The National Schools of Art of Cuba

Conservation Management Plan

Getty Foundation

Photographs by Osmara Alberteris Cañizares

Final report of the Grantee

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FOREWORD

Respecting the vision, changing perspective. A Conservation Management Plan for the National Art Schools of Cuba

I had the privilege of visiting the National Art Schools with Vittorio Garatti in April 2017. At the time I knew little about the complex, the architects and their adventurous story. I knew John Loomis, but I hadn't read his book. Entering from a secondary passage, I took a few steps on the green lawn and slowly proceeded down the stair towards the School of Ballet, offering my arm to the old master. I listened to him telling the hundred details of that long story, he explained the almost primordial meaning of his decision to hide the building right in the bend of the river, I saw the domes emerging from the tropical foliage.

History, restoration, conservation and management

Most of the essays about the National Art Schools of Cuba represent the outcome of quick visit like the one I had, widely insufficient to get in touch with such a vast site. However, that brief contact is enough to make the visitor aware of standing in front of an absolute masterpiece. A mixed feeling of enthusiasm and pity takes over, almost a sense of duty to write a paper capable of raising public awareness and helping to save the National Art Schools from that decadent oblivion. More than 150 books and papers were published mostly after 1999, basing on that emotional thrust. However, that feeling has rarely translated into a research able to mature into an original criticism on this twentieth-century architecture’s complex story and to draft a perspective for protecting and restoring it.

This path unfolded along four steps. The first coincides with the original design and construction. Its narration is entrusted above all to oral memory, with typical flaws in perspective and great emphasis on the revolutionary season, when Fidel Castro and Ernesto Che Guevara decided to turn the Havana Country Club into a school to teach the arts to any poor students of Latin America. Three young architects were appointed to put that dream into architecture. The second phase testifies to the failure to complete the buildings and to the rough start of the teaching activity. It was a painful moment although necessary from a historiographical perspective, as it laid the foundations for the subsequent consecration. In a third phase, international criticism discovered the complex. John Loomis's “Revolution of Forms” made “Cuba's forgotten art schools” emerge from the thick of tropical vegetation, like an architectural treasure sunk in the Caribbean. Loomis reconstructed the story of the project, describing that historical and cultural context. “Revolution of forms” is the first scientific essay based on a documentary and comparative research that is typical of the history of architecture. Loomis' research positioned the National Art Schools of Cuba within the international perspective of modernism and assigned them a place in the history of twentieth-century architecture. A fourth phase began in 2000: the schools were recognized as historical heritage and listed in the register of national monuments on November 8th, 2010, and the time of protection began. After fifty years, architecture stopped looking at the forms of the revolution to criticize or celebrate them, and finally started looking towards the future, asking how to preserve such buildings and restore their remains. Unfortunately, the restorations occurred in the early 2000s were not accompanied by scientific research or by an open debate, as the fame of the buildings would otherwise have asked. Today, ten years after that statement and twenty years after Loomis's book, the National Schools of Art in Cuba are in a poor state of repair.

The National Art Schools represent the architectural outcome of the early Cuban revolution. Preserving and restoring them means translating the historical criticism of that season into real actions. It is not always a benevolent story that has generated a heritage of great formal quality but in precarious health conditions and towards which historical judgment has matured in the short span of the last two generations. This is evident in Europe, where the architecture of Fascisms or the former Soviet bloc is currently undergoing a renewed critical evaluation, thanks to a more detached approach towards the political season that produced it. The heritage-related activity contains an eminently political meaning because it tackles the buildings of the past and determines the permanence or suppression of parts of the city. The political value of heritage management was the basis of most national protection laws between the 1800s and 1900s, and it is nowadays one of the pillars for the EU. When Winfried Speitkamp reconstructed the relationship between German society and cultural heritage between 1870 and 1933, he rightly called heritage protection "die Verwaltung der Geschichte" (the administration of history). He, in fact, stressed the political value of architectural restoration and the public character of memory. This is still evident in many examples, from the Berliner Schloss to the Moskow Narkomfin.

When visiting the Museum of Fine Arts of Havana accompanied by director Jorge Fernandez, I was struck by the painting *Rectificaciones a la obra de Armando Menocal "La muerte de Maceo*" from 2017. The Cuban painter José Manuel Mesías corrects a previous work dating back to 1908, depicting the same episode of the war of independence: the killing of the lieutenant-general of the liberation army. Moving from a renewed historical perspective, Mesías has painted the same scene but has "purified" it from the figurative emphasis and the characters which were artificially added. He places the point of view very close to the wounded hero lying on the ground, unlike the previous painting where his companions support him at the center of the scene. The result is a less rigid composition suggesting the immediacy and neutrality of a photographic shot. A grid is artificially applied to the surface of the canvas and seems to suggest the idea of a photographic or even photogrammetric image. As further proof that this pictorial-historiographic revision work is based on the scientific method, Mesías completes the picture with a series of secondary canvases where he performs a taxonomic and botanical examination of the tropical prairie in which the main scene takes place, which had been simplified in the 1908 painting to give space to the image of the wounded hero. Each blade of grass was accurately painted, down to details in double or triple size compared to the real one, simulating the zoom effect of a naturalist photo documentary and obtaining a surprising chromatic and compositional result.

The Conservation Management Plan means to continue that critical updating begun with "Revolution of forms", overcoming the idea of a never-ended project and accepting the outcome of that adventure as it is today, without acquittals or convictions. Like Mesias's work, the CMP is not just about preserving the memory of utopia, keeping the ruins of an unfinished dream. On the contrary, the CMP intends to scientifically assess the present state of the buildings and site and – on that basis - to design different scenarios of development. More than 70 people involved, 810 days of work, 50 days on field in Havana. The CMP operated in direct contact with the complex of buildings internationally known as National Art Schools of Cuba and with the community of students and teachers who daily study and work in this place they simply call ISA - Universidad de las Artes.

5 points (for the conservation) of modern architecture

The CMP consists of five actions that today are fundamental for an updated conservation and management of the twentieth century architecture:

1. Documentation
2. Physical conservation and restoration
3. Assessment of hydrogeological risk and landscape protection
4. Environmental sustainability and energy efficiency
5. Integrated information management and adaptation strategy

Action 1 aims at documenting the history of the complex and at taking an updated photograph of it. In fact, five decades of school use and exposure to tropical climate, repairs, and restorations have heavily transformed the iconic buildings designed in the early 1960s. The first goal of the CMP is to evaluate the results of such transformations and illustrate the current as-built situation. We investigated the historical archive comprising drawings and photographs of the construction site. In fact, to design a strategy for the restoration and reuse of spaces, it is firstly necessary to portrait the current state of use and repair, repeating the functional analysis that inspired the 1960s design. Therefore, we visited the whole complex, room by room, and recorded the state of conservation and use.

Action 2 dealt with the physical preservation of materials and structures. We assessed the structural safety of the domes, since they are the most characterizing architectural elements of the entire complex. We visited each dome and topographically recorded the information on a risk map. We focused our attention on the Ballet School's large domes because they are incomplete and lacking in maintenance, and today at risk of collapsing. This research has allowed us to uncover some surprising aspects, e.g., that the complex was entirely built using reinforced concrete instead of plain bricks as the architects always declared. In parallel, thanks to the collaboration of Assorestauro, we carried out three on-site workshops, sharing with Cuban colleagues some innovative techniques in the field of architectural conservation: laser scanner survey, humidity diagnosis in wall structures, diagnosis of pathologies of reinforced concrete. A fourth workshop featured a small pilot site, where some restoration techniques for reinforced concrete were tested.

Action 3 dealt with hydraulic risk assessment and its mitigation, given the global climate change scenario. In fact, the schools are exposed to the risk of flooding due to the presence of the Rio Quibù, which in its final stretch forms a double loop, determining a maximum risk in the depression that houses the Ballet School. Between 2018 and 2020, the School was flooded four times, confirming that the risk is even greater than climate models predict. To address this issue it is necessary to increase protection, both to continue to imagine how to reuse the buildings and to ensure their own stability. Again, we need to reconsider the original design, asking if some of those choices have contributed to mark these buildings' destiny. We also investigated the amazing resilience of this architecture, which proved able to withstand the tropical climate and the complete lack of maintenance for over half a century.

Action 4 investigated the energy behavior of the Schools. Taking into account the sustainable development in the country, we must ask ourselves how to meet the requirements of such an energy-demanding setting of buildings. Indeed, the schools were built before the oil shock and featured energy-intensive air conditioning systems such as the one designed for the School of Music. The results of this analysis will allow us to develop sustainable solutions to reduce energy demand while increasing efficiency, using low-impact solutions such as geocooling, natural ventilation, and passive protection from solar radiation. In the future, it will be necessary to further investigate the possibility of gain energy from sustainable sources, for example, by installing a micro-hydroelectric power station in the Rio Quibù river. These items will necessarily become part of the complex's conservation and management strategy in the next future. It is a crucial issue for Cuba, which must increase its energy independence and develop renewable energy sources and the energy efficiency of the building stock.

Action 5 collected the whole data within a GIS system to manage them easily and keep them up to date. We then drafted a set of guidelines to manage the complex and administer future transformations. The starting point is that today, in 2020, after sixty years and two education reforms, the teaching model is very different from the sixties, when the buildings were designed. Ballet teaching is not part of the offer. Some dance lessons are held in the remains of the unfinished Music School and other buildings off-campus. Drama lessons take place in the dormitory designed by José Mosquera. The students of Music lack a usable seat. They occupy the rectorate building (where a construction site has been ongoing for years) or scatter around the park, seeking a calm place to rehearse. It is easy to meet them playing the trumpet or the violin in the midst of the ruins of that modern architecture that should have welcomed them. Two new faculties keep attracting more and more students: the Facultad de Artes de la Conservación del Patrimonio Cultural and the Facultad de Medios de Comunicación Audiovisual.

Basically, school activity continues according to the vitality that only Cuba is capable of offering. However, the scarcity and lack of security of these buildings is hardly compatible with the purposes and ambitions of an art university. After analyzing the current demand for space and equipment, we were able to write, together with the ISA teachers, a list of the priorities for improving the Schools' activity.

A 2-scale approach to the CMP

600,000 sq m (park), 40,000 sq m (buildings), over 500 rooms and 40 domes investigated. Given the massive dimension of the complex, the five actions of the conservation and management plan were developed according to two levels or scales of investigation. At a general level, we can observe a well-integrated system that includes the park, the river, the connections to the city, and a system of buildings with different degrees of interest and historical value, partly used for teaching activities at ISA and ENA. At the scale of the single building, the five pavilions designed by architects Garatti, Gottardi, and Porro, due to their particular interest and different level of use and state of conservation, require a more detailed scale of analysis. Each of the five actions was first implemented on a large scale, evaluating the entire complex's problems. Subsequently, a specific aspect was chosen as the subject of in-depth analyses, testing the hypotheses directly on the field. This continuous dialectic between the two scales allowed us to reconcile the overall strategic vision with the concrete problems that emerged during the field activities, also thanks to our Cuban partners' collaboration.

During that walk throughout the Ballet School, Vittorio Garatti told me about the years he spent in Cuba when he worked following the vision of a more equitable world, the fulfillment of which did not allow anyone to waste time in personalism or small disagreements. I really thought that "the last architect" of the story was talking to me. No one today has the ambition of solving the problems of the complex known as National Art Schools of Cuba all at once. Architecture is called to transform an already built world, limit soil consumption, and discuss the significance of the buildings conceived in the twentieth century. It is worth remembering the comparison between the architect-conservator and the physician, which Renzo Piano has recently updated, when evoking the task of mending the architectural heritage of the twentieth century, such as urban suburbs. Similarly, Alfredo Brillembourg, recalling Yona Friedman, stated that “(...) architecture must no longer be that of the great utopian projects of the 1960s, the years of megastructures, or Superstudio's dreams. Today only what is interesting is possible, [...] the model, fundamental for us, of the architect no longer understood as a great author of visionary drawings, but as a mediator, a figure able to relate to both those who are below both with whoever is at the top. The time of the charismatic architects as in the Renaissance is really over. Today we need a role that has greater social legitimacy if we want to change things.”
Even with the National Art Schools of Cuba, we can continue to study and investigate, nourish our intelligence with positive images, which we would certainly be induced to reproduce. This does not mean to copy or indefinitely prolongue a season experienced by someone else, but to keep cultivating an idea of progress to face the future.

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An introduction to the site

The National Art Schools of Havana

An introduction to the site

History of the site

The urban context

Havana is located on La Habana Bay, on the north coast of Cuba, and it is the largest city in the whole Caribbean region (about 281 square miles/728 km^2). Due to its historical and cultural background, Havana has gained international visibility, and it is currently considered one of the most fascinating cities in the world.

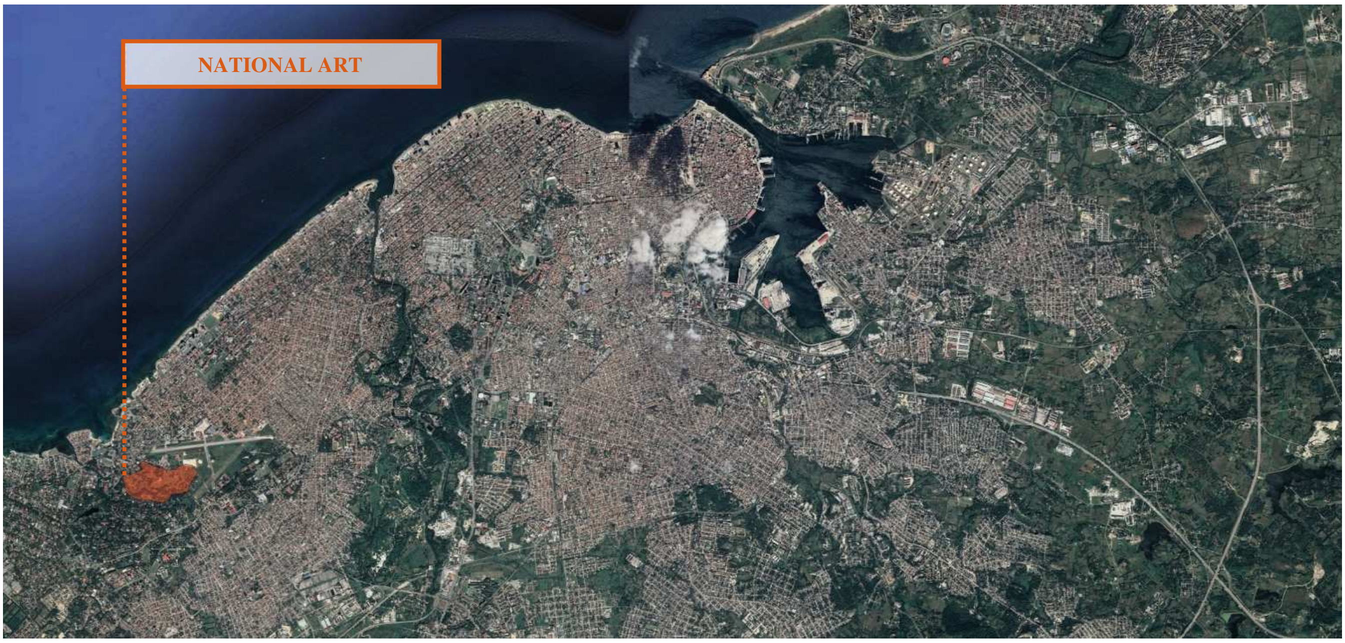
This contextual frame is extremely important for the National Art Schools, whose relevance is automatically increased by their geographical setting. Also, the complex is highly emblematic of a specific and extremely peculiar historical moment, and therefore it could not have the same value if situated in any other place. Before considering Havana's worldwide fame, it is essential to underline the fact that the city represents Cuba's central attractive hub. This is why the Schools of Art are attended by students from all over the country who altogether generate a crossroad of cultures and traditions.

The National Art Schools are located in the *Cubanacán* district of the *Playa* Municipality of Havana. They benefit from their strategic position: close enough to be easily reachable from the historical center and yet far enough to escape the chaotic nature of a Capital City.

The *Cubanacán* district, formerly nicknamed Havana's "Beverly Hills", was originally built to host the city middle class. Later on, after the schools' construction, the residential buildings were used as student housing since the original project of the ENA campus did not provide any kind of dormitory facilities. Since the '80, the neighborhood has regained its wealthy population as many Embassies were established nearby. The area currently hosts the City's grandest homes, belonging to foreign diplomats and business staff, Cuban sporting and music celebrities, and Cuba's own government.

Nested in this rich residential neighborhood, the five schools develop on what once was the golf course of the former Country Club: an undulating green area of about 56 ha crossed by the Rio Quibù. The park has the shape of an irregular polygon delimited by *Ave 120* on the north side, *Ave 23* on the east, *Ave 146* on the west, and by *Calles 11* and *130* and *Ave 9* on the north-east.

The Military Airport of Ciudad Libertad - which has been Cuba's main airport until 1930, when José Martí International Airport replaced it - is situated just a little northward from the Schools. The School complex's primary access is the Country Club's former entrance, located on *Ave 120*. This is the most direct way to reach the Schools as *Ave 120* converges with *Avenida 5ta*, a very long street connecting *La Habana Vieja* with the *Playa* district. However, each School is provided with another entry that allows direct access from the streets that circumscribe the park.



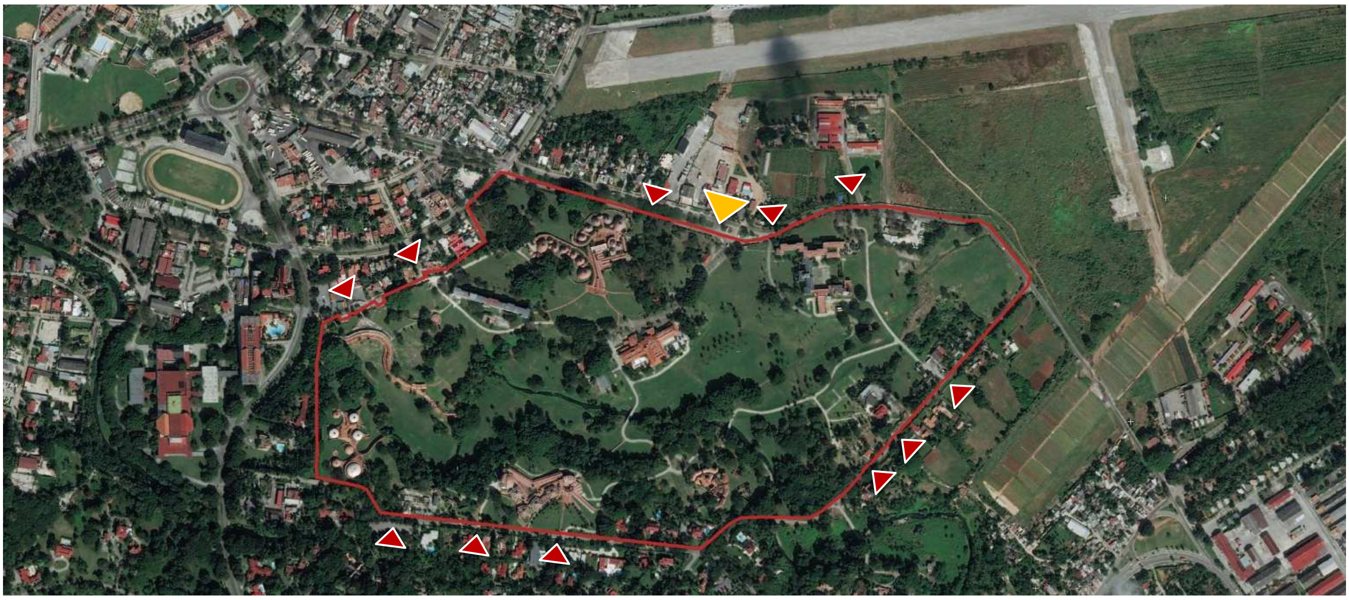


Figure 1 - On top: satellite map (from Google Maps) of Havana showing the position of the National Art Schools. On the bottom: the perimeter and immediate surroundings of the Schools' campus (from Feder 2018, tav. 1).

The proximity of the Schools to a residential area is crucial; as the architects already envisioned in the '60s, the whole complex could become an artistic hub that provides classes during the day, events, and exhibitions at night. This would bring people to the Schools all day long, granting both the good preservation of the buildings and a public service addressed to the local community.

Lately, a blooming cultural interest has led to the growth of several new artistic spaces in Havana, among them: *Gran Teatro Alicia Alonso* (2016) and *Fábrica de Arte Cubano* (2016).

According to this tendency, it is to be noted that ISA alumni Alexis Leyva Machado (alias Kcho), which is currently one of the most remarkable Cuban artists, internationally renowned, has opened in 2014 his workshop nearby the

Schools. *Kcho Estudio Romerillo. Laboratorio para el Arte* is a collective space which more than a private studio, is a nonprofit cultural space. In addition to workspace for the artist, the workshop offers a library, a theater, two galleries, an experimental graphic workshop, as well as open-access spaces for the community. In this context, the Schools of Art acquire a halfway dimension between the local and the international level.

This emerging interest in the artistic field is also proved by the Havana Biennial success, which - since 1984 - has been turning the city into an important venue for the gathering and exhibition of 'non-Western' art. The Havana Biennial has focused its attention on the artists from the South whose works represent concerns and conflicts - many times of universal scope - that are common to their regions. The exhibition, spread throughout Havana, also interests the National Schools of Art, as the School of Plastic Arts has officially become a detached pavilion of the Biennial. Some events are also held among the streets of the nearby *Romerillo* neighborhood.

Political and social history

"...Por cierto, Cuba va a poder contar con la más hermosa Academia de Artes de todo el mundo. ¿Por qué? Porque esa Academia va situada en uno de los repartos residenciales más hermosos del mundo, donde vivía la burguesía más lujosa de Cuba: en el mejor reparto de la burguesía más ostentosa y más lujosa y más inculta, dicho sea de paso, porque si en ninguna de esas casas faltaba un bar, sus habitantes no se preocupaban, salvo excepciones, de los problemas culturales. Vivían de una manera increíblemente lujosa y vale la pena darse una vuelta por allí para que vean cómo vivía esa gente; pero lo que no sabían es qué extraordinaria Academia de Arte estaban construyendo y eso es lo que quedará de lo que hicieron, porque los alumnos van a vivir en las casas que eran residencias de millonarios. No vivirán enclaustrados, vivirán como en un hogar y asistirán a las clases en la Academia; la Academia va a estar situada en el medio del Country Club, donde un grupo de arquitectos-artistas han diseñado las construcciones que se van a realizar. Ya empezaron, y tienen el compromiso de terminarlas para el mes de diciembre. Ya tenemos 300 mil pies de caoba. Las escuelas de música, danza, ballet, teatro y artes plásticas estarán en el medio del campo de golf, en una naturaleza que es un sueño. Ahí va a estar situada la Academia de Arte, con 60 residencias, situadas alrededor, con el Círculo Social al lado, que a su vez tiene comedores, salones, piscinas y también una planta para visitantes, donde los profesores extranjeros que vengan a ayudarnos podrán albergarse. Esta Academia tendrá capacidad hasta para tres mil niños, es decir, tres mil becados y con la aspiración de que comience a funcionar en el próximo curso"[1].

In the first years after the Cuban revolution, culture and education were the main targets. The military structures were converted into schools, and a massive "Literacy Campaign" was launched on January 1st, 1961: the schools were closed for a year, and 235.000 volunteer students were sent to the villages to teach farmers how to read and write. In just one-year, illiteracy decreased from 25% to 3,9%.

[1] Fidel Castro Ruz, *Palabras a los Intelectuales*, La Habana: Consejo Nacional de cultura, 30 de Junio de 1961.

In the same years, many education and training institutions were created, such as the Latin American School of Medicine (*Escuela Latinoamericana de Ciencias Médicas*), the Cuban Institute of Cinematographic Art and Industry (*ICAIC - Instituto Cubano del Arte e Industria Cinematográficos*) and the National Schools of Art.

Following Che Guevara's internationalist interest, the program of the Schools was extended to other countries, creating an international center open to trainees from Africa, Asia, and Latin America. A full scholarship would be given to about 3.000 students.

Figure 2 - Fidel Castro e Che Guevara playing golf (Photos by Alberto Korda, taken from https://www.albertokorda.photo/en/galeria-de-fotos/fotoperiodismo/#main).

"Recuerdo muy vivamente la tarde en que el companero Fidel Castro desde uno de estos balcones acompanado dal companero Hart y de algunos de nosotros delineo lo que iba a ser la Escuela Nacional de Arte. Habia sido hasta poco antes una de las sociedades aristocraticas en que los esplotadores extranjeros y nacionales se reunian exclusivamente para disfrutar de las ...danzas debidas a la extorsion de nuestro pueblo y exportacion de nuestras riquezas. En lo que era su campo predilecto de golf, en estas grandes extensiones, nuestro Secretario General con esa imaginacion creativa que le caracteriza, fue trazando entre nosotros la imagen de un nuevo plantel, de una nueva escuela, que El decidio con la aprobacion de todos, que por el emplazamiento y por las caracteristicas no deberia ser la sede de una escuela ordinaria, sino que precisamente este emplazamiento y estas caracteristicas invitaban situar en su ambito lo que debia ser la fuente de nuestros futuros artistas, de los creadores e interpretes del socialismo del manana. Y asi surgio la base de este establecimiento a la cual le dieron sustento material hermosas edificaciones de arquitectos nacionales y extranjeros y en la cual hemos empezado a desarrollar lo que sera en definitiva el sueno de aquella tarde"[2].

[2] Carlos Rafael Rodrifuez - Revolucion y Cultura, Ano 1. No 1 – 1967.

"The political objective of the schools would be to educate those artists who would give socialism both in Cuba and the Third World its aesthetic representation. Moreover, the schools were conceived as an experimental centre for intercultural education and exchange. Since the idea and the space were without precedent, it was decided that the architecture, too, should be without precedent. The visionary spirit in which the program was conceived would be symbolised in its design"[3].

Before the (1959) Cuban revolution, this site was the golf course of Havana Country Club. A year later, Fidel Castro chose it as the place to build the National Schools of Art. The site is at the western periphery of Havana in an urban, mostly residential environment, adjacent to the old military airport.

Figure 3 - The golf course before the Schools construction (from Roger Kellogg Stillson - New York 1936).

Architect Selma Diaz, the wife of Osmany Cienfuegos, head of the Ministry of Construction (MICONS), was initially put in charge of the project. However, due to the relevance and size of the construction, she asked Cuban architect Ricardo Porro to take over the project.

[3] Loomis, 1999, p. 20.

Porro understood the importance of the assignment but due to the limited time available (the schools were to be inaugurated at the official end of the Literacy Campaign, December 22nd, 1961) asked the colleagues Vittorio Garatti and Roberto Gottardi to participate.
The three had met in Venezuela before the Revolution (1957-1960), thanks to the photographer Paolo Gasparini. In fact, Ricardo Porro was exiled in Caracas for political reasons whilst Garatti and Gottardi were there because of family reasons, working in the local University and at the *Banco Obrero*, with architect Carlos Raul Villanueva.
Porro was the first to return to Cuba in 1960; here, most of the technicians and professors had fled the country after the Revolution, opening a large number of university and professional positions.
Porro, Gottardi, and Garatti began working on the schools' design in April 1961, and in the same year, the construction of the five Schools began.

Ricardo Porro remembers: *"...organicé nuestra oficina en la capilla. Era un lugar maravilloso. Trabajar en la capilla era encantador. Una serie de estudiantes brillantes de la escuela vinieron a ayudarnos también. Empecé a trabajar, Vittorio empezó a trabajar y Roberto también empezó a trabajar. Y trabajar en aquella atmósfera oscura, toda la noche y todo el día, fue una experiencia poética, lo más bella posible. Está claro que la arquitectura que nosotros desarrollamos desde el principio estaba fuertemente conectada unos con otros, pero yo no intervine en la arquitectura de los otros, ni ellos en la mía... era una arquitectura rica, orgánica"*[4].

In June of 1961, Fidel Castro himself defined the National Schools of Art as *"the most beautiful academia of arts in the whole world"* and mentioned the architects as artists.
The three originally conceived schools as a single complex with shared services, but the program changed when the directors requested a different building for each discipline.
Ricardo Porro took responsibility for the general design, Modern Dance and Plastic Art, Vittorio Garatti for the Schools of Ballet and Music, and Roberto Gottardi for the School of Dramatic Arts. Overcoming the initial idea, the Schools were placed in the park, close to the outer border.

"Modern Dance was placed on a high point overlooking the others. Dramatic Arts was located in the meadow at the edge of the valley, while Ballet was immersed in a deep gorge. Music was to occupy a middle ground along the side of a ridge. The existing clubhouse located on the plain would accommodate offices, cafeteria and other common services. Across from it and the entrance to the complex was sited Plastic Arts"[5].

Each one of the five schools is independent and has its own original design, but, at the same time, altogether the five buildings and the park constitute a unitary whole that also includes some pre-existing buildings, such as the former clubhouse, built in the colonial period and reused to host the administrative headquarters.

[4] Pizarro Juanas 2012, p. 41.
[5] Loomis, 1999, p. 24-25.

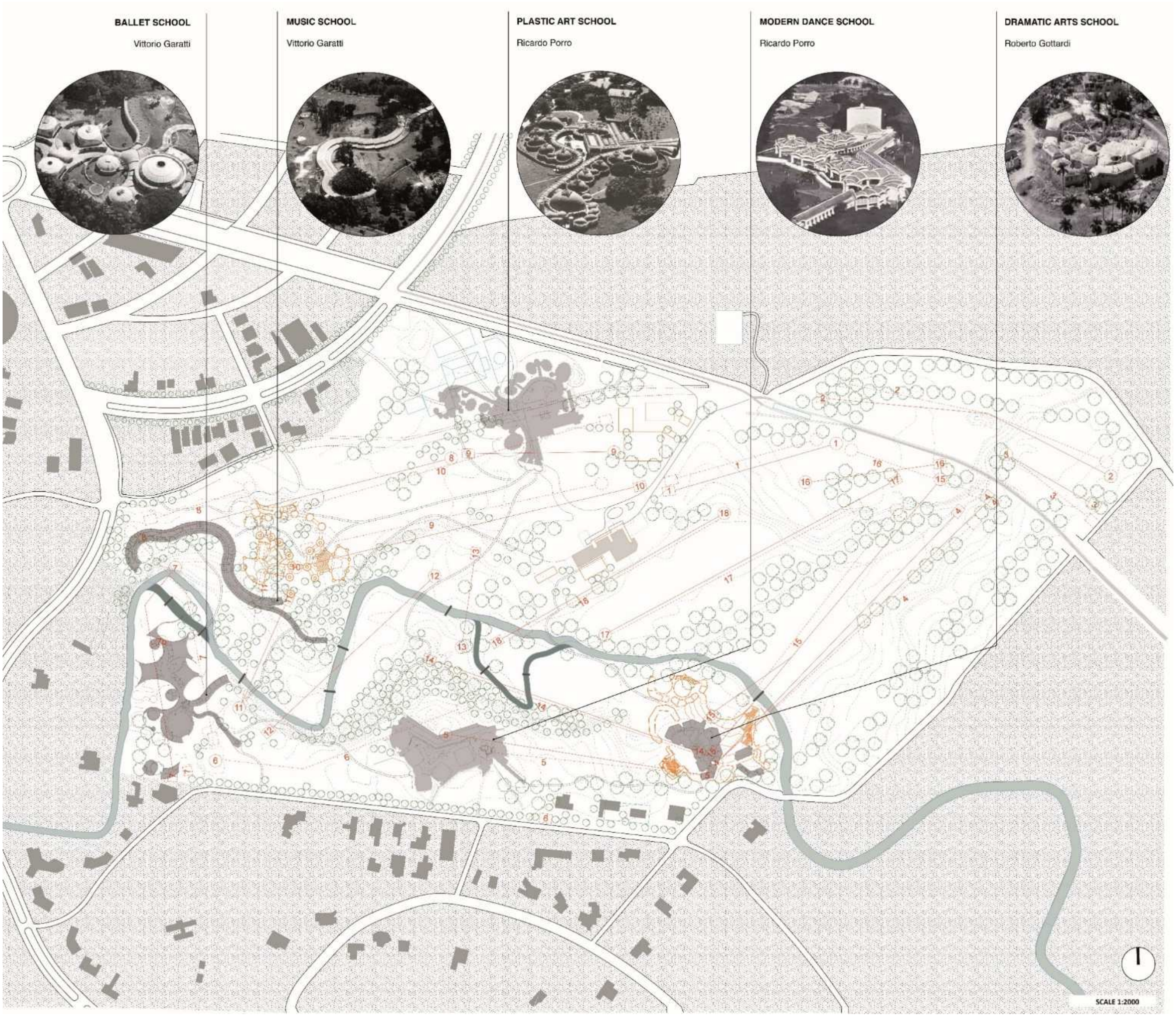


Figure 4 - Map of the Schools' campus indicating the position of each one of the five buildings (from Feder 2018, tav. 3).

On December 22nd, 1961, only the construction of Ricardo Porro's Schools of Modern Dance and Plastic Arts were well advanced. The project of the School of Dramatic Arts was repeatedly interrupted because of continuous changes to the original plan. As for the School of Ballet, Vittorio Garatti could count on the collaboration of Alicia and Fernando Alonso. On the other hand, however, the School of Music had a rather difficult start: the design began in September 1961 and the construction in January 1962.

In 1962, with the October Crisis (Missile Crisis), all the projects not strictly related to economic production were reduced, and most workers were redirected elsewhere.

In September 1963, at the UIA Congress in Havana, a visit to the construction site was organized in order to present the Schools. In 1965, the construction was interrupted. The Schools were officially inaugurated on July 26th, 1965, and declared formally finished without actually being completed.

Only two out of five schools (the School of Plastic Arts and the School of Dance) were completed, and both of them were already housing their original functions. The School of Ballet was almost finished (95% completed), but it was never used for several reasons. The Schools of Music and Dramatic Art were far from being complete.

From 1965 until today

Figure 5 - "Country Club to *Escuelas*: collage throughout times" (from Feder 2018, pp. 106-107).

For over 30 years, the Schools have been removed from the collective memory. Indeed, the cultural climate had changed, and the values and ideals expressed by these visionary architectures were not coherent with those promoted by the Soviet Union. Two of the architects, Ricardo Porro and Vittorio Garatti, had to go into exile.

«In the decades that followed, the Art Schools fell into various states of decay, succumbing to neglect and outright vandalism. Squatters on the grounds have left few traces of the once exquisitely maintained landscape, which became home to plots of plantains and corn, and herds of goats. What was not outright desecrated fell victim to exuberant vegetation. By the 1980s, the National Art Schools had reached a truly deplorable state when an interesting series of events began to unfold. In 1982, a group of young Cuban architects, all critical of the way architecture was taught and practiced in Cuba, began meeting informally. In 1988 they were given official status as a part of the Hermanos Saíz, a young artists' organization under the auspices of the Ministry of Culture. High on their agenda was the restoration of the National Art Schools to Cuba's architectural heritage. In 1986, Roberto Gottardi, the only one of the original three architects still in Cuba, was commissioned to draw up plans for the completion of the Schools, but this project was soon abandoned. By 1989 John Loomis, a North American architect and scholar, met Roberto Gottardi and the Havana Biennial of Art, and Gottardi conducted him on a tour of the schools. Moved by the compelling architecture and story, Loomis embarked on a decade-long project that produced the book Revolution of Forms, Cuba's Forgotten Art Schools. In 1995, the National Union of Cuban Architects and Engineers organized an exhibition of photographs, showcasing the work of New York photographer Hazel Hankin. The following year, Ricardo Porro, who lived in exile in Paris, was invited to return to Cuba to give a series of lectures. A similar invitation was issued in 1997 to Vittorio Garatti, who had been forced to leave the country in

1974. In the same year, the National Conservation Center conducted a preliminary study for the preservation and restoration of the schools. A few months later, the National Monuments Commission of Cuba declared the schools protected, but refused an initiative to designate them as national monuments.
Events reached a crescendo *at the beginning of 1999, when the book by Loomis,* Revolution of Forms: Cuba's Forgotten Art Schools*, was published. In Los Angeles the launch took place at the MAK Center, with an exhibition of photos of the schools by Paolo Gasparini taken in 1965. The event reunited Ricardo Porro, Vittorio Garatti, and Roberto Gottardi for the first time since 1966. Not only was there a significant buzz about the schools in the media, with numerous articles appearing in international papers and magazines, but the sites were included on the World Monuments Fund's 2000 list of the 100 Most Endangered Sites. These efforts yielded the international support necessary to ensure their further international attention, making them eligible for support for their preservation»*[6].

In 1999 a work of "*rehabilitacion y completamiento*" was thus announced, and, at the same time, the teaching program is reformulated, adding new courses related to performances and new media.
On October 6th, 1999, during a meeting with the National Council of the UNEAC, Fidel Castro indicated to restore and complete the *Cubanacan* Art Schools, according to the original projects.
Following Castro's indications, the Cuban Government commissioned the restoration intervention to the MICONS (*Ministerio del la Construcción*), and MINCULT (*Ministerio del la Cultura*) which involved its construction company (EMPROY2) and MES (*Ministerio del Educación Superior*). The operation was coordinated by arch. Universo Garcia Lorenzo (*Proyectista General*). Ing. Alejandro Pasqual (*Projectista Estructural*) and Dr. arch. Lucrecia Perez Echazabal (*Asesora Principal de Restauracion*) were also involved in the project.
At this time, a general masterplan of the complex was produced (*Plan Rector*), including the refurbishment/reuse of existing schools, the construction of new buildings, structures, bridges, and paths.
By building new residences for about 1800 students and 100 professors, a canteen, and adding new functions (*Centro de Elaboración, Centro de Información de las Artes, Facultad de Artes de los Medios de Comunicación Audiovisual, …*), the project aimed at increasing the number of enrolled students (the idea was to reach a 27% growth, from 1047 to 2135).
The whole redevelopment would have to be completed in five years, but the project took actually longer and costed more than expected. In 2003 Fidel Castro visited the Schools and criticized the slow pace of work.
In the end, only the Schools of Modern Dance and Plastic Art (the only ones that were already completed and functioning) went through a complete refurbishment, completed in 2008. However, the interventions carried out by Universo met the strong opposition of the original designers - in particular Garatti and Gottardi - who contested the added constructions because of their inconsistency with the character of the park as well as of the (unsuccessful)

[6] F. Taravella, *Teaching the Arts beyond Modern Architecture. Adaptive reuse of Havana's former Clubhouse as a contemporary school of music*, master thesis. Supervisor: Prof. Davide Del Curto, Politecnico di Milano, 2020.

solutions developed to avoid Rio Quibù's flooding. Undoubtedly, the use of incompatible materials (such as low-quality bricks) caused significant damages to the existing structures.

In the same context, the theme of the restoration and reconstruction of Gottardi's school was also addressed. The intervention was supposed to include the restoration of the portions that had already been built (and laid in a poor state of repair), the construction of those spaces that were never completed in the '60s, and an extension to the building, which was made necessary by the evolved educational needs. The latter was to be realized on a new design, prepared by Gottardi himself. In the end, however, operations only regarded existing structures, but the School was once again left unfinished.

In that same period, Garatti also prepared a project to complete both the School of Ballet and Music, which were constantly subject to tropical weathering and vandalism. The new project substantially reproduced the original one, except for a few minimal changes.

Although the designs for the School of Ballet were approved by the National Commission of Monuments in Cuba, because of the international economic crisis, in 2009, the restoration works started in 1999 came to an end.

In November 2011, the National Art Schools were declared monuments by the National Council of Conservation.

In 2012 the three architects were awarded with the "De Sica" prize, within the section "a life for architecture".

Timeline

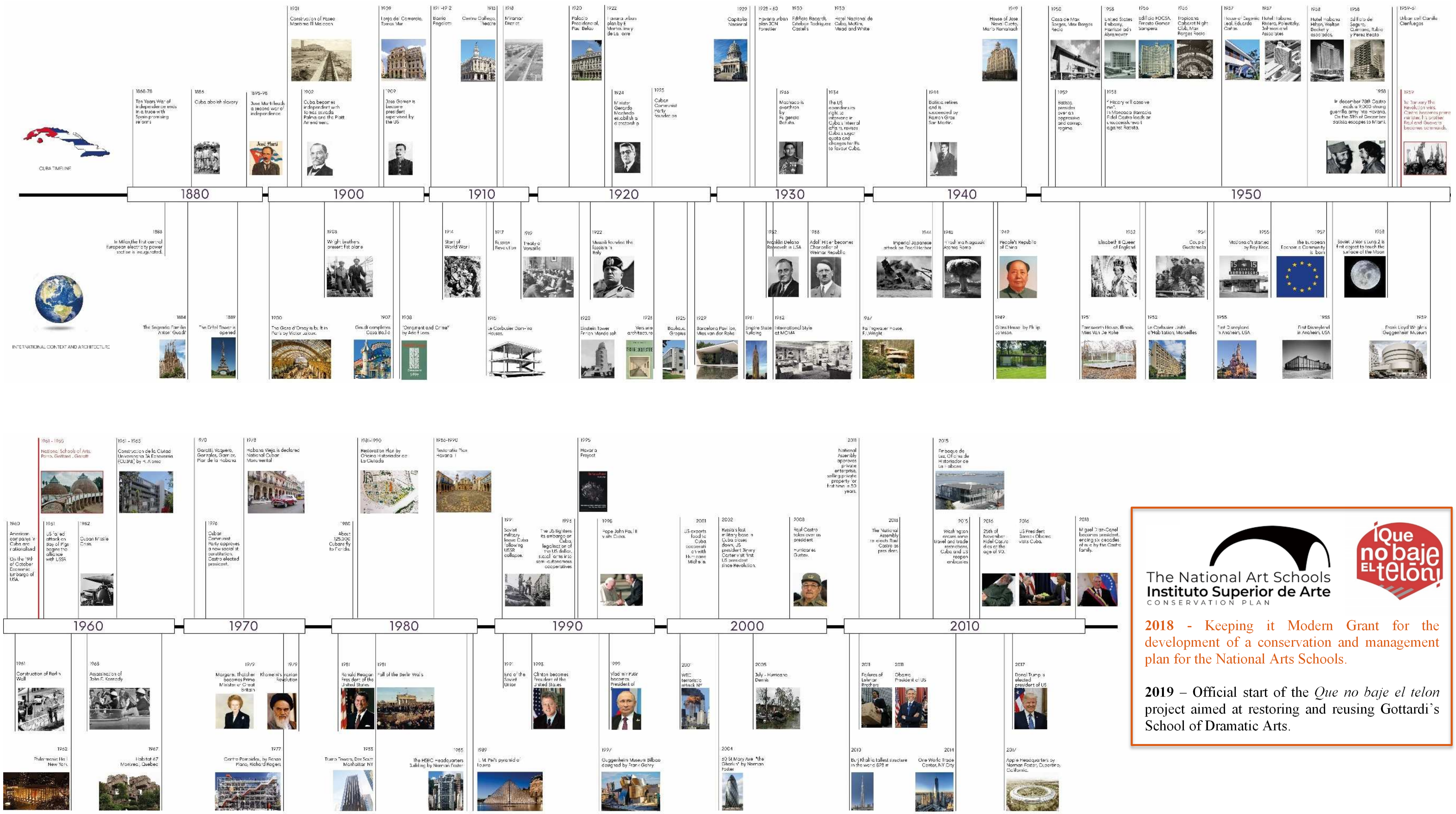


Figure 6 - Timeline of Cuban and word's political and architectural events from the end of the XIX century to current days (from Feder 2018, tav. 1).

Evolution of the Schools' site[7]

1920s

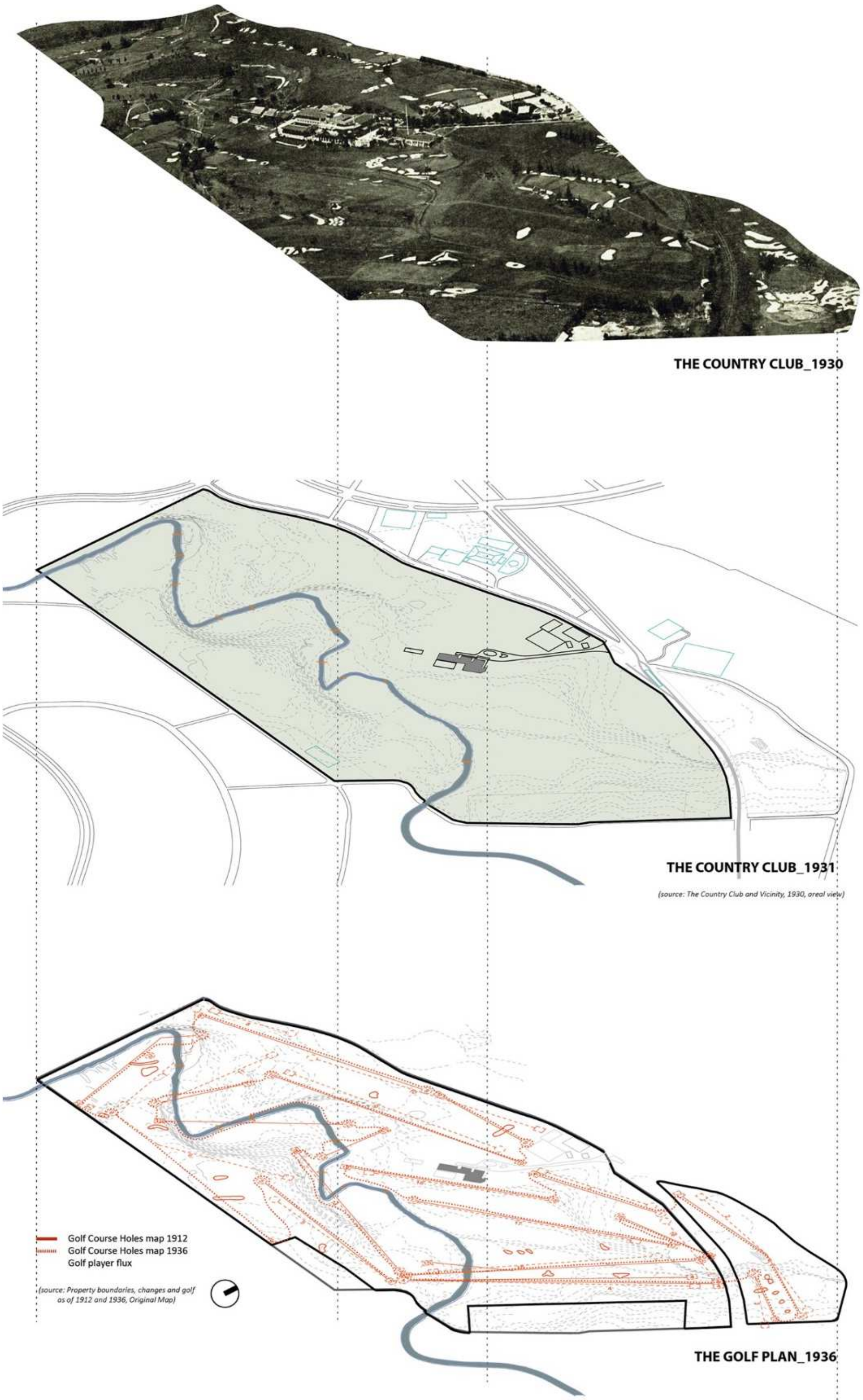
Miramar, El Vedado and La Playa district are planned and realized as urbanistic expansion for the rich american and creole bourgeoisie. The urbanistic plan is radiali, with leafy avenues, parks and big plots for housing. There were very few buidlings in Cubancacan at that time, mainly private mansons and the Casino Nacional Marianao. A tram linked the area with the Habana Vieja.

1914 - 1920

The Havana Golf Country Club was designed in 1914 by the American architect Sheffield A. Arnold, who was a student of F.L.Olmsted. Arnold applied the same principles of Naturality which at the time was called the "English Garden", with a sinuous shape, integrated with artificial lakes, a large golf field, and space for other activities. The golf player was supposed to discover the place walking and playing, as a sort of promenade in the natural space, contemplating the horizons, the green elements and the warm breeze of Caribbean Sea.

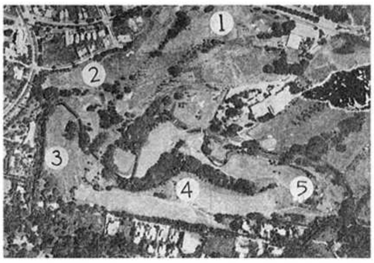
1920 - 1959

The Havana Country Club Park was a luxury leisure space for the wealthy inhabitants of the exclusive houses nearby. The golf course had 18 holes originally planned in 1912, and lately re organized in 1936. At the centre of the area, the Country Club building was hosting services like swimming pools, bowling cours, a bar, a restaurant and some guests rooms. A street was dividing the area in two allwing the tram to stop and pass.



7 The proposed images are taken from Feder 2018, tavv. 3-4.

1959-60



When the Cuban Revolution officially enters on the 1st of January 1959, the picture of Cuban culture changes drastically. Wealthy people left Cuba and their homes.The Habana Country Club was abandoned., the vegetation started to grow freely and the districts around were populated by locals.
The Casino Nacional de Marianao was teared down and its plot joined with the gold course and the northern part.

1959

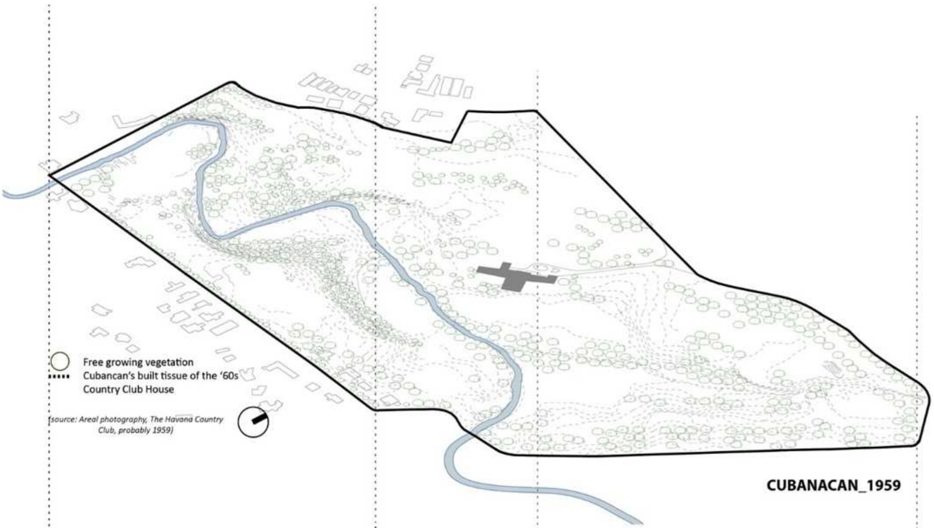
The National Art School was designed and built. Porro, Garatti and Gottardi were entrusted of the project. Here the original project of the schools. (Plastic arts, Modern Dance Schools,Ballet Music Schools and the Dramatic Arts).

