digitalmente ogni elaborato non viene più prodotto separatamente e individualmente, ma gli elaborati sono ottenuto operando per estrazione a partire da una base comune" [Docci, Gaiani, Maestri 2017, p. 365].
Simulations allowed crisscrossing trajectories, in order to favor the dynamic interpretation of architectural forms and spaces. In reality, computer animations are generated from a succession of frames per second. The illusion of movement occurs from the succession of images that are sequentially shown during a certain time. It was possible to identify a set of spatial characteristics from the renderings and animations. Vision occurs from the integrated action between the eye and the brain, creating a psychic image [Docci, Gaiani, Maestri 2017, p. 3]. In this sense, human perception is sharpened from the exploration of these simulations, leading to a phenomenological analysis of spaces. Mendes da Rocha proposed large circulations, connected to each other, to better enjoy the spatiality of the building. The procession takes place as the user moves through the space, covering the floors by ramps, walkways, and stairs. In fact, the temporal sequence of approaching the building, the frontal or diagonal access, the penetration of its interior spaces, the perspectives, and multiple views possible at each moment during the route, the relations between "full and empty", corroborate the idea of a rite of appreciating the beauty of the building as we move through it. The result is that from the five interconnected floors, arranged at different levels, it is possible to enjoy the interior spaces from multiple points of view in space. The main accesses are perpendicular to the building, initially pushing a straight-line path. However, after penetrating the building, one notices the multiple focal points in the space, causing the observer to direct his gaze in diagonal directions of the space. The animations drew attention to phenomena caused synchronically by forms, spaces, materials, and light. It was the slow motion that allowed us to be aware of every small movement and space, while the still camera froze the look at a certain time of the simulation. In this way, means envisioning different interpretations of the same observed scene. A striking feature in the analyzed work is the definition of an integrated, ascending, and spiral circulation system, in order to allow users to circulate freely, entering and leaving through more than one access. The circulation system, as an "internal street", with emphasis on the ramps, forms a spiral, taking up Le Corbusier's idea of the modern museum. Consequently, this building can be characterized by the architecture of movement. The spatial dynamism occurs because the permeable building, with few spatial subdivisions, is endowed with alternating heights. The geometry of the ramps generates even more spatial dynamism, as they cross the space and connect floors at different heights. In addition, the ramps connected to the floors that allow the free movement of people through the building while the movement of the sun that floods the spaces and generates different perceptions. Motion parallax, that is, the information produced by the relative movements of the images when we move laterally, is also very important in the formulation of MAC's notion of space. The accesses to the interior of the MAC lead users to an "architectural spectacle", employing Le Corbusier's terms. The elevated walkways, the spatial expansions, and contractions, with alternating heights, the penetration of natural light through the large zenith openings offers great formal and spatial dynamism. In fact, the architectural walk through the ramps, walkways and stairs leads users to discover multiple and interesting perspectives of the open, fluid, and integrated spaces: a real *promenade architecturale*. Mendes da Rocha's architectural promenade is normally generous, with wide circulations – stairs, ramps, and walkways– which interconnect spaces. Air connections, such as ramps and walkways are emphasized in his work. They allow users to enjoy visuals from double or triple heights. This occurs, above all, in public building projects. As a consequence, there is an emphasis on collective spaces to the detriment of private ones. The concept of continuous 'floor', which leads the user between external and internal space, is emphasized by the smoothness and uninterrupted displacement that leads the user to the interior of the building. As a continuity of the public space, the wide accesses, the building's transparency, and the wide ramps dilute the separation between internal and external spaces. As a critical reflection, we point out three main themes concerning the conduction of the research:
1. The investigation of unbuilt projects as a contribution and appreciation of our modern architectural cultural heritage. Modern architecture is of great interest to researchers and architects in the sense of analyzing, investigating and valuing concepts and materializations. Unbuilt projects are among the object of greatest challenge in preservation, as they are archived on boards and drawings, many in unfavorable conditions and close to being destroyed by time;
2. The project analysis highlighting the circulation system and its elements with great importance in the definition of the architectural parti and materialization of modern concepts. From the studies carried out so far, it is possible to verify the importance of the circulation system and its elements in the

definition of the architectural parti and in the materialization of modern concepts. In the case of Paulo Mendes da Rocha's architecture, this assumption is verified in the analysis of this project, in addition to the important issue for his architecture that involves the relationship between the public, semi-public and private, in a fluid and continuous way;
3. Difficulties and challenges of studying unbuilt projects using digital technologies.
- The interpretation of projects, of unbuilt buildings, from a few drawings, is an arduous task, as it requires knowledge of other projects by the same architect to overcome the lack of more detailed information;
- As this is a preliminary study, there are many uncertainties about the intended materiality of the project;
- 3D modeling requires attention to constructive details, demanding precision;
- Although dynamic simulations favor better interpretation than orthogonal projections on the formal and spatial characteristics of unbuilt projects, they are not sufficient for the interpretation of sensitive phenomena, arising from the textures of materials and the nuances of light penetration, natural or artificial;
- In order to achieve a greater depth of analysis of the spaces, the definition of pre-established paths for the animations requires a detailed study of the project in advance; - In the absence of other important information, such as the architect's intention to occupy flexible spaces with subdivisions for exhibitions (permanent and temporary), it prevents simulations from being carried out on the occupation and effective use of spaces;
- Care must be taken in defining the trajectories for the animations, as the interpretation of spaces, at the height of the virtual observer, walking slowly through the space, interferes with the interpretation of the spatial characteristics of the project.
Additionally, nine concepts were identified that underlie the design of projects carried out by Paulo Mendes da Rocha. The so-called 'objectivity' is present in the way of organizing the forms and spaces of buildings. Integrated spaces, without compartmentalization, provide ample internal and external visuals, allowing users to visualize the completeness of the spaces immediately. The objectivity is also in the adoption of concise geometry, 'simplicity', and formal restriction, like the 'monovolume'.
The economy is due to the formal and spatial simplicity, especially in the elimination of superfluous elements, present in the simplicity of the details, and the absence of ornaments. On the other hand, the idea of 'rusticity', exposed concrete without finishes or corrections, is present in the architect's work.
The 'technological exploration' of the reinforced concrete is present in the conception of a rational, 'daring structure', 'cantilevers', with minimal support, large spans, with a visible structure, which suspends the great form of the building. A striking feature in PMR projects and works is the 'experimentation' of innovative construction techniques. The large blind walls also serve as large beams, contributing to the structural design. The 'plasticity' of Niemeyer's architecture, resulting from the belief of the partnership with engineers for the innovative development of structures, is also present in the work of Mendes da Rocha. The creation of a welcoming environment, of transition between public and private, without defining rigid limits, and 'valuing the public space'.
Air connections, such as ramps and walkways are emphasized in his work, demonstrating the idea of a continuous floor.
As a continuity of the public space, the wide accesses, the building's transparency, without doors or defined physical limits, and the wide ramps dilute the separation between internal and external spaces.