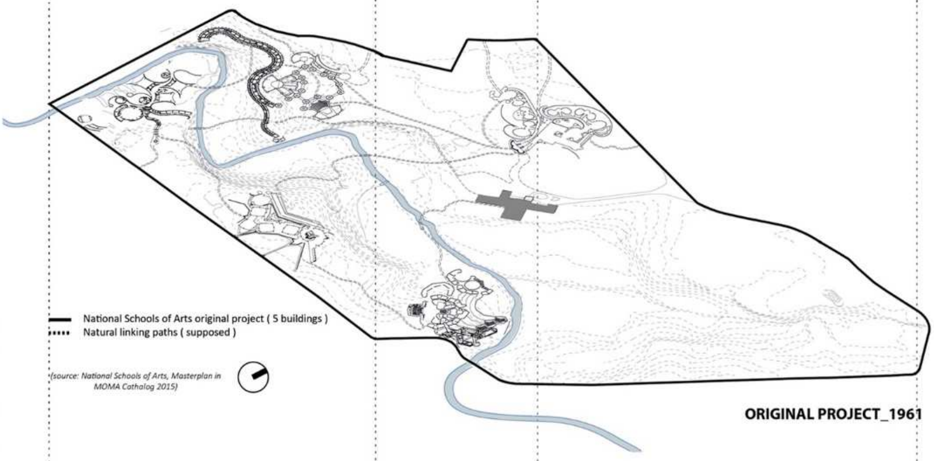
1961

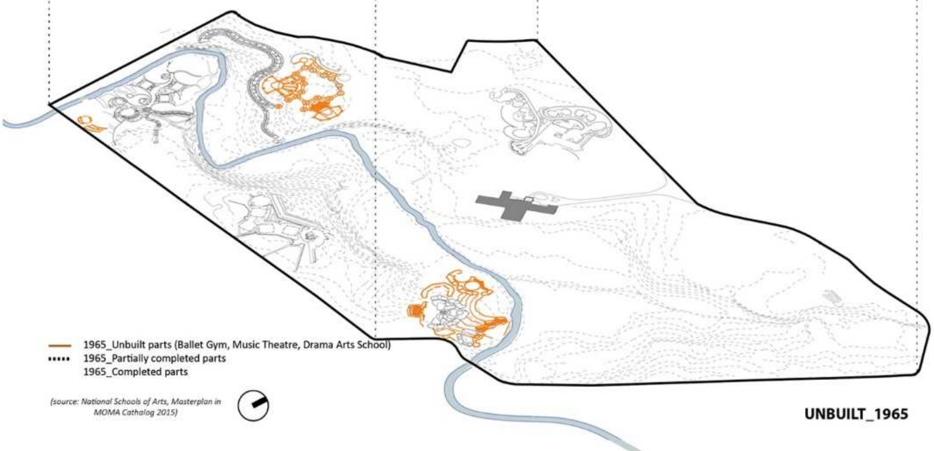
The National Art School was designed and built. Porro, Garatti and Gottardi were entrusted of the project. Here the original project of the schools. (Plastic arts, Modern Dance Schools,Ballet Music Schools and the Dramatic Arts).

1965

The building phase was stopped and some Schools remained unbuilt: The Music School's theatres, offices and services and Dramatic Art School's Theatre, classroom and Amphitheatre outside.

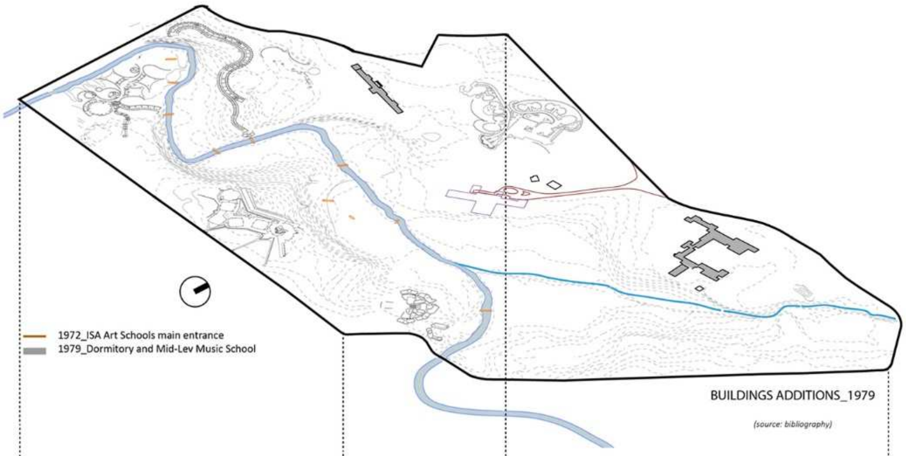






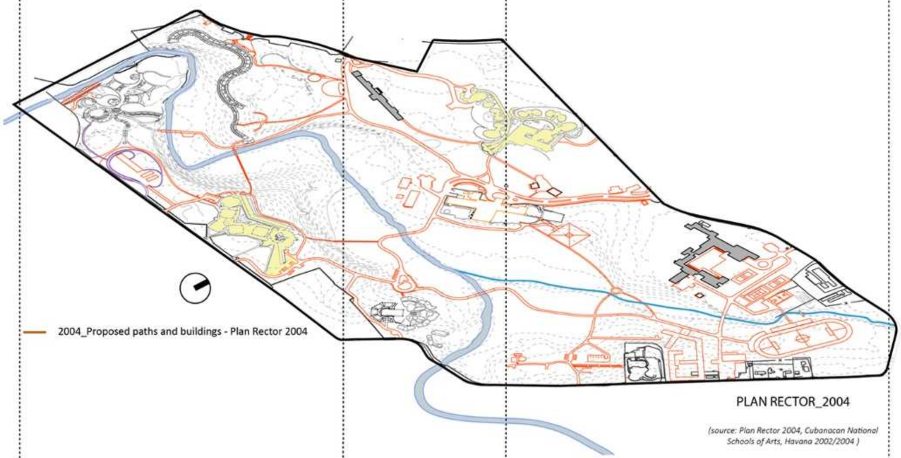
1978

A new building for the School of Music – Medium Level (ENA) was realised with prefabricated elements; and in 1979 a dormitory residence for students in prefabricated elements too. Before they used to sleep in the wealthy maisons of foreign owners before the Revolution.

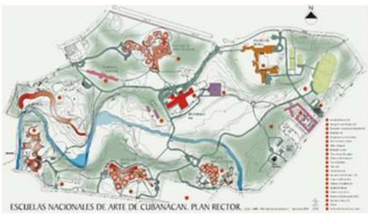


2001

After many years vegetation had grown uncontrolled, in a way that affected the conditions of buildings and speeded the decay process.
Here it is visible a google image that show the overgrowth of trees and bushes

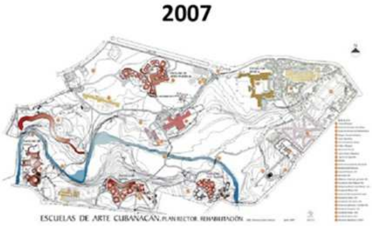


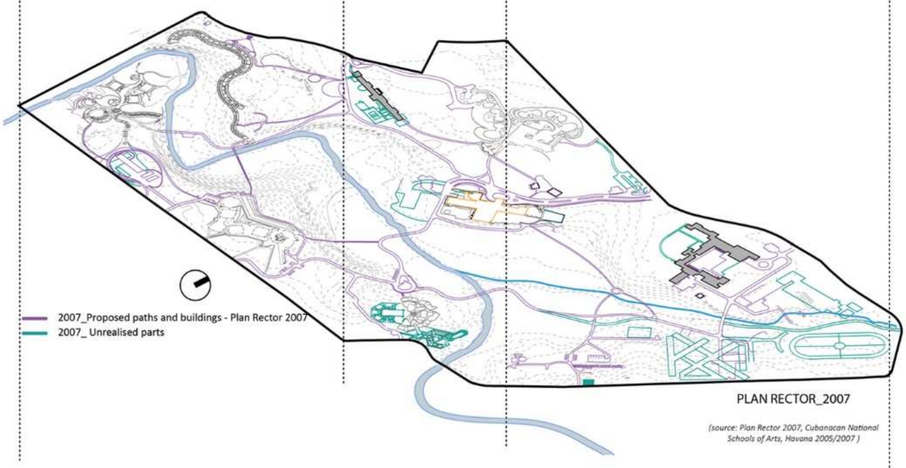
2004



After investigations on the Schools buildings status, a Plan Rector was made by a team of architect lead by Universo Garcia Lorenzo. Interventions were: Restorations of Porro's building Plastic Art and Modern Dance implementation of pedonal paths, fenches on the borders and access gates, sport center, new buildings, parkings

2007



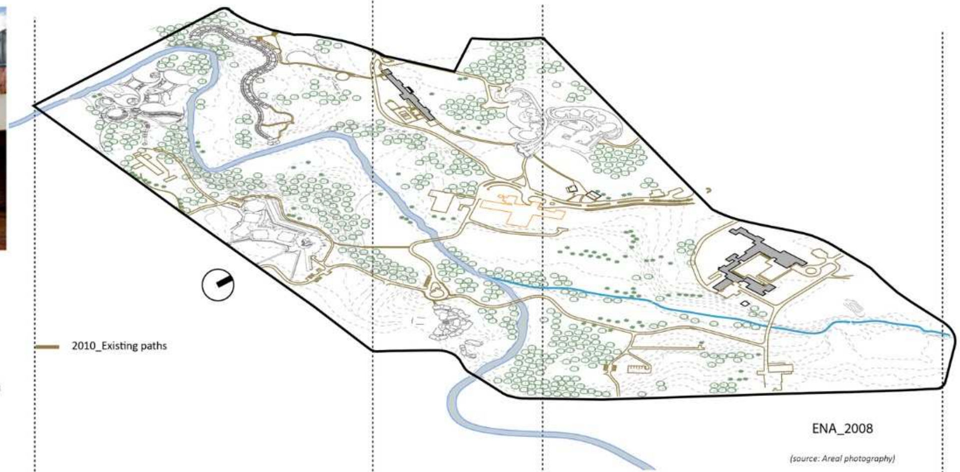


A second Plan Rector was made by the same team, about some variations in paths, new configuration of sport centre and new buildings that were not realized then.
Many proposals were made by Roberto Gottardi for his Dramatic Arts School (2001-2002-2003-2004), but none of those were actually realized.

2008

The redevelopment project has realised:

•River Quibu: Cleaning, extraction and transport of sediments, construction of retaining walls.
• Three bridges: 2 vehicular and 1 pedestrian
• 3.66 km of vehicular vials and 2 km of pedestrian paths
• Construction of 10 parking areas (1500 m2).
• Perimeter fence in concrete and metal around the park.
• Bouganville (8000 plants) and cardona (4800 plants) have been planted.
• Outdoor lighting: 5.2 km of vehicular roads and pedestrian paths with lighting.
• Reforestation of the Quibú River 6.000 new trees



2010_Existing paths

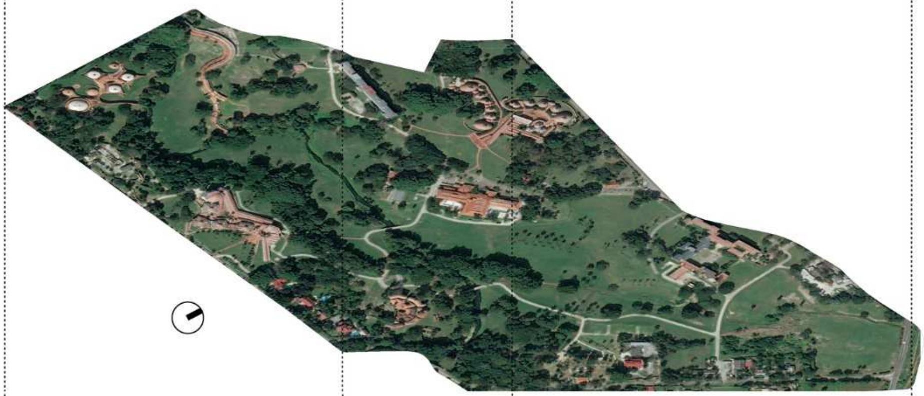
ENA_2008

(source: Areal photography)

2009 - 2017

The Google Maps view shows the high quantity of vegetation, bushes and palm trees.

The contemporary configurations is the result of Plan Rector 2004- 2007. The r unrealized areas remained on paper and the northern part for sport was not developed, as it can be seen from the Google Image. Vegetation is under control thanks to monthly keepings and the fenches ensure a quite good level of safety.



AREAL VIEW_20017

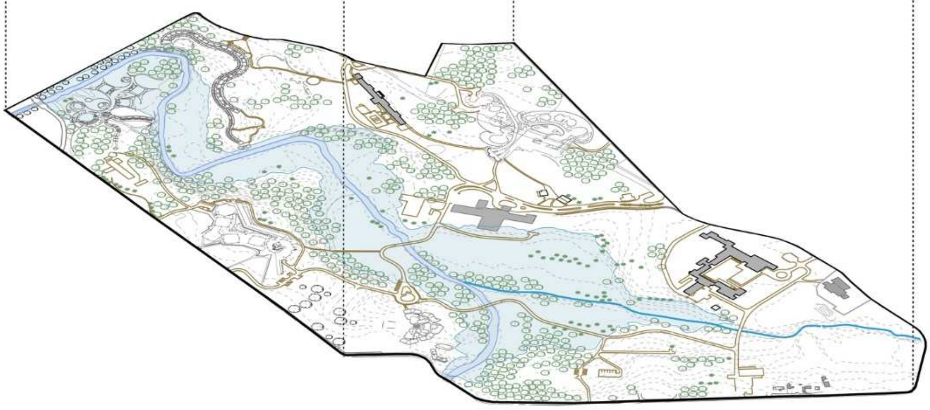
(source: Areal photography, GOOGLE MAPS)

2018

At the moment only some little path where added, but the most problematic situation is the constant flooding of the Quibu' river during rainy season.

It affects a large part of the Ballet School and the south part of Music School.

Also Dramatic Art School garden is affected by the flood



'70s - 2018_River Quibu flooding

FLOODINGS SITUATION_2018

(source: Areal photography, flooding documents)

The architects of the National Schools of Art

Vittorio Garatti

School of Ballet

School of Music

(images from ISA archive)

Vittorio Garatti was born on April 6th, 1927. In 1957 he graduated in Architecture from Politecnico di Milano, where Ernesto Nathan Rogers was a major influence.

From 1957 until 1961, he lived and worked in Venezuela, where he found employment in the *Banco Obrero* project (led by architect Carlos Raúl Villanueva) and met Roberto Gottardi. He later moved to Cuba, where he stayed from 1961 to 1974.

From 1958 to 1961, he was a Professor of Architectural Design at the Faculty of Architecture of the Central University in Caracas. Then in Cuba, he becomes Professor of Architectural Composition and Design (from 1961 to 1967) as well as Urban Planning (from 1968 to 1974) at the Faculty of Architecture (CUJAE) of the University of Havana.

In 1961 he co-founded the Cuban Institute of Physic Planning, and he thus started his studies of planning for urban and territorial development.

Since 1961, together with Porro and Gottardi, he started designing the National Schools of Arts in Havana. In 1963, he designed the block of the Technical School of Agriculture Andre' Voisin in Guines, the first intervention of precast housing in Cuba.

In 1966-67, with Sergio Baroni and Hugo d'Acosta, he designed the Cuban pavilion at the Expo 1967 in Montreal.

Since 1968 he started developing an urban plan for Havana's city (with Jean-Pierre Garnier, Max Vanquero, Eusebio Azque), designing detailed plans for the residential department Este de Havana for the *Plaza de la Revolución* (with Eusebio Azque), and for the new harbor.

In June 1974, he was arrested and kept in jail for twenty days on charges of spying. He was later forced to leave the country. He believed his expulsion to be the result of a conspiracy with the CIA, which was trying to expel foreign professionals who collaborated with the Cuban regime. Back in Italy, he becomes a self-employed professional. Since 1994, he has been an Adjunct Professor at the Faculty of Architecture of the Polytechnic of Milan[8].

Figure 7 - Pavilion Cuba Expo Montreal, ISA archive (1956).

Figure 8 - School of agriculture, ISA archive, Guines (1962-1963).

[8] Based on Machetti, C.; Mengozzi, G.; Spitoni, L. (a cura di), *Cuba, Scuole Nazionali d'Arte*, Milan: Editorial Skira, 2012, p. 186.

Roberto Gottardi

School of Dramatic Arts

(images from ISA archive)

Roberto Gottardi was born on January 30th, 1927, in Venice, where he graduated in Architecture in 1952. He studied with Albini, Scarpa, Samonà, Astengo, and Piccinato. He then moved to Milan, where he worked for the BBPR (Gian Luigi Banfi, Ludovico Belgiojoso, Enrico Peressutti, and Ernesto Nathan Rogers) architectural firm.
He moved from Italy to Venezuela - first to Maracaibo and then to Caracas - where he worked as an architect in private practice. In 1957 he worked in the architectural studio of renown Carlos Raúl Villanueva (the *Banco Obrero*), where he met Ricardo Porro and Vittorio Garatti.
In December 1960, after the Cuban Revolution's victory, he left Venezuela and moved to Cuba with a contract from the Ministry of Public Works. He also became a Lecturer at the Faculty of Architecture in Havana. Here, he took part in the design of the Art Schools together with Garatti and Porro.
From 1966 to 1968, he designed three restaurants in Havana, but only one of them was actually built: the *pizzeria "La Maravilla"*. In 1967, he designed the music room in the *"La Rampa"* Cultural Center (Havana), and in 1967 the Amphitheater for the International Festival of Popular Song in Varadero. Between 1967 and 1972, he followed the design and construction of the *"Puesto de Mando"* headquarters in Menocal for the Ministry of Agriculture. In the three decades from 1970 to the 90s, he devoted himself to teaching, designing, and building sets for several ballets, one of his greatest passions. In 1981 he started working on the National Art Schools' re-modeling project, with particular reference to his School of Dramatic Arts. In 1997 he built the restaurant-bar "Prado y Neptuno" in Havana. Starting from 2000, he has been preparing various integration and restoration projects for the Art Schools and following the construction site during restoration. He often held lectures and conferences both in Cuba and abroad (Columbia University in New York; M.I.T. in Boston; Graham Foundation in Chicago; University of Architecture of Miami). In 2012 he took part in the Gwangju Biennale in South Korea. Along with Vittorio Garatti and Ricardo Porro, in 2012, Roberto Gottardi was awarded the Vittorio De Sica Award for Architecture by Italian

President Giorgio Napolitano. In 2016 he was awarded the National Award for Architecture by Cuba. And in November 2016, the Italian government awarded him one of the prestigious Bacchelli pensions dedicated to Italians who made significant contributions to international culture and currently live abroad. He died on August 21st, 2017, in Havana[9].

Figure 9 - On the left: *"Puesto de mando"* for the Ministry of Agriculture, Menocal (1967-72), ISA archive; on the right: restaurant *"Prado y Neptuno"*, Havana (1999), ISA archive.

Figure 10 - "Giron" for the *Conjunto Nacional de Danza Contemporanea*, ISA archive (1981)

[9] Based on Machetti, C.; Mengozzi, G.; Spitoni, L. (a cura di), *Cuba, Scuole Nazionali d'Arte*, Milan: Editorial Skira, 2012, p. 182.

Ricardo Porro

School of Plastic Arts

School of Modern Dance

(images from ISA archive)

Ricardo Porro was born on November 3rd, 1925, in Camaguey. He graduated in Architecture from the University of Havana in 1949 and, in the same year, he built the *Villa Armenteros* in Havana. He then spent two years of postgraduate studies at the Institute of Urban Planning at Paris' Sorbonne.

Back to Cuba, in 1952, he designed a series of residencies in Havana: *Villa Ennis* (1953), *Villa San Miguel* (1953), *Villa Villegas* (1953), *Casa Garcia* (1954), the Abbot-Villegas' (1954), and Timothy Ennis' (1957) houses.

In 1957, Porro published an important article, *"El sentido del la Tradición"*, in which he highlighted the specificity of Cuban architecture as *"una arquitectura negra"*. Shortly after, he was forced into exile to Venezuela for his support to the cause of the Cuban Revolution. Here, since 1958, he started teaching Architecture and working at *Banco Obrero* on the project led by the famous architect Carlos Raúl Villanueva. While in Venezuela, Porro met two Italian expatriate architects: Roberto Gottardi and Vittorio Garatti. Following the Cuban Revolution's victory, Porro returned to Cuba and in 1960 was designated by Fidel Castro as the Project Manager for Havana's new National Art Schools. Porro invited Gottardi and Garatti to join him in the project, for which he designed the School of Modern Dance and the School of Plastic Arts. In 1966, Porro moved to France, where he taught History of Arts and Architecture in Paris, Lille, and Strasbourg. His drawings of the Euro - Kursaal in San Sebastian (1965) are very renowned. Amongst other projects: the architectural competitions for the *Paláis de l'air et de l'espace* (Paris) and the University of Villetaneuse, the *L'Or du Rhin* center (1969) in Vaduz (Liechtenstein), the *Youth House*, in Vaduz, a holiday village on the Island of Vela Luka, in Yugoslavia, and the *Esfahan Villa*, in Iran (1975). From 1986 he collaborated on extensive architectural works, mainly for educational institutions, with architect Renaud de la Noue. The architectural models he produced between 1961 and 1980 can be visited at the Museum *Les Turbulences FRAC Centre* (*Fonds Régionaux d'Art Contemporain*) in Orleans, France. Because of his work as an architect, artist, and urban planner, the Republic of France awarded him the titles of *Chevalier des Arts et des Lettres*, *Chevalier of the Légion d'Honneur,* and *Commandeur des Arts et des Lettres*. In 1994 he was nominated for the Pritzker Prize. In 2012 he received the Vittorio De Sica Prize for Architecture for the National Schools of Art, along with Vittorio Garatti and Roberto Gottardi. The MOMA (Museum of Modern Art) in New York included original drawings by Ricardo Porro concerning the Havana's Schools of Plastic Arts and Modern Dance in the exhibition *"Latin America in Construction: architecture 1955-1980"* held between March 29th and July 19th, 2015. Porro died at the age of 89 in Paris on December 25th, 2014[10].

Figure 11 - College of Explorers, Cergy Pontoise (1996), ISA archive.

Figure 12 - "*Espace Jeune*" and extension of a school group, *Courcouronnes* (2010), ISA archive.

[10] Based on Machetti, C.; Mengozzi, G.; Spitoni, L. (a cura di), *Cuba, Scuole Nazionali d'Arte*, Milan: Editorial Skira, 2012, p. 189.

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Figure 13 - Bibliographic timeline (summary).

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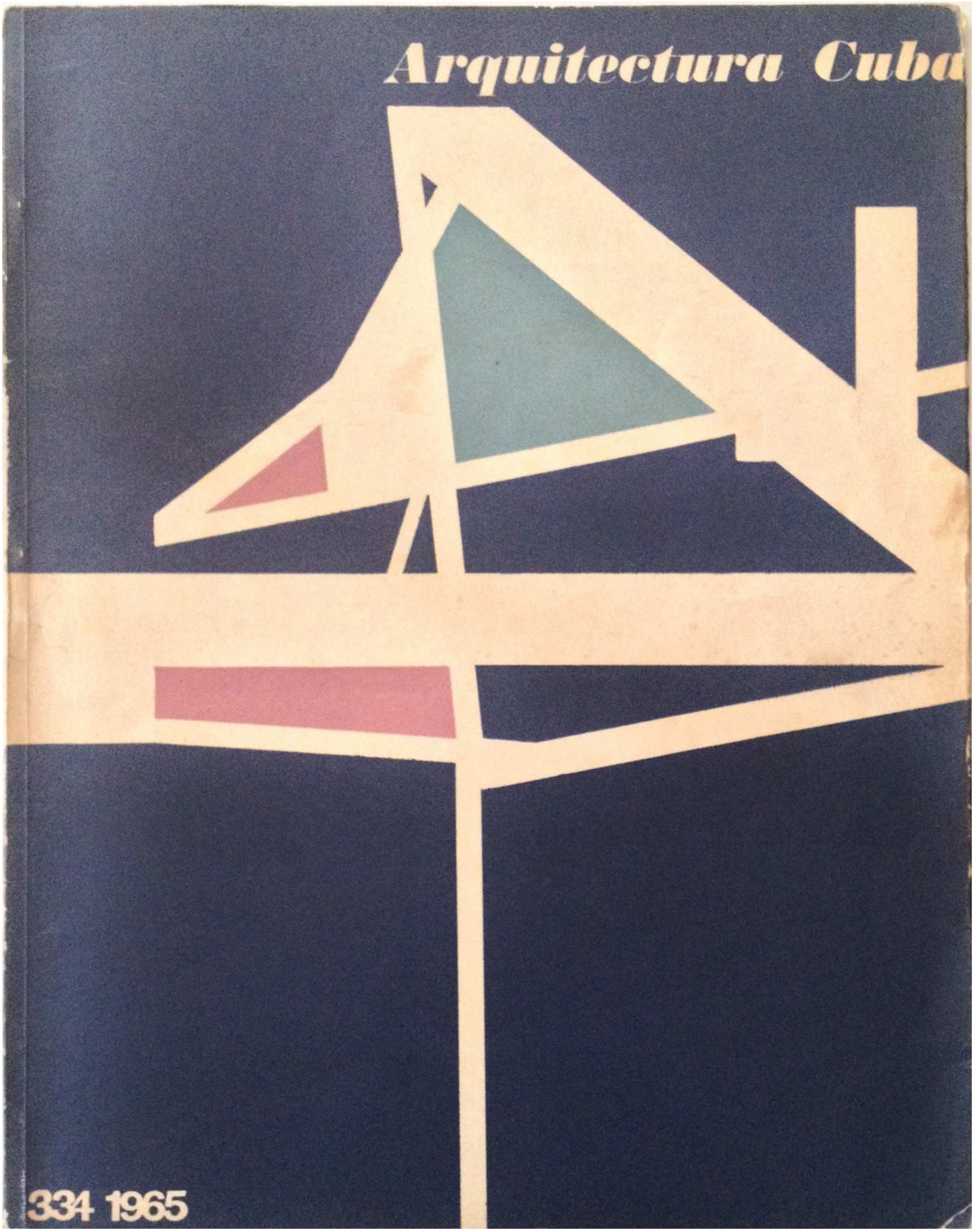


Figure 14 - Arquitectura Cuba, 1965, n° 334.

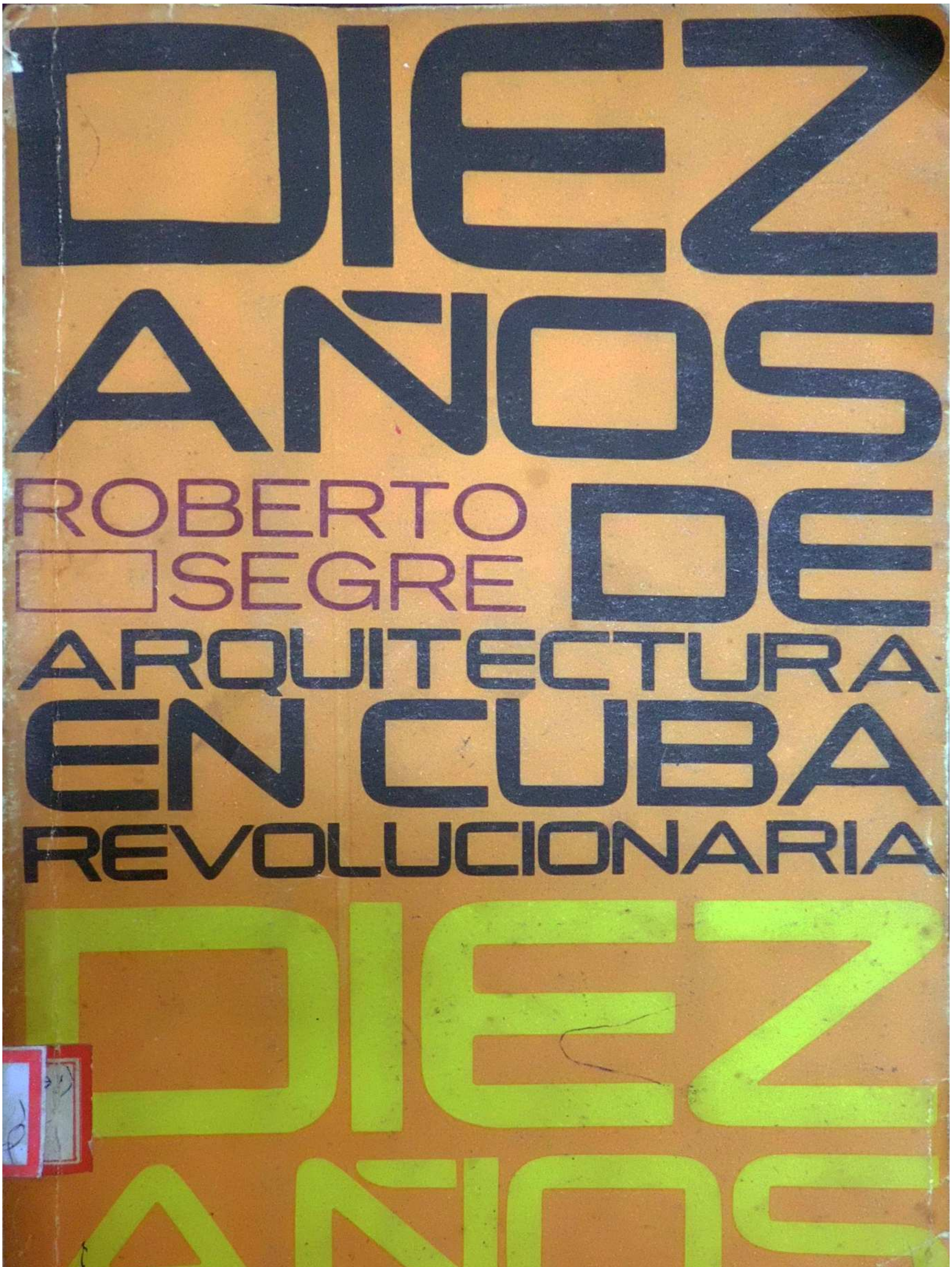


Figure 15 - Segre, R., *Diez años de arquitectura en Cuba revolucionaria*, Ciudad de La Habana: Editorial Union, 1970.

Figure 16 - Fiorese, G., *Architettura e Istruzione a Cuba*, Milano: Clup, 1980.

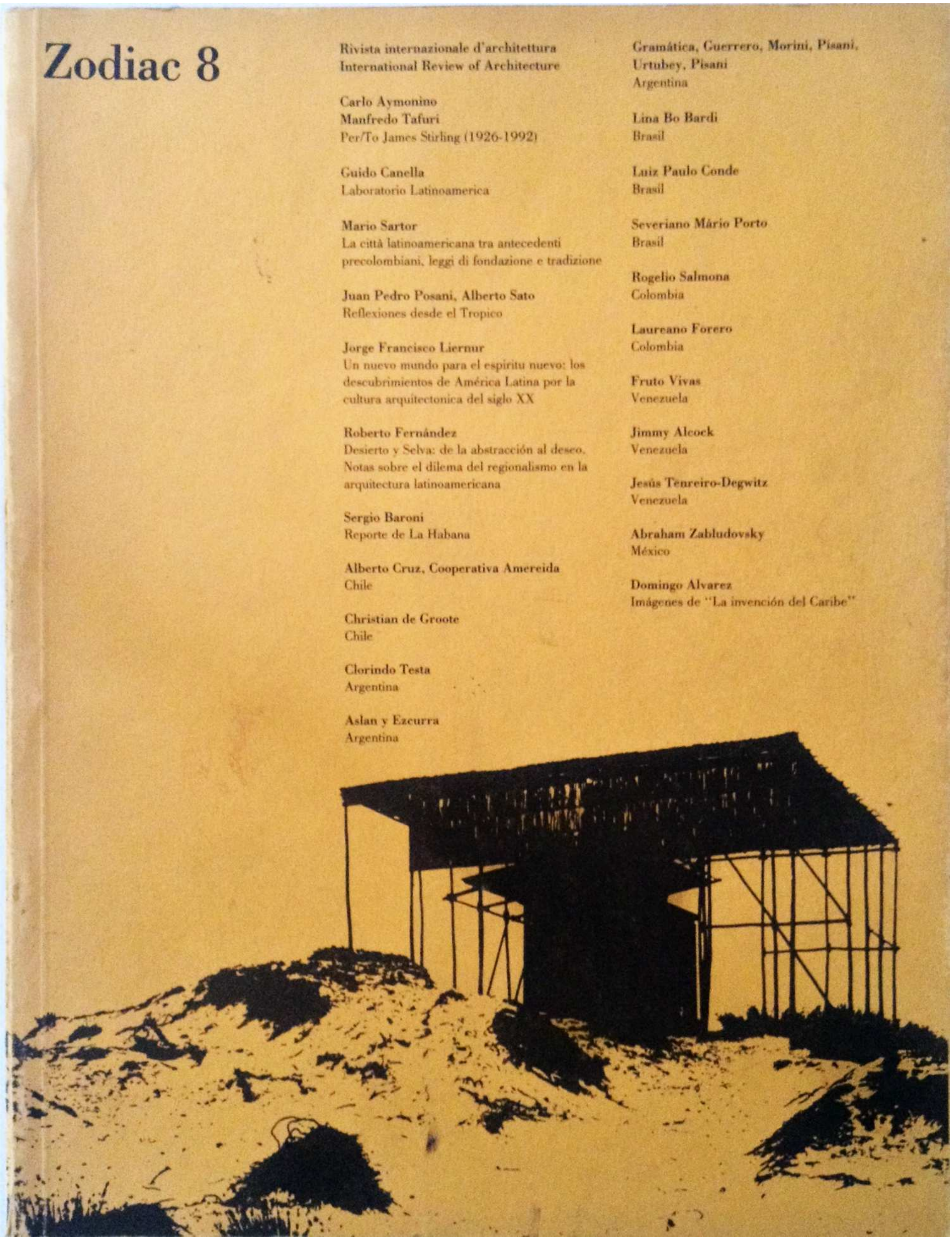


Figure 17 - Zodiac: International Review of Architecture, n. 8, 1993.

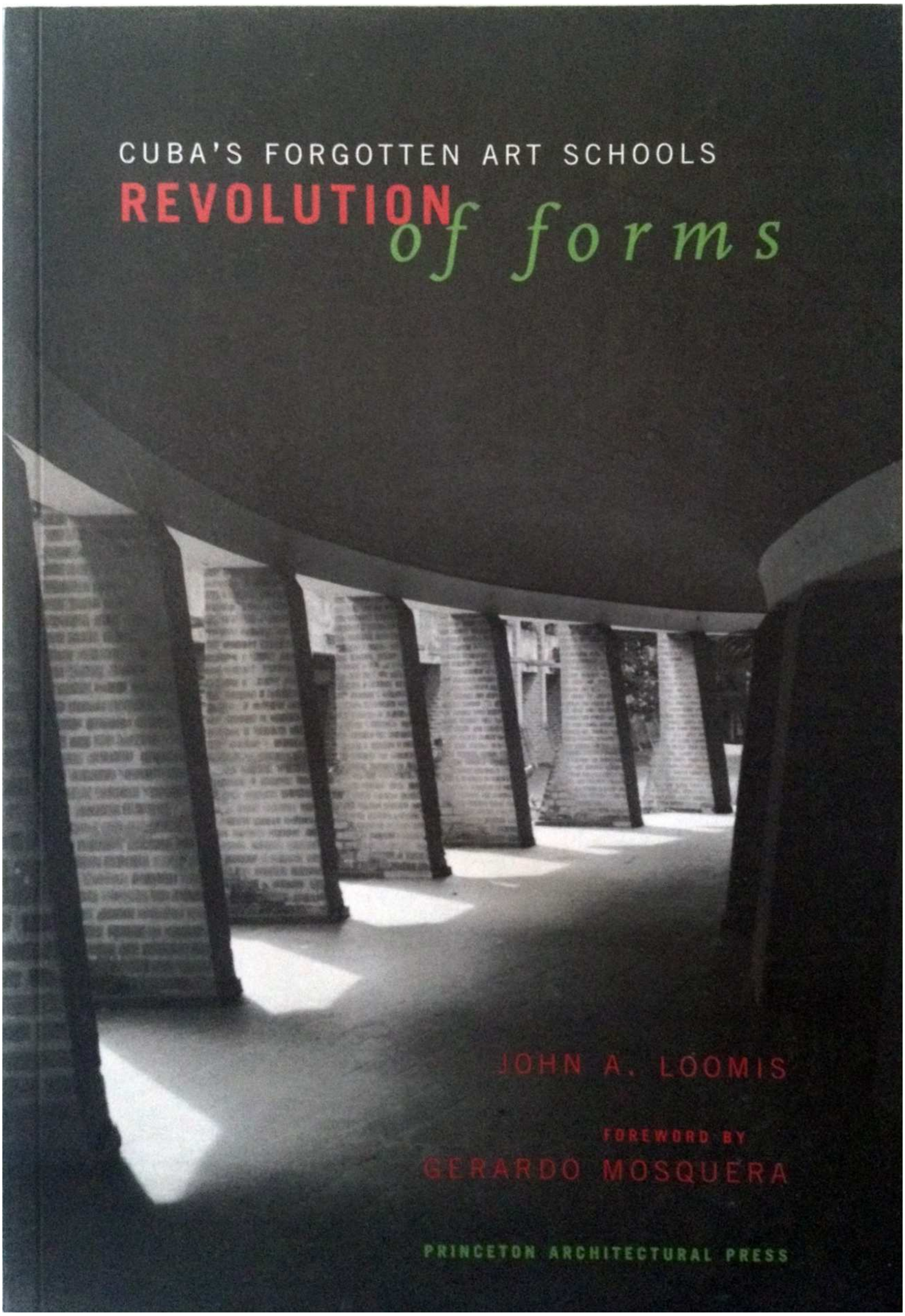
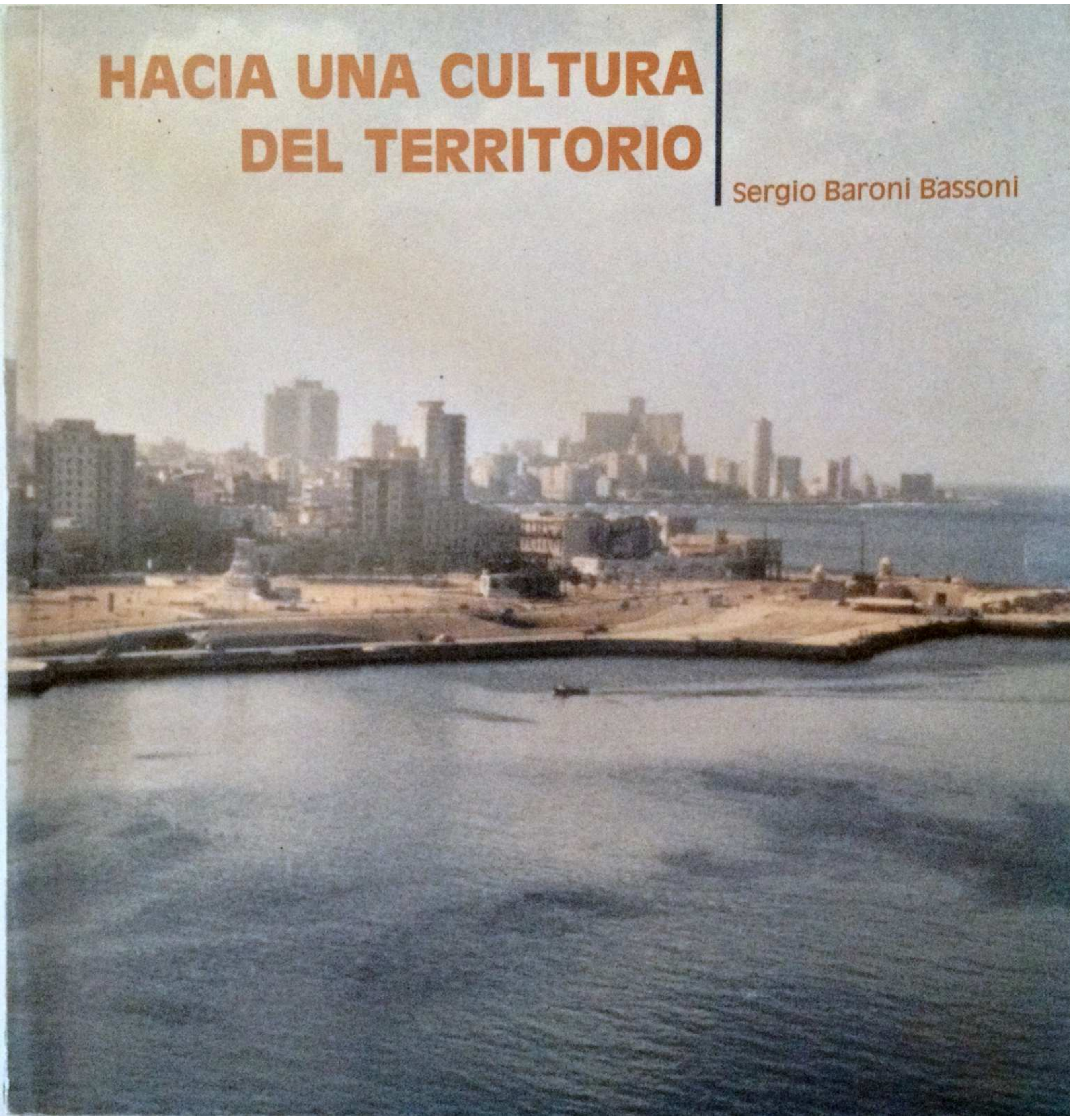


Figure 18 - Loomis, J. A., *Revolution of Forms. Cuba's Forgotten Art Schools*, New York: Princeton Architectural Press, 1999 & 2011.



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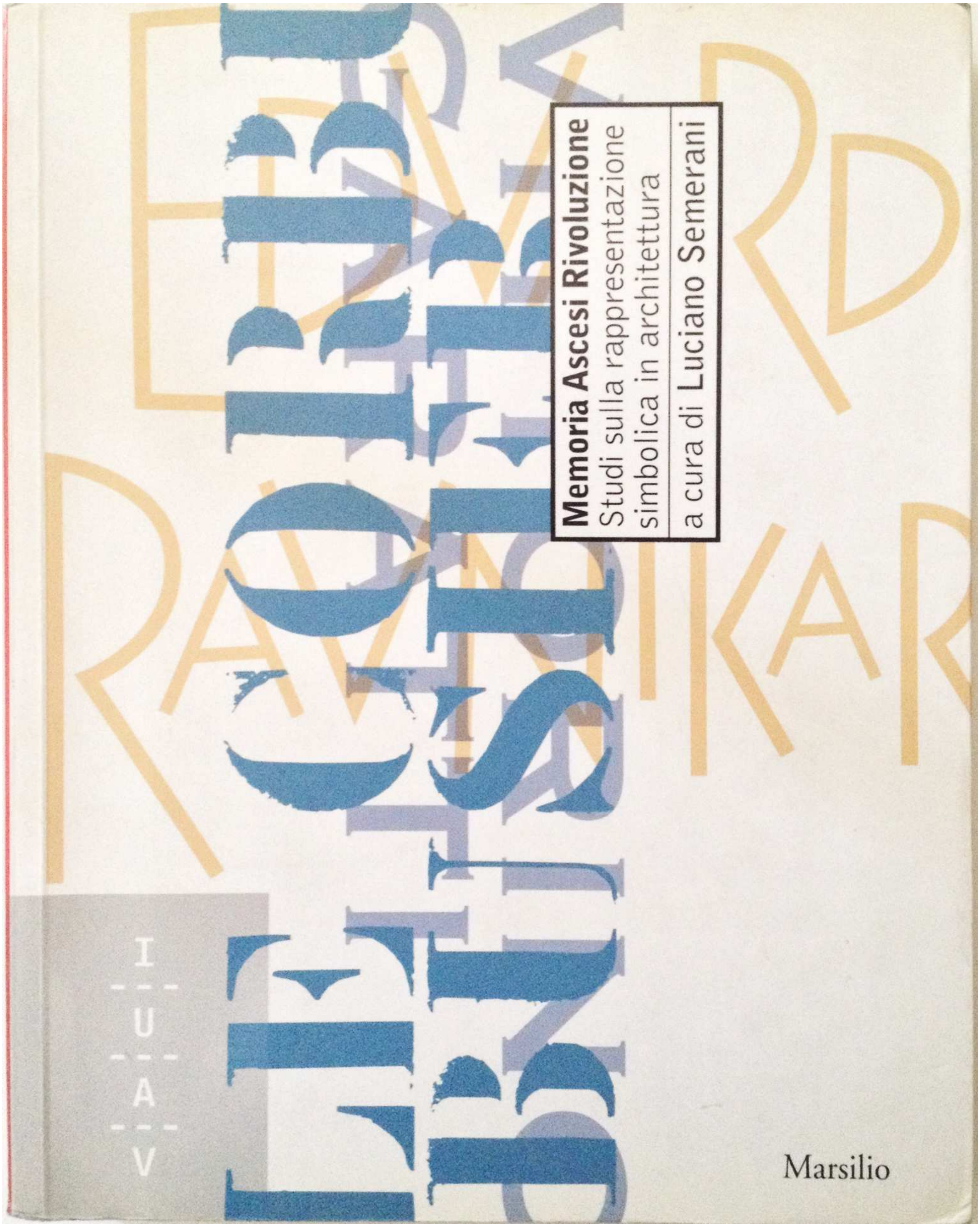

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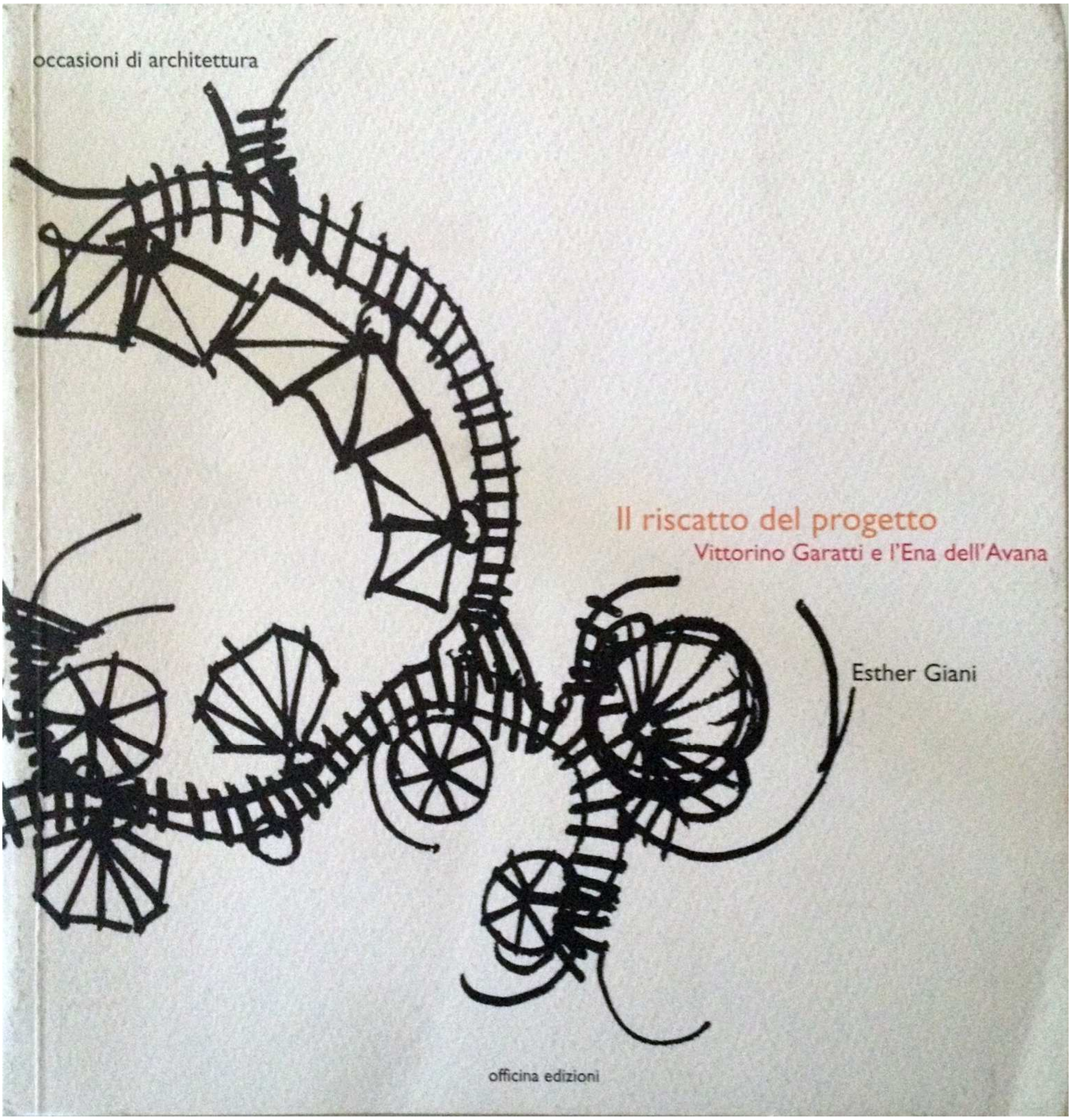

Figure 21 - Giani, E., *Il riscatto del progetto. Vittorio Garatti e l'Ena dell'Avana*, Roma: Officina Edizioni, 2007.

Figure 22 - Arquitectura Cuba, 2008, n° 380.

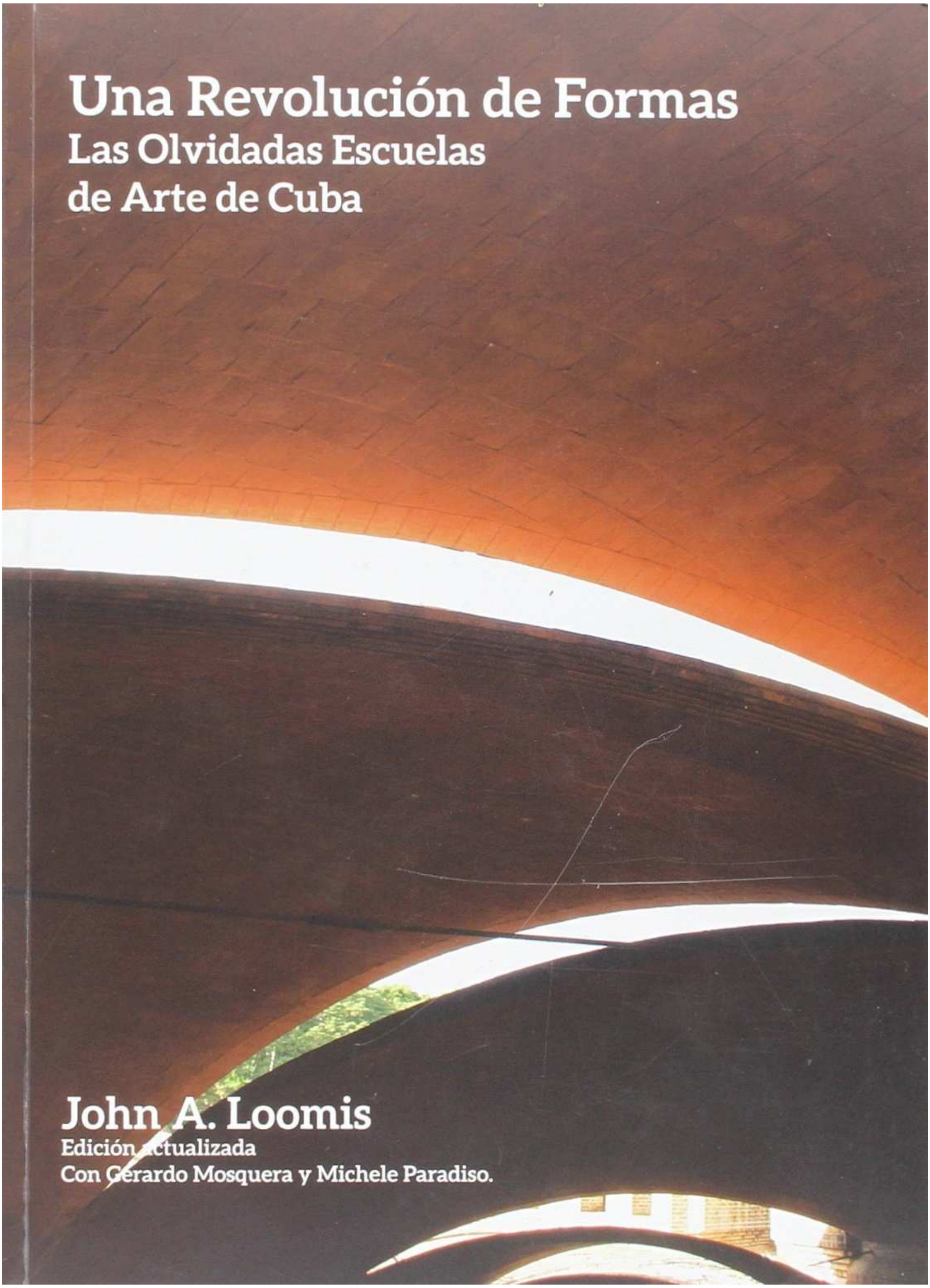

Figure 23 - Loomis J.A., *Una Revolución de Formas: Las Olvidadas Escuelas de Arte de Cuba*, Spanish edition edited by Caridad Méndez A. (translation by Hernandez A.), Dpr-Barcelona, 2015.

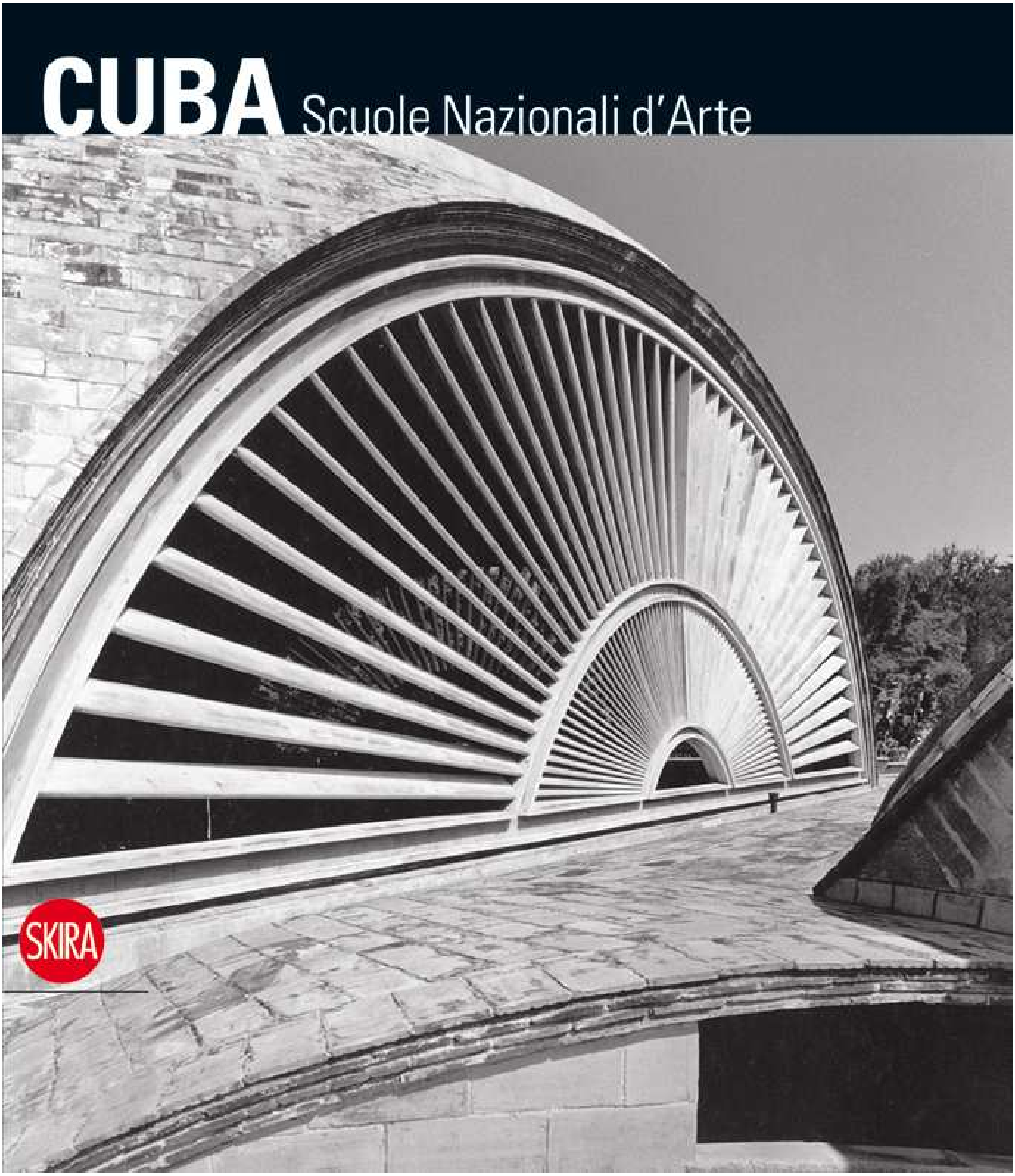

Figure 24 - Machetti, C.; Mengozzi, G.; Spitoni, L. (eds.); *Cuba, Scuole Nazionali d'Arte*, Milan: Editorial Skira, 2012.

Figure 25 - Paradiso, M. (ed.), Las Escuelas Nacionales de Arte de La Habana. Pasado, presente y futuro, Firenze: DIDA press - Dipartimento di Architettura, Università degli Studi di Firenze, 2016.

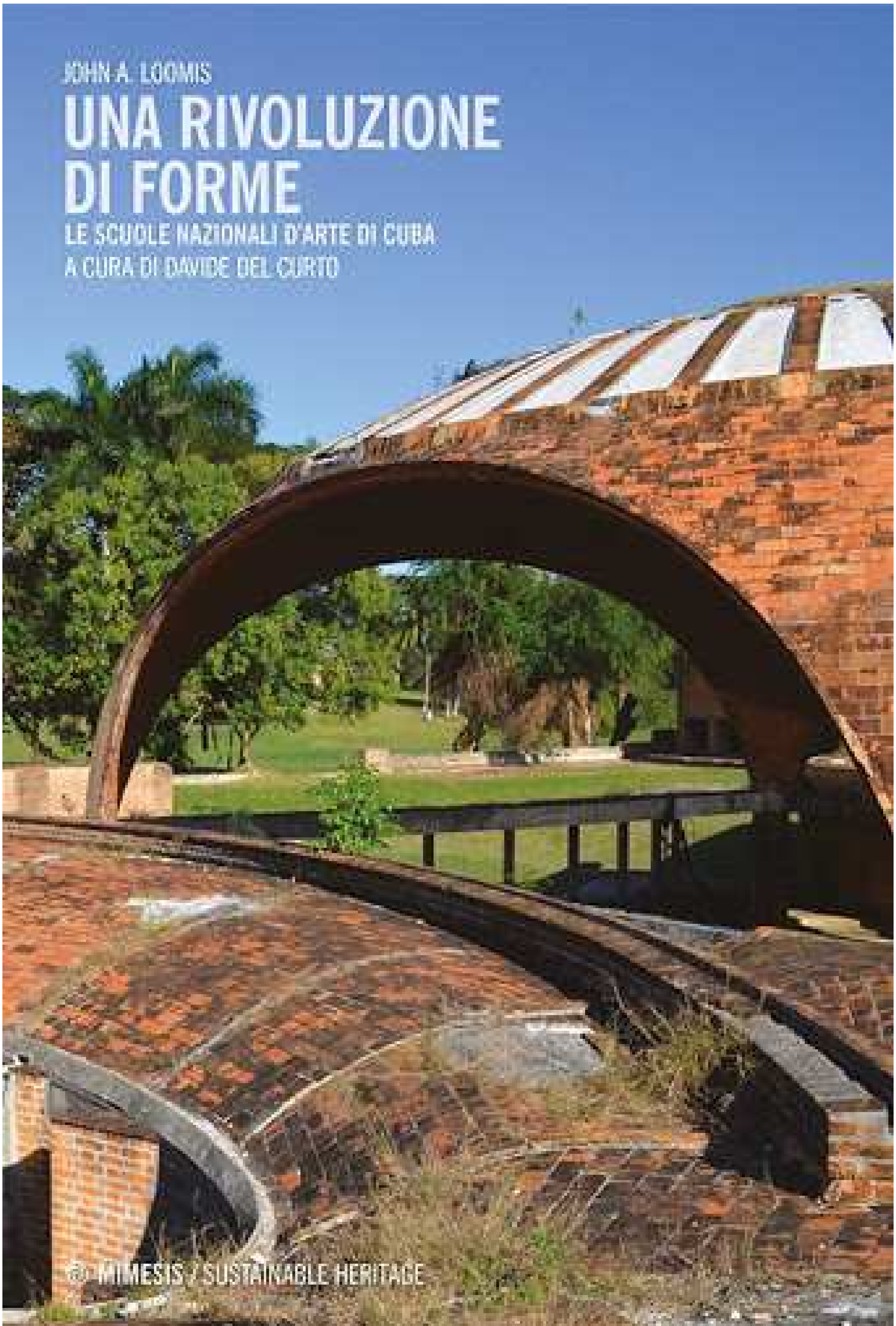

Figure 26 - D. Del Curto (eds.), Una rivoluzione di forme. Le Scuole Nazionali d'Arte di Cuba, Italian edition of *Revolution of Forms. Cuba's Forgotten Art Schools* by John Loomis, Mimesis, Milano 2019.

B. Thesis

Before 2018

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- Domenico Nuzzo, *Consolidamento e Restauro de la Escuela de Artes-Plasticas di Ricardo Porro all'Avana. Problematiche e criticità*. Supervisor: Michele Paradiso. Tesi di Laurea in Architettura, Università degli Studi di Firenze, 2008.
- Micól Simoni, *Analisi della scuola di Arte Drammatica di Roberto Gottardi all'Avana*. Supervisor: Michele Paradiso. Tesis de grado en Arquitectura, Universidad de los Estudios de Florencia, Firenze, 2008.
- Valeria Gadaleta, *Le Scuole Nazionali d'Arta di La Habana e il patrimonio moderno a cuba: ragioni di un percorso di valorizzazione*, Supervisors: Rocco Curto, Cristina Coscia, Monica Naretto, Garcia Lorenzo Universo; Tesi di Laurea Magistrale in Architettura per il Restauro e Valorizzazione del Patrimonio, Politecnico di Torino, 2013.
- Isabella Douglas, *Cuba's National School of Ballet: Redifining a Structural Icon*, Advisor: Branko Glisic, Contributor: Maria E. Garlock. Senior Thesis in Architecture and Engineering, Princeton University, 2017.

After 2018

- Riccardo Feder, *Havana's National Schools of Art. Preservation and reuse towards a conservation plan*, Supervisor: Davide Del Curto, Master's Thesis, A.Y. 2017/2018, Politecnico di Milano.
- Giuseppe Abbattista, *Il suono dell'architettura a L'Avana. Restauro e riuso della Scuola di Musica di Vittorio Garatti-ENA (Escuelas Nacionales de Arte)*, Supervisor: Federica Ottoni, Master's Thesis, A.Y. 2018/2019, Università degli Studi di Parma.
- Camille Heubner, *Refinement of Form: A New Analysis of Cuba's National School of Ballet*, Advisor: Branko Glisic, Bachelor's Thesis, A.Y. 2019/2020, Princeton University.
- Federico Taravella, *Teaching the Arts beyond Modern Architecture. Adaptive reuse of Havana's former Clubhouse as a contemporary School of Music*, Supervisor: Davide Del Curto, Master's Thesis, A.Y. 2019/2020, Politecnico di Milano.

C. Conferences

Before 2018

- *Symposium: Architecture and Revolution*

  March 8th, 1999 - MAK Center for Art and Architecture, Los Angeles (USA)

  "This symposium gathered together for the first time in 30 years the three architects of the Cuban National Art Schools (1961-1965) - Vittorio Garatti, Roberto Gottardi and Ricardo Porro - in conversation with John Loomis, author of Revolution of Forms, Cuba's Forgotten Art Schools (Princeton Architectural Press, 1999). Adolfo Nodal from the Department of Cultural Affair for the City of Los Angeles, gave an introduction, and Peter Noever, Director of the MAK Vienna, hosted the evening. Hansel Hernandez-Navarro, Researcher at the Getty Conservation Institute, acted as a translator" - (https://makcenter.org/programming/architecture-and-revolution/ - accessed on November 20th, 2020).
- *Una estrategia para La Habana*

  1999 - II Salón de Arquitectura Cubana, L'Avana

  Authors: Marco Franceschetto, Davide Guido, Gabriele Serafin

  Coordinators: Sergio Baroni, Guido Canella, Vincenzo Donato, Vittorio Garatti.
- *Book Presentation: Revolution of Forms: Cuba's forgotten Art Schools*

  June 28th, 2011 - Museo di Roma in Trastevere, Roma.

  Within the framework of the Exposition and Movie Festival "Cuba. Una storia anche italiana", John Loomis presented his book about Havana's National Art Schools in the presence of architect Vittorio Garatti.
- *Lecture: Escolas de arte do Terceiro Mundo, Havana - Cuba, 50 anos depois*

  May 15th, 2012 - Museu da Casa Brasileira (MCB), San Paolo (Brazil).

  Lecture about the history of the National Art Schools held by Vittorio Garatti.

  (http://www.mcb.org.br/pt-BR/programacao/dabates-e-palestras/palestra-escolas-de-arte-do-terceiro-mundo-havana-cuba-50-anos-depois)
- *Book presentation: Cuba, Scuole Nazionali d'Arte… Un sueño a mitad?*

  November 6th, 2012 - Casa dell'Architettura, Roma (Italy).

  November 20th, 2012 - Circolo ARCI Bellezza, Milano (Italy).

  Presentation of the book "Cuba. Scuole Nazionali d'Arte" by Claudio Machetti, Gianluca Mengozzi and Luca Spitoni. The event in Roma also featured a screening of "Un sueño a Mitad" documentary film by Francesco Apolloni.

  Vittorio Garatti, Roberto Gottardi and Ricardo Porro were also present and took part to the round table.

  (http://www.casadellarchitettura.it/mostre/cuba-scuole-nazionali-darte-un-sueno-a-mitad/)
- *Lecture: Art Schools for the third world, La Habana - Cuba 50 years later*

  November 4th, 2013 - Academy of Fine Arts, Vienna (Austria)

  Within the framework of the lecture series "Ten Informants, Another View on Ecology, Sustainability and Cultural Heritage", Vittorio Garatti held a lecture on the National Art Schools of Havana and their peculiar history.
- *Lecture: Cuba. Il racconto di un progetto*

  June 14th, 2016 - Politecnico di Milano, Milano (Italy).

  Lecture about the National Art Schools of Havana held by Vittorio Garatti and Jose Antonio Choy Lopez (president of Docomomo Cuba).

After 2018

- *La Habana 2018. Lista de Espera*

  March 16th, 2018 - Politecnico di Milano, Milano (Italy)

  The international conference dealt with the topics of Havana and its transformation, and with the topic of preservation of XX century architecture with particular reference to Havana's National Art Schools.

  Among the lecturers: Philippe Daverio, Vittorio Garatti, John A. Loomis (San Jose State University), Norma Barbacci (World Monument Fund), Jorge Fernández Torres (Director del Museo Nacional de Bellas Artes de Cuba), Alexis Seijo Garcia (Rector de la Universidad de las Artes - ISA), Maria Garlock and Branko Glišić (Princeton Univerity), Davide Del Curto (Politecnico di Milano)

Figure 27 - *Cuba. Il racconto di un progetto* (with Jose Antonio Choy Lopez) - Milano, Politecnico di Milano (14/06/2016).

Figure 28 - Program of the international conference *La Habana 2018. Lista de Espera.* - Politecnico di Milano (16/03/2018).

D. Expositions

Before 2018

- *Architecture and Revolution: Escuelas Nacionales de Arte en La Habana*
  March 10th - May 30th, 1999 - Schindler House (MAK Center), Los Angeles (USA)
  "An exhibition of photographs and drawings featuring the long-forgotten architectural landmarks of the Cuban revolution, the Cuban National Art Schools. Curated by the MAK Center and co-sponsored by the Smithsonian's Cooper-Hewitt, National Design Museum and Columbia University, symposia were presented in Los Angeles and New York City with exhibitions running concurrently at the MAK Center and Avery Hall. Featuring both historical and contemporary photographs and blueprints, the exhibition opened with a preview reception for the architects who designed the schools, Vittorio Garratti, Roberto Gottardi and Ricardo Porro".
  (https://makcenter.org/programming/architecture-and-revolution/)
- *Dal paesaggio del Country Club alle Scuole Nazionali d'Arte dell'Avana*
  October 18th - November 9th, 2008 - Festival dell'Architettura, Reggio Emilia (Italy).
  Coordinator: Davide Guido
  Curators: Patricia Baroni, Davide Guido, Claudio Pavesi
  (http://www.festivalarchitettura.it/fa4_2007/festival/IT/programma.asp)
- *Utopia Posible*
  2008 - 7th Gwangju Biennale
  2009 - 10th Havana Biennial
  April 30th - July 17th, 2010 - Graham Foundation, Chicago (USA)
  2012 - Freedom Tower Gallery, Miami (USA)
  "Artist Felipe Dulzaides' installation explores the history of the unfinished National Art Schools in Havana, which were commissioned by Fidel Castro and Che Guevara in 1961 and designed by Ricardo Porro, Vittorio Garatti, and Roberto Gottardi. Together, the schools were conceived as an art center that would symbolize and give form to the socialist ideals ushered in by the Cuban Revolution, but construction was abruptly halted in 1965, leaving many buildings incomplete and relegating them to obscurity.
  Now, the schools are widely acknowledged to be masterpieces of 20th-century architecture. In 1999, their future took a turn when the Cuban government decided to restore and complete the schools' unfinished buildings. The centerpiece of Utopía Posible focuses on Roberto Gottardi and his quest to finish the School of Dramatic Arts, a process that has taken more than 40 years and led him to develop four different schemes".
  (http://grahamfoundation.org/public_exhibitions/3699)
- *ERASMUS EFFECT. Architetti italiani all'estero.*
  December 6th, 2013 - April 6th, 2014 - MAXXI, Roma (Italy).
  The exhibition (curator Pippo Ciorra), retraced the steps of several italian architects who gained international notoriety working outside of Italy. Vittorio Garatti was included in the list, and a model of the National Art Schools was on display.
- *Antologic Exposition: Vittorio Garatti obras y protectos*
  March 7th - Abril 5th, 2014 - Centro di Arte Contemporanea Wifredo Lam, La Habana (Cuba).

The exhibition showcased the work done by the architect with particular reference to the Schools of Ballet and Music in Havana.

- *Prefigurazione di Futuro*

  June 10th - 14th, 2014 - Festival Architettura in Città, Politecnico di Torino, Torino (Italy).

  Curators: Christian Zecchin, Valeria Gadaleta, Andrea Vertua

  Photos and stories concerning the National Art Schools were displayed.

- *Latin America in Construction: Architecture 1955-1980*

  March 9th - July 19th, 2015 - MoMa, New York (USA)

  "In 1955 The Museum of Modern Art staged *Latin American Architecture since 1945*, a landmark survey of modern architecture in Latin America. On the 60th anniversary of that important show, the Museum returns to the region to offer a complex overview of the positions, debates, and architectural creativity from Mexico and Cuba to the Southern Cone between 1955 and the early 1980s.

  This period of self-questioning, exploration, and complex political shifts also saw the emergence of the notion of Latin America as a landscape of development, one in which all aspects of cultural life were colored in one way or another by this new attitude to what emerged as the "Third World." The 1955 exhibition featured the result of a single photographic campaign, but *Latin America in Construction: Architecture 1955-1980* brings together a wealth of original materials that have never before been brought together and, for the most part, are rarely exhibited even in their home countries.

  The exhibition features architectural drawings, architectural models, vintage photographs, and film clips alongside newly commissioned models and photographs. While the exhibition focuses on the period of 1955 to 1980 in most of the countries of Latin America, it is introduced by an ample prelude on the preceding three decades of architectural developments in the region, presentations of the development of several key university campuses in cities like Mexico City and Caracas, and a look at the development of the new Brazilian capital at Brasilia. Architects met these challenges with formal, urbanistic, and programmatic innovation, much of it relevant still to the challenges of our own period, in which Latin America is again providing exciting and challenging architecture and urban responses to the ongoing issues of modernization and development, though in vastly different economic and political contexts than those considered in this major historical reevaluation".

  Havana's National Art Schools were included in the exhibition. A model and several drawings and pictures were on display. (https://www.moma.org/calendar/exhibitions/1456)

- *PASSAGGI*

  December 13th, 2016 - January 4th, 2017 - Museo della Permanente, Milano (Italy).

  The exhibition, organized by Accademia delle Belle Arti di Brera and Bice Bugatti Club, showcased the work of three artists: Vincenzo Agnetti (1926-1981), Vittorio Garatti (1927) and Davide Nido (1966-2014).

  Through drawings and photographs Garatti's exposition ("L'auto generazione di un progetto: Cuba, scuole d'arte per il terzo mondo") recounted the history of Havana National Art Schools, with particular reference to the Schools of Ballet and Music (http://www.lapermanente.it/mostra-passaggi-inaugurazione-12-dicembre-ore-18-00/)

After 2018

- *Cuba. Arte e Rivoluzione - Las Escuelas Nacional De Arte, La Habana*

  February 28th - September 1st, 2019 - Triennale di Milano

  October 16th - November 7th, 2019 - Università degli Studi di Firenze

  November 15th - 29th, 2019 - Università degli Studi Roma Tre

  The 23rd Architecture Triennale, named *"Broken Nature: Design takes on human survival"*, focused on the concept of restorative design and study the state of our connection with the natural environment, exploring architecture and design objects and concepts at all scales and in all materials.

  The Cuban pavilion at the Triennale was entirely dedicated to the National Schools of Art of Havana and to their controversial relationship with nature. An entire wall of the pavilion was dedicated to the K.I.M./Getty project. After the Triennale, the exhibition was also displayed in Florence and in Rome.

  Curator: Jorge Fernández Torres

  Co-curators: Umberto Zanetti, Christian Zecchin

  (https://triennale.org/eventi/in-mostra-al-padiglione-cuba-il-progetto-delle-scuole)

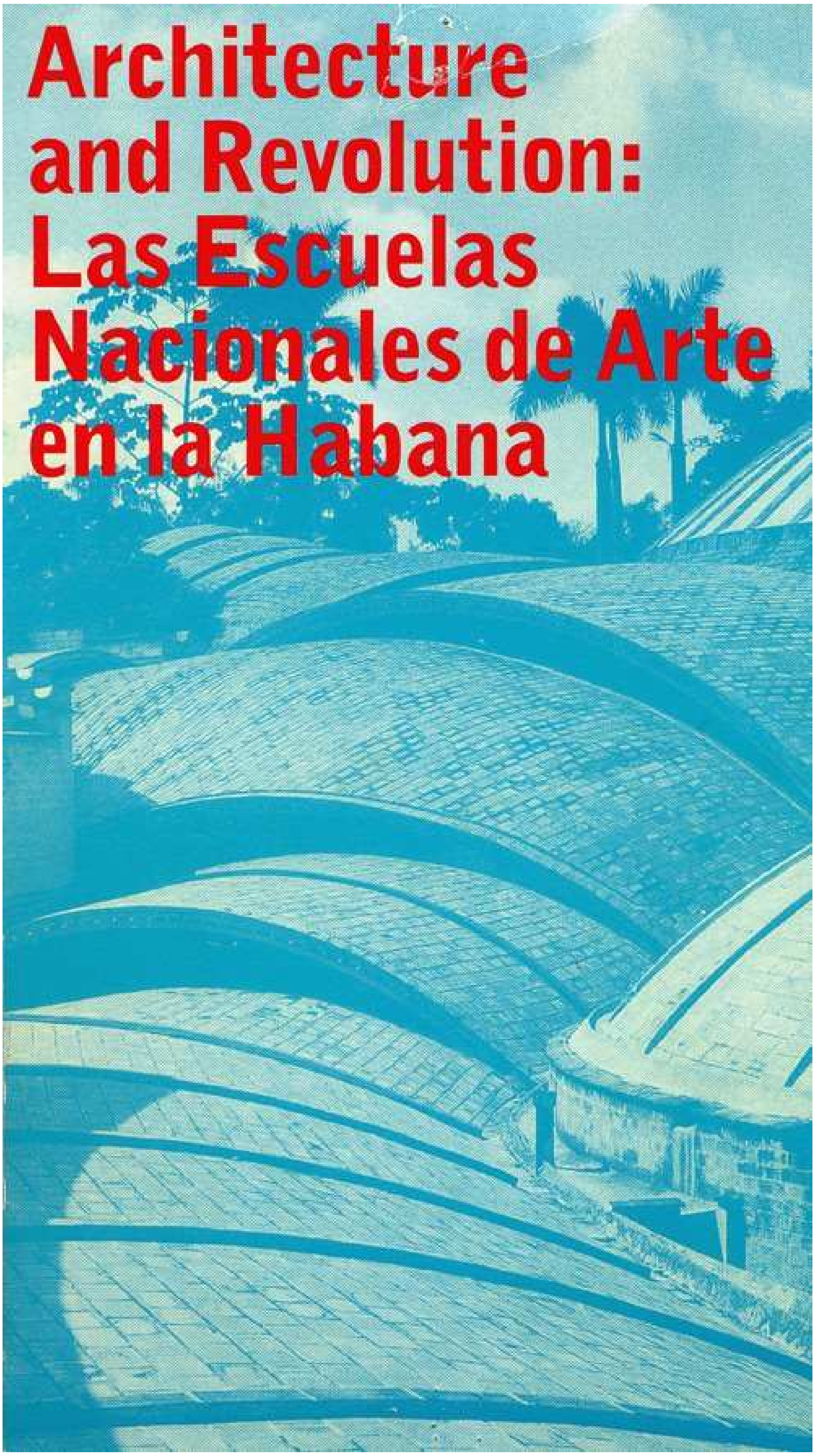


Figure 29 - “Architecture and Revolution: Escuelas Nacionales de Arte en La Habana”. Leaflet of the 1999 exhibition.

Figure 30 - "Architecture and Revolution: Escuelas Nacionales de Arte en La Habana". View of the installation (photos by Joshua White, retrieved from https://makcenter.org/programming/architecture-and-revolution/).

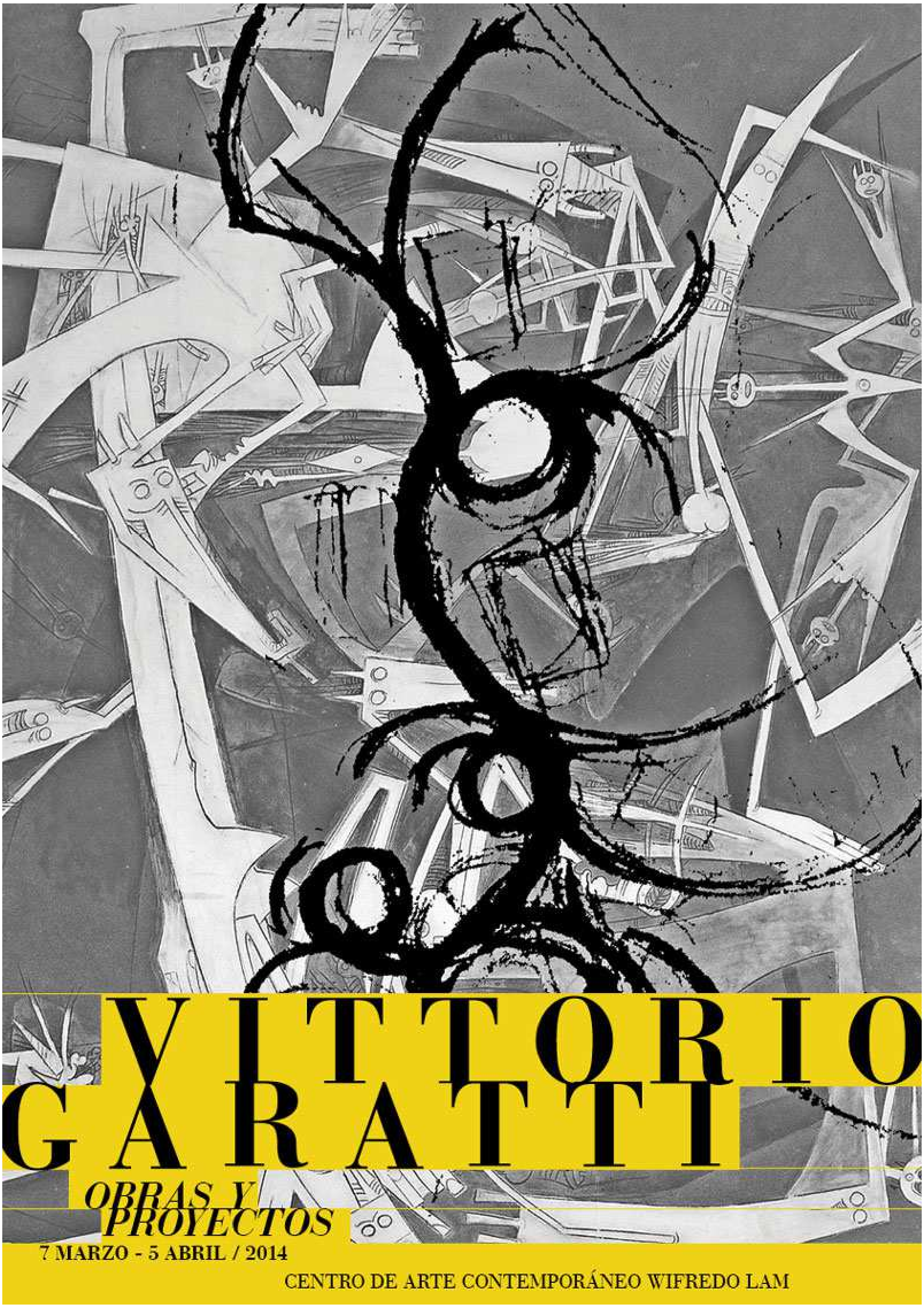


Figure 31 - *Vittorio Garatti obras y proyectos*, La Habana, Centro de Arte Contemporaneo Wifredo Lam (2014).

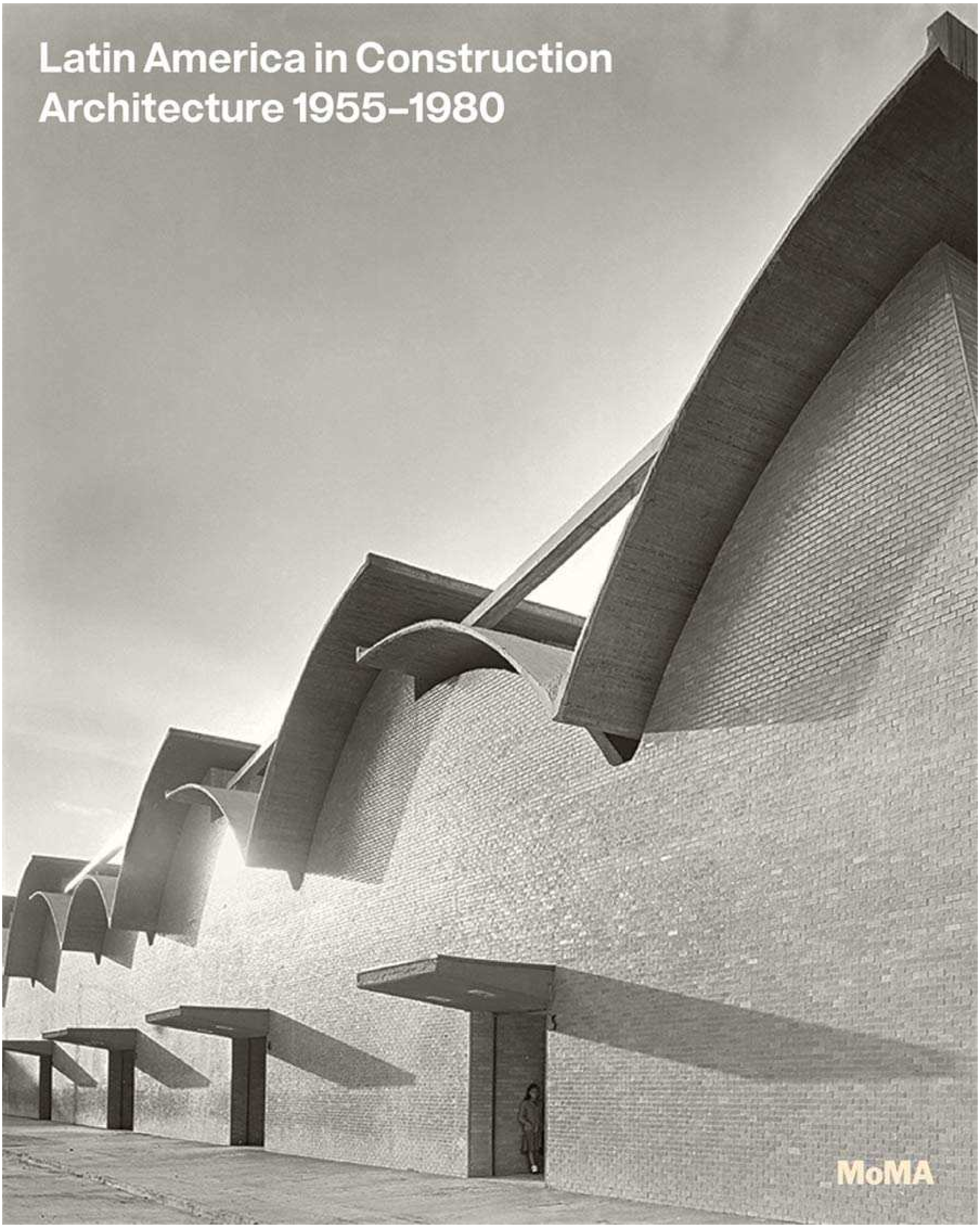


Figure 32 - Havana's National Art Schools at the *Latin America in Construction: Architecture 1955-1980* exhibition (MoMa,New York).

Figure 33 - Invitation leaflet to the Cuba Pavilion at the XXII Triennale di Milano.

Figure 34 - View of the Cuba Pavilion at the XXII Triennale di Milano.

Figure 35 - View of the installation in Florence.

E. Videos

- *Interview to Ricardo Porro*

  May 2005 - Interview (extract) conducted by Davide Guido

  The architect talks about the School of Plastic Arts and its concept.

  http://www.festivalarchitettura.it/fa4_2007/laboratorio/laboratorioVideo.asp?sLang=IT&nLab=lab_2b&ID=1
- *National Art Schools*

  August 2009 - Produced and directed by Alysa Nahmias and Ben Murray for the World Monuments Watch

  The three architects briefly talk about the National Art Schools and the revolutionary ideas which generated them.

  https://www.wmf.org/content/national-art-schools
- *Unfinished Spaces*

  2011 - Documentary film directed by Alysa Nahmias and Benjamin Murray

  The 86 minutes movie retraces the story of the National Art Schools from their origin to their current abandonment. The World Monuments Fund took part to the interviews for the film as an educational and advocacy effort to bring attention to the National Art Schools. It also provided support to the final production stages of the film.

  http://www.unfinishedspaces.com/about.html
- *Un sueño a mitad*

  2011 - Documentary film directed by Francesco Apolloni

  The documentary tells the story of Vittorio Garatti, Roberto Gottardi and Ricardo Porro as they were appointed by Fidel Castro to build the revolutionary complex of the National Schools of Art.

  http://www.rai.it/dl/RaiTV/programmi/media/ContentItem-90d9390f-0134-41ef-b098-f5082a1fd227.html
- *Utopia mas grande*

  March 18th, 2012 - Il Capitale di Philippe Daverio (RAI)

  Philippe Daverio encounters Vittorio Garatti to talk about the tormented history of the National Art Schools.

  http://www.rai.it/dl/RaiTV/programmi/media/ContentItem-5f6e4ef2-b015-4d84-a24f-fd186e5b6665.html
- *Next time it rains*

  1999-2010 - Video directed by Felipe Dulzaides

  "The Ballet school was 90 percent complete in 1965 but never occupied and left to be overgrown by jungle. The jungle has been cleaned out but the school remains unrepaired and unused. This video features Vittorio Garatti discussing different aspects of it design, his inspirations and views on life, and architecture in general. Different actions performed by a dancer; a child and Dulzaides activate the unused architecture restoring its function. A turning point of the piece is when a group of young students arrive at the site. The project started in 1999 when Dulzaides visited the site and cleaned one of the water conducts activated ten years later".
- *Broken Glass. A conversation with Ricardo Porro*

  2012 - Video directed by Felipe Dulzaides

  The video features Ricardo Porro's School of Modern Dance, departing from its design concept: a broken glass as the metaphor for a radical social process with utopian ideals.

  http://grahamfoundation.org/grantees/4820-broken-glass-a-conversation-with-ricardo-porro
- *El ISA/L'Institut superieur des arts de La Havane Cuba*

October 7th, 2013 - Medialibrecine Documentaires
https://www.youtube.com/watch?v=JpPqbP-RdY4&ab

- *Revolution of Forms: Cuba's Forgotten Art Schools*
  2013 - Van Alen Institute
- *Cuba's National Arts School*
  2014 - Authentic Cuba Travel
  Video showing Ricardo Porro's Schools of Plastic Arts and Modern Dance and their students.
  https://www.youtube.com/watch?v=KUPS6C8bxpo
- *Will Carlos Acosta get to the Pointe?*
  March 8th, 2014 - Interview with Carlos Acosta, BBC World Service
  "In, *Will Carlos Acosta Get to the Pointe*, Acosta travels back to his native Cuba with producer, Cecile Wright, to report on his bid to save the school [*ed.* Garatti's School of Ballet], and in exploring the importance of music and dance to Cuba's national identity, he examines what the fate of the ballet school symbolises about the country's artistic legacy".
  http://www.bbc.co.uk/programmes/p01t39bc
- *Viva la Arquitectura*: *Episode 166*
  May 26th, 2015 - 99% Invisible Website
  "Producer Avery Trufelman spoke with John Loomis, author of *Revolution of Forms*, Alysa Nahmias, co-producer of the documentary *Unfinished Spaces*, and Felipe Dulzaides, who has does a series of performances and works based around the schools. Archival tape of Ricardo Porro and Roberto Segre courtesy of Alysa Nahmias and Ben Murray, who interviewed him for their film *Unfinished Spaces*".
  https://99percentinvisible.org/episode/viva-la-arquitectura/
- *Cuba's National Art Schools: Reassessing Utopia*
  July 2015 - World Monuments Fund
  Cuban architect and architectural historian Eduardo Luis Rodríguez discussed the complexities of recent restoration and rebuilding efforts, and reflected on the schools' future in light of Cuba's evolving circumstances.
  https://www.wmf.org/video/cuba%E2%80%99s-national-art-schools-reassessing-utopia
- *Cuba's National Art Schools*
  2016 - CNN Style
  The video proposes clips taken from Alysa Nahmias and Benjamin Murray's documentary *Unfinished Spaces.*
  http://edition.cnn.com/videos/arts/2016/06/02/cuba-abandoned-art-school-cnn-orig.cnn
- *La Escuela de Musica*
  October 4th, 2016 - Video by Vittorio Garatti published by «Arquitectura Cuba»
  The video displays the current conditions of Vittorio Garatti's School of Music as well as the completion project designed by Vittorio Garatti and his co-workers starting from 2000.
  http://www.arquitecturacuba.com/2016/10/la-escuela-de-musica-vittorio-garatti.html

Chronology

Taken from D. Del Curto (ed.), *Una rivoluzione di forme. Le Scuole Nazionali d'Arte di Cuba*, Italian edition of "Revolution of Forms. Cuba's Forgotten Art Schools" by John Loomis, Mimesis, Milano 2019.

1925	3 novembre	Nasce **Ricardo Porro Hidalgo.**
		Viene fondato il Partido Socialista Popular (PSP, Partito Comunista).
1926	13 agosto	Nasce Fidel Castro Ruz.
1927	30 gennaio	Nasce **Roberto Gottardi.**
	6 aprile	Nasce **Vittorio Garatti.**
1928	14 giugno	Nasce Ernesto "Che" Guevara.
1936		Joaquín Weiss: *Arquitectura cubana colonial.*
		Oscar Niemeyer, Lucio Costa: Ministero dell'Educazione, Rio de Janeiro.
1939		Eugenio Batista: Casa Falla Bonet, L'Avana.
1940		Fulgencio Batista è eletto presidente col sostegno del PSP. Resta in carica fino al 1944.
		La nuova costituzione proibisce la segregazione razziale.
1943		ATEC: *Trinidad... lo que fue, es y será*, mostra.
1944		Eugenio Batista: Casa Batista, L'Avana.
1945		Walter Gropius conferenziere a L'Avana.
1947		Luis Barragán: Casa Barragán, Tacubaya.
		Colin Rowe: "Mathematics of the Ideal Villa".
		Francisco Prat Puig, *El prebarroco en Cuba – una escuela criolla de arquitectura morisca*
		"Quema de los Viñola", Frank Martínez, **Ricardo Porro**, Nicolás Quintana, Università de L'Avana.
1949		Frank Lloyd Wright: Laboratory Tower, Johnson Wax Co., Racine.
		Philip Johnson: Johnson House, New Canaan.
		Rudolf Wittkower: *Architectural Principles in the Age of Humanism.*
		Silverio Bosch, Mario Romañach: Casa Noval, L'Avana.
		Ricardo Porro si laurea in architettura all'Università de L'Avana.
		Ricardo Porro: Casa Armenteros, L'Avana.
1950		**Ricardo Porro** si trasferisce a Parigi per gli studi specialistici.
1951		SOM (Gordon Bunshaft): Lever House, New York.
		J.M. Coderich: ISM Apartment Block, Barcelona.
		Eugenio Batista, Alberto Beale: *Los bateyes de los centrales azucareros.*
		Harwell Hamilton Harris è nominato Preside della facoltà di ar-

		chitettura dell'Università del Texas. Bernard Hoesli, Colin Rowe, John Hejduk, Robert Slutzky *et al.* iniziano la riforma della pedagogia di design.
		CIAM ospita a Venezia una serie di lezioni tenute da Ernesto Nathan Rogers, Giulio Carlo Argan, Le Corbusier, Carlo Scarpa, Bruno Zevi ed altri, che vengono frequentate da **Ricardo Porro**.
1952		Alvar Aalto: Town Hall, Säynätsolo.
		Le Corbusier: Unité d'Habitation, Marseilles.
		Alfonso Eduardo Reidy: Pedregulho housing, Rio de Janeiro.
		Max Borges Jr.: Sala de los Arcos de Cristal, Club Tropicana, L'Avana.
	10 marzo	Fulgencio Batista al potere con un colpo di stato, impone sette anni di dittatura.
		Roberto Gottardi si laurea presso l'Istituto Superiore di Architettura di Venezia.
		Si costituisce il gruppo di Arquitectos Unidos.
		Ricardo Porro torna a L'Avana.
1953		Gabetti e Isola: Bottega d'Erasmo, Torino.
		Harrison e Abramowitz: US Embassy, L'Avana.
		Oscar Niemeyer: Casa Niemeyer, Rio de Janeiro.
		Silverio Bosch, Mario Romañach: Casa Aristigueta, L'Avana.
		Ricardo Porro: Casa García, L'Avana.
		Ricardo Porro, Nicolás Quintana et al: *Las villas pesqueras.*
		Bruno Zevi: *La Poetica dell'architettura neoplastica.*
	marzo	Muore Joseph Stalin.
	luglio	CIAM 9, Aix-en-Provence, Alison e Peter Smithson, Aldo van Eyck, Jacob Bakema e altri formano il nucleo del Team 10.
	26 luglio	Attacco alla caserma Moncada a Santiago di Cuba. Fidel Castro ed altri sopravvissuti sono fatti prigionieri. "La storia mi assolverà".
1954		Le Corbusier: Chapel di Notre-Dame-du-Haut, Ronchamp.
		Mario Ridolfi: INA-Casa, Roma.
		Bodiansky-Candilis-Woods: ATBAT housing, Algieri.
		Aquiles Capablanca: Tribunal de Cuentas, L'Avana.
		Ricardo Porro: Casa Villegas, L'Avana.
		Vittorio Garatti: "Mostra di strumenti musicali", Triennale di Milano.
		Max Bill *et al.*, "Report on Brazil", *Architectural Review*.
		Harwell Hamilton Harris: "Regionalism and Nationalism" (discorso).
		Nikita Khrushchev, "Eliminare le carenze nel design, migliorare il lavoro degli architetti" (discorso).
	gennaio	La mostra di protesta, l'*Anti-Bienal* si inaugura a L'Avana.
	giugno	CIA promuove il golpe di stato del governo guatemalteco.
	novembre	Batista "eletto" per un altro quadriennio.

		Ricardo Porro incontra Luis Barragán in Messico.
1955		Le Corbusier: Maison Sarabhai, Ahmedabad.
		Josep Lluís Sert e Paul Lester Wiener consulenti per il piano regolatore a L'Avana.
		Manuel Gutiérrez: Casa Verdera, L'Avana.
		Moenck y Quintana: Cabañas, Hotel Kawama, Varadero.
		Harwell Hamilton Harris costretto a dimettersi dall'Università del Texas. Hoesli, Rowe, Hejduk, Slutzky *et al.* sono espulsi di conseguenza dalla facoltà.
		Ernesto Nathan Rogers: "Le preesistenze ambientali e i temi pratici contemporanei", *Casabella-Continuità*, (Feb/Mar).
		Henry-Russell Hitchcock, *Latin American Architecture Since 1945*, MoMA, New York.
	aprile	Amnistia concessa da Batista per i prigionieri sopravvissuti di Moncada. Liberati ed esiliati in Messico, dove fondano il Movimento del 26 Luglio ed iniziano a formarsi come guerriglieri.
		Costituzione del Directorio Revolucionario condotto dallo studente di architettura José Antonio Echeverría.
		Imposto il divieto di riunione per Arquitectos Unidos ad opera del BRAC batista.
1956		Le Corbusier: Monastero de La Tourette.
		Hans Scharoun, Scuola femminile, Lunen.
		Eero Saarinen, Kresge Chapel, MIT.
		Fruto Vivas: Club Táchira, Caracas.
		Richard Neutra: Casa Schulthess, L'Avana.
		Philip Johnson: Hotel e Casinò Monaco (non costruito), L'Avana.
		Moenck y Quintana: Casa Ramírez Corria, L'Avana.
	30 novembre	Insurrezione a Santiago organizzata da Frank País e Arturo Duque de Estrada.
	2 dicembre	Sbarco del *Granma*. I ribelli sopravvissuti cercano rifugio in Sierra Maestra.
1957		Luis Barragán (Mathias Goeritz): Torri per la Ciudad Satélite, Città del Messico.
		Mario Romañach: Casa Álvarez, L'Avana.
		Emilio del Junco: Casa del Junco, L'Avana.
		Ricardo Porro: Casa Ennis, L'Avana.
		Vittorio Garatti si laurea al Politecnico di Milano.
		Vittorio Garatti si trasferisce in Venezuela.
		Ricardo Porro: "El sentido de la tradición" *Noticias de Arte*.
		Muore Diego Rivera.
		Prima vittoria della campagna di guerriglia in Sierra Maestra.
	13 marzo	Attacco fallito al Palazzo Presidenziale condotto dal Directorio Revolucionario, durante il quale viene ucciso José Antonio Echeverría, giovane architetto e leader.
	30 luglio	Frank País viene assassinato a Santiago.
	settembre	Soppressa l'insurrezione della Marina di Cienfuegos dal governo.

	novembre	**Roberto Gottardi** parte per il Venezuela.
1958		Belgiojoso, Perressutti e Rogers (BBPR): Torre Velasca, Milano.
		Walter Gropius (TAC) e Pietro Belluschi: Pan American building, New York.
		Ludwig Mies Van der Rohe: Seagram Building, New York.
		Fernando Salinas: Casa Higinio Miguel, L'Avana.
		Welton Beckett: Havana Hilton, L'Avana.
	9 aprile	Lo sciopero generale fallisce.
		Ricardo Porro parte per il Venezuela.
		Offensiva del governo contro la guerriglia in Oriente.
	agosto	Sotto gli ordini dei comandanti Fidel Castro, Che Guevara e Camilo Cienfuegos i ribelli avanzano nel paese.
	28 dicembre	Cade Santa Clara, una vittoria decisiva per Che Guevara.
	31 dicembre	Fulgencio Batista si trasferisce a Miami.
1959		Louis Kahn: Jewish Community Center Bathhouse, Trenton.
		Frank Lloyd Wright: Guggenheim Museum, New York.
		Paolo Soleri: Earth House, Scottsdale.
		Ralph Erskine: Kiruna Center, Norvegia
		Otto Glaus: Aeroporto, Lugano.
		Oscar Niemeyer: Cappella e Palazzo dell'Alba, Brasilia.
	1 gennaio	Si dichiara la vittoria della Rivoluzione Cubana.
	8 gennaio	Fidel Castro arriva a L'Avana.
	1 febbraio	Fidel Castro diventa Primo Ministro e nomina presidente Manuel Urrutia.
	marzo	Esce il primo numero di *Lunes de la Revolución*, rivista culturale, punta di diamante dell'avanguardia artistica.
	aprile	Reyner Banham pubblica "Neoliberty – The Italian Retreat from Modern Architecture", *Architectural Review*, dove attacca Ernesto Nathan Rogers.
		Sequestro dei casinò e arresto del boss mafioso Santo Trafficante Jr. a L'Avana.
	giugno	Ernesto Nathan Rogers risponde alla critica di Banham in "L'evoluzione dell'architettura: Risposta al custode dei frigidaires", *Casabella-Continuitá*.
	giugno	Walter Gropius accetta di scrivere un articolo per *Integración* su invito di Hugo Consuegra, Direttore del Dipartimento di Belle Arti del Ministero dei Lavori Pubblici.
	maggio	Prima legge sulla riforma agraria che limita la proprietà terriera e dà inizio all'esproprio. Prima legge sulla riforma urbanistica che limita i diritti di proprietà.
	18 luglio	Manuel Urrutia, nominato Presidente di Cuba, è obbligato a dare le dimissioni in favore di Osvaldo Dorticós.
	ottobre	Aleksandr Alekseev e altri alti funzionari del KGB si recano in segreto a L'Avana per stabilire contatti con i membri della leadership rivoluzionaria.