Fig. 10. Frames of an animation of the penetration of solar rays during summer January 1st, and during the night, with moonlight.



Note

[1] Interview with the architect on 01/08/2007, in São Paulo.

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Reference List

Artigas, R. (2007). *Paulo Mendes da Rocha. Projetos 1957-1999*. São Paulo: Cosac Naify.

Bartolomei, C., Ippolito, A., Vizioli, S. (Eds.). (2022). *Digital Modernism Heritage Lexicon*. Cham: Springer.

Chini Solot, D. (2020). *Paulo Mendes da Rocha. Horizonte Urbano*. Rio de Janeiro: PUC Rio.

Docci, M., Gaiani, M., Maestri, D. (2017). *Scienza del disegno*. Seconda edizione. Novara: CittàStudi Edizione.

Foscari, A. (2010). *Andrea Palladio. Unbuilt Venice*. Baden: Lars Muller Publishers.

Galli, M., Mühlhoff, C. (2000). *Virtual Terragni. CAAD in Historical and Critical Research*. Basel: Birkhäuser Publishers.

Guidi, G., Russo, M., Angheleddu, D. (2013). Digital Reconstruction of an Archaeological Site Based on the Integration of 3d Data and Historical Sources. In *Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci.*, XL-5/W1, 2013: <Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XL-5/W1, 99-105, 2013> (accessed 22 April 2022).

Harbison, R. (1991). The Built, the Unbuilt and the Unbuildable. In *Pursuit of Architectural Meaning*. London: Thames and Hudson.

Johnson, P. (1965). Whence & Whither: The Processional Element in Architecture. In *Perspecta*, v.9/10, pp.184-186.

Larson, K. (2000). *Louis I. Kahn. Unbuilt Masterworks*. New York: Monacelli Press.

Le Corbusier, Boesiger, W. (1936). *Le Corbusier et Pierre Jeanneret. Oeuvre Complète*. Zurich: Les Éditions D'Architecture.

Le Corbusier (1961). *Mensagem aos estudantes de arquitetura*. São Paulo: Martins Fontes.

Martens, B., Peter, H. (2010). Displacing the frontiers of reconstructed cultural heritage representation of the non-existing within an urban context. In B. Dave, A. I. Li, N. Gu, H. J. Park (Eds.). *New Frontiers: Proceedings of the 15th International Conference on Computer-Aided Architectural Design Research in Asia CAADRIA 2010*. Hong Kong, 7-10 april 2010, pp. 63-72. Hong Kong: Association for Research in CAADRIA.

Otondo, C. (2013). *Desenho e espaço construído: Relações entre pensar e fazer na obra de Paulo Mendes da Rocha*. PhD in Architecture Thesis. Coordinator A. M. de Moraes Belluzzo. Universidade de São Paulo, FAUUSP.

Pfeiffer, B. B. (1999). *Treasures of Taliesin: Seventy-seven unbuilt designs*. San Francisco: Pomegranate.

Rushton, H, Schnabel, M. A. (2020). Exhibiting Digital Heritage. In D. Holzer, W. Nakapan, A. Globa, I. Koh (Eds.). *RE: Anthropocene, Design in the Age of Humans. Proceedings of the 25th International Conference of the Association for Computer-Aided Architectural Design Research in Asia (CAADRIA) 2020*. Bangkok, Thailand, 5-6 August 2020, Vol. 2, pp.193-202. Hong Kong: Association for Research in CAADRIA.

Sdegno, A. (2011). The Masieri Memorial by Frank L. Wright in Venice. Reconstructing an Unbuilt project on the Canal Grande. In T. Zupancic, M. Juvancic, S. Verovsek, A. Jutraz (Eds.). *Respecting fragile places, Proceedings of eCAADe 29*. Ljubljana, 21-24 september 2011, pp. 960-966. Brussels: Education in Computer Aided Architectural Design in Europe and UNI Ljubljana, Faculty of Architecture.

Wilson, L., Rawlinson, A., Frost, A., Hepher, J. (2017). 3D digital documentation for disaster management in historic buildings: Applications following fire damage at the Mackintosh building. The Glasgow School of Art. In *Journal of Cultural Heritage 31*: <https://www.sciencedirect.com/science/article/abs/pii/S1296207417304685> (accessed 22 April 2022).

Zevi, B. (1994). *Saber ver a arquitetura*. São Paulo: Martins Fontes.