	21 ottobre	Huber Matos, capo del governo militare di Camagüey è accusato di tradimento e condannato a 20 anni di prigione.
	28 ottobre	Scompare misteriosamente l'aereo che trasporta Camilo Cienfuegos.
1960		Aldo Van Eyck: Children's Home, Amsterdam. Carlo Scarpa: Casa Veritti, Udine. Jordi Bonet: Iglesia di San Medi, Barcelona. SOM (Natalie de Blois): Sede legale della Pepsi-Cola Co., New York. Candilis, Dony, Josic & Woods: abitazioni, Algeri. Eladio Dieste: Iglesias de Atlántida, Uruguay. Carlos Raúl Villanueva: Ciudad Universitaria (iniziata nel 1944), Caracas.
	gennaio	Sequestro da parte del governo delle piantagioni di canna da zucchero e dei grandi allevamenti di bestiame, di cui molti di proprietà degli Stati Uniti. Nicolás Quintana parte per Caracas e più tardi per Miami.
	13 febbraio	Visita di Anastas Mikoyan, vice-presidente del Consiglio dei Ministri sovietico e firmatario del primo accordo commerciale. Aereo non identificato (CIA) incendia i campi di canna da zucchero. Seguono altri atti di sabotaggio. Il governo chiude i periodici *Diario de la Marina*, *Prensa Libre* e *Carteles*.
	marzo	Visita a Cuba di Jean-Paul Sartre e Simone de Beauvoir.
	giugno	Le raffinerie della Texaco, Esso e British Shell sono nazionalizzate.
	3 luglio	Il Congresso degli Stati Uniti autorizza Eisenhower a ridurre le quote sullo zucchero. Fidel Castro risponde con un'azione legale che abilita la nazionalizzazione della proprietà statunitense.
	23 luglio	Primo accordo commerciale con la Repubblica Popolare Cinese.
	agosto	**Ricardo Porro** torna a Cuba dal Venezuela per lavorare al progetto di pianificazione urbanistica. Arrivo di sicari da Miami inviati dalla CIA e dalla mafia per uccidere i dirigenti cubani. Il KGB cambia il nome in codice di Cuba da *Yountsie* (Giovanotti) to *Avanpost* (Avamposto). Ancora nazionalizzazioni di grandi imprese commerciali di proprietà statunitense.
	settembre	Fidel Castro e la delegazione cubana in visita all'ONU ospiti all'Hotel Theresa ad Harlem, ricevono Khrushchev, Nasser, Nehru, Malcolm X e altri.
	ottobre	Di ritorno da Cuba, Sartre e de Beauvoir dichiarano che la luna di miele rivoluzionaria è finita. Silverio Bosch parte per gli Stati Uniti.
	14 ottobre	La seconda Legge di Riforma Urbana nazionalizza tutte le locazioni immobiliari, i proprietari possono avere solo una casa.

	19 ottobre	L'embargo economico degli Stati Uniti proibisce ogni esportazione eccetto alimenti e medicinali.
	25 ottobre	Più di 166 attività commerciali e immobili sono nazionalizzati.
	dicembre	**Vittorio Garatti** e **Roberto Gottardi** arrivano a L'Avana.
1961		Le Corbusier: Carpenter Center, Harvard University.
		Luis Barragán: Las Arboledas (iniziata nel 1957), Città del Messico.
		Walter Betancourt: Centro Culturale, Velasco (terminato nel 1991).
	1 gennaio	Inizia la Campagna Nazionale di Alfabetizzazione.
		Fidel Castro richiede un intervento militare e ordina agli Stati Uniti di ridurre a 11 membri il personale dell'ambasciata.
	3 gennaio	Gli Stati Uniti chiudono tutti i rapporti diplomatici con Cuba.
	gennaio	Fidel Castro e Che Guevara giocano a golf al Country Club e decidono di creare una scuola internazionale per le arti.
		Sotto "il comando" di **Ricardo Porro** comincia a breve il progetto delle **Scuole Nazionali d'Arte** e **Porro** invita poco dopo **Garatti** e **Gottardi** a collaborare.
	febbraio	Sigari avvelenati e altre iniziative bizzarre da parte della CIA per assassinare i dirigenti cubani.
		Humberto Alonso parte per Miami.
	16 aprile	Dopo attacchi aerei agli aeroporti, Castro dichiara il carattere socialista della Rivoluzione Cubana.
	17-20 aprile	Vittoria sui controrivoluzionari appoggiati dagli Stati Uniti a Playa Girón e Playa Larga nella Bahía de Cochinos (Baia dei Porci). John F. Kennedy si assume la responsabilità del disastro compiuto dagli Stati Uniti.
		Dopo la vittoria si intensificano i lavori per il progetto delle **Scuole Nazionali d'Arte**.
	giugno	Le "Palabras a los intelectuales" di Castro, definiscono i principi culturali "tutto con la Rivoluzione; niente contro la Rivoluzione".
		Viene censurato il film *PM* di Sabá Cabrera Infante e Orlando Jiménez e viene chiusa la rivista culturale *Lunes de Revolution*.
		Castro loda i progetti di **Porro**, **Gottardi** e **Garatti** come "la più bella accademia d'arte del mondo".
	agosto	Al vertice OSA in Uruguay, a Punta del Este, viene presentata l'Alleanza per il Progresso.
	settembre	Iniziano i lavori di costruzione delle **Scuole Nazionali d'Arte**. Il progetto prosegue mentre gli architetti spostano il loro centro operativo al Circolo del ex Country Club.
	ottobre	Crisi sino-sovietica. I libri di Mao sono ritirati dalle librerie cubane.
	novembre	Kennedy stanzia 50 milioni di dollari per l'operazione "Mangusta" della CIA volta a destabilizzare e rovesciare il governo cubano con azioni di spionaggio, sabotaggio, attacchi militari e attentati.
		Il libro sulla razza di Walterio Carbonell "*Crítica: cómo surgió la cultura nacional*", viene bandito e ritirato dalla circolazione dopo tre mesi dalla pubblicazione.

		Prima persecuzione ufficiale degli omosessuali cubani che vengono arrestati e inviati nei campi di rieducazione.
	2 dicembre	Fidel Castro si dichiara Marxista-Leninista.
	22 dicembre	Termina ufficialmente con grande successo la Campagna Nazionale di Alfabetizzazione.
1962		Eero Saarinen: Samuel F. B. Morse e Ezra Stiles College, Yale University.
		Eladio Dieste: Chiesa di Atlantide, Montevideo.
		Félix Candela: Cappella, Cuernavaca.
		Jane Jacobs: *The Death and Life of Great American Cities*.
		Khrushchev denuncia l'arte moderna come deviante.
		Nel discorso commiato all'università, prima del suo pensionamento, Joaquín Weiss critica la crescente burocratizzazione e tecnocratizzazione dell'architettura a Cuba.
	gennaio	Cuba espulsa dall'OSA
	3 febbraio	Kennedy vieta tutte le esportazioni a Cuba in un embargo con il conseguente aumento di restrizioni.
	marzo	Epurazione dei comunisti della vecchia guardia. Aníbal Escalante viene esiliato a Praga per due anni. Si fonda il Partido Unificado de la Revolución Socialista (PURS).
	30 maggio	Cuba accetta l'offerta di missili nucleari dall'Unione Sovietica.
	ottobre	Crisi di Ottobre. Blocco navale statunitense nell'isola. Unione Sovietica accorda il ritiro dei missili da Cuba che provoca tensioni tra i due paesi.
	novembre	L'opera di Wifredo Lam accusata di essere controrivoluzionaria. **Ricardo Porro** e Carlos Franqui organizzano una mostra per difendere Lam come artista marxista e rivoluzionario.
1963		Hans Scharoun: Sala da concerti, Berlino.
		Paul Rudolph: Arts and Architecture Building, Yale University.
		Charles Moore: Moore House, Orinda, California.
		Vittorio Garatti, José Mosquera: Scuola Tecnica-Agraria André Voisin, Güines.
		Le opere di Hugo Consuegra, Guido Llinás e Tomás Oliva sono accusate di avere contenuti "controrivoluzionari"
	8 luglio	Ulteriori restrizioni dell'embargo statunitense.
		Guido Llinás lascia Cuba per Parigi
	settembre	Si tiene a L'Avana il VII Congresso Internazionale de l'UIA.
	4 ottobre	La Seconda Legge di Riforma Agraria estende ulteriormente la nazionalizzazione dei terreni agricoli.
		Colegio de Arquitectos e la pratica professionale privata sono ufficialmente aboliti. **Ricardo Porro** si dimette dalla facoltà di architettura.
		Donata dall'Unione Sovietica la prima fabbrica (Gran Panel) per i pannelli prefabbricati.
	22 novembre	Assassinio di John F. Kennedy.

1964		Carlo Scarpa: Museo di Castelvecchio, Verona (iniziato nel 1956).
		Giovanni Michelucci: Chiesa dell'Autostrada, Firenze.
		Bernard Rudofsky, *Architecture Without Architects*.
		Humberto Alonso: CUJAE, Havana. (costruzione terminata da altri)
		Aumentano gli attacchi della CIA contro Cuba, con sequestri, sabotaggi, e incursioni armate contro il commercio marittimo.
		Colpo di stato militare in Brasile.
	marzo	Edith García Buchaca viene destituita dal ruolo politico e culturale e messa agli arresti domiciliari per il resto della sua vita.
	agosto	L'"incidente" del Golfo del Tonchino fornisce il pretesto per l'inasprimento della guerra in Vietnam.
	settembre	Ulteriori sanzioni dell'OSA contro Cuba.
	ottobre	Khrushchev viene destituito da Primo Ministro.
	25 ottobre	Fidel Castro, "Discorso di chiusura al primo congresso dei costruttori cubani", nell'edilizia si richiedono misure standardizzate e industrializzazione.
	novembre	Richard M. Nixon eletto presidente.
	dicembre	Fondazione del politecnico Ciudad Universitaria José Antonio Echeverría (CUJAE).
		Mostra d'arte di Hugo Consuegra alla Galeria Habana, con opere con titoli provocatori come *Ángel exterminador*.
1965		Louis Kahn: Salk Institute, La Jolla.
		Aldo Rossi: Monumento ai Partigiani, Segrate.
		Freidrich Kiesler, Santuario del Libro, Gerusalemme.
		Fruto Vivas si trasferisce a Cuba come architetto volontario.
	marzo	Gli studenti della Facoltà di Architettura si organizzano in gruppi volontari di lavoro nei campi a Matanzas.
		Al ritorno a L'Avana, la Facoltà di Architettura viene posta sotto l'autorità del MICONS con espulsioni e riorganizzazioni.
	aprile	Visita di Allen Ginsberg a Cuba e sua espulsione.
	25 aprile	Che Guevara parte per il Congo.
	28 aprile	20 mila truppe americane occupano Santo Domingo.
	26 luglio	Le **Scuole Nazionali d'Arte** sono ufficialmente aperte e i lavori ufficialmente sospesi.
	3 ottobre	Si costituisce formalmente il Partido Comunista de Cuba (PCC), che sostituisce il PURS che aveva a sua volta assimilato il precedente Movimento del 26 Luglio, il Direttorio Rivoluzionario e il PSP.
	ottobre	Guillermo Cabrera Infante lascia Cuba per l'Europa, in esilio diplomatico.
		Hugo Consuegra difende pubblicamente le **Scuole Nazionali d'Arte** e i loro architetti in *Arquitectura Cuba*.
1966		Jørn Utzon: Opera House, Sydney.
		Peter Cook and Archigram: Plug-in City.
		Gian Carlo De Carlo: Casa dello Studente, Urbino.

	novembre	Che Guevara arriva in Bolivia nel tentativo di fomentare la guerriglia popolare.
	luglio	**Ricardo Porro** si trasferisce a Parigi con sua moglie e suo figlio dove esercita la libera professione.
		Hugo Consuegra rassegna le dimissioni dalla facoltà di architettura e lascia Cuba per la Spagna.
1967		Mario Coyula Cowley e Emilio Escobar Loret de Mola: Parco dei Martiri, L'Avana.
		Vittorio Garatti, Sergio Baroni e Hugo D'Acosta: Cuba Pavilion, Expo '67 Montreal.
		Salvador de Alba Martín: Mercato di San Juan de los Lagos, Jalisco.
		I campi di rieducazione per gli omosessuali vengono chiusi dopo una protesta da parte degli intellettuali cubani.
		Muore per attacco cardiaco Joaquín Rallo, a Jagüey Grande.
	8 ottobre	Che Guevara viene ucciso in Bolivia.
	dicembre	Aníbal Escalante ed altri trentasei della vecchia guardia comunista vengono accusati di promuovere una divisione settaria. Escalante prende una sentenza di quindici anni di prigione.
1968		Kevin Roche e John Dinkeloo: Ford Foundation, New York.
		Ralph Erskine: Byker Wall, Newcastle-upon-Tyne (completata nel 1975).
		Roberto Gottardi: Istituto Agrario, Menocal.
		Roberto Segre: *La Arquitectura de la Revolución Cubana* è la prima pubblicazione che condanna le **Scuole Nazionali d'Arte**.
		George Collins, "The Transfer of Thin Masonry Vaulting from Spain to America", *Journal of the Society of Architectural Historians*.
	gennaio	Walterio Carbonell, Sara Gómez, Manuel Granados e altri intellettuali afro-cubani sono puniti per aver sollevato questioni sull'ineguaglianza sociale nel cosi detto "Black Manifesto".
	31 marzo	Offensiva del Têt, Vietnam.
		Guillermo Cabrera Infante, in esilio viene espulso dal sindacato degli scrittori UNEAC.
	4 aprile	Assassinio di Martin Luther King Jr.
	6 giugno	Assassinio di Robert F. Kennedy.
1970		**Vittorio Garatti:** Piano Regolatore de L'Avana.
1972		**Roberto Gottardi:** Commando Nazionale dell'Agricoltura, L'Avana.
		Ricardo Porro, Centro commerciale e a "L'Oro del Reno", Vaduz, Liechtenstein
1974	giugno	**Vittorio Garatti** viene arrestato, messo in prigione per 21 giorni ed espulso da Cuba.
1976	29 luglio	Le ***Escuelas Nacionales de Arte*** vengono riorganizzate come *Insituto Superior de Arte* (ISA).
1982		Muore Wifredo Lam a Parigi.

1986		I progetti di **Roberto Gottardi** per la ristrutturazione delle **Scuole Nazionali d'Arte** sono commissionati e archiviati.
1988	giugno	**Vittorio Garatti** torna in visita a Cuba, riceve il benvenuto scritto da Vicepresidente Carlos Rafael Rodríguez.
		Deconstructivist Architecture, mostra organizzata da Philip Johnson y Mark Wigley, Museum of Modern Art, New York.
1989	9 novembre	Caduta del Muro di Berlino.
		Le **Scuole Nazionali d'Arte** sono parte della mostra di architettura cubana al CUJAE.
		Vittorio Garatti: Casa Garatti, Milano.
1990		**Ricardo Porro** (Renaud de la Noue): Collège "Elsa Triolet", Saint Denis.
1991		**Roberto Gottardi:** Dedalo, scenografia Danza Contemporanea di Cuba, L'Avana.
		Roberto Gottardi: Giròn, scenografia Danza Contemporanea di Cuba, L'Avana.
		Rosendo Mesias: *Revolución es Costruir…Arquitectura*, opera d'arte provocatoria con immagini delle **Scuole Nazionali d'Arte** presentata alla Galleria Plaza Vieja a L'Avana.
1992		**Vittorio Garatti:** Excelsior Hotel Gallia, Milano.
1993		**Riccardo Porro** (Renaud de la Noue): Collège "Fabien", Montreuil.
1995	febbraio	"Revolution of Forms": conferenza alla Harvard Graduate School of Design.
	aprile	Mostra delle fotografie di Hazel Hankin delle **Scuole Nazionali d'Arte** all'UNAICC.
		Le **Scuole Nazionali d'Arte** ed altre opere architettoniche contemporanee non vengono riconosciute come patrimonio nazionale dal Comisión Nacional de Monumentos.
1996		**Ricardo Porro** (Renaud de la Noue): Collège des Explorateurs, Cergy Pontoise.
	marzo	**Ricardo Porro** torna a Cuba per una serie di conferenze pubbliche.
	aprile	"The **Escuelas Nacionales de Arte** and the End of Modernism": simposio "The New Inside the New, Latin America and the Crisis of Modernism", Harvard Graduate School of Design.
		Le autorità cubane non firmano per le **Scuole Nazionali d'Arte** la domanda per il World Monuments Watch.
1997		Frank Gehry: Museo Guggenheim, Bilbao
	gennaio	**Ricardo Porro** torna ancora a Cuba, invitato da Selma Díaz, per la conduzione di una charrette di tre settimane per gli studenti di architettura. Intervista con i funzionari del turismo riguardo ad un progetto di un hotel a Varadero.
		Le **Scuole Nazionali d'Arte** sono dichiarate ufficialmente "zona protetta" dalla Comisión Nacional de Monumentos.
		Ernesto Jiménez García: *La Escuela Nacional de Artes*. Studio finanziato dal CENCREM per l'analisi dei costi per il restauro delle **Scuole Nazionali d'Arte**.

	giugno	**Vittorio Garatti** ritorna a Cuba e viene invitato a tenere una conferenza al Colegio de Arquitectos.
1998	gennaio	Papa Paolo Giovanni II visita Cuba.
	aprile	"Una architettura scomparsa", mostra al Politecnico di Milano delle **Scuole Nazionali d'Arte.**
	maggio	**Ricardo Porro** partecipa al convegno di architettura cubana moderna a L'Avana.
	luglio	**Vittorio Garatti** si incontra con i colleghi a Cuba durante una vacanza con sua moglie a Varadero.
		Il n.377 di *Arquitectura Cuba* è dedicato all'opera di **Ricardo Porro.**
		Il n.378 di *Arquitectura Cuba* è dedicato all'opera di **Roberto Gottardi.**
1999		**Vittorio Garatti:** Complesso Castellare di Capecchio, Todi, Italia
		Roberto Gottardi: A Prado y Neptuna, Ristorante, L'Avana.
	marzo	Viene pubblicato *Revolution of Forms, Cuba's Forgotten Art Schools*, Princeton Architectural Press, con presentazioni del libro a Los Angeles e New York.
		"Architecture and Revolution", convegno sulle **Scuole Nazionali d'Arte** con **Ricardo Porro, Roberto Gottardi, Vittorio Garatti** e John Loomis, MAK Center, West Hollywood.
		"Revolutionary Visions", convegno sulle **Scuole Nazionali d'Arte** con **Ricardo Porro, Roberto Gottardi, Vittorio Garatti** e John Loomis, Columbia University.
		Mostra: "Architecture and Revolution: **Escuelas Nacionales de Arte** en La Habana", MAK Center, West Hollywood.
		Felipe Dulzaides, *La próxima vez que llueva el agua va a correr*, video installazioni e performance che documentano lo stato di degrado della **Scuola di Balletto** di **Vittorio Garatti.** Da questa opera prende avvio il progetto *Utopia Posible.*
	settembre	"Architecture and Revolution: **Escuelas Nacionales de Arte** en La Habana", mostra a MAK Austrian Museum of Applied Arts, Vienna.
	6 ottobre	Al Congreso Nacional del Union de Escritores y Artistas Cubanos (UNEAC) si discute l'importanza e la situazione difficile delle **Scuole Nazionali d'Arte** segnalandone l'attenzione a Fidel Castro che ne richiede il "*restauración y completamiento*".
		"Architecture and Revolution: **Escuelas Nacionales de Arte** en La Habana", mostra a Tulane University, New Orleans.
	dicembre	**Ricardo Porro, Roberto Gottardi** e **Vittorio Garatti** si riuniscono a L'Avana, con alcuni funzionari di alto livello del governo per discutere e programmare il "restauro e il completamento" delle **Scuole Nazionali d'Arte.**
2000	gennaio	Il governo cubano assegna il "restauro e il completamento" delle **Scuole Nazionali d'Arte** al Ministero della Costruzione (MICONS), al Ministero della Cultura (MINCULT) e al Ministero della Educazione Superiore (MES).

		Inserimento delle **Scuole Nazionali d'Arte** nel "Watch List" dei monumenti al rischio del World Monuments Fund (WMF).
2001	marzo	"Mirando al Sur", convegno sulle **Scuole Nazionali d'Arte** con **Ricardo Porro, Roberto Gottardi** e **Vittorio Garatti**, Politecnico di Milano e Istituto Universitario di Architettura (IUAV) di Venezia.
2002	gennaio	Rinserimento delle **Scuole Nazionali d'Arte** nel "Watch List" del WMF.
	dicembre	"Castro's Dream, the Rediscovery of Cuba's National Art School" ICON World Monuments, World Monuments Fund, New York.
2003	gennaio	Inserimento delle **Scuole Nazionali d'Arte** nella lista "Provvisoria" del Patrimonio Mondiale dell'UNESCO.
		Ricardo Porro (Renaud de la Noue): Casernement CRS, Vélizy-Villacoublay
2004		**Ricardo Porro** (Renaud de la Noue): lycée hôtelier Georges Baptiste à Canteleu.
		Ricardo Porro (Renaud de la Noue): école Samira Bellil'.
	24 gennaio	Muore Hugo Consuegra
	aprile	"Preserving Havana's Art Schools". The Getty Center, Los Angeles.
	dicembre	**Roberto Gottardi** e Felipe Dulzaides *Invitation*, installazione alla Fototeca de L'Avana che mette in scena il processo di costruzione della **Scuola di Arti Drammatiche.**
2005	marzo	"Revolution of Forms", conferenza, Stanford University.
	luglio	Robert Wilson e Charles Koppelman, atelier per la messa in scena di brani dall'opera, basata sulla storia delle **Scuole Nazionali de Arte**, *Cubanacán: A Revolution of Forms,* Watermill, New York.
2007		**Ricardo Porro** (Renaud de la Noue): Commissariat de police, Plaisir.
2008	13 agosto	Muore Walterio Carbonell.
	sett/nov	Felipe Dulzaides, *Utopía Posible,* Gwanju Biennial, Corea del Sur.
		Ricardo Porro (Renaud de la Noue): atelier des Arts et du Patrimoine au Puy-en-Velay.
2009	18 gennaio	Muore Max Borges Jr.
	aprile	Felipe Dulzaides, *Utopía Posible*, X Bienal de La Habana. L'installazione è formata da una gran quantitá di mattoni che saranno offerti per il completamento della **Scuola di Arti Drammatiche** di **Roberto Gottardi.**
		Come risultato della crisi economica globale, il lavoro di riabilitazione e completamento delle **Scuole Nazionali d'Arte** si chiude ufficialmente.
		Ricardo Porro (Renaud de la Noue): Groupe scolaire Jean Jaurès, Ermont.
2010	ottobre	Felipe Dulzaides, *Utopía Posible,* presentazione di "Vidrios rotos", Graham Foundation, Chicago.
	8 novembre	Le **Scuole Nazionali d'Arte** vengono riconosciute monumento nazionale dalla Comisión Nacional de Monumentos.

		Ricardo Porro (Renaud de la Noue): Lycée Julie Victoire Daubié, Argenteuil.
	1 maggio	Brani dall'opera lyrica *Cubanacán: A Revolution of Forms*, sono presentati all'interno del programma VOX, New York City Opera, New York.
2011	marzo	Nuova edizione aggiornata del libro *Revolution of Forms, Cuba's Forgotten Art Schools*, Princeton Architectural Press. Presentazione all'Institute of Fine Arts, New York University.
	19 giugno	Anteprima mondiale di *Unfinisched Spaces*, documentario filmico di Alysa Nahmias e Benjamin Murray, Los Angeles Film Festival. **Ricardo Porro**, **Roberto Gottardi** e **Vittorio Garatti** vengono ricevuti calorosamente.
	25 giugno	Presentazione dell'edizione aggiornata di *Revolution of Forms*, presso il Centro Culturale di Cennina (Arezzo, Italia). Sono presenti oltre l'autore, Osvaldo Righi, Felipe Dulzaides, Michele Paradiso e Richard Ingersoll.
	28 giugno	"Le **Scuole Nazionali d'Arte**" conversazione con **Vittorio Garatti** e Marco Marini, CubaItaliana, Museo di Roma in Trastevere.
	24 ottobre	*Unfinished Spaces* vince il premio per il miglior film documentario al Festival Internacional de Cine a Valladolid.
	4 dicembre	Anteprima a Cuba di *Unfinished Spaces* al Festival de Nuevo Cine Latinoamericano a L'Avana. Sono presenti gli autori Alysa Nahmias e Benjamin Murray, gli architetti **Roberto Gottardi** e **Vittorio Garatti** e gli artisti Manuel Lopez-Oliva, Mirtha Ibarra e Ever Fonseca.
		*Cuba. **Scuole Nazionali d'Arte***, Claudio Machetti, Gianluca Mengozzi e Luca Spitoni; Skira Edizioni, Milano.
	15 dicembre	Protocollo d'accordo firmato presso il Ministero della Cultura che concede al danzatore cubano Carlos Acosta, étoile della danza classica, il diritto di ripristinare e riutilizzare la **Scuola di Balletto** di **Vittorio Garatti** come Centro di Danza Carlos Acosta.
2012	febbraio	Il film *Unfinished Spaces* partecipa al prestigioso programma Sundance Film Forward e riceve, nello stesso anno, il premio del Miami Film Festival e del San Diego Latino Film Festival.
	marzo	Abel Prieto, progressista visionario e ministro della cultura cubana, si dimette per motivi di salute e viene sostituito dal suo subalterno Rafael Bernal Alemany.
	marzo/aprile	Felipe Dulzaides, *Utopia Posible*, installazione presso Miami Dade Art Gallery con nuovi elementi: "El contexta importa", "Interrogar vidrios rotos", "Monologo" e "Dialogo Roto".
	1 maggio	Presentazione di brani estratti dall'opera lirica *Cubanacán: A Revolution of Forms*, presso la chiesa di San Francesco a L'Avana.
	mag/giugno	*El Instante Irreversible*, installazione dell'artista messicano Gabriel Orozco alla **Scuola di Balletto**, IX biennale del L'Avana. "No trabajamos con nada que no hubiésemos encontrado en le

		lugar, las acumulaciones de pollo, las gota de agua, los losetas rotas, las marca del sol.”
	12 giugno	Robin Progrebin riporta nel *New York Times* che Carlos Acosta ha scelto l’architetto Norman Foster per trasformare la **Scuola di Balletto** di **Vittorio Garatti** nel Centro di Danza Carlos Acosta.
	14 giugno	Suscita un acceso dibattito la decisione di negare a **Vittorio Garatti** il diritto di restauro della **Scuola di Balletto**. La notizia risuona sulla stampa a livello internazionale e come conseguenza si apre una discussione pubblica che coinvolge importanti intellelettuali cubani con il ministro della cultura Rafael Alemany.
	ottobre	Il film *Unfinished Spaces* è presente nella produzione statunitense PBS, e successivamente nella HBO per tutta l’America latina e altri paesi in tutto il mondo.
	6 novembre	**Vittorio Garatti, Roberto Gottardi** e **Ricardo Porro** ricevono il premio “Vittorio de Sica” per l’architettura dal Presidente della Repubblica Italiana Giorgio Napolitano.
2013	10 marzo	Muore Roberto Segre a Rio de Janeiro.
	13 novembre	**Vittorio Garatti** scrive una lettera a Norman Foster chiedendo il rispetto del diritto di autore sulla **Scuola di Balletto**.
2014		**Ricardo Porro** (Renaud de la Noue): L’école Saint-Exupéry de Bois-Colombes, Francia.
	marzo	**Vittorio Garatti**, “Obras y proyectos”, Centro de Arte Contemporáneo Wifredo Lam, La Habana. Grande successo della mostra curata da Jorge Fernández y Felipe Dulzaides.
		Raul Castro sostituisce Rafael Bernal Alemany con il nuovo Ministro della Cultura Dr. Julián González Toledo.
	7 luglio	Muore Mario Coyula Cowley.
	luglio	Proposta per il consolidamento e restauro funzionale delle **Scuole Nazionali d’Arte** con un progetto di cooperazione internazionale curata da Michele Paradiso e del Ministero della Cultura della Repubblica di Cuba.
		Felipe Dulzaides espone “Interrogar vidrios rotos” alla mostra *Beyond the Supersquare: Art and Architecture in Latin America after Modernism;* The Bronx Museum of the Art, New York.
	17 dicembre	Il presidente americano Barak Obama annuncia il ripristino delle relazioni diplomatiche ed economiche con Cuba.
	25 dicembre	Muore a Parigi **Ricardo Porro Hidaldo.** Viene sepolto nel cimitero di Pere Lachase.
2015	gen/feb	Brani dell’opera lirica *Cubanacán: A Revolution of Forms* vengono presentati dal produttore Charles Koppelman, ed eseguiti dal compositore Roberto Varela e dalla cantante Barbara Llanes a New York, San Francisco, Los Angeles.
	marzo	La mostra al MoMa di New York *Latin America in Construction 1955-1988*, presenta le **Scuole Nazionali d’Arte**.
		Il World Monuments Fund organizza il convegno *Latin American Modernism at risk – challenges of presenting modern mas-*

		terpieces of World Monuments Watch, in cui erano presentate le **Scuole Nazionali d'Arte**, MoMa, New York.
		Pubblicazione in castigliano di *Una Revolución de Formas, Las Olvidadas Escuelas de Arte de Cuba* dalla casa editrice dpr-barcelona.
	23 maggio	Prima mondiale della opera lirica *Cubanacán: A Revolution of Forms*, L'Avana.
2016	gennaio	Rinserimento delle **Scuole Nazionali d'Arte** nel "Watch List" del WMF.
	febbraio	Commissione internazionale di studio per il futuro delle **Scuole Nazionali d'Arte** organizzata dal Ministro della Cultura.
	6 marzo	Presidente Barack Obama vista L'Avana.
	ottobre	Mostra e catalogo *Sin dogmas y con muchas dudas*, opere di **Roberto Gottardi**, Fabrica de Arte Cubano, L'Avana.
	25 novembre	Muore a L'Avana Fidel Castro.
2017	10 febbraio	World Monuments Fund "Watch Day" dedicato alle **Scuole Nazionali d'Arte.**
	20 agosto	Muore a L'Avana **Roberto Gottardi.**
2018	23 luglio	La Getty Foundation, nell'ambito dell'iniziativa *Keeping it Modern*, assegna al gruppo di ricerca coordinato dal Politecnico di Milano un grant per la redazione di un piano di conservazione e gestione delle Scuole Nazionali d'Arte.
	31 luglio	Prende avvio il progetto di cooperazione *¡Que no baje el telón!*
2019		Pubblicazione in italiano di *Una Rivoluzione di Forme. Le Scuole Nazionali d'Arte di Cuba*, Mimesis Edizioni.

Listing and protection

National listing

The National Schools of Arts are subject to the highest level of protection, according to the Cuban legislation (*Ley de Monumentos Nacionales y locales n. 2 of 4 august 1977*) and are therefore supervised by the National Commission for the Monuments.

In 1997 the Schools' campus was declared a Protected Area. That means that in the area near a Local or National Monument the Commission should approve any new construction. Then, appropriate mitigation measures can be imposed, and the commercial activities may be proscribed or regulated.

In November 2010, Eusebio Leal Spengler, then-president of the Commission, declared the Schools National Monument (*"Monumento Nacional de la República de Cuba"*).

"Se entiende por Monumento Nacional todo centro histórico urbano y toda construcción, sitio u objeto que, por su carácter excepcional, merezca ser conservado por su significación cultural, histórica o social para el país y que, como tal, sea declarado por la Comisión Nacional de Monumentos" (art. 1).

(A National Monument is any historical urban center or construction, site or object that deserves to be conserved due to its exceptional nature because of its cultural, historical or social significance to the Nation and be declared by the National Monuments Commission.)

The declaration (art. 2) depends on different values (historical, artistic, landscape, social, natural) and implies the supervision of the National Commission, which imposes the adoption of the strictest conservation measures and also authorizes the installation of signs, decorations, and any public event.

The declaration issued for the National Schools of Art asserts that:

"El conjunto de edificaciones que conforman en la actualidad la Escuela Nacional de Arte y el Instituto Superior de Arte, situadas en los terrenos del antiguo Country Club de La Habana, actual reparto Cubanacán, municipio Playa, constituye uno de los ejemplos más sobresalientes de la arquitectura cubana del Movimiento Moderno y un hito de la arquitectura de la Revolución".

Este conjunto es la obra arquitectónica cubana más importante y divulgada internacionalmente desde mediados de la década del 60. Es a la vez única y también representativa de un momento histórico; y motivó una polémica fecunda sobre la función social de la arquitectura, su utilidad práctica y su valor cultural e ideológico.

Su construcción se debió a una iniciativa del Comandante en Jefe Fidel Castro de conjunto con el Comandante Ernesto Ché Guevara, para erigir, en los terrenos de golf de la burguesía cubana, una escuela modelo para el Tercer Mundo que ha formado a los principales protagonistas del Arte Nuevo Cubano en la etapa revolucionaria. Las escuelas devinieron en un extraordinario ejemplo de campus escolar desarrollado en los años sesenta, con la particularidad arquitectónica de haber sido concebidas como una unidad dentro de la diversidad de cada autor, imbricadas a la naturaleza del sitio y con el uso de recursos materiales locales y técnicas constructivas

tradicionales, que significaron en lo expresivo-volumétrico, una renovación del panorama de la arquitectura moderna cubana, por su organicidad e integración paisajística".
The very document thus calls for the restoration of the National Art Schools, advocating for the preparation of a Management/ Maintenance Plan to guarantee the conservation of the buildings, under the technical supervision of the National Monuments Commission.

World Monuments Fund
Since the 90s, the World Monuments Fund has supported local and international advocacy efforts to protect and preserve the heritage of Cuba. In particular, the organization has promoted the preservation of the National Schools of Art through their support of several initiatives, including technical and academic exchanges, exhibits, publications, and a documentary film.
In 2000, 2002 and 2016, the Schools were included in the World Monuments Watch List of 100 Most Endangered Sites, becoming the first 20th century Cuban buildings to be inscribed in the Watch List (https://www.wmf.org/project/national-art-schools). The inclusion on the World Monuments Watch aimed to build on its new-found international prominence and highlight the need for a comprehensive and integrated approach to the management of the site.

World Heritage Tentative List UNESCO
In 2003 the School complex was also inscribed in the UNESCO Tentative List under criteria I, III, III, IV, V.
(http://whc.unesco.org/en/tentativelists/1798/).
The site is described as follows:

"The set of buildings conforming the National Schools of Art, created in 1962, constitutes one of the most outstanding examples of contemporary Cuban architecture, with an acknowledged artistic value, reuniting testimonial values stemming from the historic moment in which it was built to serve as a the training school for artists. Some of the graduates form part of the history of contemporary Cuban art and the schools constitute a well-acknowledged set of Cuban architecture at an international level.
The architects who implemented the project made the decision of constructing the buildings based on two essential constructive elements: bricks and Catalan domes, given the scarcity of cement and concrete at that time. This has been the main characteristic of the set, regardless of the specificity of each school, inserted within an important natural context.
The creation of these National Schools of Art pursued a fundamental premise, that of serving as the training school for Cuban artists in five specialties: Plastic Arts, Music, Ballet, Drama, Modern and Folkloric Dancing and to establish cultural cooperation with other underdeveloped countries.

Its faculty, during the 60s and 70s, was formed by outstanding Cuban and Latin American artists and graduated the most representative artists of Cuban art.
Given all these reasons the schools are considered the most advanced example of an all-encompassing and multidisciplinary pedagogical and artistic project".

If the application was to be accepted, the site would be added to the 9 UNESCO Cuban sites (of which 7 cultural sites) already inscribed, among which the old city of Havana and its Fortifications. It would, however, be the first UNESCO site referring to modern architecture on the island.

Action 1

Analysis and documentation of the site and of the buildings

Action 1: Analysis and documentation of the site and of the buildings

1.1 Historical and archival research

Havana's National Art Schools have a rather long and eventful history: designed and partly built between 1961 and 1965, the complex was abandoned shortly after, only to be rediscovered in the last decade of the 20th century.
Over time, the schools' fascinating architecture sparked interest on an international level, fostering the production of a wide range of materials, including monographs, essays, videos, and studies. However, except for the research conducted by John Loomis, most of this production has always been of narrative, critical, or celebratory nature. Until today, no systematic archival researches had been conducted. The absence of a scientific approach denied the possibility to efficiently retrace the schools' construction history, from the building site to current times, through fifty years of use, abandonment, and slow decay.

1.1.1 A Summary of Archival Events

To address this issue, one of the main goals of Action 1 has been to locate - and possibly acquire - the existing documentation regarding the National Schools of Art.
Whereas the collection of drawings and photographs concerning the two schools designed by Vittorio Garatti (School of Music and School of Ballet) has been rather quick, gathering information regarding the other three schools has been quite challenging. As a matter of fact, the involvement of former members of the Garatti Committee in the project has guaranteed easier access to the materials that have been produced by the architect over the years. On the other hand, being Roberto Gottardi and Ricardo Porro both deceased, the work records regarding the Schools of Plastic Arts, Modern Dance and Theater have been dispersed and are now in the hands of several different organizations.
The documentation gathered and stored by Politecnico di Milano hence consists of heterogeneous materials produced by different individuals and bodies (both institutional and private), regarding for the most part Vittorio Garatti's work.
The original drawings and photographs illustrating the 1960s project were kept by the Ministry of Construction (MICONS) in Cuba until 2008 when its dismantling caused their dispersion. However, immediately before the MICONS Archive shut down, several individuals managed to make digital copies of the stored materials without properly reorganizing or inventorying them. Today, some of the digital materials collected over the years are stored at the Universidad de las Artes (ISA), currently housed in the National Art Schools.
The digital archive includes about 800 drawings, photographs of the site, as well as other documents. In June 2019, in the context of the collaboration between the Politecnico di Milano and the ISA's Faculty of Conservation of Cultural Heritage, the mentioned documentation was handed over to the Fondazione Politecnico di Milano in order to continue the research activities.

The Archive and Bibliographic Authority of the Lombardia Region also participated in the protection and promotion of the materials, providing its support with both the ongoing reorganization and the managing of institutional relationships with Cuba.

While the materials coming from the ISA archive were immediately located, vicissitudes concerning the work of Roberto Gottardi and Ricardo Porro were a bit harder to unravel.
Concerning Roberto Gottardi's School of Theater, it has been found that most of the documentation is currently split between the Princeton University Library and the Universidad de las Artes (ISA).
In 2017, on Professor Rubén Gallo's[1] suggestion, Princeton University bought part of the papers stored in Gottardi's house in Havana. The purchase - arranged with Gottardi's widow, Luz Maria Collazo - consists of 8 boxes of documents and 9 rolls of drawings. The materials have been stored at Princeton's Firestone Library (Special Collection department) but are currently not available for consultation because of their poor state of conservation.
In fact, although - according to the Library standard procedures - the acquired materials usually become immediately available both to Princeton affiliates and to public users[2], the poor conditions of the mentioned documents have resulted in a significant delay in this process, forcing to proceed to a preliminary mold treatment to avoid further decay of the paper support before making it available for consultation.

Little is known about the exact nature of the materials, as they have not been organized yet. From professor Gallo's recollection, the boxes include miscellaneous documents ranging from design sketches to teaching notes[3], whereas the rolls of drawings contain the original blueprints of Roberto Gottardi's designs, including the numerous solutions developed by the architect over the years to complete the unfinished School of Theater. The amount of large-size drawings should be approximately one hundred.
Further information was provided by librarian Fernando Acosta Rodriguez who also pointed out that the papers are extremely heterogeneous and have never been organized, nor meant to be in any specific order from the beginning. He has, however, inspected the boxes and has been able to provide a more detailed - although not definitive - list of the materials, which include:

- Roberto Gottardi's correspondence;
- educational notes on several topics;
- teaching programs related to its courses at the Universidad de La Habana;
- photographs of some of its works (both during the building site and when completed);

[1] Professor in Language, Literature, and Civilization of Spain at the Department of Spanish and Portoguese, Princeton University.
[2] As the main priority is to allow researchers to access the documentation, materials become available even without previous re-arrangement. However, reorganization shortly follows the acquisition.
[3] Mr. Fernando Acosta-Rodriguez is the librarian for Latin American, Iberian, and Latino Studies at Princeton University Library.

- sketches and preliminary ideas for his designs;
- articles, magazines, and brochures concerning its works;
- essays from several authors.

It is thus clear that the documentation acquired by Princeton University does not merely regard the National Schools of Art, as the newly-formed archive is all-embracing of the professional activities carried out by Gottardi from the '60s until his death.

However, Princeton University did not acquire the whole of Gottardi's archive. In fact, a consistent portion of his materials (books, journals, magazines, …) are currently stored at the ISA (Universidad de las Artes, Havana). This part of the archive also needs to be organized and comprises different kinds of materials.

Finally, the attempt to locate Ricardo Porro's archive reached a dead end, as the materials might be stored in Paris - where the architect based his architecture firm - or elsewhere.

The following paragraphs describe the work done within the Keeping it Modern initiative to catalogue and rearrange the documentation regarding Vittorio Garatti's School of Music and Ballet. However, the archive has been structured to be implemented with further materials concerning the other Schools.

1.1.2 Composition of Archived Material

The set of documents composing the newly created *Escuelas Nacional de Arte archive* consists of various fonds, including materials of different typologies, origin, format, and medium. This situation called for the institution of a *superfond*, which is defined by SIUSA (Unified Information System of the Archival Authority)[4] as a *"set of funds (…) sharing, for some reason, a mutual genetic or institutional bond, or otherwise similarly conserved, so that they now constitute a unitary item within a concentration archive"*. This definition is well suited to the case of the *National Art Schools of Havana*'s documentary heritage, which is estimated to consist of tens of thousands of items.

In particular, the *ISA* Fond includes:

- a selection of about 300 photographs taken by different authors, spanning from the beginning of the building site (1961) to current days (2020);
- digital copies of the 509 drawings describing the original design of the Schools of Music and Ballet, as planned in the 1960s. In particular, this section consists of scanned heliographic or paper copies of some of the original blueprints;
- documents concerning the renovation interventions carried out between 2004 and 2007;
- documents regarding the renovation interventions carried out between 2007 and 2008.

[4] This definition is not found in international standards but was introduced in the manual by the Unified Information System of Archival Authority (SIUSA), version 0.1, December 2004, p. 39.

Further fonds, collected over several decades, form an archival entity composed of approximately 30,000 items, including:

- 8,400 photographs;
- 15,000 files of various nature covering a period of about sixty years (1961 - 2020), including 3D models, technical reports, studies, and more;
- 11,000 files concerning exhibitions, presentations, conventions, and lectures;
- 300 files including monographs, essays, publications, as well as doctoral and graduate thesis;
- 280 files collecting the correspondence between various institutions (both Cuban and foreign) and between private individuals and bodies somehow involved with the Schools;
- 368 videos;
- 2,500 heterogeneous papers, currently filed in a Miscellaneous section.

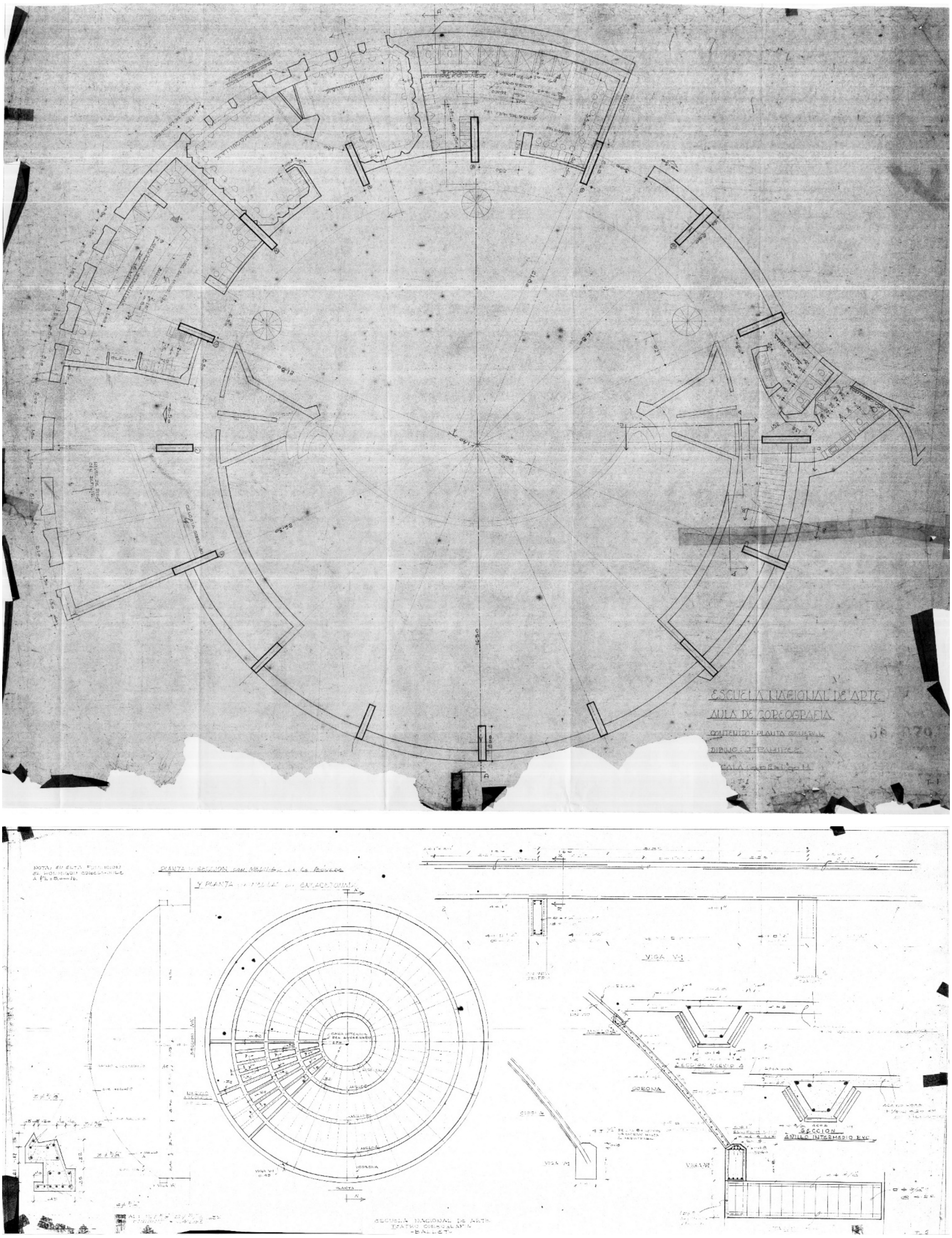


Figure 1 - Original drawings of the School of Ballet's Choreography Theater (ISA archive).

Getty Foundation

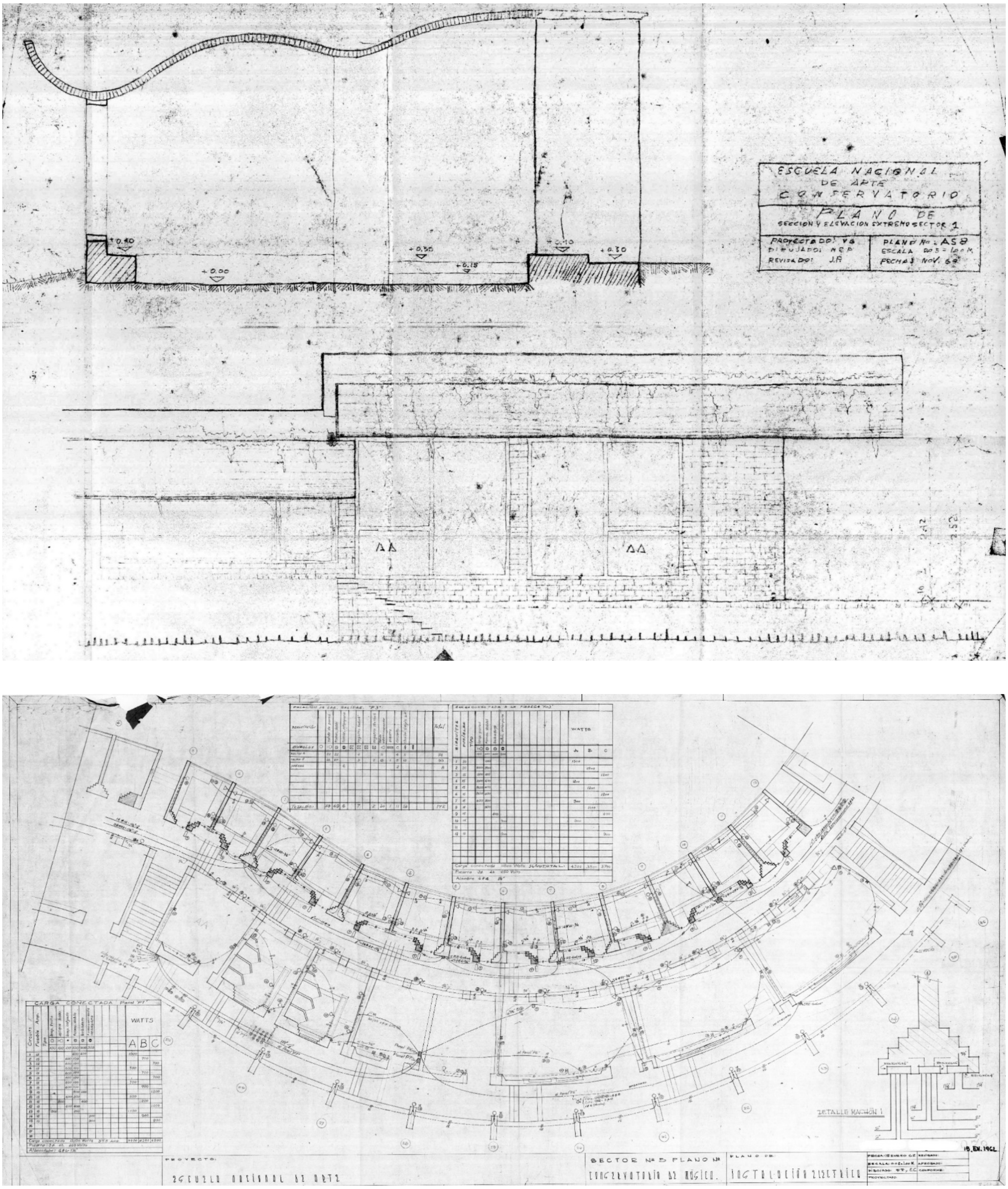
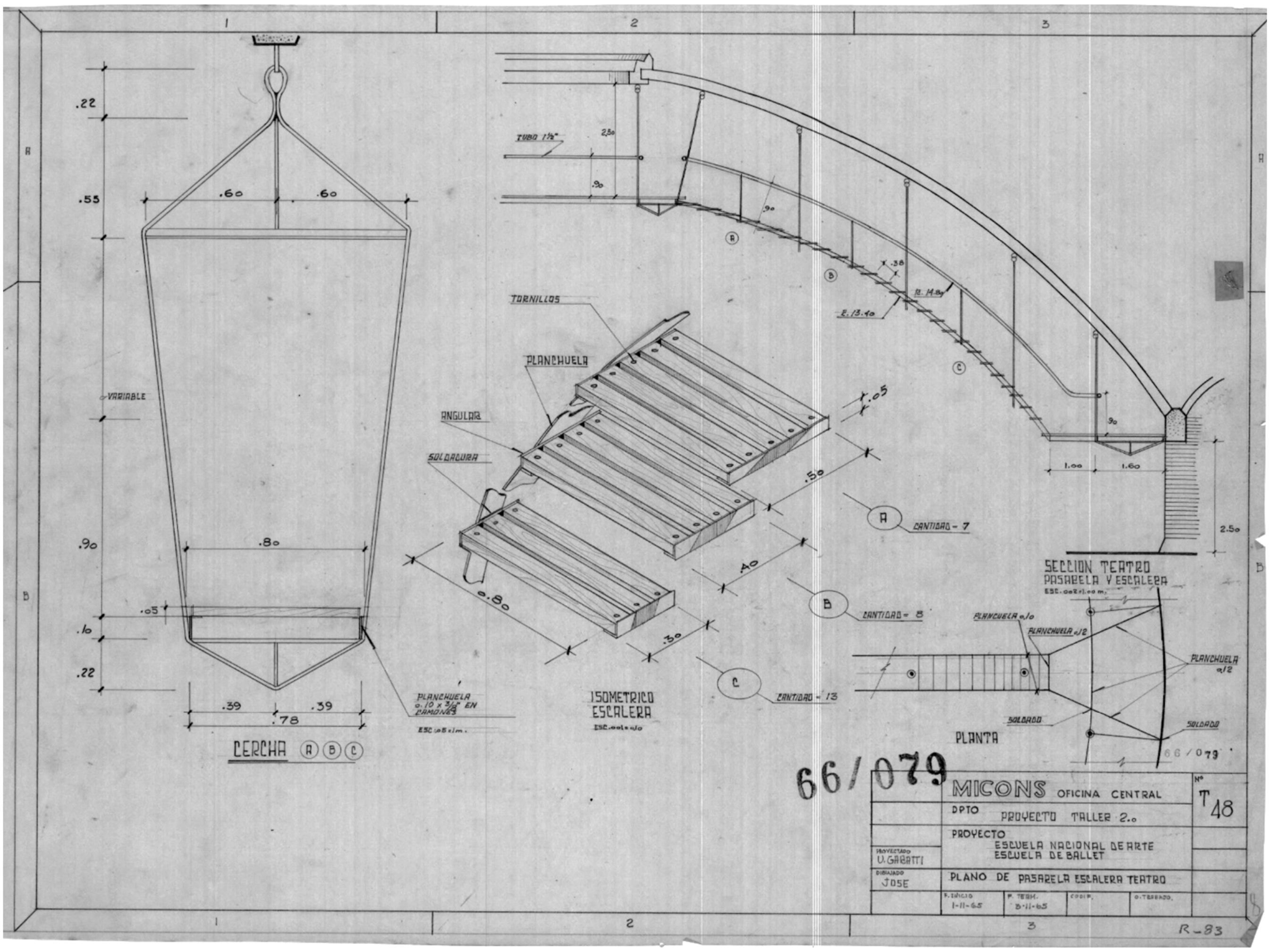


Figure 2 - Original drawings of the School of Music (ISA archive).



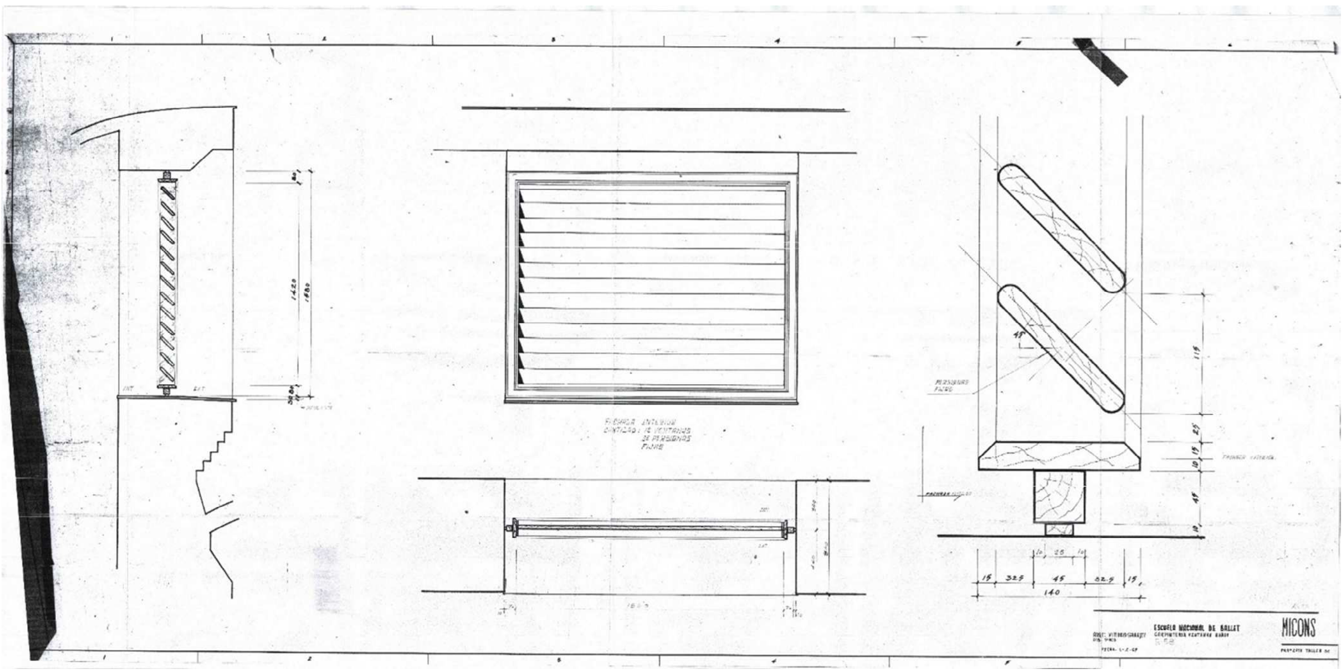


Figure 3 - Vittorio Garatti's original drawings for the School of Ballet. On top: the metallic catwalk of the Choreography Theater; on the bottom: the window frame for the Dance pavilions' changing rooms (ISA archive).

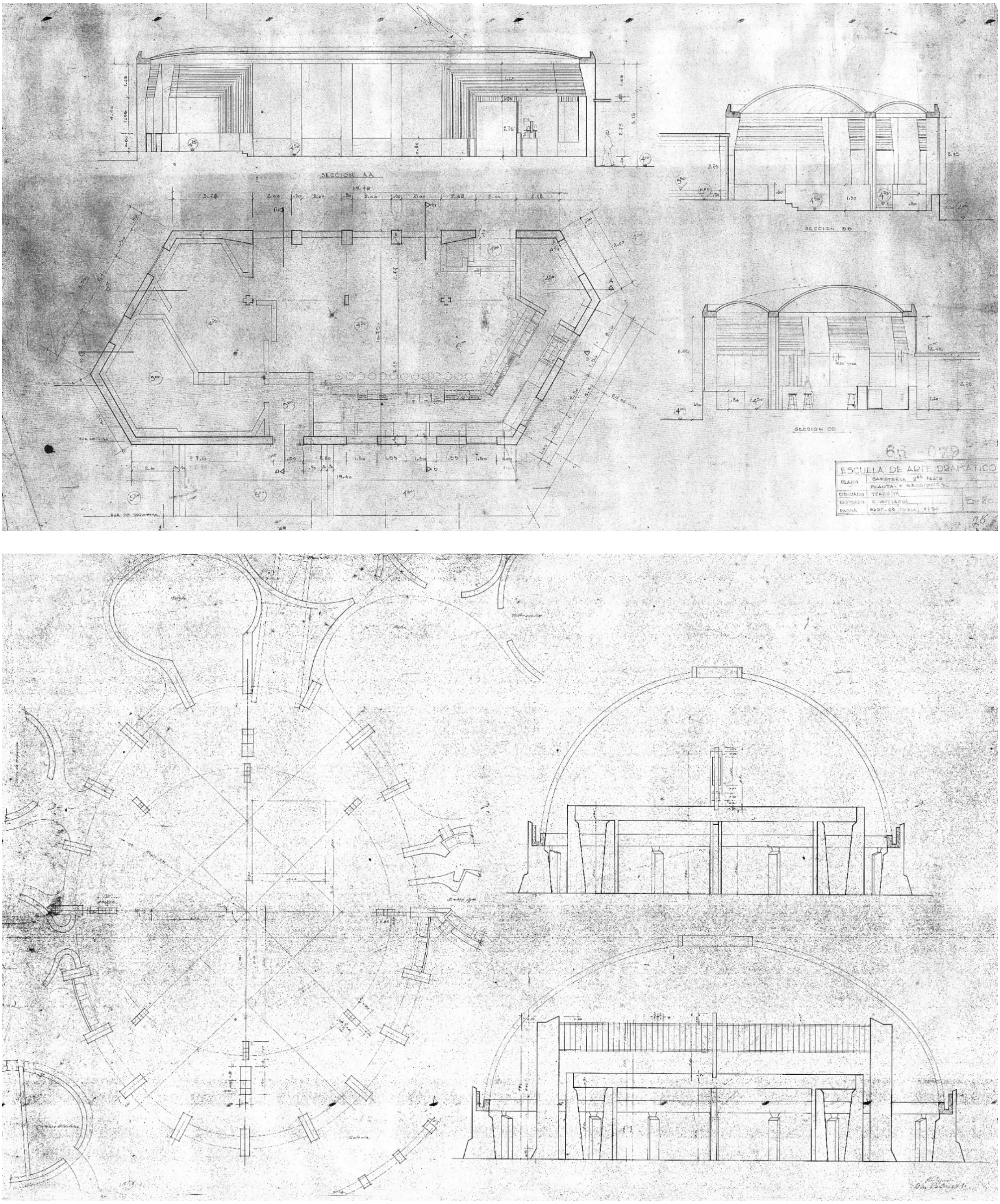


Figure 4 - Roberto Gottardi (top) and Ricardo Porro's (bottom) original drawings for the Schools of Dramatic Arts (top) and Plastic Arts (bottom). Images from the ISA archive.

Figure 5 - A page from Josè Mosquera's photographic album, documenting the golf course conditions before the start of the Schools building site (ISA archive).

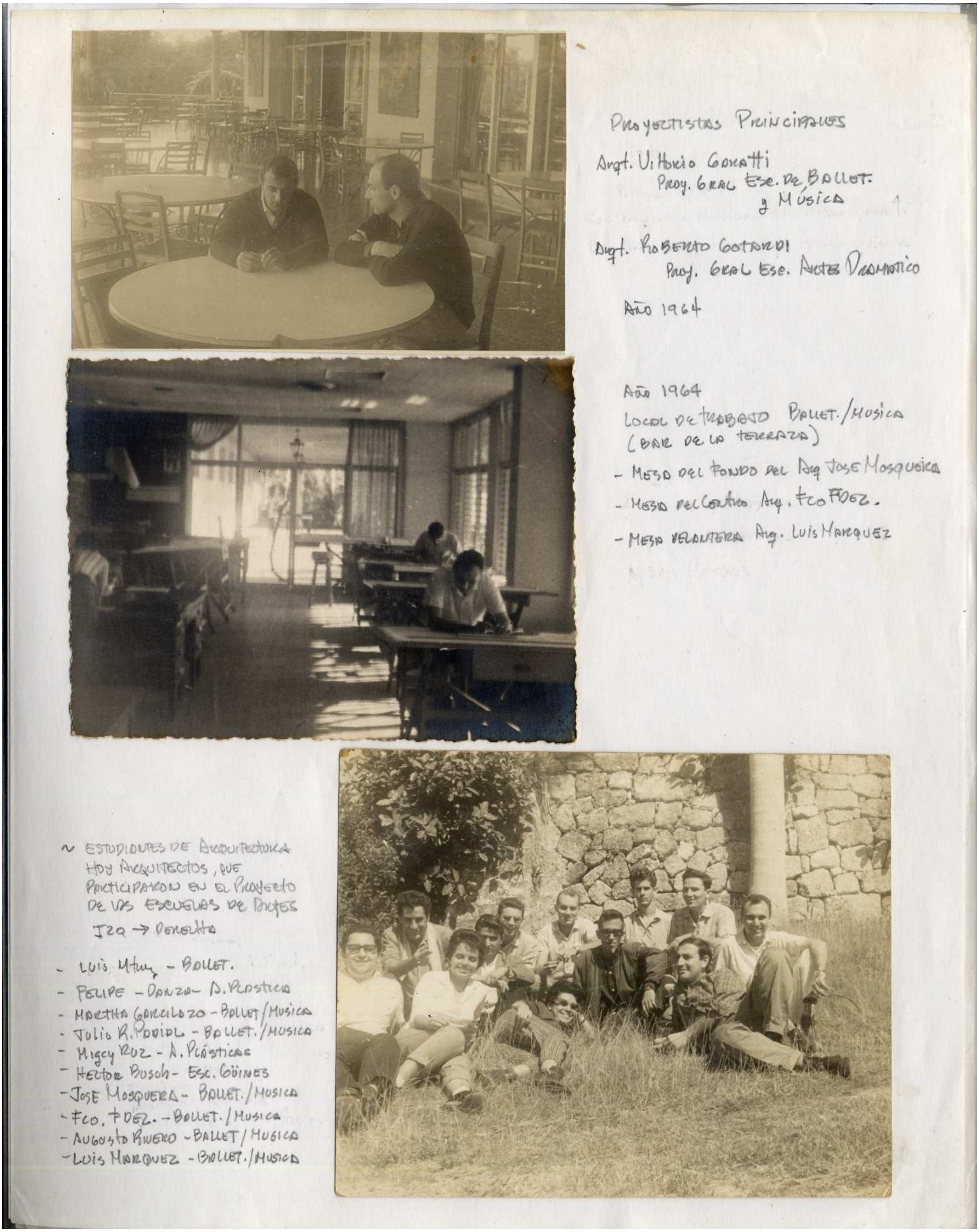


Figure 6 - Josè Mosquera's photographic album: the workgroup (ISA archive).

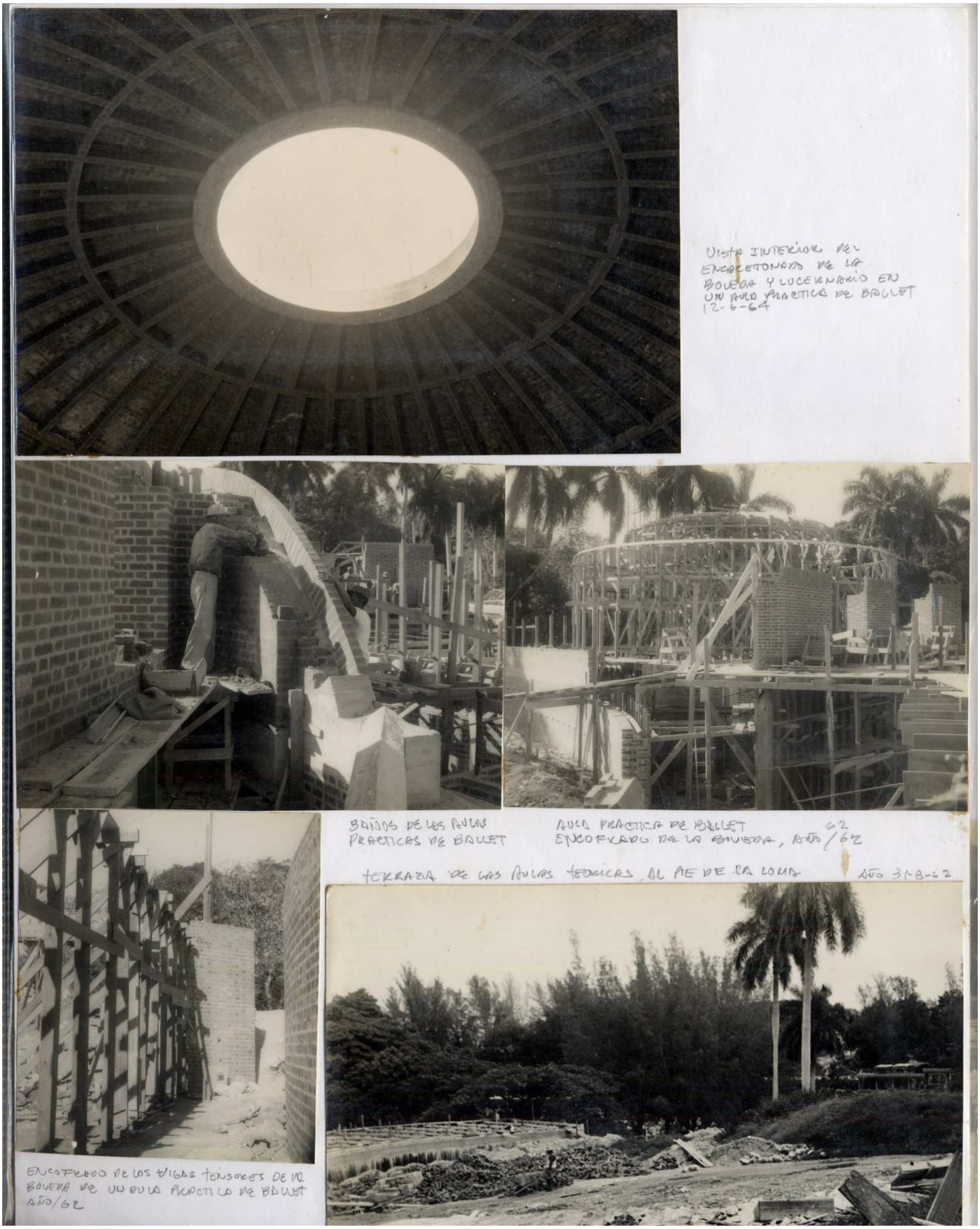


Figure 7 - Josè Mosquera's photographic album. The School of Ballet under construction (ISA archive).

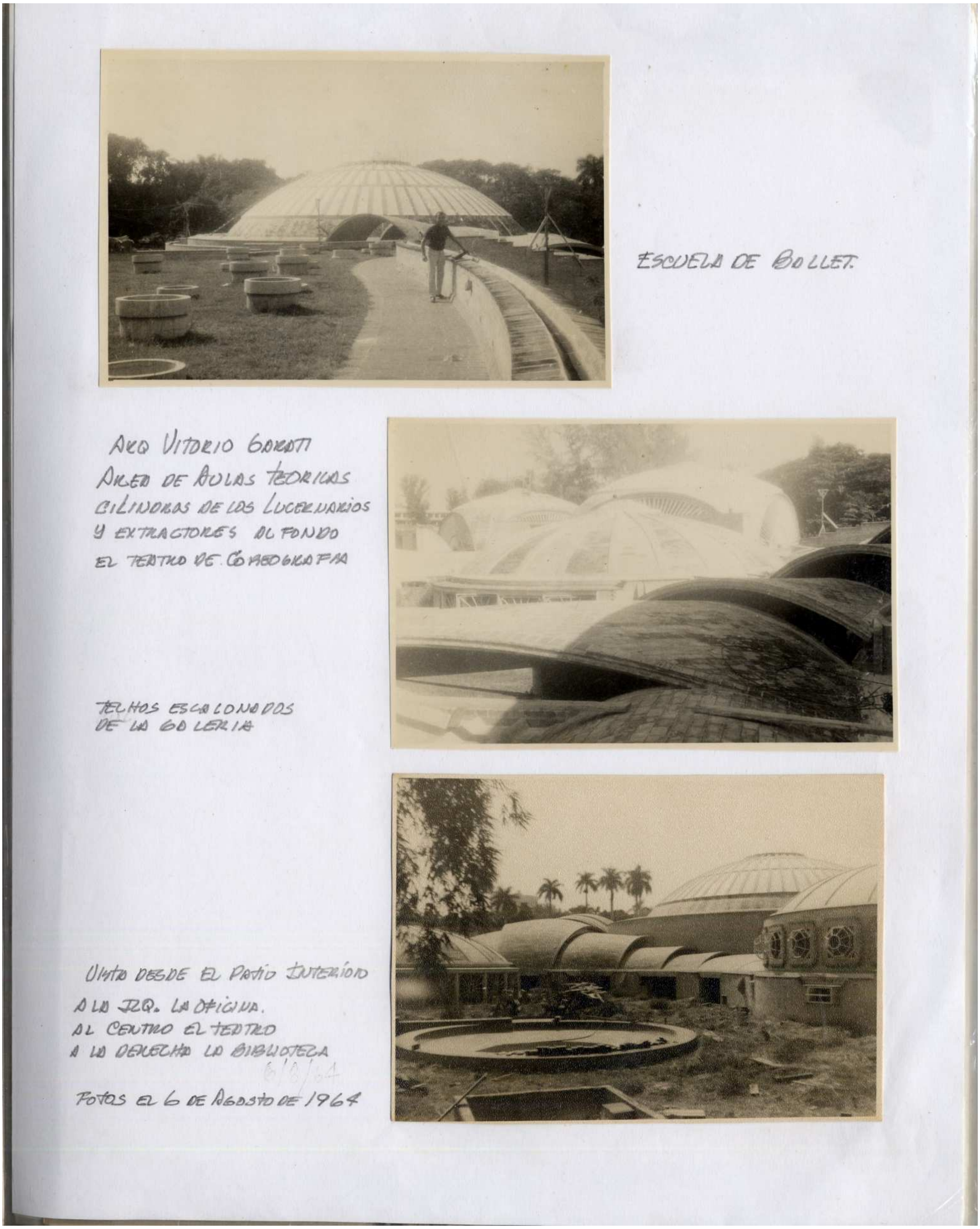


Figure 8 - Josè Mosquera's photographic album: the School of Ballet after completion (ISA archive).

1.1.3 The Escuelas Nacional de Arte Archive Superfonds and Its Reorganization

Although configuring as a duplicate of the original *unicum*, each collected document (i.e., the smallest archival unit of the *Escuelas Nacional de las Artes*) maintained its own intrinsic features. MICONS' drawings and photographs were grouped together in "units" and thus filed with other materials, according to current archives' usage methods (print texts, videos, documentaries, convention reports, doctoral and graduate thesis, and many others).

The careful examination of the information made available by the archival files represented an essential step in the knowledge process. Indeed, it is configured as the starting point to define and carry out further analytic activities on the Schools.

The reorganization of the Archive's materials thus aimed to support the researchers, allowing them to evaluate the documentation critically while easily searching for data and exchanging information. Indeed, such a large amount of information, both in quantitative and qualitative terms, represents the key to piece together a history of both the architecture (in its material essence) and the architectural process, including construction, technological and economic factors.

The knowledge connected to the history of the *Escuelas Nacional de las Artes* Archive (hereinafter also the Schools Archive) led the reorganization activities, preceded by a preliminary census of the materials. The samples analysis[5] showed a stratified archival activity resulting from the above-mentioned events (See 1.1.1 A Summary of Archival Events), which are also accountable for their atypical form. In fact, the Schools Archive's materials currently display a complex and varied morphology. In particular, the copies of the 1961-1965 drawings retrieved from the MICONS represent a subsequently formed - and rather incomplete - unit. The relations connecting the papers to one another were lost when the records were relocated according to practical usage needs during the Schools' construction. They were further adulterated by a selective reproduction of the original materials, dictated by contingent requirements during the dismantling of the MICONS Archive.

The articulation of the *Escuelas Nacional de Arte* superfond is perhaps one of the most problematic aspects of the archival reorganization. Indeed, there were no additional sets, inventories, or transfer/deletion lists complementing the ISA documentation. Moreover, the other fonds produced by different bodies cannot be considered historically consolidated sets (i.e., archives formalized through inventories and their relevant markings) or organic. Thus, the choice of reorganization methodologies (See 1.1.4 Reorganization Methodology) privileged the maintenance of the archival structure outlined by the latest authors, who organized some sections by thematically grouping part of the documents.

The census of the superfond also highlighted the presence of several files reflecting a spontaneous sedimentation (typical of current archives) owed to scholars and professionals who continued working on the Schools. Such files can mostly be found in the SITE PHOTOGRAPHY and CORRESPONDENCE series, as well as in the ARTICLES-ESSAYS-BOOKS-VIDEOS-CONFERENCES, LOOMIS ARCHIVE, LETTERS, DOCUMENTS,

[5] Only a few of the 30,000 documents were analyzed. The choice fell on a selection of representative documents for each section of the Archive.

CONTRACTS, INTERNATIONAL PROJECTS, EXHIBITIONS, CONFERENCES, LECTURES, CUBANACAN COUNTRY CLUB, ACOSTA - FOSTER, OTHER SCHOOLS fonds.

These materials are linked by important genetic connections and, thanks to their specific location within the Archive, convey a series of precious metatextual information[6]. Concerning these fonds and series, the superfond's inventory follows the same reorganization criteria of the drawings - without, however, changing their original position. Thus, these fragments were considered *"the pieces of a mosaic to be restored, and not as modular bricks to be placed according to a new abstract scheme or one derived from other archives."*[7]

The possible integration of further traceable materials could contribute to the recreation of an *"ex post"* Schools Archive and, therefore, to reconstruct (even if only partially) its original structure and its "consistent blocks"[8]. Future implementations might include the documentation produced by Ricardo Porro and Roberto Gottardi, as well as possible drawings in possession of private individuals that may still be in Cuba or may have been exported to other countries. A further outcome of the ISA archive's reorganization is the accurate recording and cataloguing of the documents, which will help avoid their dispersion. To this purpose, an analytical inventory and other research instruments have been developed as complementary tools to the archive.

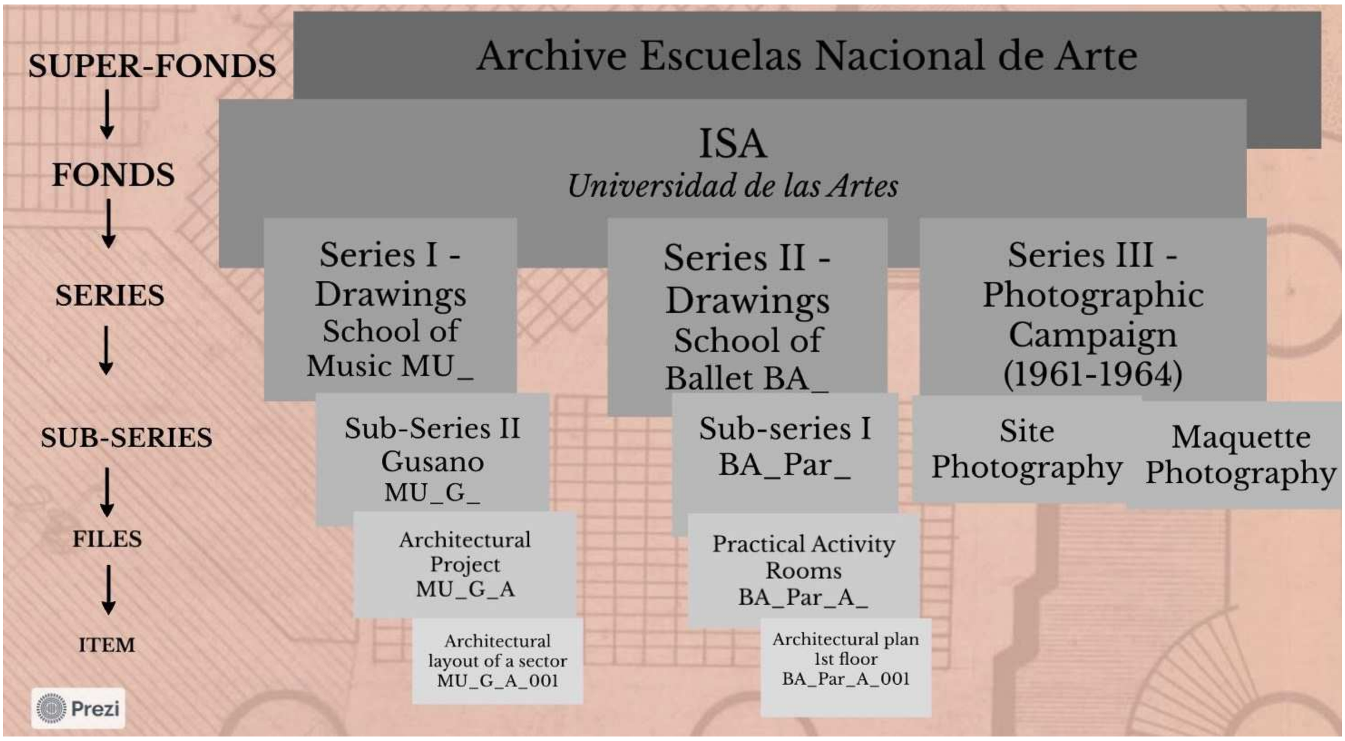


Figure 9 - The hierarchical structure of the Escuelas Nacional de Arte archive.

[6] See R. Ramella, *Il documento*, in M.B. Bertini, V. Petrilli (edited by), *I custodi della memoria. L'edilizia archivistica italiana statale del XX secolo*, Biblioteca di Architettura, Maggioli editore, 2014, p. 46.
[7] MIBAC, Archive Authority of Piemonte and Valley d'Aosta Regions, D. Robotti (edited by), *Archivi storici degli enti pubblici riordinamento e inventariazione, guida per gli archivisti incaricati*, Turin, July 2005, revised in 2012, p. 14.
[8] In this regard, some working hypotheses are specified in paragraph 1.1.5 1.1.5 Reorganization of SERIES I, DRAWINGS - SCHOOL OF MUSIC (1961-1965).

1.1.4 Reorganization Methodology

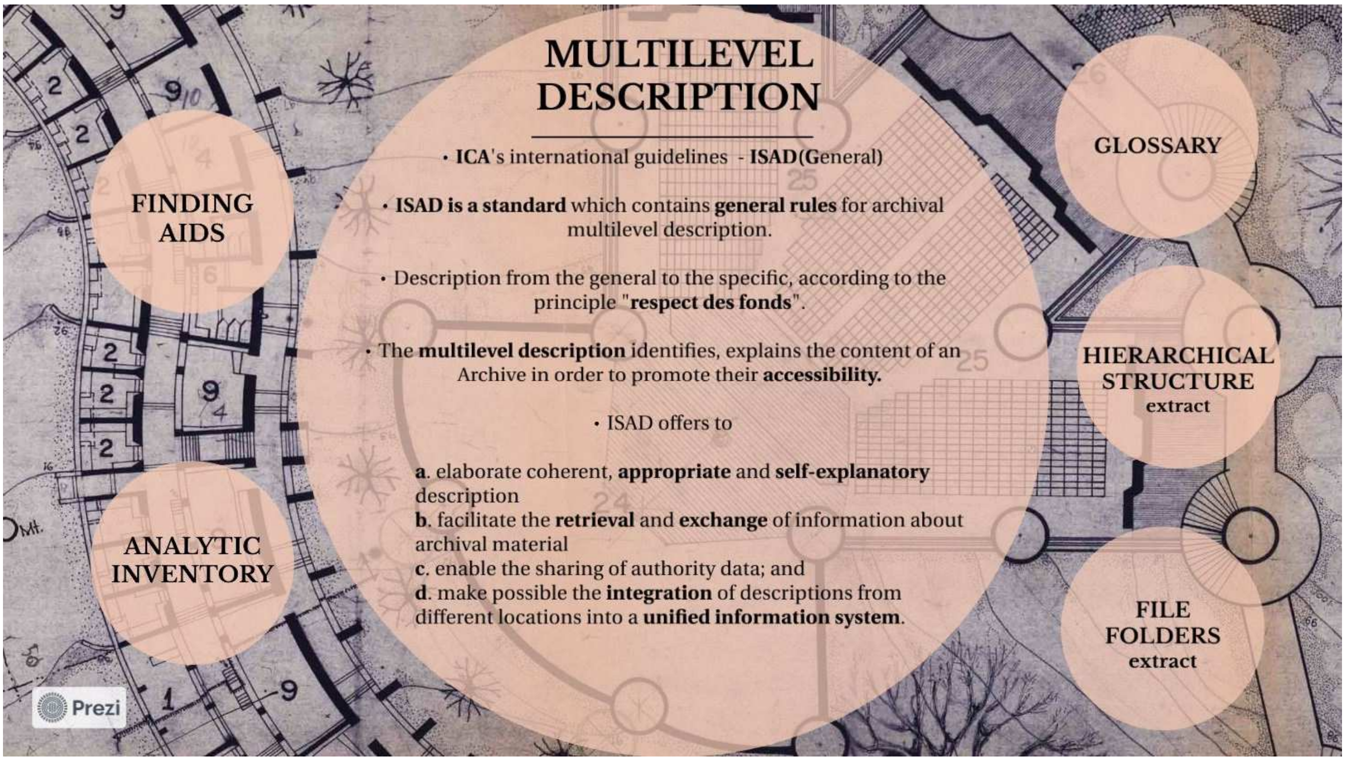


Figure 10 - Outline of the reorganization methodology adopted.

Given the large amount of the materials included in the *Escuelas Nacional de Arte Archive*, the reorganization activities were divided into different stages. As mentioned, the Archive encompasses documents collected at different times by different persons, that were not always able to keep their original links to other documents or institutions. This chaotic situation brought to the first step of the reorganization, which consisted of the grouping of chronologically subdivided *series*. In particular, this task was performed on ISA's digital documents concerning the School of Music. "Series I" - named "Drawings - School of Music (1961-1965)" - thus collects the original blueprints drawn by Vittorio Garatti between 1961 and 1965.

The criterion leading the reorganization of the superfonds is regulated by the *ISAD(G)* archival description standards, which are defined by the International Council on Archives (ICA), an international body for the effective management, conservation, maintenance, and use of the archival heritage of the world.

This technique is called *multilevel description* and can be applied independently from the nature, type, or medium of the document or the file size. It allows to *"elaborate coherent, appropriate and self-explanatory descriptions"*, as well as to *"facilitate the recovery and the sharing of archival information"*[9].

[9] Retrieved from http://media.regesta.com/dm_0/ANAI/anaiCms/ANAI/000/0111/ANAI.000.0111.0002.pdf , p. 2, (English version: https://www.ica.org/en/search/site/isad) - ISAD(G), *General International Standard Archival Description*, second edition, p. 12 et seq.

The introduction to the *ISAD(G) Standards* states that: *"the purpose of archival records is to identify and illustrate the context and content of archival records in order to promote their accessibility. This is achieved by creating accurate and appropriate representations and organizing them according to predetermined models"*[10].
The archival description is hierarchically organized and provides different detail levels, proceeding from general to particular, according to an acknowledged and shared principle descending from the theory of the *respect des fonds*. The aim is to identify for each unit of description the right level within the Archive order.

The following glossary is intended to facilitate the understanding of the specific terminology used during the reorganization activity.

Fonds (e.g., *ISA*)
"The whole of the records, regardless of form or medium, organically created and/or accumulated and used by a particular person, family, or corporate body in the course of that creator's activities and functions."
Series (e.g., DRAWINGS - SCHOOL OF MUSIC 1961-1964)
"Documents arranged in accordance with a filing system or maintained as a unit because they result from the same accumulation or filing process, or the same activity; have a particular form; or because of some other relationship arising out of their creation, receipt, or use."
Sub-Series (e.g., *Gusano*)
"The sub-series level, with reference to any further articulations of the series level, may be used with any partition hierarchically depending from a series."
File (e.g., Architectural Project)
"This descriptive level must be assigned to archival or physical units (envelopes, folders, registers, bundles, etc.) part of the document collection or of its series and sub-series, and corresponding to an administrative practice, or to the grouping of different documents into the same container during reorganization". According to ISAD(G), a File is: "An organized unit of documents grouped together either for current use by the creator or in the process of archival arrangement, because they relate to the same subject, activity, or transaction. A file is usually the basic unit within a record series."
Item (e.g., Classrooms & small rooms' layouts)
"The smallest descriptive archival unit (e.g., documents, attachments, etc.)". According to the ISAD(G), an item is: "The smallest intellectually indivisible archival unit, e.g., a letter, memorandum, report, photograph, sound recording," which can be hierarchically connected to the cards of other items."
Other terms used in this work are intended to have a different meaning[11].

[10] Ibidem.
[11] http://www.ica.org, ISAD(G), *General International Standard Archival Description*, ibid., pp. 6-8.

Access

Access or "readability" of an Archive consists of its ease of consultation and in the researcher's ability to make use of materials.

Access Point

"A name, term, keyword, phrase, or code that may be used to search, identify, and locate an archival description."

Archival Description

"The creation of an accurate representation of a unit of description and its component parts, if any, by capturing, analyzing, organizing, and recording information that serves to identify, manage, locate and explain archival materials and the context and records systems which produced it. This term also describes the products of the process."

Arrangement

"The intellectual and physical processes and results of analyzing and organizing documents in accordance with archival principles."

Author (e.g., Designer)

"The individual or corporate body responsible for the intellectual content of a document. Not to be confused with the creators of records."

Collection

"An artificial assemblage of documents accumulated on the basis of some common characteristic without regard to the provenance of those documents. Not to be confused with an archival fond."

Corporate Body

"An organization or group of persons that is identified by a particular name and that acts, or may act, as an entity."

Creator

"The corporate body, family or person that created, accumulated and/or maintained records in the conduct of personal or corporate activity. Not be confused with collector."

Custody

"The responsibility for the care of documents based on their physical possession. Custody does not always include legal ownership or the right to control access to records."

The digital copy of the Schools Archive, which was authorized for use within the *Keeping It Modern* initiative by the *Universidad de las Artes* of Havana, may become responsibility of any of the project's partners, including the Politecnico di Milano and its Foundation.

Document

"Recorded information regardless of medium or characteristics."

Finding Aid

"The broadest term to cover any description or means of reference made or received by an archives service [or by the archivist in charge of reorganizing an Historical Archive] in the course of establishing administrative or intellectual control over archival material."

Form

"A class of documents distinguished on the basis of common physical (e.g., water colour, drawing) and/or intellectual (e.g., diary, journal, daybook, minute book) characteristics of a document."

Formal Title

"A title which appears prominently on or in the archival material being described."

Level of Description

"The position of the unit of description in the hierarchy of the fonds."

Medium

"The physical material, container, and/or carrier in or on which information is recorded (i.e., clay tablet, papyrus, paper, parchment, film, magnetic tape)."

Provenance

"The relationship between records and the organizations or individuals that created, accumulated and/or maintained and used them in the conduct of personal or corporate activity."

Record

"Recorded information in any form or medium, created or received and maintained, by an organization or person in the transaction of business or the conduct of affairs."

Supplied Title

"A title supplied by the archivist for a unit of description which has no formal title," where, in the reorganization of the Schools' Archive, corresponds with the subject."

Title

"A word, phrase, character, or group of characters that names a unit of description."

Unit of Description

"A document or set of documents in any physical form, treated as an entity, and as such, forming the basis of a single description."

1.1.5 Reorganization of SERIES I, DRAWINGS - SCHOOL OF MUSIC (1961-1965)

All documents were collected through duplication, creating a consistent - and yet incomplete - repertoire of (often identical) "copies". Several drawings - probably produced as a support to the designing and construction phase - are missing, and no complementary sets, inventories, or transfer/deletion are to be found. It is thus quite hard to evaluate the extension of the material loss incurred. At the moment, there are no known Cuban institutions who might be in possession of the missing materials, but further investigation might turn out to be fruitful.

Moreover, there are no records concerning the structure originally given to the *Escuelas Nacional de Arte's* documentation by the *MICONS*, nor any information on the standard method to file architectural projects adopted in Cuba at the time. This lack of information made it particularly challenging to reorganize the Schools' Archive according to its original structure (*ex post*).

Reorganization started from the reconstruction of Series I, which includes the scans or paper copies of the blueprints produced between 1961 (start date) and 1965 (end-date). This task was carried out to facilitate a later reorganization based on typology (file).

The presence of numerous identical or similar copies, as well as some of the files' features (the 1960's originals were often ripped, faded, or worn at the borders, and scans were sometimes hard to read) - contributed to slowing down the systematic examination of the documents. As previously stated, the filing process's main objective was to organize Series I and make it available to current and future research. The implemented table had to contain all possible data connected with any relevant item to fulfill this purpose. The final product of such operations is the analytic inventory[12].

The inventory, compiled at the end of the reorganization process, can be used in several different ways. Firstly, allowing to navigate the documentation through keyword search, it provides researchers quick access to the Archive and to documents' inherent or extrinsic information. At the same time, however, this tool guarantees the safeguard of the intended order of the units of the description as well as of the related file folders (as detailed below) containing the digital drawings. Indeed, the inventory *"represents far more than a simple list of ordered documents. It may be considered the essential result of the reorganization process"*[13], allowing the archivist to share the knowledge acquired in its most content-oriented form. The inventory should also be gauged to meet apparently incompatible requirements, such as acting as a plain and simple consultation tool and containing as much and detailed information as possible.

For the purpose of the reorganization of the *Schools' Archive*, three complementary research instruments were created:

- the upside-down tree diagram, which describes the fonds' organization levels;
- the analytic inventory, to catalogue the documents contained in the file folders;
- the files folders themselves.

[12] See *Annex 1A The analytic inventory.*
[13] MIBAC, Archive Authority of Piemonte and Valle d'Aosta Regions, D. Robotti (curated by), cit. p. 21.

1.1.5.1 Diagrams of the Archival Description Levels

"The multi-level organization provided for by ISAD(G) is showcased through the integration of the different description levels into a single, vertical hierarchy, which must be appropriate and/or functional for the standard's purposes"[14]. It must be noted that some levels might result superfluous to the reorganization process. For instance, during the reorganization of Series I, no sub-fonds or file levels were added to Sub-Series II, since it contained the "Structures" drawings. This instrument allows having an immediate overview of the Archive's structure, illustrating the hierarchy underlying the fonds and its parts, as well as the background context. It highlights the relationship between the individual parts and the whole, clarifying the position of the unit of description within the structure of the archive.

ARCHIVE OF THE NATIONAL ART SCHOOLS OF HAVANA (CUBA)[15]
SUPERFONDS

ISA (Universidad de las Artes)
FONDS

DRAWINGS - SCHOOL OF MUSIC (1961-1965)
SERIES I

General Plans
SUB-SERIES I

GENERAL ARCHITECTURAL PLAN
FILE

GENERAL ELECTRICAL PLAN
FILE

GENERAL HYDRAULIC PLAN
FILE

Structures
SUB-SERIES II

Gusano
SUB-SERIES III

ARCHITECTURAL
FILE

000
ITEM

ELECTRICAL
FILE

000
ITEM

CARPENTRY
FILE

000
ITEM

TOILETS
FILE

000
ITEM

[14] http://www.ica.org, ISAD(G), *General International Standard Archival Description*, second edition, 18 March 2000, p. 48.
[15] The diagram illustrates the structure given to the superfonds at the end of the preliminary examination, and it refers to the inventorying system. However, only Series I has been completely reorganized and described.

FURNISHING
FILE
000
ITEM

Gusanito
SUB-SERIES IV
Architectural Project
FILE
000
ITEM
Electrical Project
FILE
000
ITEM
Carpentry
FILE
000
ITEM

Symphonic Theatre
SUB-SERIES V
Architectural Project
FILE

Chamber Theatre
SUB-SERIES VI
Architectural Project
FILE

DRAWINGS - SCHOOL OF BALLET (1961-1965)
SERIES II

Practical Activity Rooms
SUB-SERIES I

Lecture Rooms
SUB-SERIES II

Library
SUB-SERIES III

Dean's Office
SUB-SERIES IV

SITE PHOTOGRAPHY
SERIES III

CORRESPONDENCE
SERIES IV

ARTICLES-ESSAYS-BOOKS-VIDEOS-CONFERENCES
FONDS

LOOMIS ARCHIVE
FONDS

PHOTOGRAPHY
FONDS

LETTERS, DOCUMENTS, CONTRACTS
FONDS

INTERNATIONAL PROJECTS
FONDS

EXHIBITIONS, CONFERENCES, LECTURES
FONDS

CUBANACAN COUNTRY CLUB
FONDS

ACOSTA - FOSTER
FONDS

OTHER SCHOOLS
FONDS

1.1.5.2 Analytic Inventory

The analytic inventory, organized as a table, dedicates an item for each archived drawing providing its particulars. The document was drafted according to ISAD(G) rules concerning the description areas[16]. The inventory was written in Italian, with the only exception of the main titles of the drawings, which, according to the drafting criteria below, kept their original language.

The grid allows for double-entry: the upper row lists a series of entries to facilitate the identification and codification of the information contained in the drawings. The archive marking assigned during the reorganization process is contextually provided. The extract below illustrates the adopted criterium. Each file is introduced by a code, which must be used to identify and easily locate its descriptive level in the tree diagram (see 1.1.5 Reorganization of SERIES I, DRAWINGS - SCHOOL OF MUSIC).

Each item includes the following entries, which must be compiled according to the data retrievable from the drawing itself (except for Marking, which, as already specified, was assigned during the reorganization process).

[16] The descriptors can be categorized into seven groups: IDENTIFICATION, CONTEXT INFORMATION, CONTENT AND STRUCTURE INFORMATION, ACCESS AND USAGE CONDITIONS, LINKED DOCUMENTATION INFORMATION, ANNOTATIONS, DESCRIPTION CONTROL. At the moment, some of the categories contain no information. For instance, the Linked Documentation Information group will become viable in the future, when the archive will be linked to other collections - like those containing the materials produced by Architect Roberto Gottardi or by Architect Vittorio Garatti.

Marking

The code is composed of meaningful acronyms in multi-level succession:

MU_(School of Music) **PLG_**(General Plans) **A_**(Architectural Project) **001** (document's unique progressive number).

LEVEL 4 ITEMS.

MU_(School of Music) **PLG_** (General Plans) **E_** (Electrical System) **001** (document's unique progressive number).

LEVEL 4 ITEMS.

MU_(School of Music) **PLG_** (General Plans) **Id_** Hydraulic System) **001** (document's unique progressive number).

LEVEL 3 ITEMS.

MU_(School of Music) **S_** (Structures) **001** (document's unique progressive number).

LEVEL 32 ITEMS.

MU_(School of Music) **G_** (Gusano) **A_** (Architectural Project) **001** (document's unique progressive number).

LEVEL 12 ITEMS.

MU_(School of Music) **G_** (Gusano) **E_** (Electrical System) **000** (document's unique progressive number).

LEVEL 31 ITEMS.

MU_(School of Music) **G_** (Gusano) **Ca_** (Carpentry) **001** (document's unique progressive number).

LEVEL 6 ITEMS.

MU_(School of Music) **G_** (Gusano) **Ba_** (Furnishing) **001** (document's unique progressive number).

LEVEL 1 ITEMS.

MU_(School of Music) **G_** (Gusano) **Ar_** (Furnishing) **001** (document's unique progressive number).

LEVEL 2 ITEMS.

MU_(School of Music) **Gu_** (Gusanito) **A_** (Architectural Project) **000** (document's unique progressive number).

LEVEL 21 ITEMS.

MU_(School of Music) **Gu_** (Gusanito) **E_** (Electrical System) **001** (document's unique progressive number).

LEVEL 4 ITEMS.

MU_(School of Music) **Gu_** (Gusanito) **Ca_** (Carpentry) **001** (document's unique progressive number).

LEVEL 1 ITEMS.

MU_(School of Music) **TECA_** (Chamber Theatre) **A_** (Architectural Project) **001** (document's unique progressive number).

LEVEL 11 ITEMS.

MU_(School of Music) **TESI_** (Symphonic Theatre) **A_** (Architectural Project) **001** (document's unique progressive number).

LEVEL 17 ITEMS.

Subject

It is a summary of the contents of the drawing. It also acts as a search access key.

Title (Title Block)

Shows all the information concerning the plate's contents, which might be found in the title block (if present) or on the drawing's margins. This entry was kept in its original language (Spanish).

Author/Illustrator

List of all the people who took part in creating and drafting the drawing, i.e., the designer, the illustrator, the reviser, as well as any other data concerning the acceptance and conformity operations.

Most drawings are signed with the Author's initials: V.G. [Vittorio Garatti], F. P. Purõn, E. C. Cañizares, G. R. Guillermo Romas, R.G. Guerra, A.B. Rabelo, M. L. Lafuente, and others. T.L., J.R., T.R.D., M.E.P., J.P., H.N., and L.P. are still to be attributed.

Scale

Provides information regarding the scale of representation as indicated on the drawing (sometimes according to the US system, sometimes according to the metrical system).

Notes

The column contains further relevant information that does not have a dedicated entry. It is hierarchically organized:

1. FILING STAMP Most scanned drawings show the 66#079 stamp. However, some files display a second, smaller version of the same stamp (66-079). Only one drawing bears the stamp No. 67#079, and a few others had the number 66-033 handwritten on them. These codes may be the IDs used by the *MICONS* Archive.
2. CONSERVATION OF PAPER OR HELIOGRAPHIC ORIGINALS. Any signs of tearing, scraping, or wearing out on the original drawings (from which the digital copies derive) have been reported, as they often concurred to the information loss. Some information might be recovered by locating the original paper plate (as it happened with one drawing with cropped-out margins).
3. SUBSEQUENT HANDWRITTEN ADDITIONS. All handwritten additions were also recorded, even attempting to identify their author (in most cases, Vittorio Garatti).
4. CODE. An alphanumeric code is often visible at the bottom of the original drawing. The code always starts with the letter R (as register) followed by a series of numbers, and it may refer to the file's original position in the *MICONS* Archive.
5. MISCELLANEOUS. It includes any other considerations noted while examining the drawings and not included in any of the above categories (e.g., the presence of a key instead of a title block).

Information provided in the NOTES section has been organized in order to make the reader aware that any non-informative entry indicates missing data.

1.1.5.3 Drafting Criteria and Abbreviations

In order to regulate the transcription, the Title (Title Block), Author/Illustrator, Scale, and Date boxes were drafted following a set of criteria. Usage of *italics* indicates a philological transcription of the original text. When the drawings show signs of scraping, are hard to read, or missing specific information (title, author, scale, illustrator, etc.), the following conventions were used:

(...) illegible;

[] illegible, yet inferred thanks to recognizable portions of the composing letters;

-- missing information (expected but not included), e.g., several drawings show slots that are specifically dedicated to the name of the designer, illustrator, or reviser, that are not compiled; Where illegible texts were only partially inferable, the transcription includes partial reconstructions recorded as, e.g., (… [ñizares]).

Any explanatory annotations added by the person in charge of reorganization are recorded in normal character.

The abbreviations used to indicate the presence of entries that were never compiled in the originals are:

- s.a. no author
- s.d. no date
- s.c. no title block
- s.t. no title
- s.s. no scale

V.G. stands for Vittorio Garatti.

The following figures provide an example of the outcome of the reorganization work. The table (Figure 11), illustrates the previously mentioned descriptive levels, which are compiled retrieving information directly from the corresponding drawing (the first raw refers to Figure 12). Indeed, for the purposes of consulting the Archive, the two research instruments are intended as complementary of each other.

ISA ARCHIVE FONDS						
DRAWINGS SCHOOL OF MUSIC SERIES I						
GENERAL PLANS SUB-SERIES I						
ARCHITECTURAL PROJECT (MU_PLG_A_000) FILE						
MARKING ITEM	SUBJECT	TITLE (Title Block)	AUTHOR/ ILLUSTRATOR	ORIGINAL SCALE	DATE	NOTES
MU_PLG_A_001	General Plan Architectural	*ESCUELA NACIONAL DE ARTE* *ESCUELA DE MUSICA* *PLANTA GENERAL*	[ARQ. VITTORIO GARATTI]	Metrical System	s.d.	Bears filing stamp No. 66-079. Copied from original with damaged lateral margins, and lower margin cropped when scanned. Subsequent handwritten additions on the drawing (V.G.) Added in long hand: *ROLLO* [register] *C6/034/034.* *LEYENDA* [key] showing at the bottom of the drawing.
MU_PLG_A_002	General Plan Architectural	*ESCUELA NACIONAL DE ARTE* *MUSICA* *PLANTA GENERAL.*	s.a.	Metrical System	s.d.	Bears filing stamp No. 66/079. Drawing with cropped margins. Subsequent handwritten addition: *sc 1:20.* *LEYENDA* [key] showing in the upper section of the right margin.
MU_PLG_A_003	General Plan architectural	*ESCUELA NACIONAL DE ARTE* *ESCUELA DE MUSICA* [PLANTA GENERAL]	[Arq. Vittorio Garatti]	Metrical System	s.d.	Negative drawing of MU_PLG_A_002. Orientation recorded.

Figure 11 - Extract from the analytic inventory.

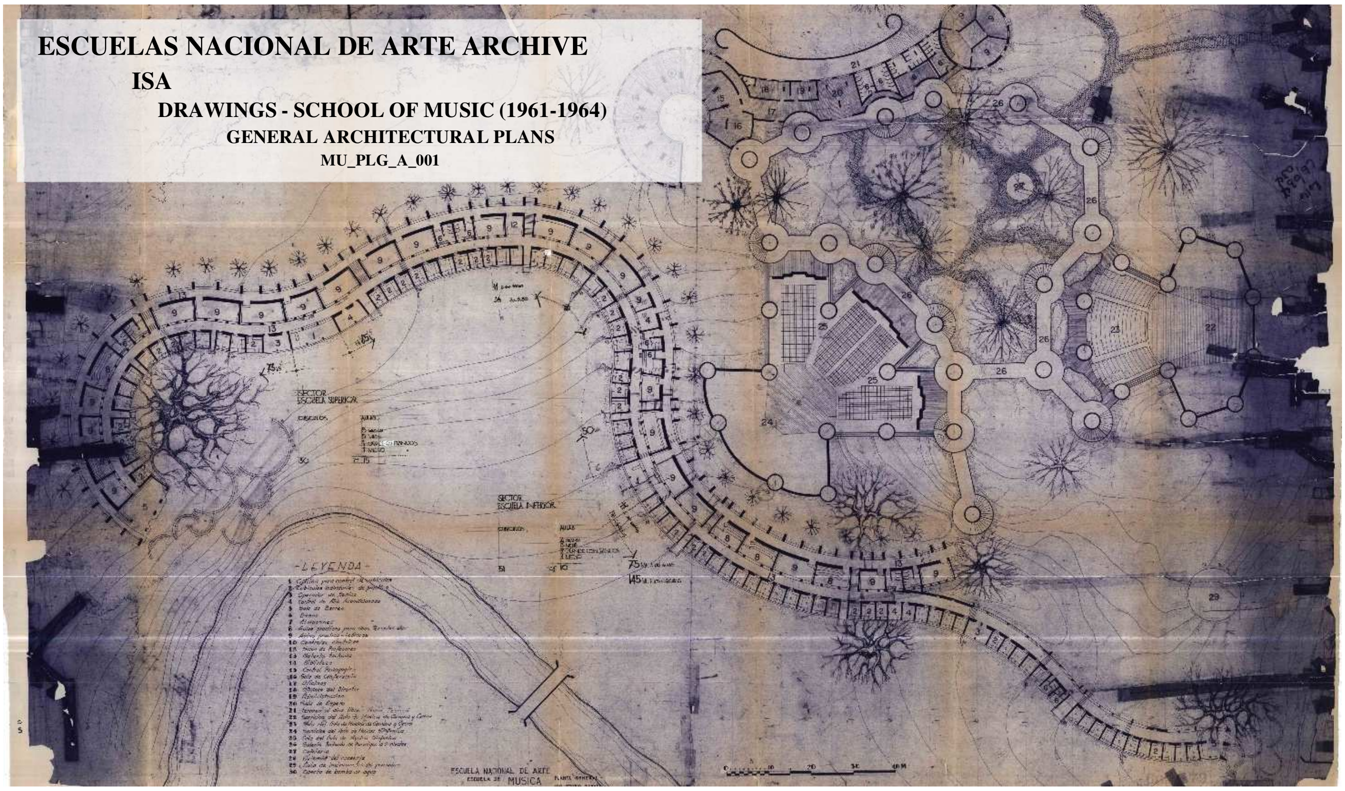


Figure 12 - Scanned drawing (MU_PLG_A_001) with specifications regarding the descriptive levels and unique marking.

1.1.5.4 File Folders

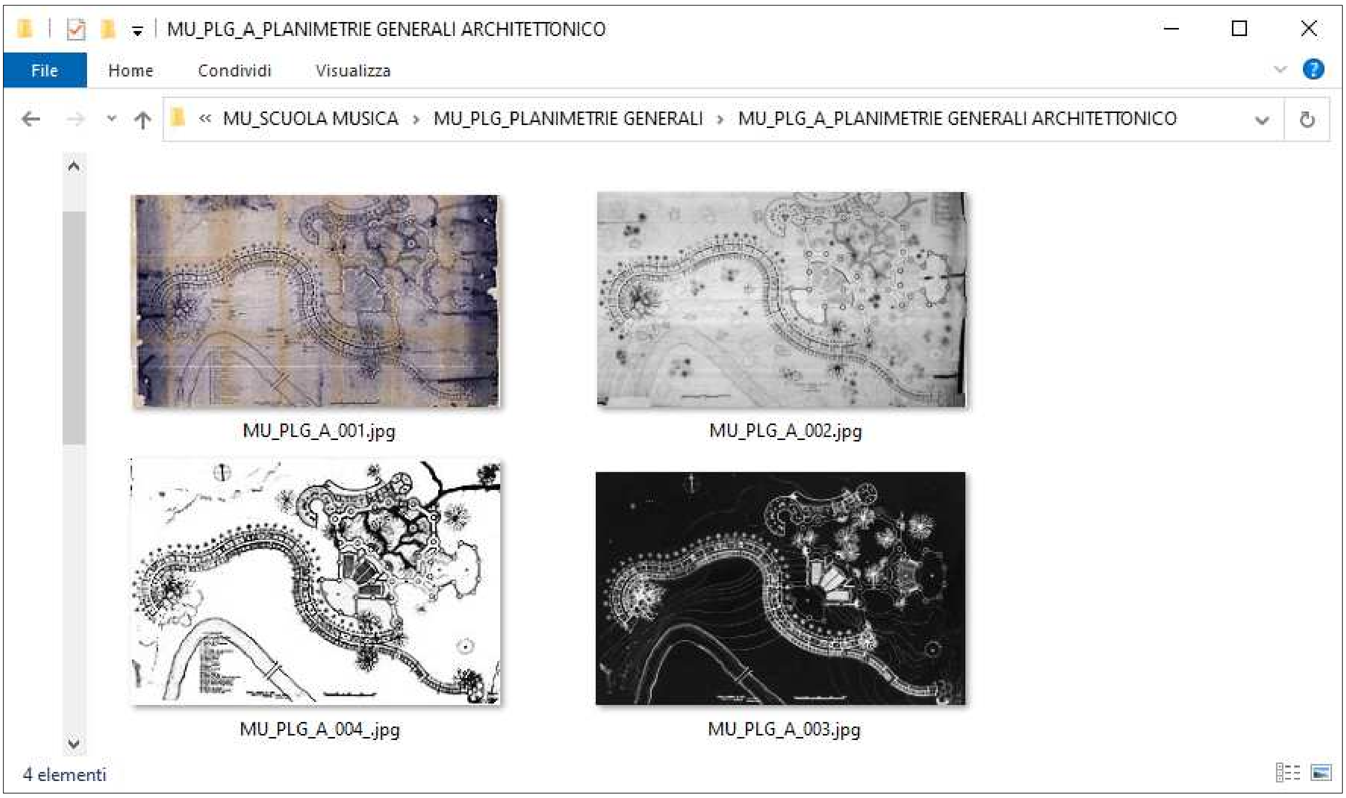


Figure 13 - General Architectural Project plans of the School of Music.

According to the structure defined in the upside-down descriptive tree diagram and the analytic inventory, all documents included in Series I are organized into folders. Each scan of an original is organized inside the folders following the archival description, hierarchically ordered from general to particular. Nonetheless, the marking of the drawing unambiguously matches it to the analytic inventory.

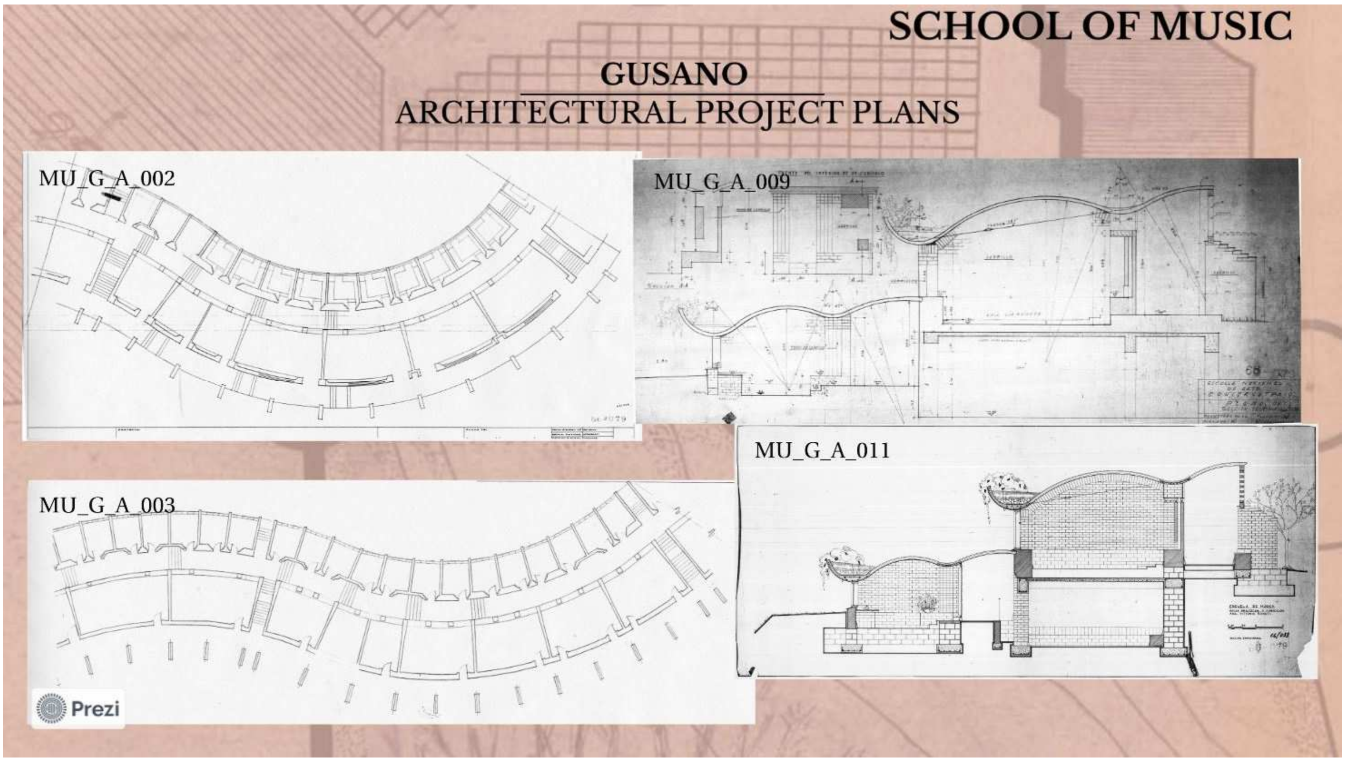


Figure 14 - Architectural plans for the Gusano (School of Music).

1.1.6 Final Observations

As anticipated, the National Art Schools site is stratified and gathers a plurality of stories concerning its very architectures and, in broader terms, the culture and the architectural production of a particular region.

In order to properly study and come to know the history permeating this place, it is necessary to access existing information and, sometimes, to analyze documents referring to a wide range of different topics firsthand.

The proposed superfonds includes a valuable and rather consistent amount of records, produced over a span of sixty years, and documenting the Schools' from their construction until today. Such data might prove essential to researches in different fields: from studies regarding the site's architectural features to investigations concerning the design and construction process, or even the social, financial, sociological, and cultural contexts behind Cuban arts and music production. Indeed, there are several other stories yet to be told.

The School superfonds can contribute to a plurality of scopes. It constitutes a precious resource for any researcher who might need to acquire an in-depth understanding of these architectures and their surroundings.

A further implementation of the superfonds (i.e., investigating, examining, and organizing any other series and fonds) would contribute to generate an inextinguishable academic resource of international relevance.

The first outcome might concern the Schools. Indeed, the analysis and reorganization of the drawings of the School of Music (Series I) led to a number of findings regarding the materials' metadata. One of the most interesting discoveries is understanding the technical relations connecting some of the drawings, especially from a chronological point of view. However, the meaning of the numbers, codes, and entries recorded in the drawings' title block box is yet to be fully understood and remains mostly unknown. Perhaps, through further research, it will be possible to gain deeper insight into them and turn them into the missing piece linking the documentary structures observed and described.

Within the *Keeping It Modern* initiative, further materials were produced, increasing the overall knowledge of the Schools complex. Such documentation may also be organized and added to the superfonds *Escuelas Nacional de las Artes*.

1.2 As-built drawings of the Schools

The acquisition of reliable drawings of the Schools also represented a primary issue to address. Indeed, in order to carry out all the activities required to develop an effective Conservation and Management Plan, it was crucial to obtain accurate representations of the five buildings in their current configuration.

As previously remarked (1.1.2 Composition of Archived Material), thanks to the possibility to access the materials stored in the ISA archive, we were able to acquire the original blueprints of the Schools as designed by Porro, Garatti, and Gottardi in the '60s. Although extremely valuable, such drawings are not fully representative of the current conditions of the buildings. As often happens, what is drawn on paper does not exactly correspond with what is actually built. During construction problems might emerge, causing changes to the original plans, which - most of the time - are not reported on blueprints causing the mentioned discrepancies.

Considering the construction process of the National Schools of Art, this aspect was particularly impacting in our case. The large quantity and heterogeneity of actors working on the building site and making decisions resulted in a multitude of minor changes that can only be read on built evidence. In fact, the social and political context that led to the National Art Schools' ideology greatly influenced the construction phase. That spirit of equality, freedom, and inclusion spread to the design and the actual realization of this utopian project. Hierarchies were overruled, thus the architects - although in command - were open to suggestions and ideas coming from the construction workers, or even from those young architecture students who volunteered to help out. The three architects themselves were rather young when asked to design the Schools and had little experience. On top of everything, the choice of using catalan vaulting as the principal construction system caused further difficulties[17], given that neither the architects nor the masons were in any way accustomed to this specific technique. One of the outcomes of this chaotic situation was the lack of consistency between the 1960's original blueprints and the buildings as we see them today. It should finally be noted that as sixty years have passed since the Schools' inauguration, some transformations became necessary in order to meet the requirements of an evolving educational offer (note that majors taught at ISA went from five to seven, coming to include the *Facultad Arte de los Medios de Comunicación Audiovisual* and the *Facultad de Artes de la Conservación del Patrimonio Cultural*).

However, while being the first to be retrieved, the original blueprints were not the only drawings we were able to locate. Indeed, as will be illustrated in later paragraphs (1.3 Description and general assessment of the state of conservation), several proposals for the completion and restoration of the Schools have been developed. In particular, completion/extension projects were designed for the three schools that were never completed (Music, Ballet and Dramatic Arts), while a restoration intervention regarding the Schools of Modern Dance and Plastic Arts took place between 2000 and 2005. Because of these specific aims, some vector drawings of the Schools were made, starting either from the digitalization of the original blueprints or from the geometric survey.

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[17] Note that, although the original idea was to build the Schools using catalan vaulting, the buildings are actually made (for the most part) of reinforced concrete. Please refer to paragraph 1.3.7 Materials and techniques for further information.

With regards to Garatti's Schools, both kinds of drawings were found. In fact, besides the materials resulting from architect Universo Garcia Lorenzo's survey (which interested all five schools)[18], other drawings were developed by Garatti and his co-workers themselves. In this case, plans and sections result from the digital re-drawing of the original blueprints and their updating on the basis of spot measurements taken on-site. However, neither of the two was considered entirely satisfactory.

In general, the main issues regarding the "digitalization" of the original drawings are related to the following aspects:

- *Low accuracy*: as previously highlighted, when converting designs into reality, it is not unusual to incur slight modifications. Original drawings compared to the as-built show differences both in terms of measures and geometries (minimal divergences in curvatures). Consistent discrepancies regard the internal partitions and overall organization of the School of Music. Indeed, while some of these errors were corrected following on-sight inspections, many others still stand.

  As for geometrical aspects, the three architects' aim to integrate architecture and nature, and the organic shapes they employed to fulfill this purpose made it rather difficult to follow the original designs faithfully. Given the difficulties in controlling the landform and the sinuous unfolding of the buildings, it is not surprising to encounter a few inaccuracies.

  Finally, it should be noted that the complexity of these architectures calls for 3D representations. In fact, 2D drawings are hardly suitable to convey the sense of these spaces efficiently. On the bright side, while not completely accurate, the work carried out by Vittorio Garatti and his team also produced a 3D model of the School of Music in its original configuration (including the parts of the building that were never completed).
- *Stratification of information*: the digital re-drawings in question tend to blend together information coming from the original design, as-built configuration, and possible completion projects. In this sense, when using them as graphic bases, it might be difficult to distinguish between what truly exists and what is only real on paper. In fact, as previously mentioned, such drawings were developed by Vittorio Garatti and his firm as a support for further designs to bring the Schools to completion and use finally. Some versions of the new designs also included additional pavilions to suit better the renewed requirements of the School of Ballet's current educational offer.
- *Poor representation of building and landscape morphology*: when observing the original plans of the buildings, the impression is that they develop on only one level, which, in general terms, is quite accurate but ends up overlooking some important features. This is particularly evident when analyzing the School of Music, where the higher and lower floors are conventionally represented together, in a deceptive refiguration (Figure 15 - top). Indeed, one is led to think that the building is organized on a single story,

[18] EMPROY-2 Arquitectura e Ingenieria, ISA archive.

with a central corridor distributing the spaces. Of course, this is far from true and becomes immediately clear when looking at the cross-section (Figure 15 - bottom). Nonetheless, such kind of drawings are faulty and needed adjustments. Analogous issues were detected in the School of Ballet, where distinctions among different levels were not completely clear. In short, the vertical arrangement of the Schools could not be easily deduced from the original drawings.

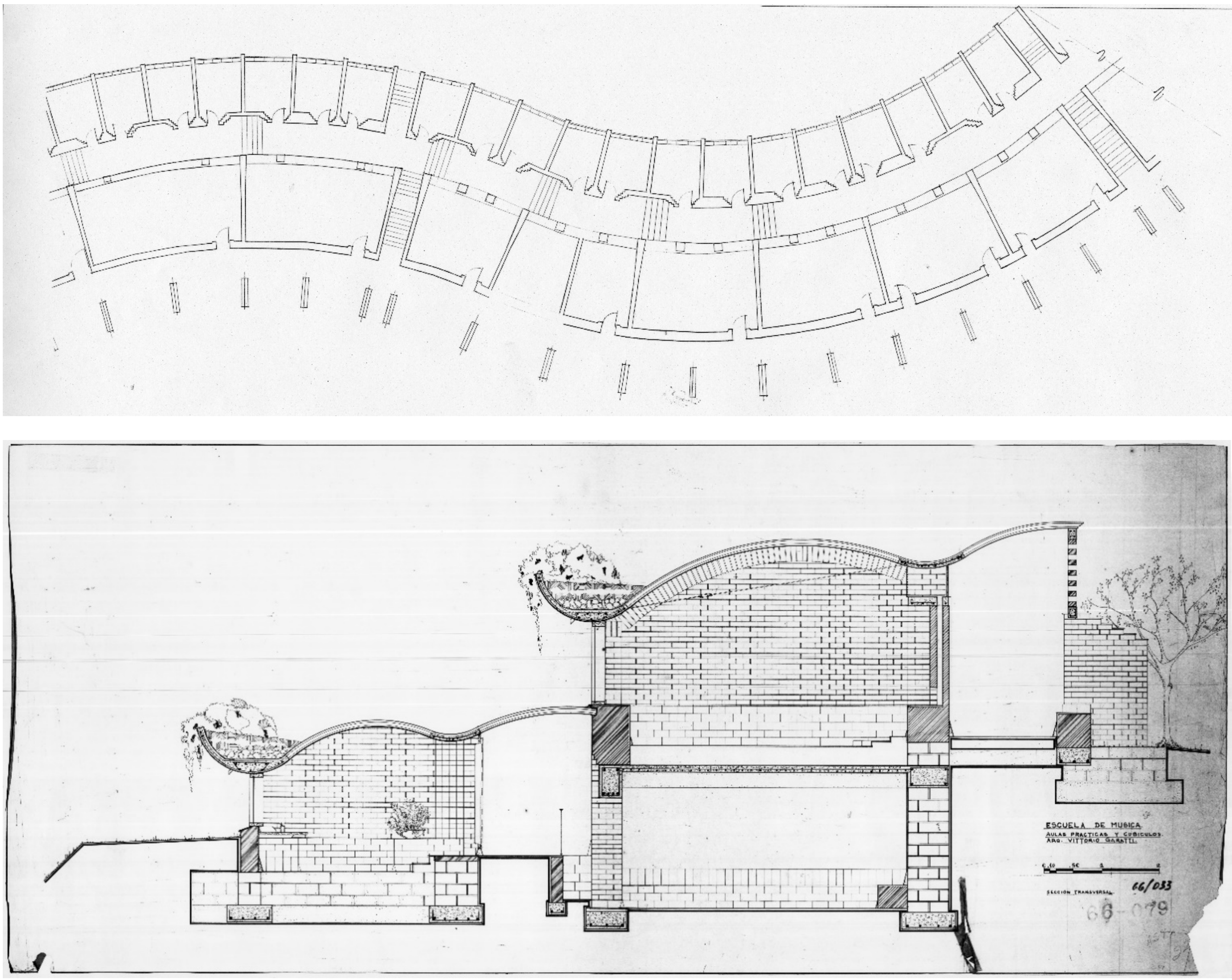

Figure 15 - School of Music: the deceptive plan representation of the Gusano (Archive *Escuelas Nacional de Arte* - MU_G_A_002), compared with the clearer cross section (Archive *Escuelas Nacional de Arte* - MU_G_A_010).

As for the geometric survey conducted by architect Universo Garcia Lorenzo, there were other issues to address. Although the drawings he produced are the ones that are currently used to plan maintenance interventions and manage the Schools, some inconsistencies emerged during on-site verifications.

Indeed, the assessment of the accuracy of the available drawings was one of the first tasks to accomplish in order to proceed to further actions. In this regard, the laser scanner survey carried out in June 2019[19] proved essential to highlight a few criticalities. As a matter of fact, the survey outcome did not exactly overlap with the drawings provided by Universo Garcia Lorenzo in 2007. Imprecisions were found both on a local scale (single building) and on a territorial scale (school's campus).

As for the former matter, measures do not coincide, which is especially evident when considering pillars and internal partitions (Figure 16). On the other hand, the schools' general plan's problem generates from erroneous rotations (Figure 17).

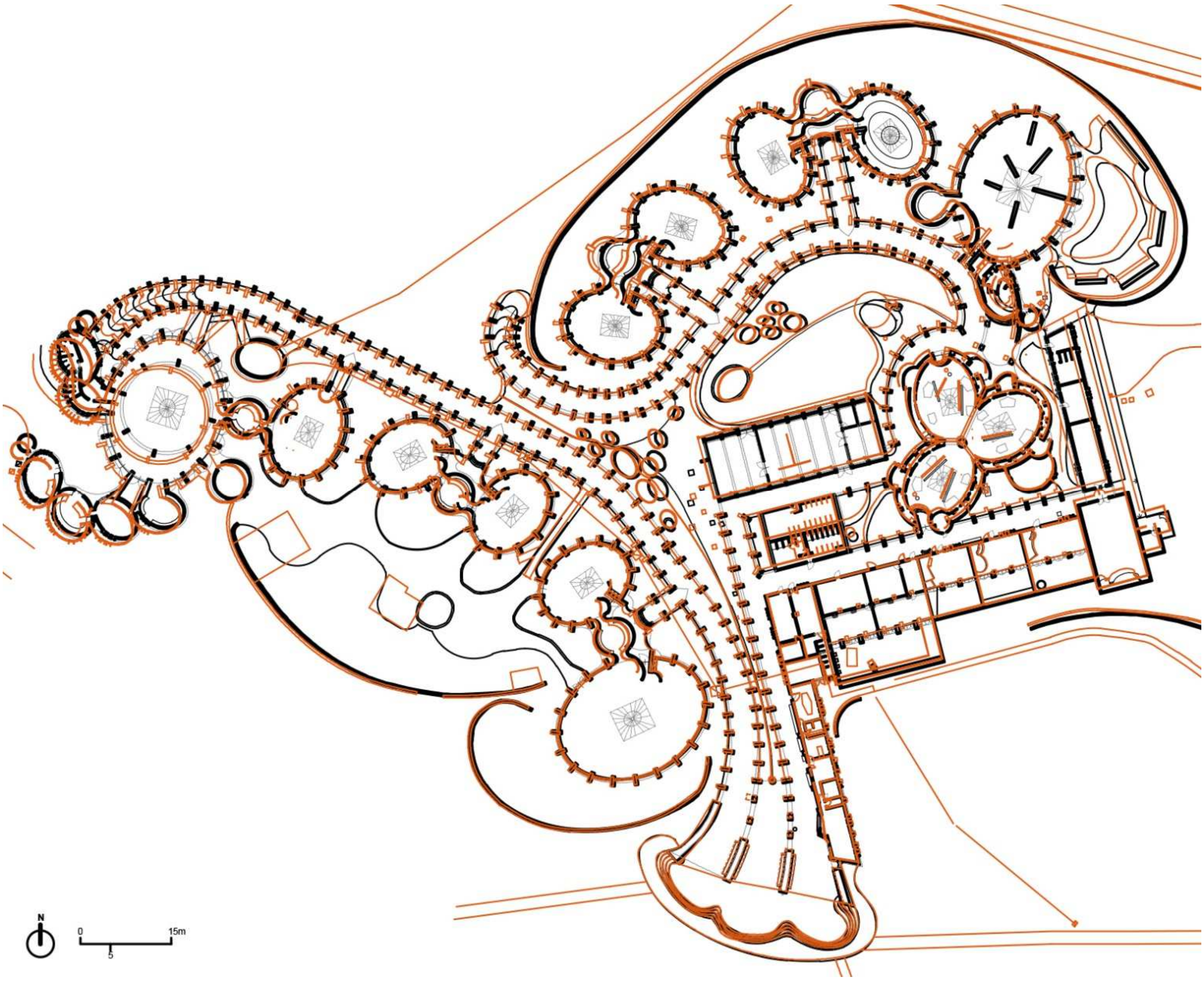

Figure 16 - Superimposition of the CAD drawing of the School of Plastic Arts derived from Universo's survey in orange (ISA archive), and the one developed as a support for the Conservation and Management Plan (black).

[19] See *Annex 2B GNSS and Laser Scanner Survey*, *5.1.2.2 The three-dimensional data as support to the management system* and *5.1.2.5 Update and correction of large- and small-scale vectorial drawing*s.

When superimposing the Plan Rector's vectorial drawing to satellite maps retrieved from Google or Bing, it is possible to notice consistent discrepancies in the five buildings' positioning (Figure 18). Although satellite maps naturally contain errors resulting from geometric distortion, the deviation emerging from the overlapping seems to be related to inaccuracies in the geometric survey mostly. The reasons that led to these discrepancies can be multiple. Certainly, the individual survey activities were not organized as a single documentation project, which led to inaccuracies in the single buildings' general positioning. In addition, considering the morphology of the area and the presence of vegetation, the topographic network created during the individual survey activities did not fully cover all the detected sections. Therefore, the network has more weak points in which it can rotate, thus leading to metric errors. This also applies to the building's level of detail. Given the particular conformation of the structures, the single topographical network has many pivot points without effective control. The result is a partial correctness of some rooms or sectors of the building, which, when joined in a single planimetry, return geometrically inaccurate and unverifiable data.

However, it should be noted that the vectorial file we acquired did not directly come from architect Universo Garcia Lorenzo, but from other sources (ISA archive, ISA's maintenance technician). This means that the drawings were possibly retouched and partly modified, as proven by the large number and variety of layers contained in the AutoCAD files. As a result, the drawings are hardly intelligible or manageable. Moreover, we were only able to collect some of the materials delivered by Universo in 2007, as many sections are missing and, most importantly, there is no technical report describing the operations conducted during the survey.

Figure 17 - Superimposition of the vectorial drawing of the School of Ballet derived from Universo's survey in orange (ISA archive), and the one developed as a support for the Conservation and Management Plan (black).

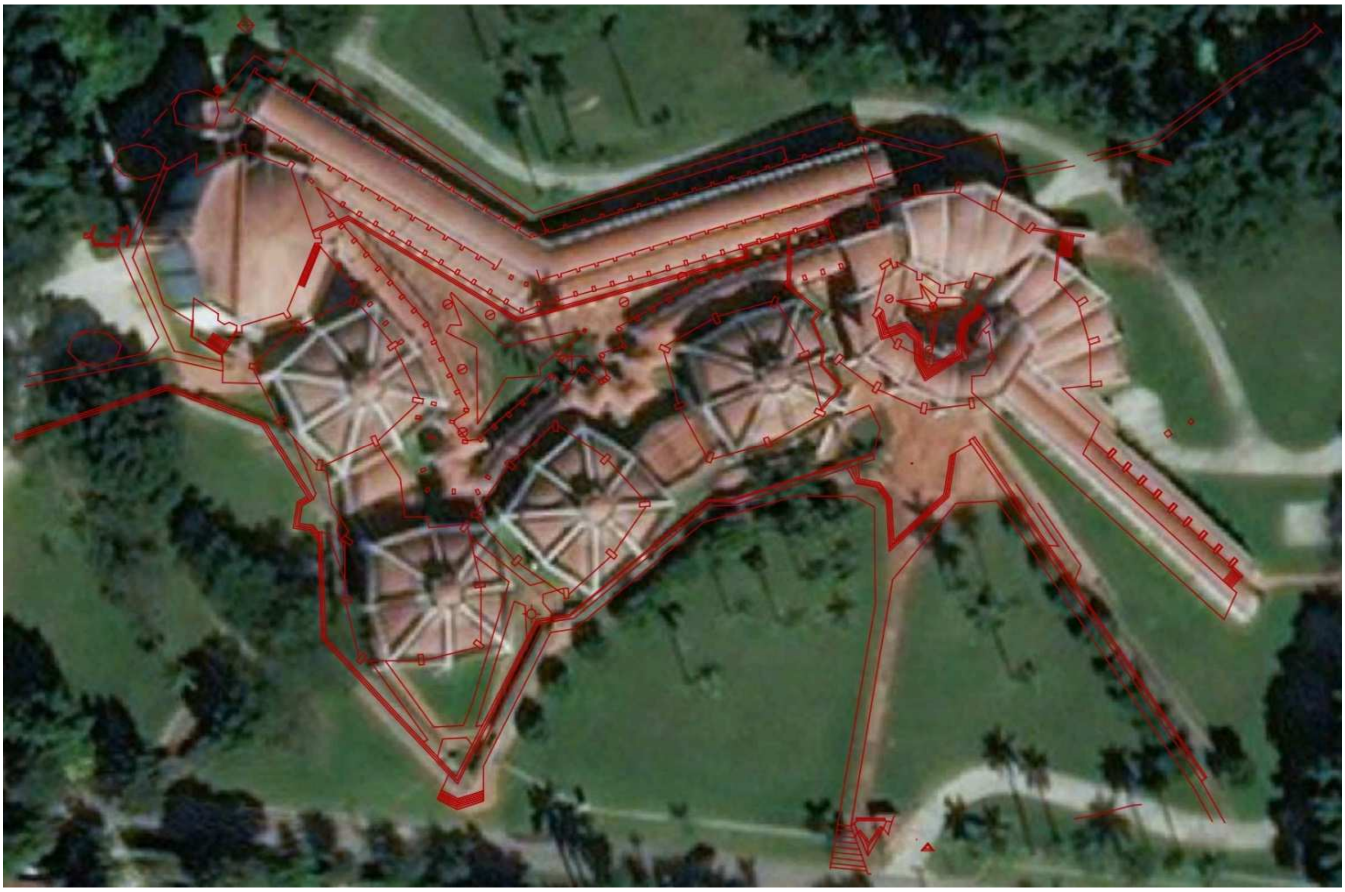

Figure 18 - Superimposition of the Plan Rector in orange (ISA archive) on the satellite images retrieved from Bing.

To overcome this set of problems, the five schools' plans were re-drawn, adjusting Universo's plans to the data collected in the most recent laser scanner survey[20]. Since the latter did not concern all buildings at an architectural level, the 2007 drawing has been essential to provide a solid base for the GIS tool[21]. However, general metric information and reference points for the correct positioning of the buildings within the campus were collected by means of a territorial survey. The map of the schools' campus was also updated accordingly.

Furthermore, starting from the point cloud, it has been possible to create a 3D model of some of the School of Ballet pavilions. In particular, due to the specific aims of action 2[22], the modeling concerned the choreography theater domes and of one of the three dance pavilions. Beyond providing a more faithful and clear representation, 3D models were essential to conduct Finite Element Analysis (FEA) and hence to assess the structural conditions of the considered pavilions.

Finally, the ISA also provided us with drawings of the auxiliary buildings comprehended in the campus area. Some of these drawings could only be found on paper support and have thus been digitalized in order to be included in the GIS tool. The reliability of such drawings was also verified by means of on-site measurements and observations.

[20] A thorough description of surveying operation can be found in *5.1.2.5 Update and correction of large- and small-scale vectorial drawing*s.
[21] See *5.1 Designing a management and decision supporting tool.*
[22] See *Action 2 Conservation and restoration activities.*

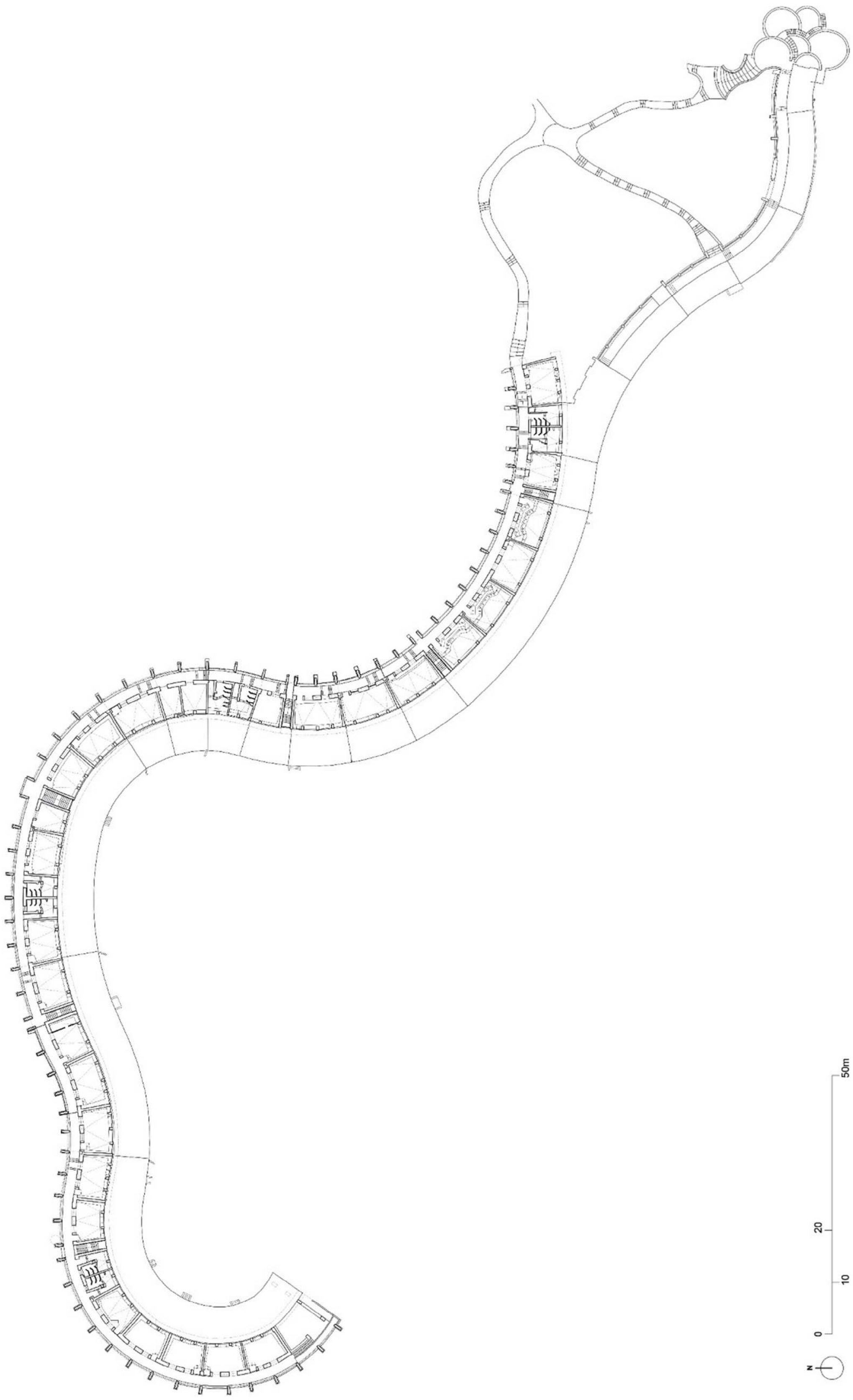

Figure 19 - As-built drawing of the School of Music resulting from the updating and rectification of previous drawings.

1.3 Description and general assessment of the state of conservation

Figure 20 - Aerial view of the School of Ballet. Photo by Vittorio Garatti, ISA archive.

1.3.1 School of Ballet

Year of construction: 1961-64

Architect: Vittorio Garatti

Original use: School of Ballet

Current use: dismissed

State of completion: mostly completed

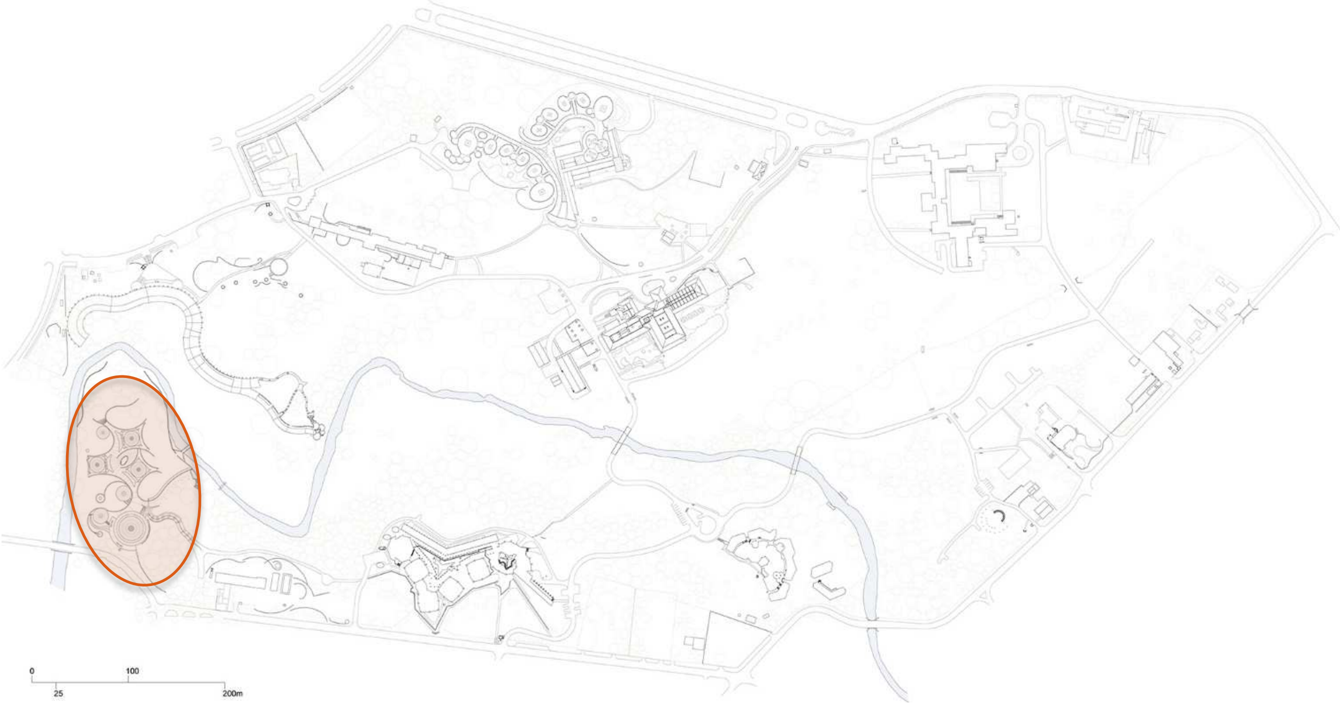

Figure 21 - Location within the Schools' campus.

"...For the School of Ballet, we found a small valley from which the approach was from above: that permitted to almost hide it. At first I thought of burying the School of Ballet, but that way proved too expensive. (....) The first sensation looking at the terrain was to descend towards the opening below, describing an S with open arms like a child playing airplane. This S became the spine structure for the design. (...) I wanted the School to be extremely dynamic, in part as a response to the dynamism of the dance. Not only because it was a ballet school, but because it was to be a vision of our future (....). I imagined that in the evening would gather up to the roof and stroll, study, exercise or dance at the sun set. The School of Ballet was to be something which could be used, experienced throughout..."[23].

[23] Vittorio Garatti commenting on the School of Ballet (from Loomis 1999).

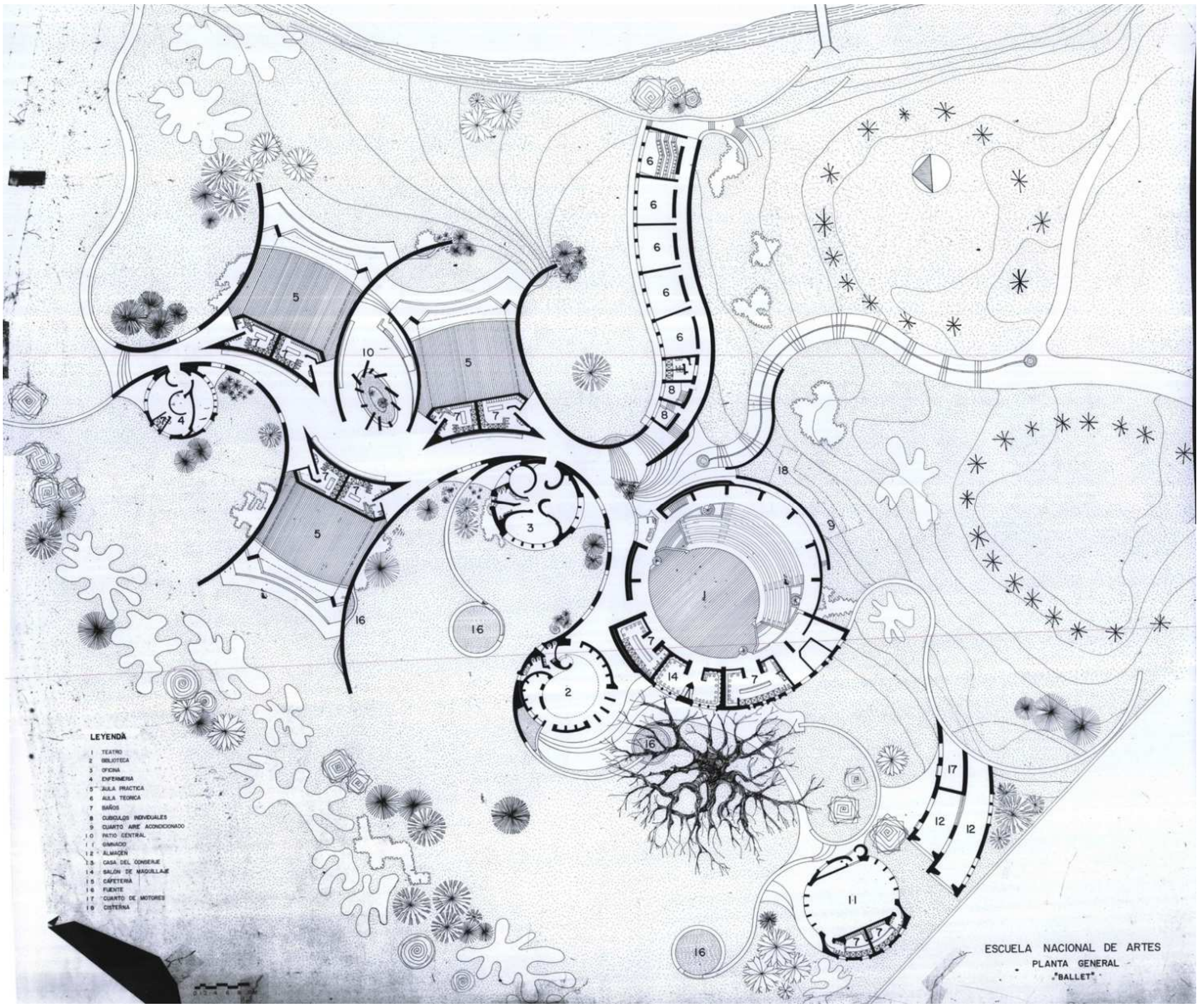

Figure 22 - Original Masterplan (ISA archive).

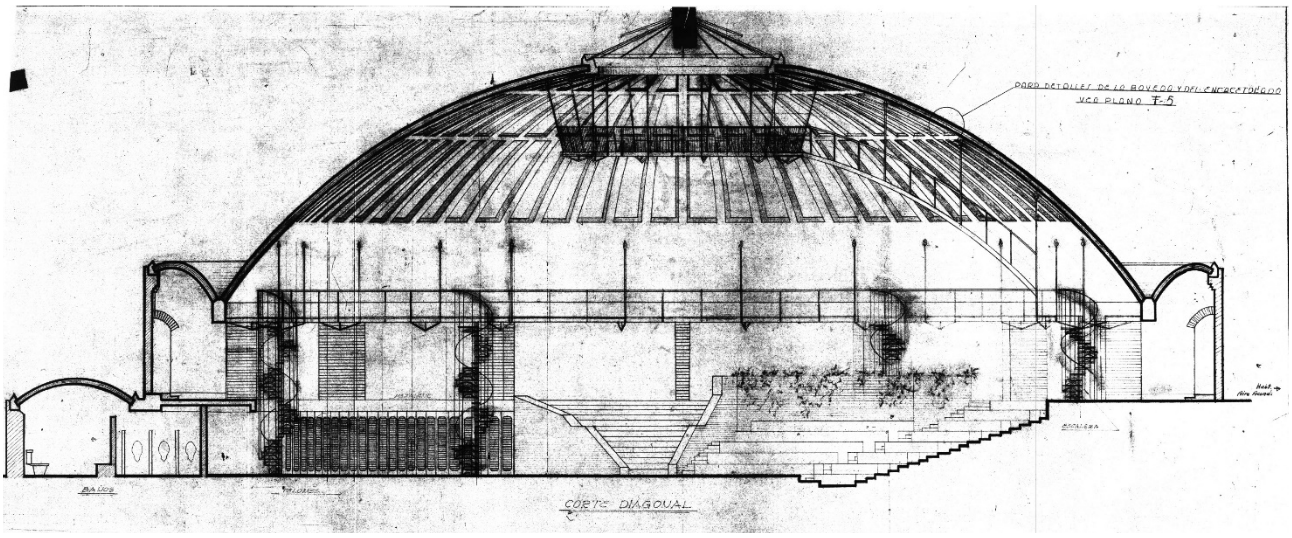

Figure 23 - Choreography Theater main cross-section (ISA archive).

The school of Ballet was designed to host higher-level education courses, and it was built to hold Classic dance classes. The building lies on a plot of approximately 2.8 hectares, just South of the School of Music, across the Rio Quibú, nestled into a lushly vegetated ravine at its bend. The construction is surrounded by tall trees, among which the "*Algarrobo*" stands out, and its umbrella-shaped foliage becomes an integral part of the architecture. The architectural design and its perfect integration with the surrounding environment create an effect of the constant discovery of the spaces while gradually approaching them, as if at each step the school emerged from the ground, according to the first idea of Vittorio Garatti to "bury" the school.

Indeed, the building recalls hypogeal constructions and has a strong connection with the nature of the site (the trees, the river, the topography of the site), as Garatti himself recalls in an interview:

“Respetamos la huella del campo de golf. (En Ballet) Yo tenía un bunker cercano. Cuando vi que la loma bajaba y que había un elemento referencial, un algarrobo, entendí que podía ser como un teatro griego, pensé: “voy a construir una cavidad que dialogue con el algarrobo”[24].

To pursue this goal, the architect did not make a true distinction between internal and external spaces: patios, internal gardens, and balconies are opened to the interiors, and big windows are framed by simple medio-punto jalousie wooden structures. For the architect's precise willingness, coherent with the revolutionary ideas, hierarchy in accesses and accessibility is totally reversed: there is no main entrance, but several accesses to the School. One can reach the School from the top of the ravine down towards the serpentine gallery, following the terrain, shaped with organic steps or vice versa from the river up to the top. The vaulted system covering the corridors is walkable and becomes an additional space for students to socialize or perform.

The fluid covered gallery links together all the spaces composing the School from the interior, namely: the three dance pavilions, the choreography theater, the theoretical classrooms, and the three smaller domes (library, infirmary, administrative offices). The sinuous path runs smoothly through the building, creating the so-called *paseo arquitectonico*. Patios and windows, as well as the gradual uplifting of the rib vaults, bring light to the passageway. A small channel of water running from the entrance of the School in between ceramic tiles ensured a constant sound of running water, thanks to a hidden pump that was supposed to push water up the hill. This small detail reveals the inspiration to the Alhambra courtyard and Villa d'Este gardens, with their water channels to refresh air and carry rainwater. The water channels run along all the perimetral walls of the School to finish in an underground raceway. Visibility is also an important feature of the architecture: light partitions in between rooms guarantee continuous sight throughout the whole building. Visual continuity expands to the outside as well fostering a constant relation between indoor and outdoor spaces. For instance, the dance pavilions' enormous arched windows are only partially closed by *medio-punto* wooden frames. These elements - typical of Cuban architecture - consist of radially disposed brise-soleil, which ensures the outside's visibility.

[24] Pizzarro Juanas, 2012, p. 307.

The construction started in 1961, following the original functional program, and, when in 1965 the building site had to shut down due to the tightening of the embargo against Cuba, although closed to be completed, it still lacked some finishing.

The trail coming from *calle* 134 leads to the school's main entrance, from where it is either possible to directly access the choreography theater or carry on along the covered walkway to reach the other pavilions. Each pavilion of the School has direct access to the park; this feature perfectly fits with garden architecture's essence, nurturing the relationship between the surrounding landscape architecture.

As previously mentioned, the vaults covering the internal corridors are also an integral part of Garatti's *paseo arquitectónico*. The architect imagined that in the evening, students would gather up there and stroll, study, exercise or dance at sunset. The whole building reflects the dynamic movements of the dancers, which have inspired the curved walls and the domes, characterized by different heights and spans. As Garatti stated:

«I wanted the school to be extremely dynamic, in part as a response to the dynamism of dance. But I wanted the school to be dynamic not only because it was a ballet school, but because it was to be a vision of our future. Dynamic, at the same time expressing freedom, open in all directions where you could come and go as you wished».

The plan of the School of Ballet is articulated in a series of spaces, connected to one another by means of the *paseo arquitectonico*. The school comprises seven domed pavilions, namely:

- *Choreography Theater*, which covers a diameter of approximately 34 m. The vault structure, which stands upon 16 brick walls, consists of a reinforced concrete grid of ribs and rings. However, the whole concrete structure, covered with clay tiles, is hidden to the view.

  Architecturally, the choreographic theater has been conceived as a performance space where the audience becomes part of the stage. Since there is no pre-established separation between the dancers and the public, it is possible to reorganize the scene every time, in the most suitable way for each exhibition. The dome covers all theater areas, including the stage and the seating steps that can seat up to two hundred people. The mezzanine floor, basically consisting of a ring gallery, allows to walk around the entire hall without interruptions. Five spiral metallic staircases are used to guarantee access to a higher gallery designed to host the stage lighting instruments. From here, it is possible to access a further utility level, located under the top of the dome, right below the skylight.

  The dressing rooms for the dancers, utility rooms, and storage rooms are situated around the stage, hidden by a curtain of shutters that can be opened to access the performance area directly.
- *Dance pavilions*: dance classes were supposed to be held inside three analogous domed pavilions. The dome has a span of about 17 meters, and it stands on four clay-tile covered concrete pendentives, transmitting the thrusts to four angular walls.

- *Minor domes:* the remaining three domes, similar to one another in terms of construction technique, are dedicated to the administration, the library, and the infirmary. Such domes stand on plain brick walls that are about 60 cm thick.

In addition to the above-mentioned spaces, the school is provided with some theoretical classes built on descending seating steps that follow the ground's natural slope. The rooms are divided by longitudinal and cross supporting walls that sustain two constant section vaults, one covering the distribution gallery and the other the classrooms. The inclined concrete slab upon the vaults is waterproof, and it carries the load of about 30 cm of soil, creating a green roof that blends into the surrounding park. This way, while the classrooms beneath appear to be underground, the terrace becomes an observation deck overlooking the surrounding buildings and landscape[25].

[25] The description is based on John A. Loomis, *Revolution of forms*, pp. 97-98.

Figure 24 - The inner patio in 1965. Photo by P. Gasparini (ISA archive).

The School of Ballet in 1965

Figure 25 - View of the patio and one of the dance pavilions. Photo by P. Gasparini (ISA archive).

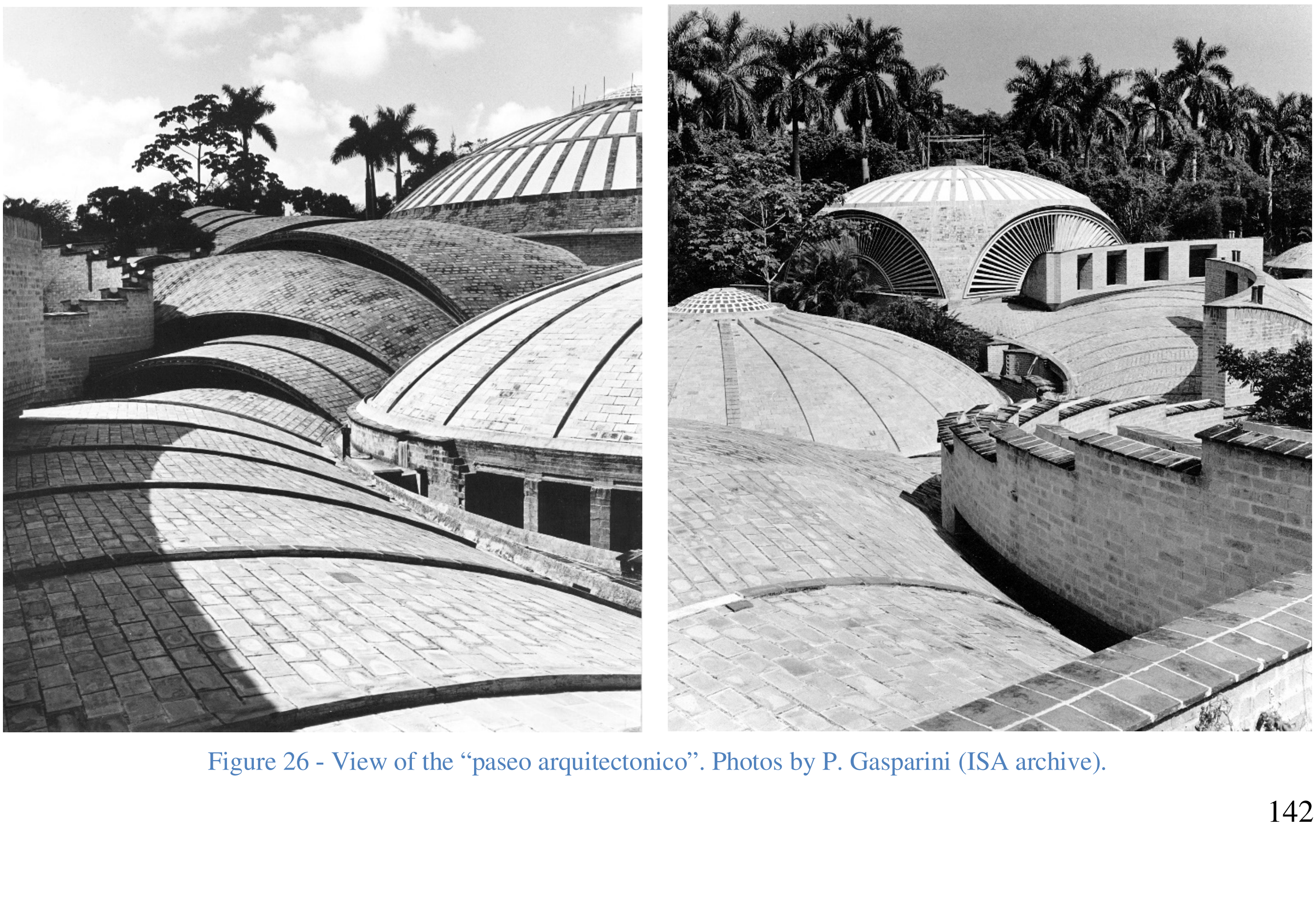

Figure 26 - View of the “paseo arquitectonico”. Photos by P. Gasparini (ISA archive).

Figure 27 - Foster and Partners. Plan of the Choreography Theater designed for the Carlo's Acosta foundation (2011), ISA archive.

Figure 28 - Vittorio Garatti. View of the Dance Pavilions (left) and library (right) according to the original project (2016), ISA archive.

Other projects

Although very close to be completed, Garatti's School of Ballet was never finished and remained vacant for a very long time. In fact, famous dancer Alicia Alonso, who was supposed to teach at the School, did not find the spaces to be fitting with the educational program proposed and thus decided to open her own Ballet School elsewhere in El Vedado (Havana). The building was hence abandoned and slowly damaged by vegetation, floods, and vandalistic acts. Starting in the late Nineties, a series of projects took place to redeem, complete and renovate the Schools.

In 2011 a British Foundation, represented by a Cuban internationally recognized ballet dancer Carlos Acosta offered to restore the School of Ballet in order to install its own private School.

The main goal was to create a "Multifunctional Centre" for the promotion of the performing arts. The proposal entailed the construction of a new building, designed by Norman Foster, able to host those functions that could not be accommodated in the original ballet school.

Although accepted by the Cuban Ministry of Culture, the proposal met with fierce opposition, especially from architects and artists. Garatti himself opposed to the realization of the project triggering an international debate on the opportunity and ethics of such an operation. Even with some differences, everyone criticized the method, which had Garatti excluded from the very beginning. In 2013 the argument finally ceased, and Carlos Acosta's plans were put aside.

Since 2007 arch. Vittorio Garatti intensely worked on a project to complete and renovate the School of Ballet with the supervision of architect José Mosquera Lorenzo (who also took part in the National Art Schools construction). The project, that resumes and updates the project developed in the 60s, with some technical and functional improvements, was submitted to the National Committee of Monuments in Cuba in 2009.

The School of Ballet today

Figure 29 - Views of the School of Ballet in its current conditions (2019).

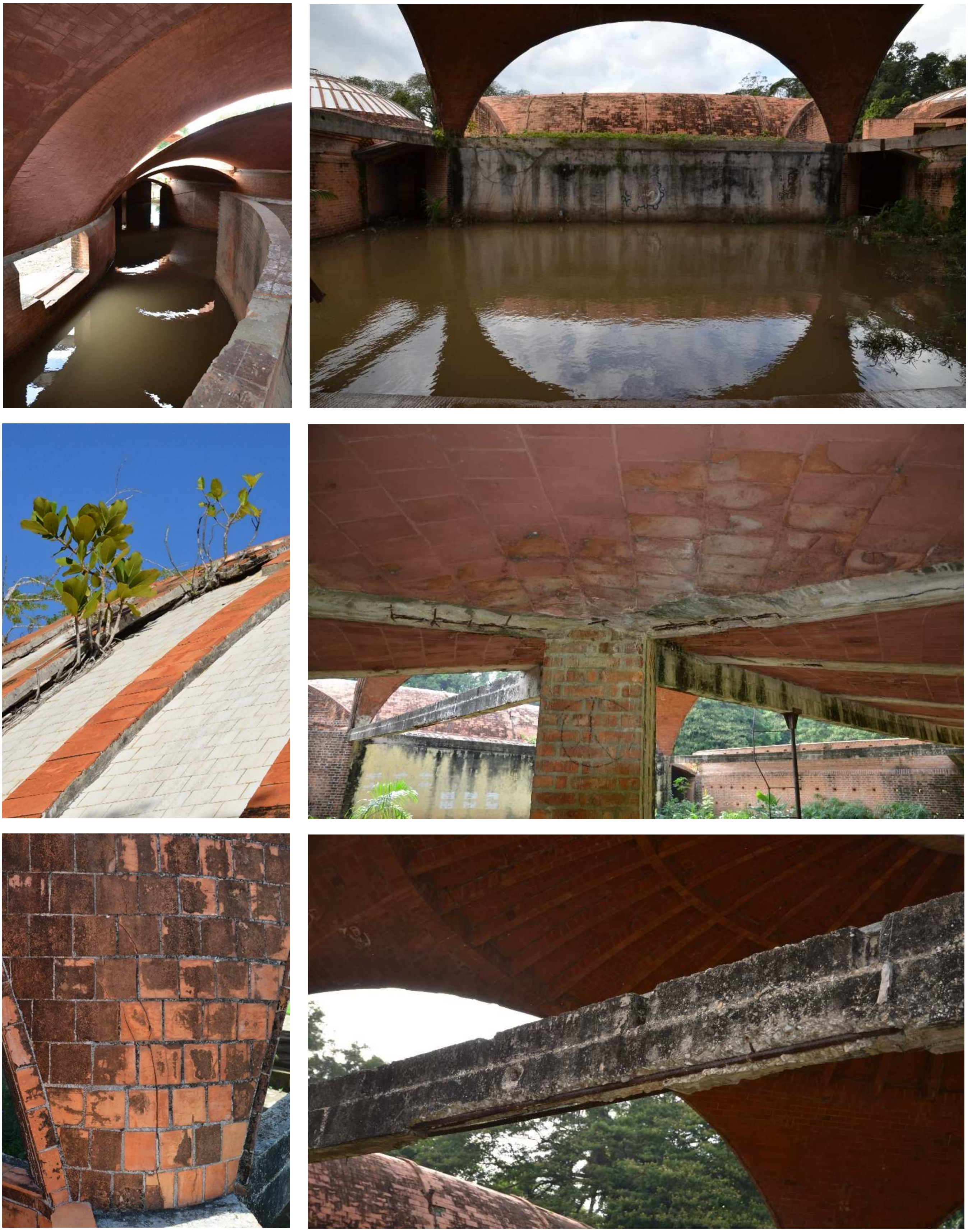

Figure 30 - Main deterioration phenomena detected (2019-2020).

State of repair and current issues

Although the School of Ballet was pretty much completed when the construction site shut down in 1965, over the years, the building was gradually pillaged of all those elements that could find other employment. In particular, all the window frames, made of fine and robust wood, gradually disappeared, worsening the overall state of repair.

Nowadays, the School of Ballet appears to be affected by severe deterioration mostly caused by lack of maintenance which, over time produced a diffused decay of building materials (terracotta tiles and reinforced concrete).

The causes of deterioration are various, but the main issues can be summarized in the following:

- exposure to weathering and tropical vegetation;
- acts of vandalism;
- dismissal/improper use of the building;
- theft of building materials;
- lack of maintenance.

The most relevant issue to address concerning the School of Ballet is that of Rio Quibù floods. Indeed, among the five schools of the complex, it is undoubtedly the most impacted by this factor (Figure 30 - top). Because of extensive damages, the retaining wall became unable to prevent water from inundating the building's main spaces. The only rooms that are not affected by this phenomenon are the theoretical classrooms because their elevation is slightly higher than the rest of the building. Frequent floods are responsible for non-invasive mold infestations and surface deposits of residual mud affecting both pavements and vertical elements.

Roofs probably suffered the most, as the concrete vaults and domes extensively lost the outermost tile layers. This issue is partially caused by the numerous shrubs that have grown into the roof tiles' interstices or between the ribs of the domes' joints. The roots, extending through the layers composing the roof, lifted up the tiles, causing their detachment from lower layers. This phenomenon has been exposing the structure to weathering, leading to corrosion and water infiltrations (Figure 30 - middle). On top of that, the inefficacy of the rainwater drainage system causes further infiltration issues. Unable to correctly flow down, water seeps through the walls and vaults, resulting in soiling, efflorescence, and biological colonization (Figure 30 - middle). However, aside from the presence of the mentioned humidity-related phenomena, masonry elements show a rather good state of repair. Pavements are almost completely missing in the corridors connecting the classrooms, while they appear well preserved in the library pavilion, in the administrative offices, in the infirmary, and in the theoretical classrooms. The wooden floors meant to be installed in the Dance Pavilions and in the Choreography Theater were never laid, leaving the concrete slabs/the ground at sight. The electrical and sanitary systems are unusable and need renovation. There is no illumination to grant the use of the building during the evening.

While the Choreography Theater appears well preserved and does not display particular structural failure signs, a few more issues were detected within the Dance Pavilions. The pendentives display several crack paths, and the concrete tie-rods connecting them at their bases are inflected and lost consistent portions of concrete cover (Figure 30 - bottom).

Figure 31 - Intended use according to Garatti's original design.

Use

	Area [SQM]	%
Building footprint	4682,07	-
Didactic spaces	2025,43	43,26
Auxiliary spaces	0	0,00
Connective spaces	1520,53	32,48
Technical rooms	619,00	13,22
Specific functions	517,11	11,04
Outdoor spaces and paths	955,54	-
Used *(w/o connective spaces)*	0	0
Dismissed *(w/o connective spaces)*	3161,54	100

Table 1 - Use distribution according to the original arrangement.

Code	Original use	Current use
Ae.01	Theater	dismissed
Ap.01; 02; 03	practical classroom	dismissed
At.01; 02	classroom - individual practice	dismissed
At.03 → 07	classroom (theoretical courses)	dismissed
Sa.01	Library	dismissed
Sa.02	Office	dismissed
Sa.03	Infirmary	dismissed
Te.01; 02	technical room (air conditioning)	dismissed
Be.01a; 01b; Se.01a; 01b	toilet and showers (for the performers)	dismissed
Bp.01a; 01b; 02a; 02b; 03a; 03b	toilet (for the practical classroom)	dismissed
Ba.t.01	toilets (classrooms)	dismissed
Pc01; 02	covered path	dismissed
Pc.t01	covered path- access to the theoretical classrooms.	dismissed
Pe.p01; p02; p03	porch - practice classrooms	dismissed
Pe.01	external path - main access - stairway with water path	dismissed
Pe.02; 03	external path - secondary access	dismissed

Table 2 - Chart comparing the functional distribution according to the original masterplan to the current use situation.

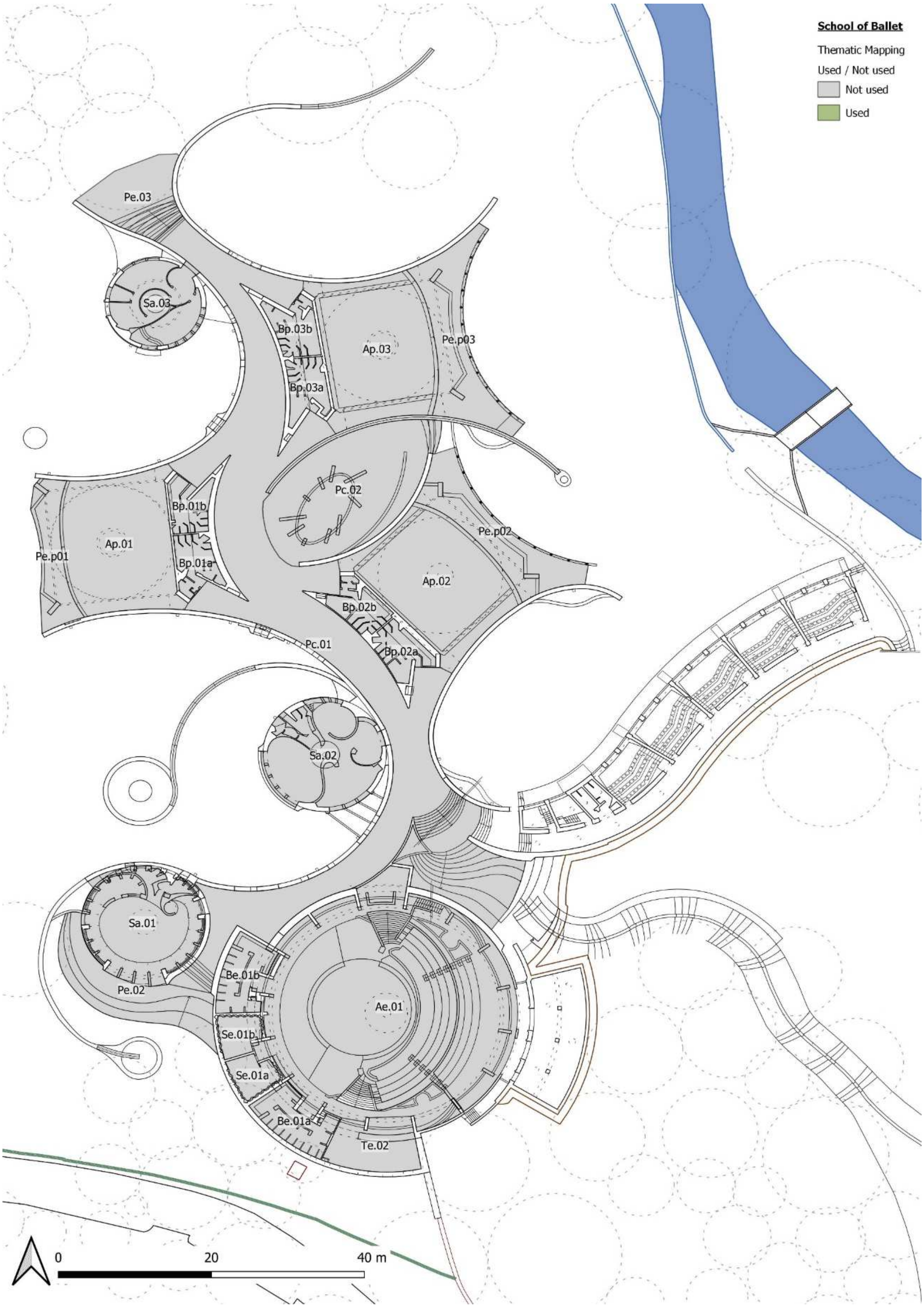

Figure 32 - Plan illustrating the current use of the School of Ballet. As can be observed, today the building is completely dismissed.

Although nearly finished at the time of the National Art Schools’ inauguration (1965), the School of Ballet never served its function. Its suggestive spaces were soon abandoned and left to perish.

Despite the natural decay of the structure, some of the school's spaces were briefly used in the ’80 to host a Russian school of the circus. After this short experience, the building went back to its condition of complete dismissal.

In recent times it has occasionally been used as a detached pavilion of the Havana Biennial, hosting exhibits of artists such as KCHO (2009) and Gabriel Orozco (2012). The School also hosted some choreographic exhibitions, among which the 2012 Man_Go, created by Spanish choreographer Miguel Rubio (Figure 33).

The building's surroundings are currently used by ISA students to practice and perform, as well as to spend their spare time.

Figure 33 - The choreographic exhibitions of Man_Go by Miguel Rubio (2012), ISA archive.

Figure 34 - View of the School of Music.

1.3.2 School of Music

Year of construction: 1961-64

Architect: Vittorio Garatti

Original use: School of Music

Current use: dismissed

State of completion: uncompleted

Figure 35 - Location within the Schools' campus.

"...Primary among our design principles was the intention for the architecture to be integral with the landscape. I selected the two sites where the character of the terrain would have to inform the design. There are several vectors of analysis the lead the design. First is the analysis of the landscape and the physical context (...)...one must consider cultural vectors, and there are vectors are internal forces and some are external in the way they influence the design process..."[26].

[26] Vittorio Garatti commenting on the School of Music (from Loomis 1999).

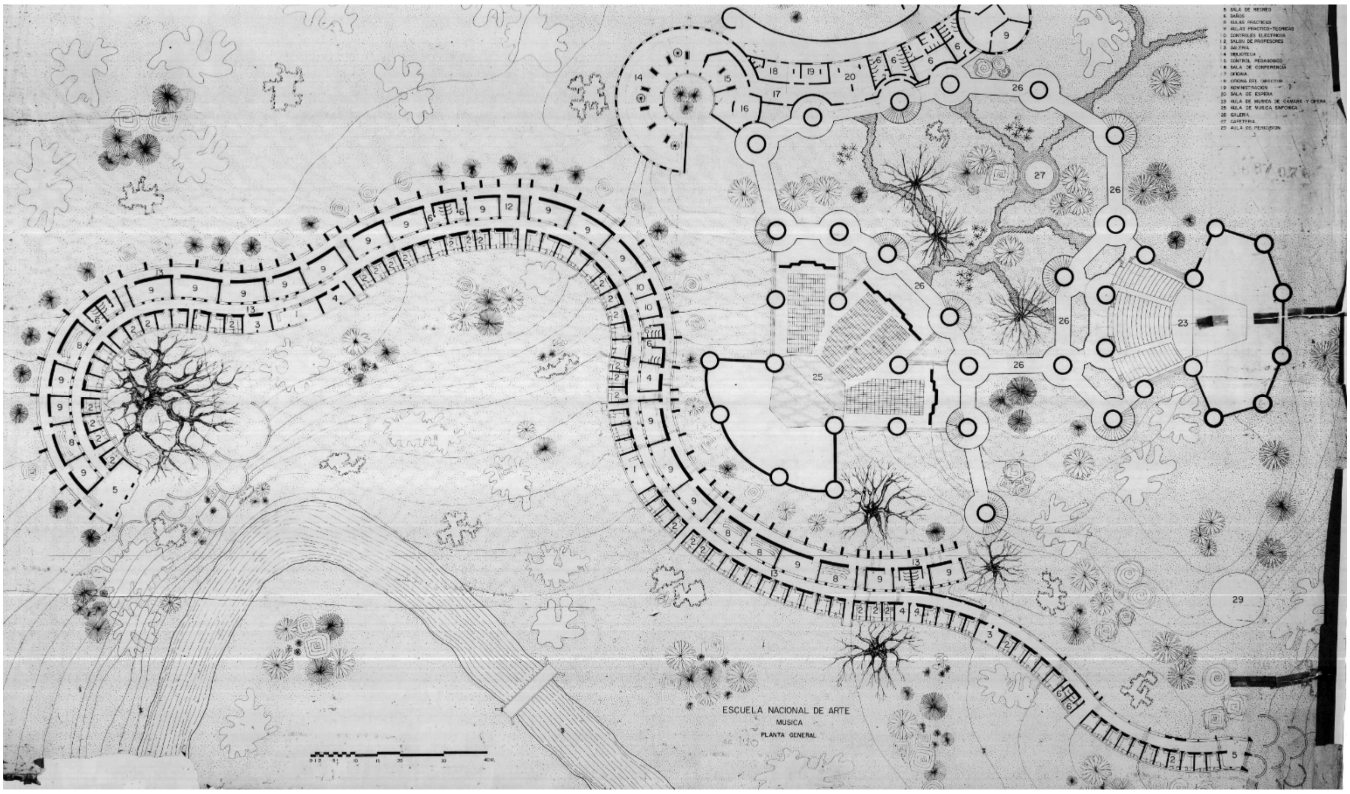

Figure 36 - Original masterplan by Vittorio Garatti. (ISA archive).

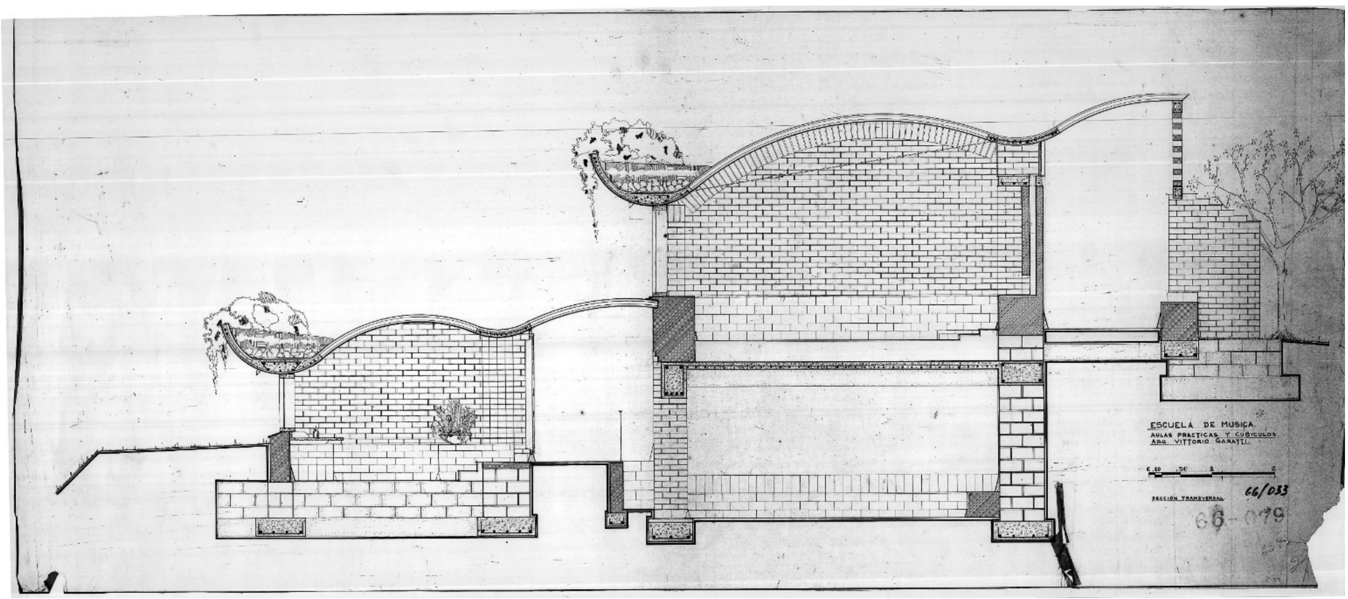

Figure 37 - Architectural cross section. Original drawing by Vittorio Garatti (ISA archive).

The School of Music stands on an area of 5 hectares, and it embraces a hillside roughly paralleling the river. The original plan was composed of several buildings designed for the teaching of different musical disciplines:

- the *"gusano" (serpentine),* composed of 92 cubicles for individual practice and group rehearsal;
- the *"gusanito" (little serpentine),* which was supposed to hosts administrative services, the choir halls, the library, and three conference rooms;
- two concert halls: a symphonic concert hall and a secondary hall for chamber music.

The buildings were intended to be connected through an elevated pathway - somehow resembling a bicycle chain - which shaped a central patio, located at the same level of the park.

"The School of Music is constructed as a serpentine ribbon 330 meters long, traversing the contours of the landscape and almost touching the river at both its "head" and "tail". Adjacent to the central body of the ribbon was to have been a piazza around which the concert hall, chamber music hall, library and administration would have been constructed. The serpentine scheme and its paseo arquitectónico *begins with the "tail" where a group of curved brick planters step up from the river, initiating the sequence. At first the curvilinear band contains individual practice rooms and the exterior colonnade. This passage then submerges as the band is joined by another layer containing larger group practice rooms and another exterior colonnade, shifted up in section from the original band. The idea was to facilitate easy movement between individual practice and group practice. There is also a series of other upward displacements that occur along the procession. These displacements are read in the roofs as a series of terrace-like planters for flowers. Garatti likens the development of the classrooms, which follow the terracing, to the Bath Crescent. Transversally, this 15-meter-wide "tube", broken into two levels is covered by undulating Catalan vaults. These layered vaults emerge organically from the landscape, traversing the contours of the ground plane. Garatti's meandering* paseo arquitectónico *presents an ever-changing contrast of light and shadow, of dark subterranean and brilliant tropical environments. The functional organization along the path continues to proceed programmatically in scale from smaller to larger uses, culminating in a concert hall that wraps around an ancient and monumental jagüey tree from whose branches drape huge roots. The constructed landscape again steps downward with a series of curved brick planters that return to the river".*[27]

At the time of the building site interruption in 1965, the School of Music was far from being complete, as the only - and yet uncompleted - building was the *"gusano"*.
The serpentine building is composed of two levels, which run in parallel for about 265 meters and then part ways moving towards the extremity overlooking the Rio Quibù. While the lower layer continues for other 88 linear meters, ending against the cylindrical terraces in front of the river, the higher level only proceeds for about 13 meters keeping the same curvature and virtually completing the area of the unbuilt *piazza*. Both extremities of the

[27] Loomis 2011, p. 86.

building present a deep porch overlooking the park. Further terraces were supposed to be built nearby the *jagüey* tree, but they were never constructed.

The two levels are connected through a series of stairways accessible through the corridors. Indeed, both levels include a distribution hallway (porticoed on the higher level and completely and closed on the lower level) and a series of almost identical classrooms. The higher level comprises larger classrooms for group rehearsal, while the cubicles for individual study are located at the lower level.

The hallway running along the higher level is open towards the park, overlooking the unbuilt *piazza* where the symphonic concert hall was supposed to be built. Indeed, the concavity located in the central portion of the *Gusano* was designed to accommodate the concert halls, which were conceived as a cluster of three different buildings: two concert halls facing each other and the *gusanito* hosting services and administrative offices. Connection between the buildings was guaranteed by an elevated pathway (the *"catena"*) sustained by reinforced concrete towers (which were partially built). The aim of this massive connection element was to allow students to shorten the time required to move from one place to the other. The central plaza, planted with palms and tropical vegetation, serving both the theatre and the School of Music, was intended as an open-air foyer for concerts and exhibitions.

However, the whole theater cluster never saw the light of day, since in 1965, only a small circular building (currently used for dance lessons) and part of the concrete foundations and supporting pillars had been built.

Overall, the School's articulation in its original configuration aimed at reflecting the essence of the symphonic orchestra where each instrument, according to its own characteristics, gives a unique contribution to the final exhibition. Here, more than in the other buildings of the Schools of Art, each element was meant to embrace a peculiar nature related to its function, generating a small town whose main square provided the most relevant public services[28].

[28] The description is based on John A. Loomis, *Revolution of forms*, 2011, pp. 85-86; Garatti, 2007.

The School of Music in 1965

Figure 38 - The School of Music after completion. Photos by P. Gasparini (ISA archive).

Figure 39 - Digital reconstruction of the original Garatti's design as a proposal of completion (2016), ISA archive.

Other projects

With the support of José Mosquera, architect Vittorio Garatti and his firm proposed a project to complete the School of Music adding the buildings that were never constructed, namely the two concert halls, the *gusanito* and the *catena* (elevated connection pathway).

According to the new design (substantially analogous to the original one), the symphonic concert hall develops on the central axis of one of the curves that shape the *"gusano"* and is supported by twenty reinforced concrete pillars. The proposed hall is smaller than planned in the original project and can host up to 1.100 people. Green houses inspire the non-load-bearing glass walls of the external shell. The roofs are umbrella structured and define the internal spaces of the symphonic hall. The two biggest ones cover the central hall. Of the three smaller roofs - all of the same dimension - only the central one, covering the foyer located at level +6 m, presents filling between the supporting ribs. Indeed, the two lateral ones are open, as they only consist of load-bearing ribs and arches, creating two large greenhouses nurturing the integration with the natural landscape.

The main hall has several entryways positioned on different levels. The inside of the room is conceived as an organic space, with no interruption between different sectors, which are structured as terraces surrounding the orchestra's central stage. The audience can either be placed in front or behind the orchestra, granting higher flexibility.

The orchestra's space is conceived to host a complete symphonic ensemble, leaving the possibility of using part of the audience seating space to locate the choir. Circulation inside the hall is continuous and fluid: all the sectors are connected, giving to the audience the chance to walk around the whole hall, starting from the foyer - connected to the *"catena"* - and ending in the basement terraces overlooking the *gusano* and the School of Ballet.

A minor hall for chamber orchestras, individual instrument performances or small ensembles is located underneath the south-west sector's seating steps. The room is accessible both from the main hall and from the *gusano*.

The open foyer, located at level +6 m, can only be reached by using the elevators and stairways situated around and inside the pillars supporting the *"catena"*. While guaranteeing the connection between all the buildings composing the School of Music, the latter delimits the central *piazza,* a big outdoor foyer for the symphonic concert hall.

From the "catena" it is also possible to access the *gusanito*: a curved building that, on one end, terminates with a round central-plan wing hosting deposits and storage units (lower levels) and a choir room (upper level). On the other side, it ends with a construction shaped like 3/4 of a circle, open towards the symphonic concert hall, containing the library and some study rooms. The central unit of the *gusanito* develops around the ground floor entrance hall providing administrative and student services. The mezzanine floor gives access to the multi-purpose rooms, which are available to both students and professors. Three conference rooms with a capacity of about 50 people are located on the higher level, and each of them has direct access from the "catena".

A few interventions for the *gusano* were also planned: "cubicles" are supplied with soundproofing systems. The walls are covered with bamboo and each cubicle is provided with a countertop that can also be used as a writing desk. In front of the *jagüey* tree, there are new cylindrical terraces and a painted glass wall[29].

[29] Based on Garatti, 2007.

The School of Music today

Figure 40 - The *Gusano* in its current conditions (2019-2020).

Figure 41 - Main criticalities detected (2019-2020).

State of repair and current issues

As previously mentioned, due to the abrupt interruption of the building site, today, the School of Music only consists of the *"gusano"* building.

Currently, the most deteriorated portion of the construction is the part of the lower level located in the proximity of Rio Quibù, starting from the point where the higher and lower level divide. Extensive portions of the roofs collapsed, and pavements disappeared under the rubbles making the entire area hard to access (Figure 41 - bottom).

The central portion of the building, organized on two levels, also shows signs of deterioration, mostly caused by the lack of maintenance and the consequent decay of building materials. The main issues are related to the diffuse detachment of the outermost layer of tiles on the vaults, which resulted in water infiltrations and humidity stains at the intrados. Also, due to the complete absence of windows, wind and water often enter the cubicles, leaving mud and deposits on the ground (Figure 41 - top).

Although the unit located nearby the *Jagüey* tree is the best preserved one, the very presence of the tree caused significant problems to the roofing. Due to overgrown vegetation, consistent portions of the covering layers have detached, leaving some the inner structure exposed to the erosive action of weathering.

In general, the cubicles located on the lower level appear to be in a bad state of repair, but only a few of them are completely impracticable. The situation appears better on the higher level, where almost constant use of the classrooms helped their preservation. In particular, over the past years, the building's head and central portions have been subjected to repairs and maintenance interventions.

Overall, the masonry elements are in good state of repair, although there are several non-invasive mold infestations caused by residual mud and overgrown vegetation. The well-preserved portions' roofs are also in good shape, except for the negligible loss of a few covering tiles. It should be noted that an increased attention toward the maintenance of the building has lately brought to regular cleaning of the vaulted roofs.

Longitudinal cracks run along with the seemingly catalan vaults of the porticoed corridor on the upper level, suggesting a true thin-shell nature (Figure 41 - middle, left). Given that several original vaults already collapsed, the cracking seems to indicate a serious structural failure. Collapsed vaults were replaced with new reinforced-concrete ones.

The reinforced concrete structures also show signs of deterioration. In particular, the beam-planters completing the tile-covered vaults lost part of the concrete cover, leaving rebar exposed to weathering (Figure 41 - middle, right).

The sanitary system is unusable and needs renovation. Spaces that are currently used are provided with electricity (e.g., the carpenter's workshop). A water tank has been positioned on the rooftop, towards the head of the *gusano* building.

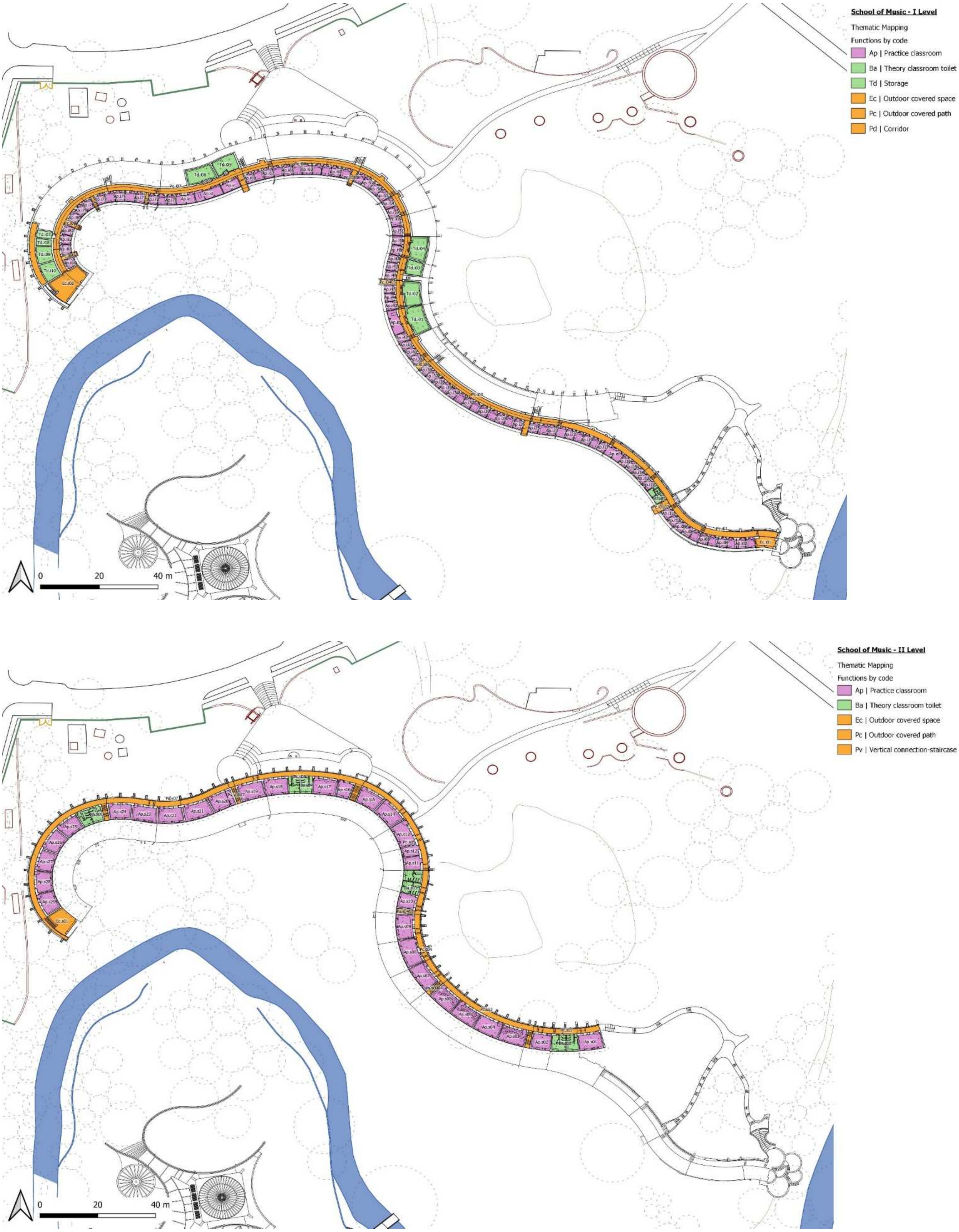

Figure 42 - School of Music: intended use according to Garatti's original design.

Use

Original function (1965)	Code
Individual cubicles	Ap.i01→20; 23→84
Group rehearsal classrooms/theoretical classrooms	Ap.s01;02;04;07→10; 12→15; 17→24;26;27;29
Duos/trios	Ap.s03;05;06;25;28
Teachers room	Ap.s16
Sound operator	Ap.ai; ei
Cubical control offices	Ap.bi; di
Air conditioning control	Ap.i21; 22; ci; s10; 11
Recreational spaces	Ec.02
Storage	Td.01→10
Restrooms	Ba.i01→05
Project (2000s review)	
Individual cubicles	Ap.i12→14; 17→37;69→76
Brasswind	Ap.i01→03
Woodwind	Ap.i06→08
Singing and choral director	Ap.s04;05;ci;ei
Multipurpose cubicles	Ap.i04;05;09→11; 77→83
Percussions	Ap.s25→29
Chamber music	Ap.s06→08
Theoretical classrooms	Ap.s17→23; 12→14
Orchestral conducting	Ap.s01→03
Electronic music	Ap.i38→41;bi
Audition rooms	Ap.i42→44;52→54
Music library and laboratory	Ap.i45→47; s11
Library	Ap.i15; 16; ai
Computing and internet	Ap.i48→51;s09
Language	Ap.s24
Secretariat and administratione	Ap.di;i55→57; s15;16
Teachers room	Ap.i58→68
Shop	Ap.i84
Current use	
Painting studio (for ISA students)	Ap.s10; 16

Carpentry workshop - artisan in charge of ISA Maintenance	Ap.s11
Storage - Empresa de Seguritad de Instituciones de Cultura (ESIC)	Aps12→15; 17; 19,20
Storage - Empresa de Gastronomia (Playa municipality)	Ap.s18; 21→23

Table 3 - Chart comparing the proposed uses for the School of Music (original design and 2000's project review) and its current use.

	Area [SQM]	%
Building footprint	4565,86	-
Didactic spaces	2295,73	50,28
Auxiliary spaces	0,00	0,00
Connective spaces	1693,89	37,10
Technical rooms	576,24	12,62
Specific functions	0,00	0,00
Outdoor spaces and paths	0,00	-
Used *(w/o connective spaces)*	545,97	19,01
Dismissed *(w/o connective spaces)*	2326,00	80,99

Table 4 - Use distribution within the School of Music (original arrangement).

The School of Music was never completed and was thus abandoned right after the building site shut down. Indeed, it was never used as a conservatory as originally intended by its designer and, even worse, it has not generally been used at all. Today, the *gusano* is, for the most part, dismissed, as Music classes are held in a wing of the rectorate building.

In particular, the cubicles for individual study located on the lower floor are completely dismissed, while on the top floor, a few of the larger classrooms are currently in use. The current functions are heterogeneous: some rooms are occupied by students who set their studios there, others are used as storage or yet as classrooms and laboratories[30]. Like the School of Ballet, the School of Music's surroundings are often used by local students to rehearse and perform, according to Garatti's wishes.

In 2015, on the occasion of the XII Havana Biennial, artist Hector Zamora and composer Wilma Alba created a show within the cubicles of the School where the students of the school performed a concert (Figure 44).

[30] For further details refer to *Action 5 Developing a management strategy and tools.*

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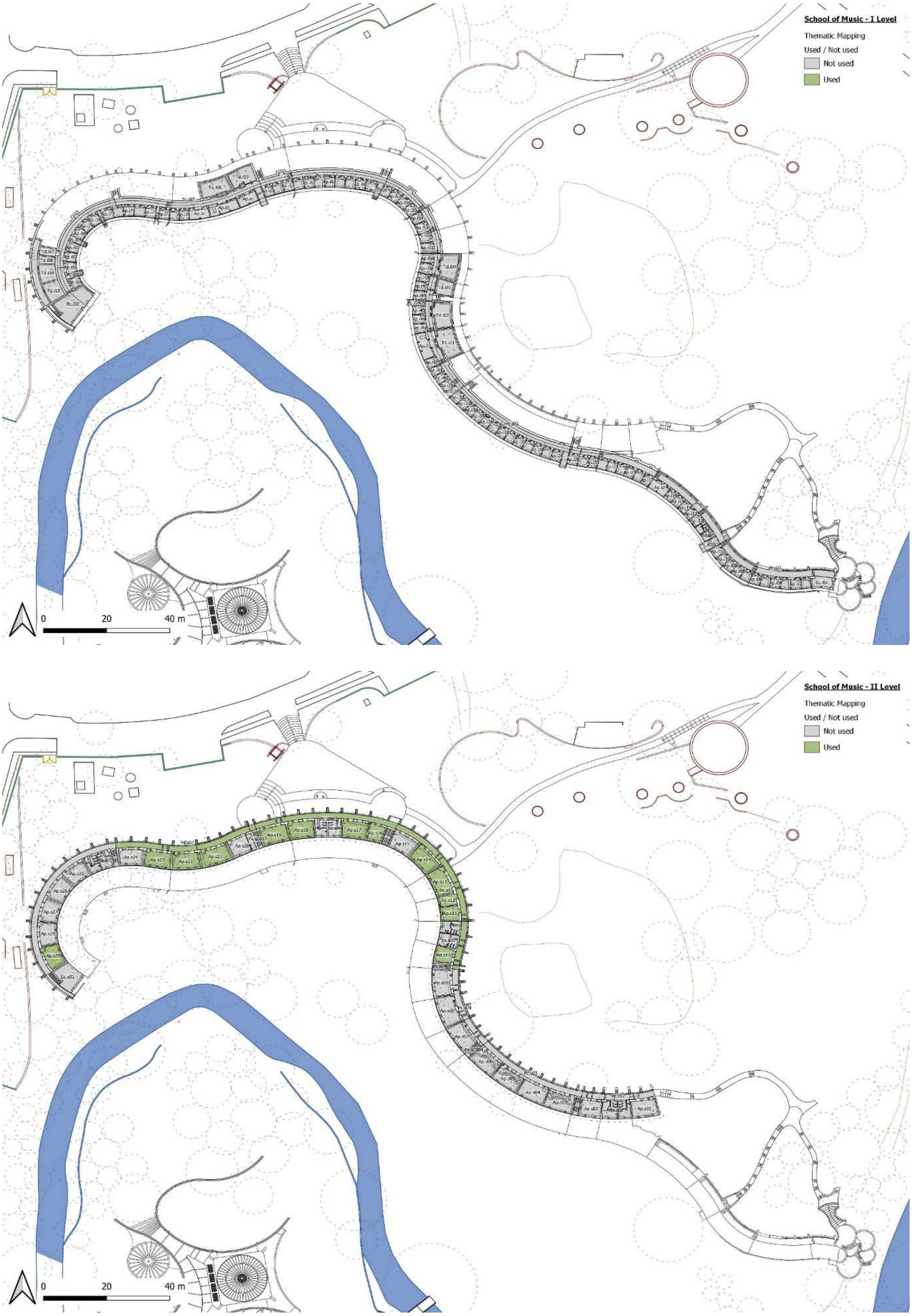


Figure 43 - Plan illustrating the current use of the School of Music.

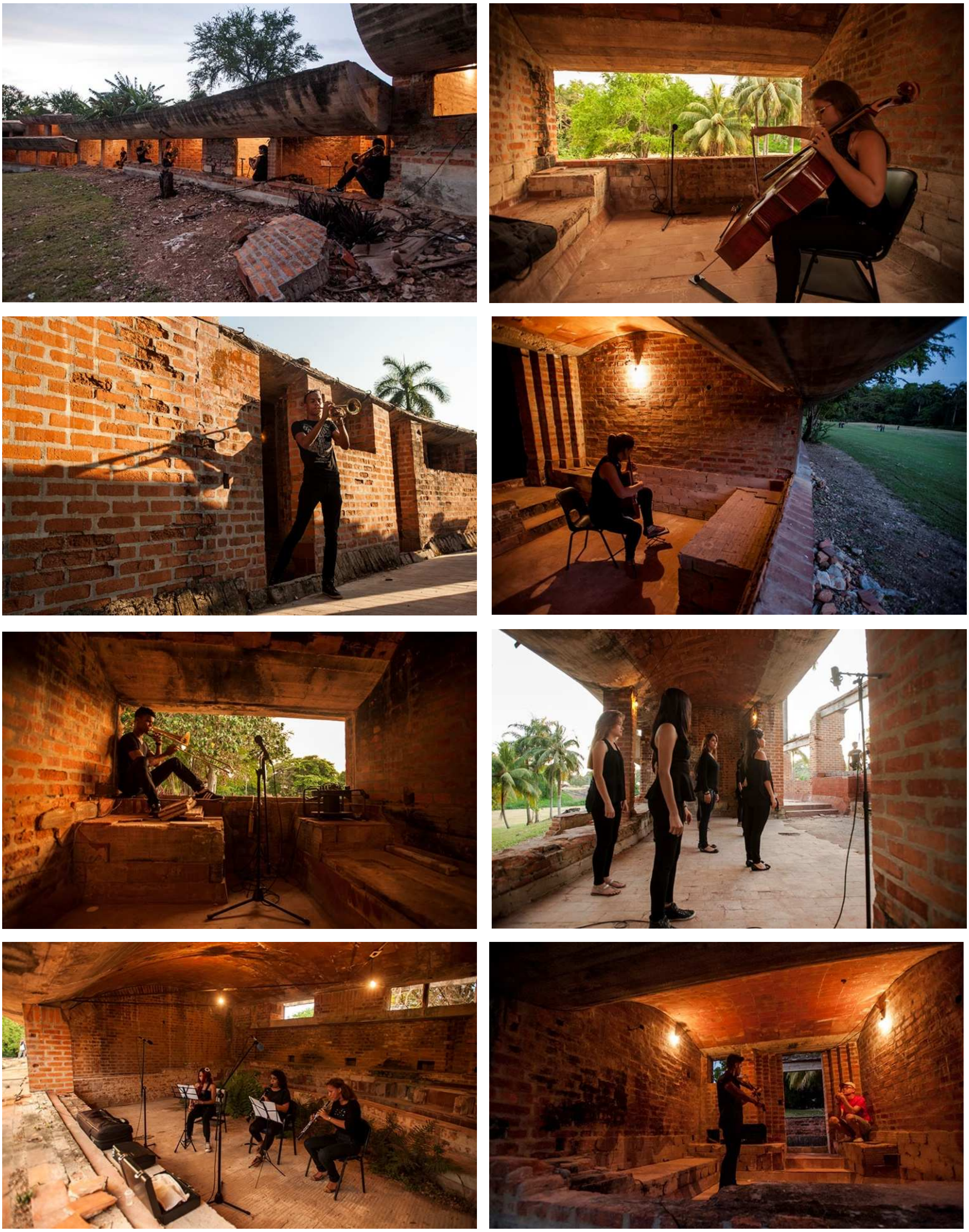


Figure 44 - Hector Zamora’s show during the XII Havana Biennial (2015), ISA archive.

Figure 45 - Aerial view of the School of Dramatic Arts while under construction (photo by P. Gasparini), ISA archive.

1.3.3 School of Dramatic Arts

Year of construction: 1961-63

Architect: Roberto Gottardi

State of completion: uncompleted

Original use: School of Dramatic Arts

Current use: Dismissed

Figure 46 - Location within the Schools' campus.

"Conceptually, the theatre constituted a centre of mass from which other functions, technical pedagogical, support were organised. The more theoretical classes were located on the exterior, the more practical classes just inside, and at the centre, experimentation within the theatre itself. When it was time for a performance, everything would come together. The attention towards the theatre was accentuated by the roofs which were inflected inward toward the theatre. The school was organised like a small community bearing in mind the character of a theatre company. Theatre is made with actors, directors, sounds, technicians, set designers, costume designers, etc. It is important to see all the members as part of a community. The streets are the means to both bring together all the disciplines and to provide informal places for the individuals of the community to meet and sit. Inside the complex there is a sense of being in an environment completely apart from the outside, like the hermetically social experience of being part of a theatre company. The circular form facilitates a certain independence. It provides a special experience that could not derive from a linear form. The spaces follow in an unanticipated manner. Also, many spaces that are not theatre, can be used as theatre. In a certain sense, all parts of the school can be used as a theatre. The theatre is a school and the school is a theatre, like Antonin Artaud's concept of the "theatre and its double"[31].

[31] Roberto Gottardi commenting on the School of Dramatic Arts (from Loomis, 1999).

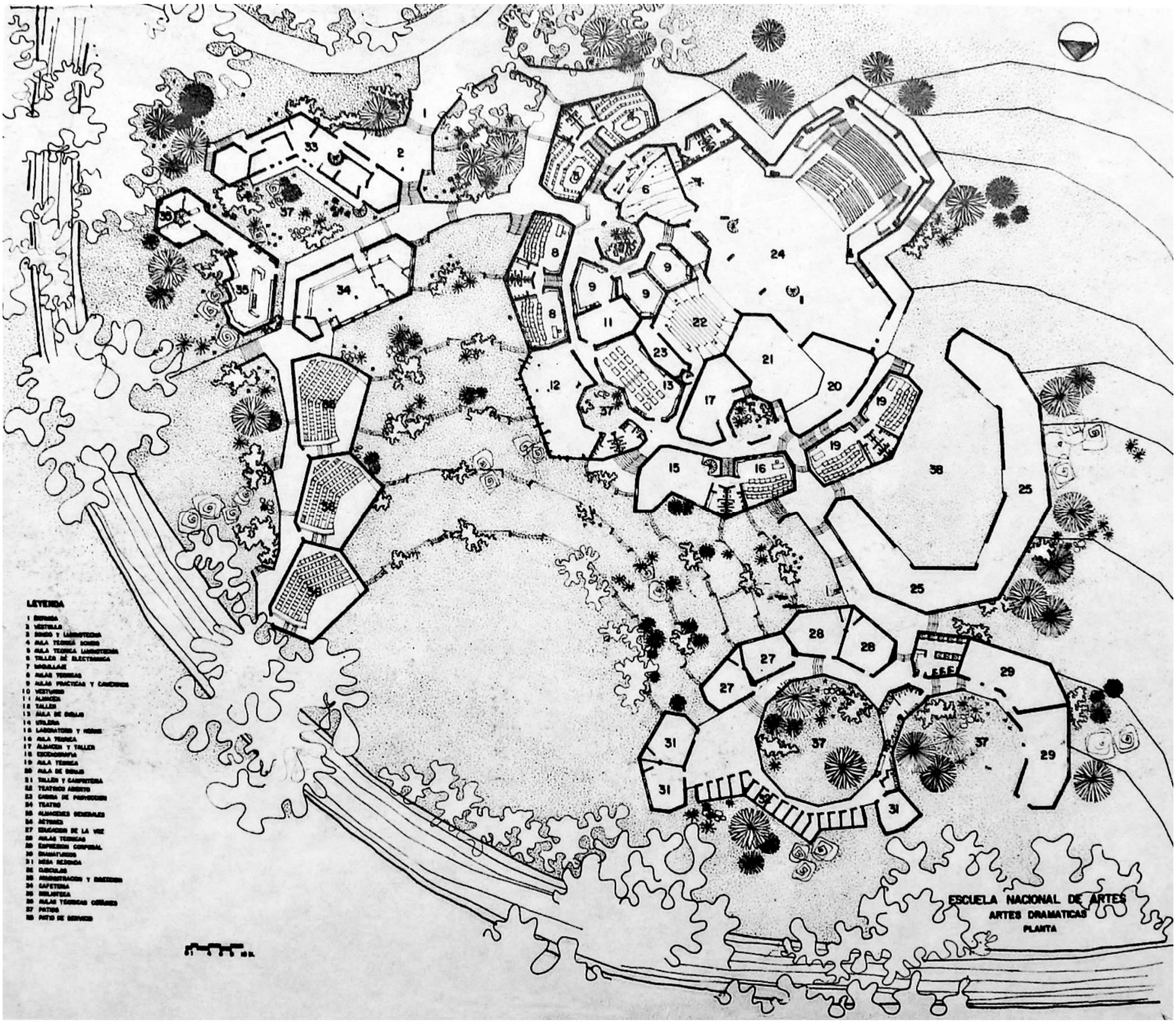


Figure 47 - Original Masterplan of the School of Dramatic Arts. Copy stored in the ISA archive.

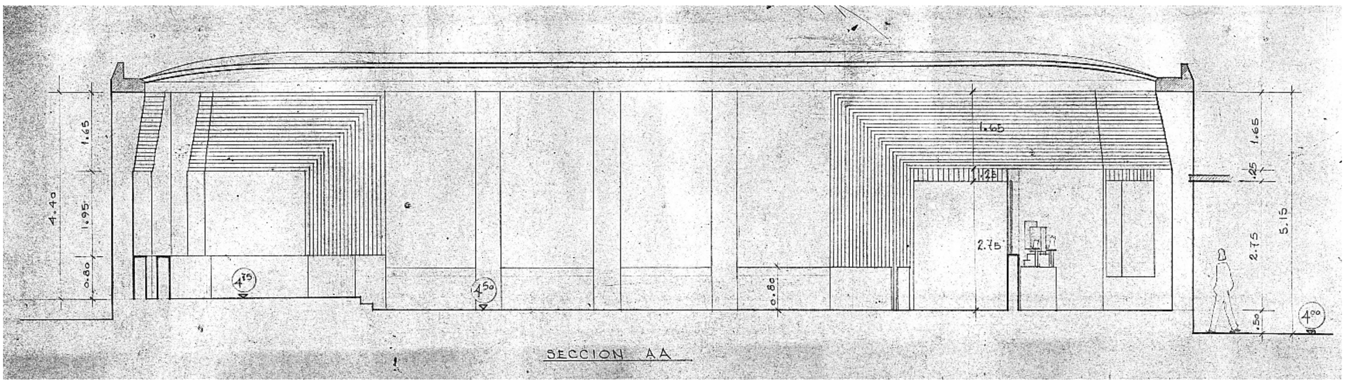


Figure 48 - A Section taken from the original blueprints by Roberto Gottardi (ISA archive).

The School of Dramatic Arts stands to the east side of the School of Modern Dance, on a slight hill stepping down into a densely vegetated bend of the Rio Quibù. If completed, this school and the School of Music would have been the largest of the complex; however, due to the building site's interruption, they ended up being the most contained. The original program for the School of Dramatic Arts was extensive, complicated, and without clear precedents. The school contained both a large indoor theatre and a smaller amphitheater with a shared stage and technical support. Various types of classrooms, studios, and administrative facilities made up the rest of the program, which also included a cafeteria and a library.

The complex was supposed to be composed of three clusters, each organized around open courts and connected to one another by the landscaped terraces descending towards the river. While the administrative offices, library, and cafeteria were partially built but left unfinished, the double patios' unit housing classrooms were never built, just like the flanking storage facility.

The main theatre, part of the primary complex, was never constructed, except for few pillars, leaving an opening where there should have been a closed system. The inbuilt theatre would have functioned in three ways: opening to an enclosed auditorium as a typical proscenium theatre, opening to an exterior courtyard audience, or opening to an audience surrounding the performance on all sides.

Finally, the only portion that was actually built is the tightly knit complex of classrooms surrounding the courtyard amphitheater. The School of Dramatic Arts - or what was built of it - manages to blend together learning and performing experiences and embody the true essence of collectivity.

Like Ricardo Porro, Roberto Gottardi conceived his school as a small town. The building is organized as a very compact, axial, cellular plan around the central courtyard. The amphitheater, fronting the unbuilt theatre, represents the focal point of the subsidiary functions grouped around it. The narrow leftover interstices, open to the sky like streets, serve as circulation routes between the volumes of the masonry cells. This feature appears quite the opposite to the other schools, where the *paseo arquitectónico,* with its vaulted passageways, assumes a pivotal role.

Winding more or less concentrically through the complex, the circulation experientially denies the axiality and generalized symmetry characterizing the plan, resulting in an interesting formal contradiction. While quite ordered in plan, the experience of walking through the open corridors feels random and spontaneous.

The School of Dramatic Art turns its back to the landscape and looks inward to an interiorized environment that is evocative of a North African, or Mediterranean urban vernacular. Like a true vernacular, the harmony of its forms and materials is a unified organic construct that provides architectural continuity despite the missing elements[32]. Gottardi also refers to Carlo Scarpa's Venetian paths, which are reflected in the narrow and labyrinthic routes connecting the spaces of the School of Dramatic Arts.

[32] Based on John A. Loomis, *Revolution of forms*, 1999, pp. 71-72.

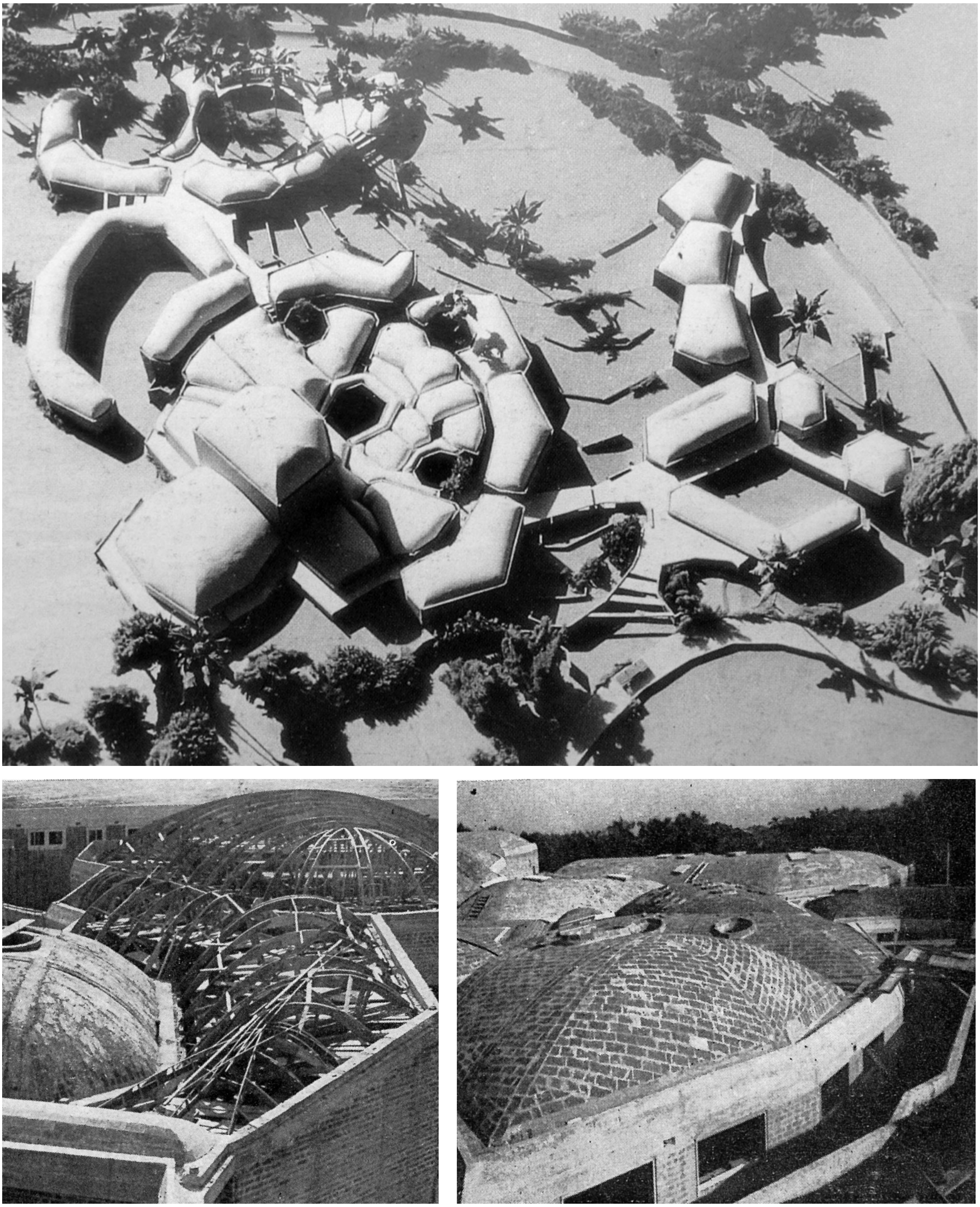
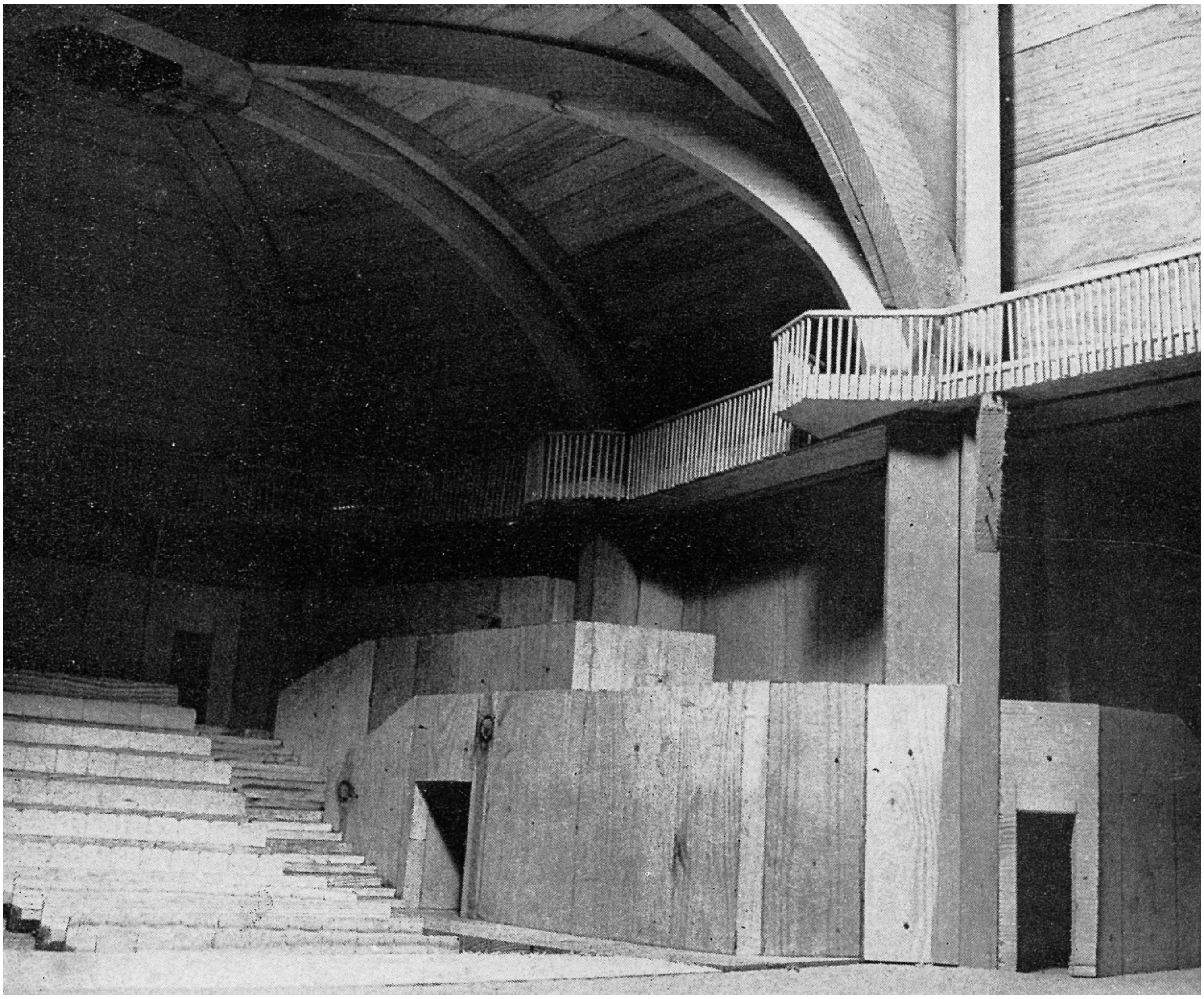


Figure 49 - The School of Dramatic Arts in 1965 (from *Arquitectura Cuba*, 1965, n° 334, pp. 78-89), ISA archive.

The School of Dramatic Arts in 1965



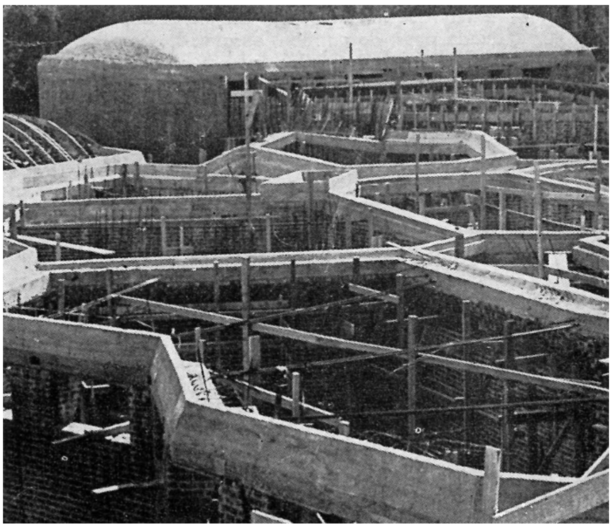


Figure 50 - On top: a wooden model of the main Theater designed for the School. On the bottom: School of Dramatic Arts under construction (from *Arquitectura Cuba*, 1965, n° 334, p. 88; bottom-right from ISA archive).

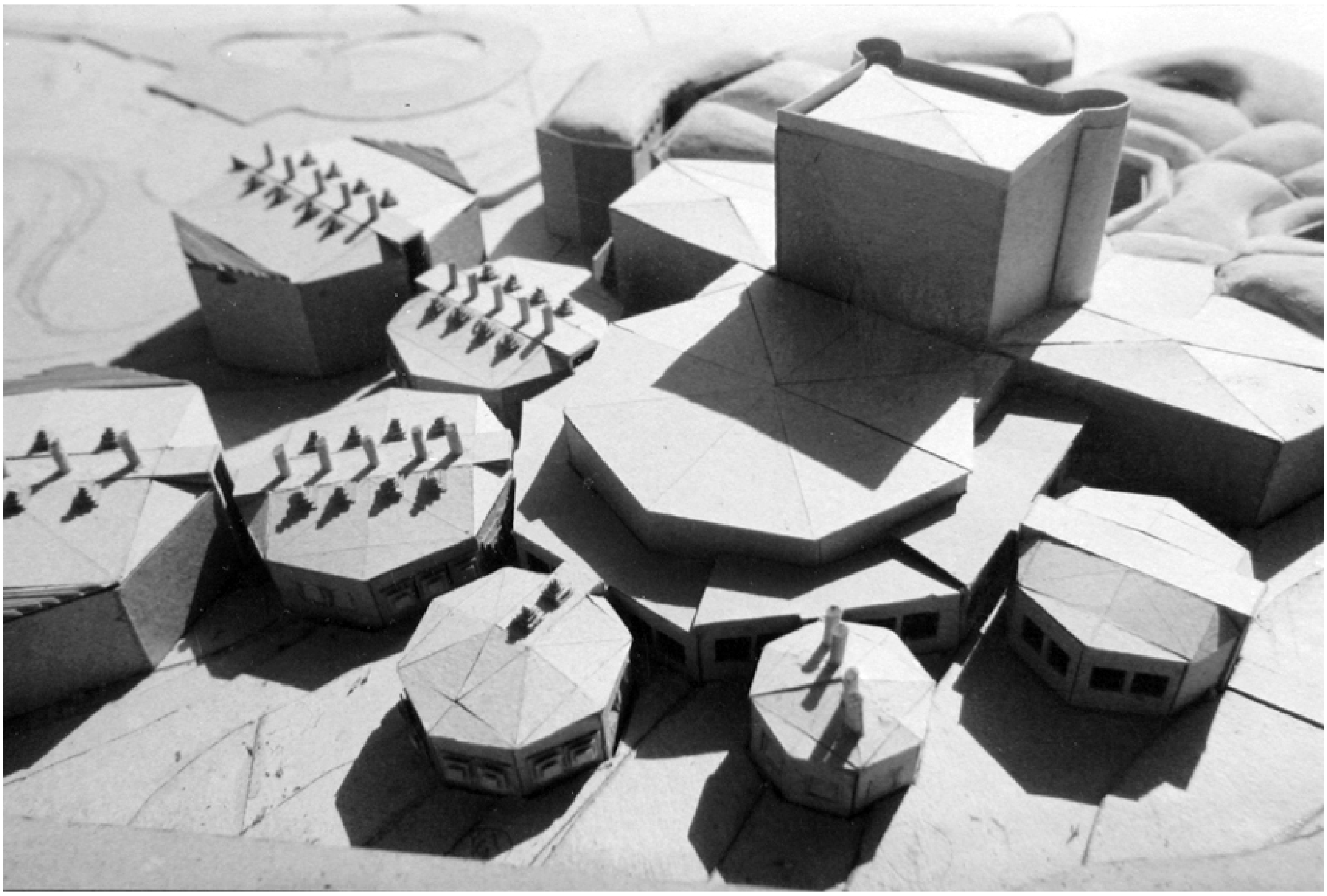


Figure 51 - Model representing Gottardi's completion proposal for the School of Dramatic Art (2001).

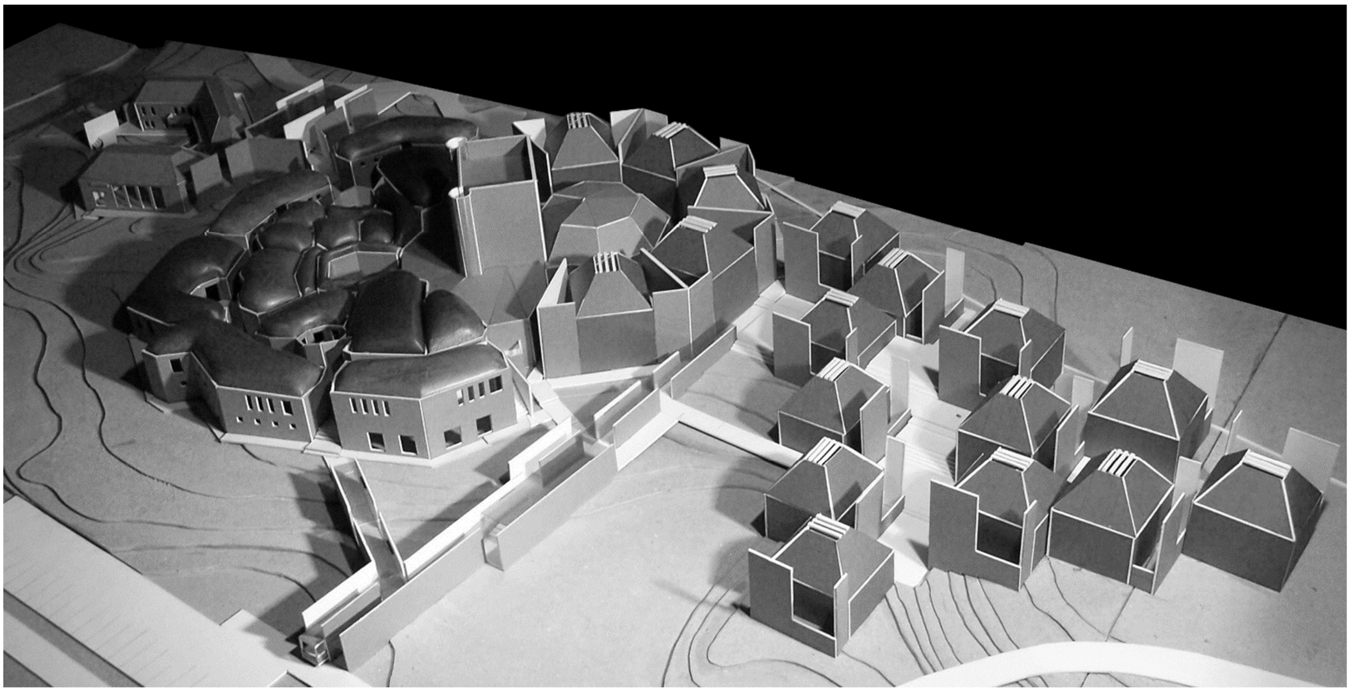


Figure 52 - Model illustrating a completion proposal by Roberto Gottardi (2007).

Other projects

Between 1981 and 2011, Roberto Gottardi developed several projects to complete the School of Dramatic Arts, trying to match the different functional needs that emerged over time. However, none of them was ever realized.

In his latest projects, the architect shifted the volumes that were originally located nearby the Rio Quibù to the other side of the theatre to avoid frequent floods. Nevertheless, in each project, the School of Dramatic Arts reflects a precise concept of theatre, understood as a community of artists, and not just as a performance.

While studying possible completion designs, Gottardi also proposed restoration interventions of the existing building. In particular, he gave dispositions regarding how to treat decayed bricks. Although the most immediate solution would have been to replace the deteriorated masonry portions, the architect wanted to convey the sense of time passing by, as well as of the degradation that his architecture suffered. He thus wanted to freeze the deterioration process by applying to the scarred areas a silicone substance to both prevent further damages and maintain the aesthetic effect as if it was a fresco painted on the wall by the force of nature. However, this proposal was considered a merely epistemological question, reflecting a concept of restoration that is typical of Europe but not really suitable for the Latin American world.

Finally, the project developed by Gottardi in 2011 was acquired by the MINCULT (*Ministerio de Cultura de la Republica de Cuba*) which instructed its own construction company (ATRIO) to prepare a detailed project in order to obtain the cooperation funds issued by IILA (*Istituto Italo-Latino Americano*).

In 2012 the restoration campaign started, primarily focusing on covering structures. Before the works stopped in 2014, the following activities were conducted:

- the vaults were shored up using wooden props that remain to this day;
- the outermost protective layer of the roofs was to be removed in order to apply waterproof insulation (this task was never completed);
- some of the clay tiles of the ceilings were replaced, but they were never grouted afterward;
- larger cracks were injected with sealing material.

Due to lack of funds, the restoration intervention was never completed, causing significant deterioration phenomena even where there were none before.

The latest initiative concerning the School of Dramatic Arts is the project *Que no baje el telón*, one of the outcomes of the cooperation agreement between the Italian and Cuban governments. Officially started in 2019, the project involves several different institutions, such as the *Centro de Colaboración Internacional* of the Cuban Ministry of Culture, the *Agencia Italiana de Cooperación para el Desarrollo* of Havana, the Architecture Department (DIDA) of Florence University, as well as the Universidad de las Artes (ISA).

The objective is to preserve Gottardi's architecture (which, along with the other Schools, was declared a National Monument in 2010), reversing its current state of decay and dismissal. According to the original masterplan, the proposal is that of restoring the building actually to use it as a Theater School. Of course, the teaching programs have since then evolved, and the project also aims to improve and boost educational activities.

The School of Dramatic Arts today

Figure 53 - The School in its current state (2019-2020).

Figure 54 - Main deterioration phenomena detected (2019-2020).

State of repair and current issues

The unfinished School of Dramatic Arts is overall in a rather good state of repair. Although the building's appearance clearly suggests a complete the lack of maintenance, the restoration intervention that occurred in 2012 - along with the spontaneous use of a few spaces - guaranteed its partial preservation, delaying the natural deterioration process.

Human intervention appears to have caused the most consistent changes, as in order to use the construction for purposes that are slightly different from the ones that were originally foreseen, some modifications were required (for instance, Figure 54 - middle, left - shows the demolished partition walls of one of the restrooms).

Even if limited, weathering's erosive action is visible on masonry (Figure 54 - bottom, right). The pulverization phenomenon of the masonry is mainly caused by wind erosive action and water capillary ascent. When blowing, wind is facilitated by the articulation of the building, which helps to convey air currents in the corridors, resulting in masonry erosion. Moreover, the quality of the bricks employed for the School of Dramatic Arts was found to be lower than that of the other four buildings.

Exposure to weathering is also accountable for the diffused presence of soiling, which can be observed both on reinforced concrete and masonry elements, sometimes worsened by biological colonization (Figure 54 - bottom, left). Vegetation growth on the vaulted roofs locally damaged the coverings. This phenomenon, in addition to the absence of waterproof insulation, fostered water infiltration, resulting in humidity stains and efflorescence at the intrados (Figure 54 - top).

Some of the reinforced concrete elements partially lost the concrete cover, leaving the rebar exposed. This issue was, however, partly addressed by previous restoration interventions (Figure 54 - middle, right).

The foundations of the unfinished theater’s fly tower have been heavily damaged by overgrown vegetation, which covers them almost entirely. The electrical and sanitary systems are unusable and need renovation.

Use

Although uncompleted, the School of Dramatic Arts has often been used to hold theater, cinematography and scenography classes, as well as other activities related to drama (Figure 55). Today the school appears completely dismissed and the only spaces that are still in use have been spontaneously occupied by students seeking for a working space (Figure 56).

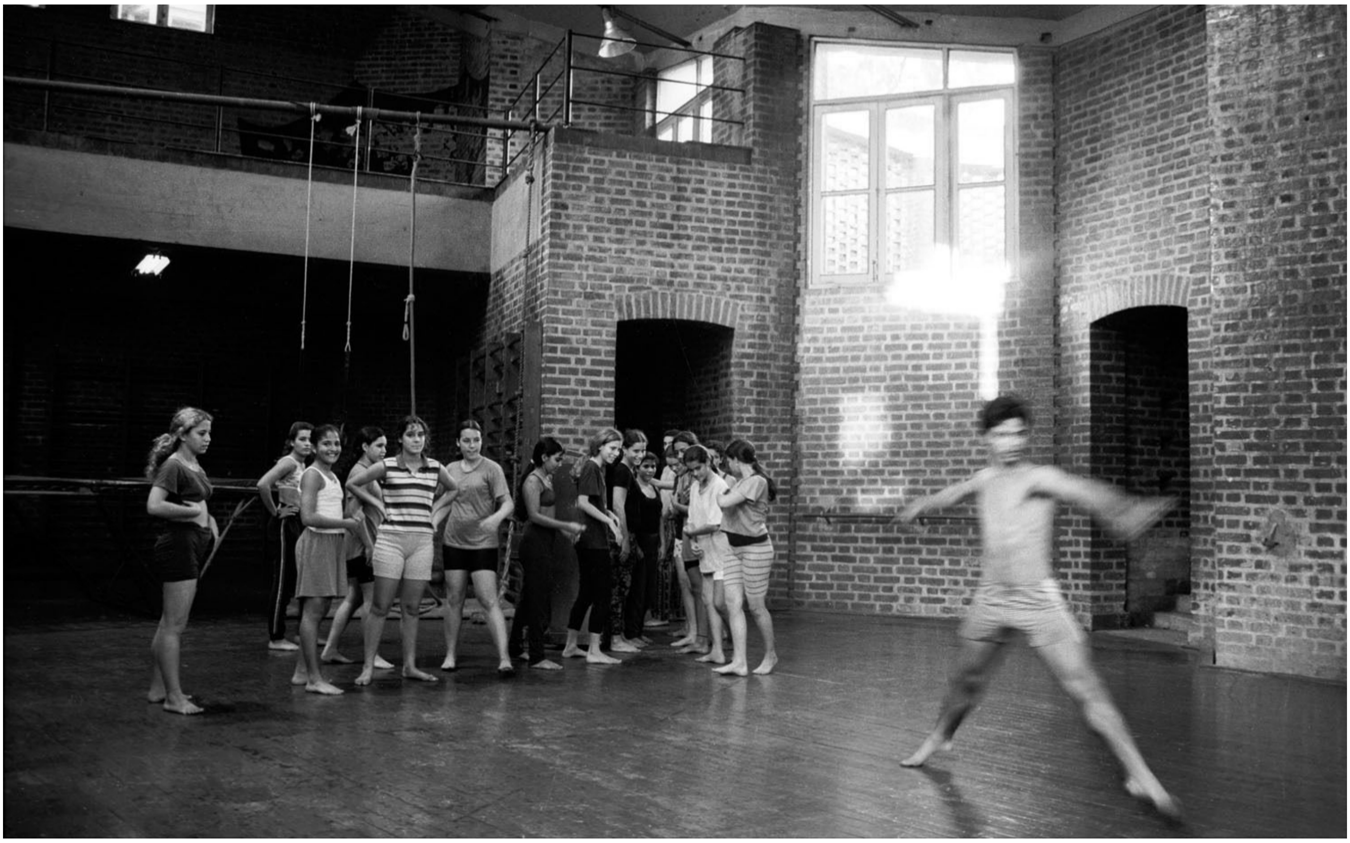


Figure 55 - Students rehearsing in the School of Dramatic Arts. Photo by Hazel Hankin (‘1990s).

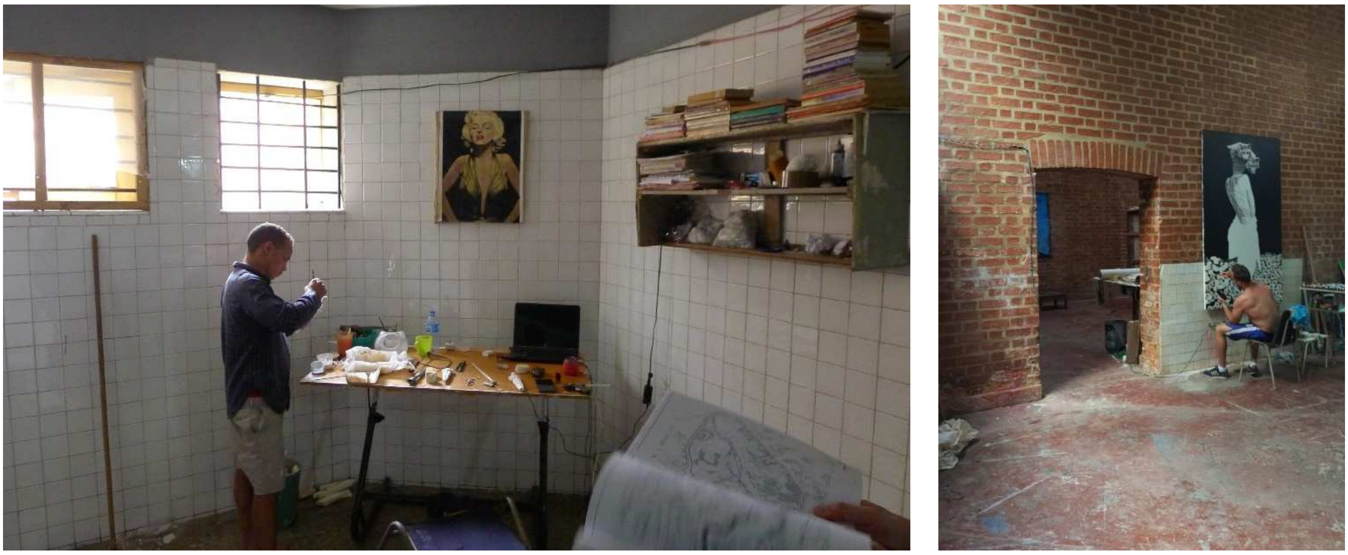


Figure 56 - Spontaneous use of the abandoned spaces of the School of Dramatic Arts (2019).

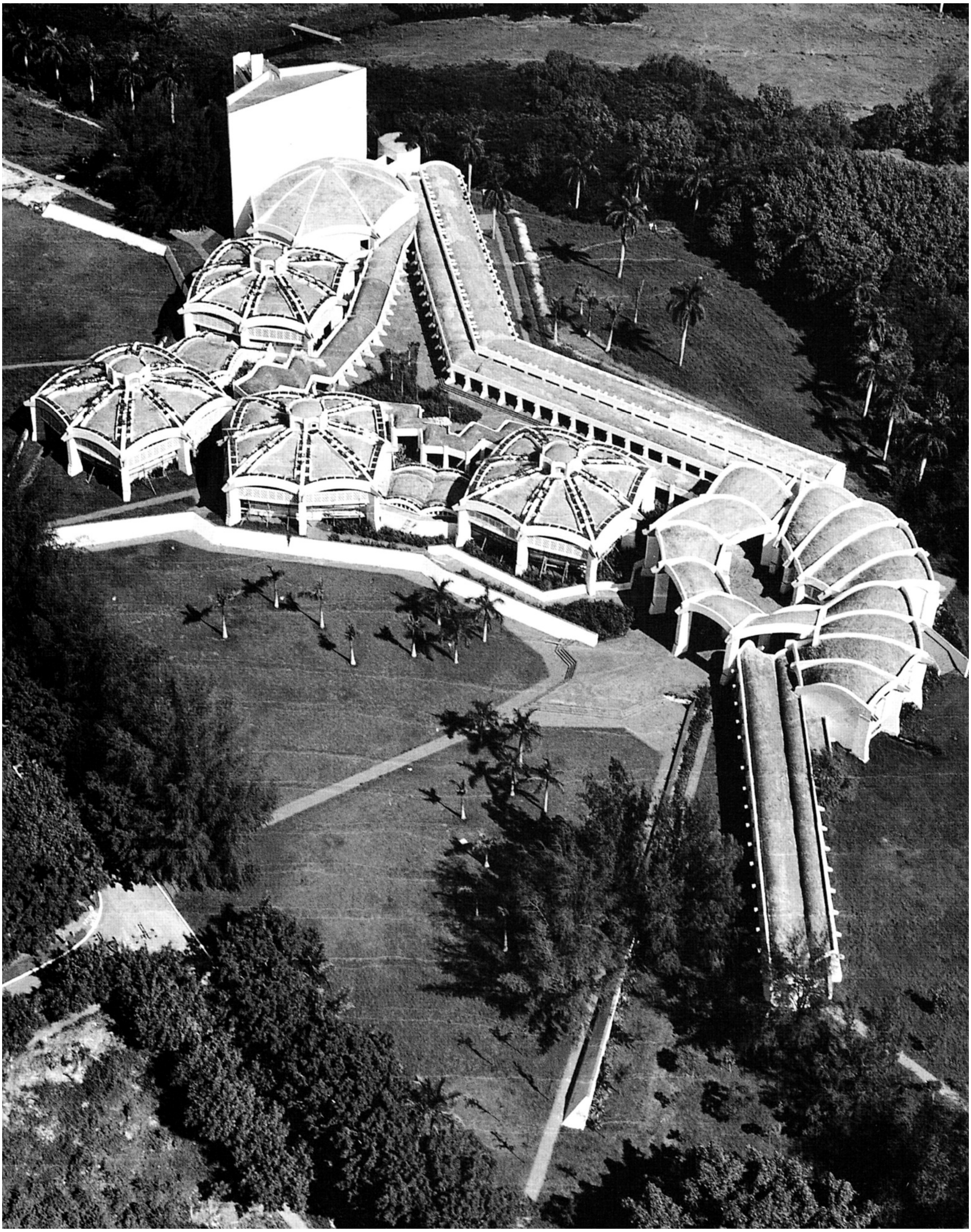


Figure 57 - Aerial view of the School of Modern Dance in 1965. Photo by P. Gasparini (ISA archive).

1.3.4 School of Modern Dance

Year of construction: 1961-63

Architect: Ricardo Porro

State of completion: completed

Original use: School of Modern Dance

Current use: Faculty of Performing Arts and Dance (ENA)

Figure 58 - Location within the Schools' campus.

"In the School of Modern Dance I wanted to express two very powerful sentiments produced by the first stage, the romantic stage, of the Revolution: the exaltation, collective emotional explosion, but at the same time a sense of anguish and fear confronting to a unknown future. The entrance and the dance pavilions are the image of exaltation. The fragmented vaults above appear inflated by an expansive force. Upon passing through the portal that lead to the plaza the angles of the columns point in different directions, breaking the order and provoking disorientation, anguish. At the same time I tried to play with the dancer's sense of movement. When the dancer leaps, the surroundings space expands - explodes - around him. And this is what I tried to create in the interior of the dance pavilions. But at the same time the sensation of explosion was that of the emotional explosion that the country was living at that moment"[33].

[33] Ricardo Porro commenting on the School of Modern Dance (from Loomis 1999).

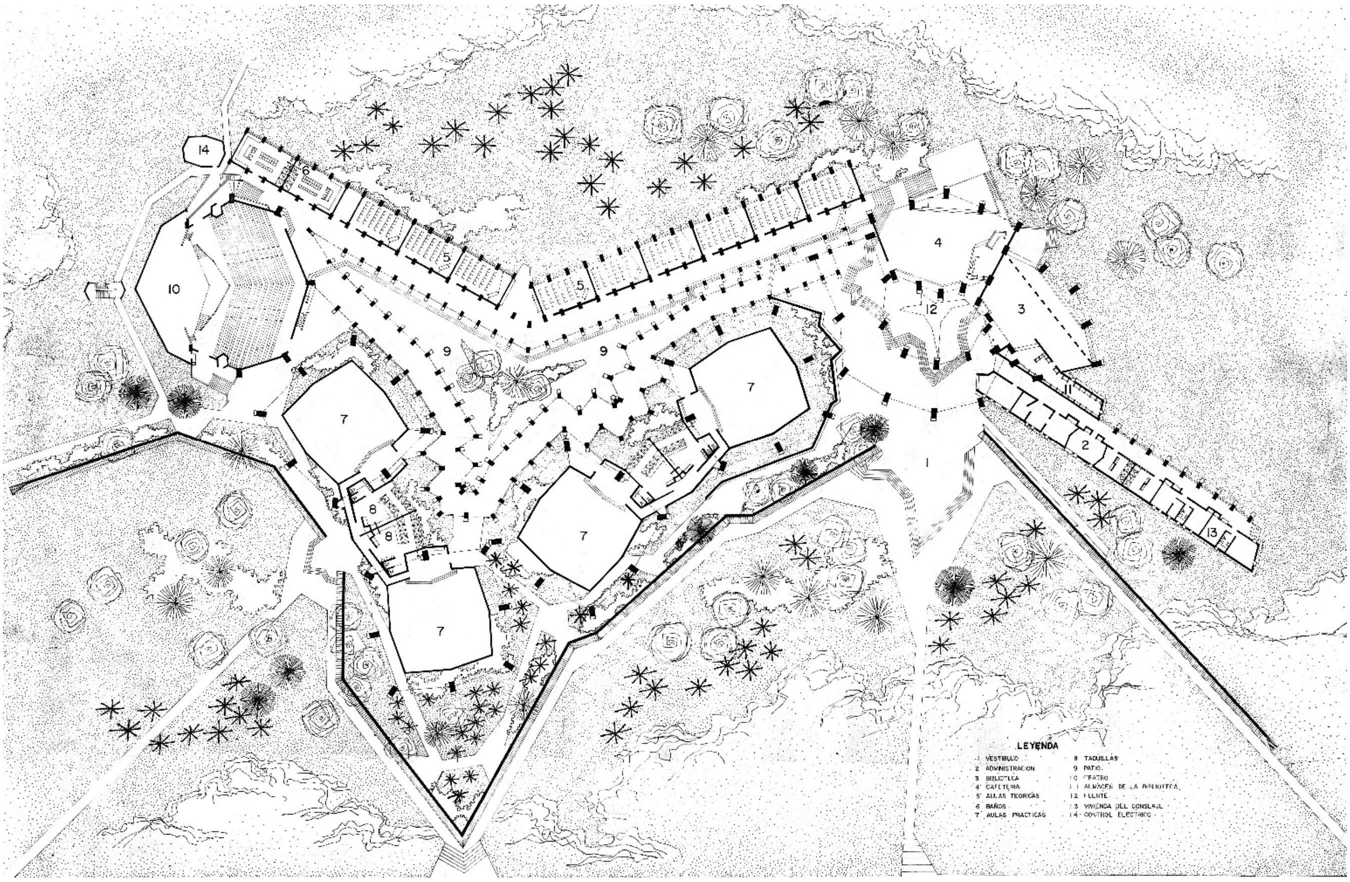


Figure 59 - Original plan designed by Ricardo Porro (ISA archive).

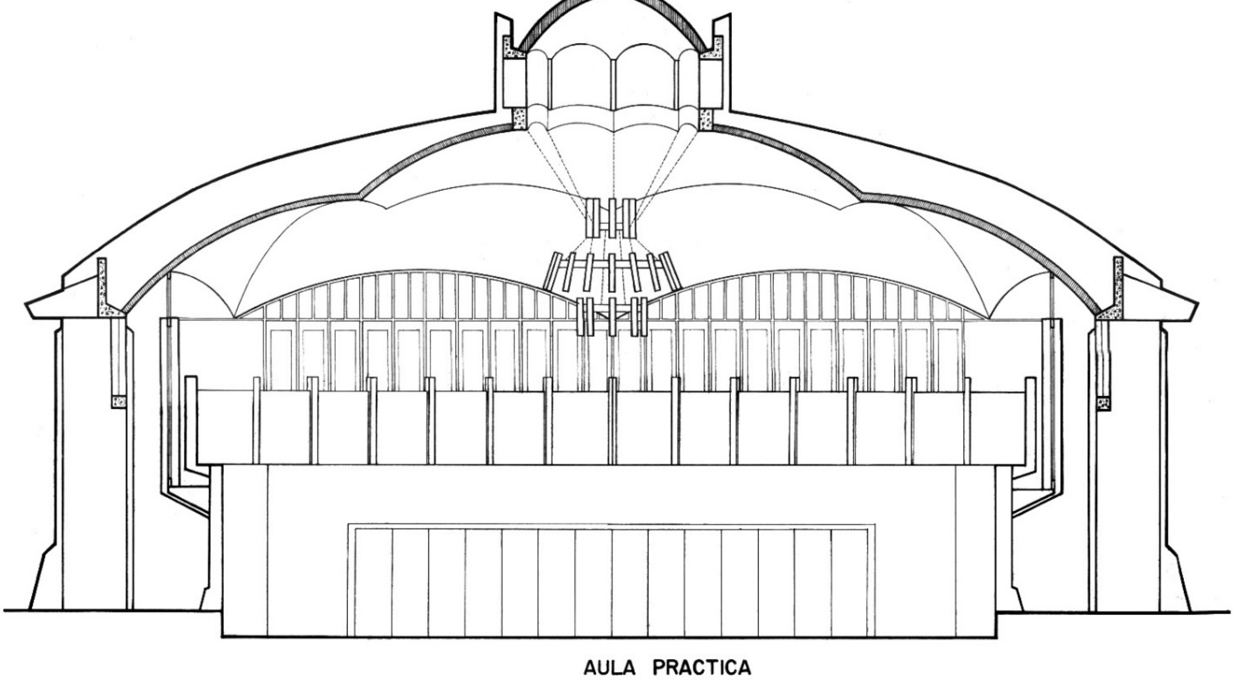


Figure 60 - Section of the dance pavilions according to the original design (ISA archive).

When describing the concept behind the design of the School of Modern Dance, Loomis states:

"Porro conceived the plan metaphorically as a sheet of glass that had been violently smashed by a fist and fragmented into shifting shards, symbolic of the Revolution's overthrow of the old order. The fragments gather around an entry plaza - the locus *of the "impact" - and develop into an urban scheme of linear, thought non rectilinear, shifting streets and courtyards. Three Catalan vaults celebrate a triumphal entry. Others form the enclosures of the studios, classrooms and administration buildings, softening in volume what is angular in plan. The shifting geometries of the plan cause the exterior spaces and passageways to expand and contract in a dynamic construct (…). The entry arches form a hinge around which the library and administrative bar rotate away from the rest of the school. The south side of the fragmented plaza is defined by the rotating dance pavilions, paired around shared dressing rooms. The north edge, facing a sharp drop in terrain, is made by two line bars containing classrooms, that form an obtuse angle. At the end of the angular procession, farthest from the entry, where the plaza once again compresses is the performance theatre"*[34].

The School of Modern Dance sits on the very Southside of the Country Club, overlooking the rest of the area.
The program called for a performance theatre, four dance pavilions, several theoretical classrooms, library and administration facilities. In the School of Modern Dance design, Porro wanted to praise the social-political moment he was living in Havana: the triumph of the revolution. Thus, the design process aimed to reflect and absorb the feeling of exaltation, the collective emotional explosion, and, at the same time, a sense of anguish and fear towards the unknown future of the newborn Cuban society.
This contrast is evident when moving to access the School from the main entrance, whose tall arches convey a sense of confidence and positivity. However, just across the plaza, the feeling changes, as the strict lining of the rectangular pillars of the porticoed corridors, pointing towards different directions, is quite disorienting.
The architect himself defined his architecture as an *"emotional explosion"*. Adapting to topography, the planimetric articulation creates a series of pointed angles, offering a counterpart to the School of Plastic Arts' fluid curves.
Inside the Dance Pavilions, light is carefully studied and controlled by means of skylights and sun blockers.
The raw plaster layer covering the vertical elements of the School (walls and pillars), resembling the one applied by Le Corbusier at Ronchamp, is a peculiarity of this specific building. Ricardo Porro took this decision to overcome possible problems connected to the poor quality of the employed bricks, which started deteriorating only a few months after they had been laid.

[34] Loomis 2011, pp. 43-47.

Figure 61 - The School in 1965. Photo by P. Gasparini (ISA archive).

The School of Modern Dance in 1965

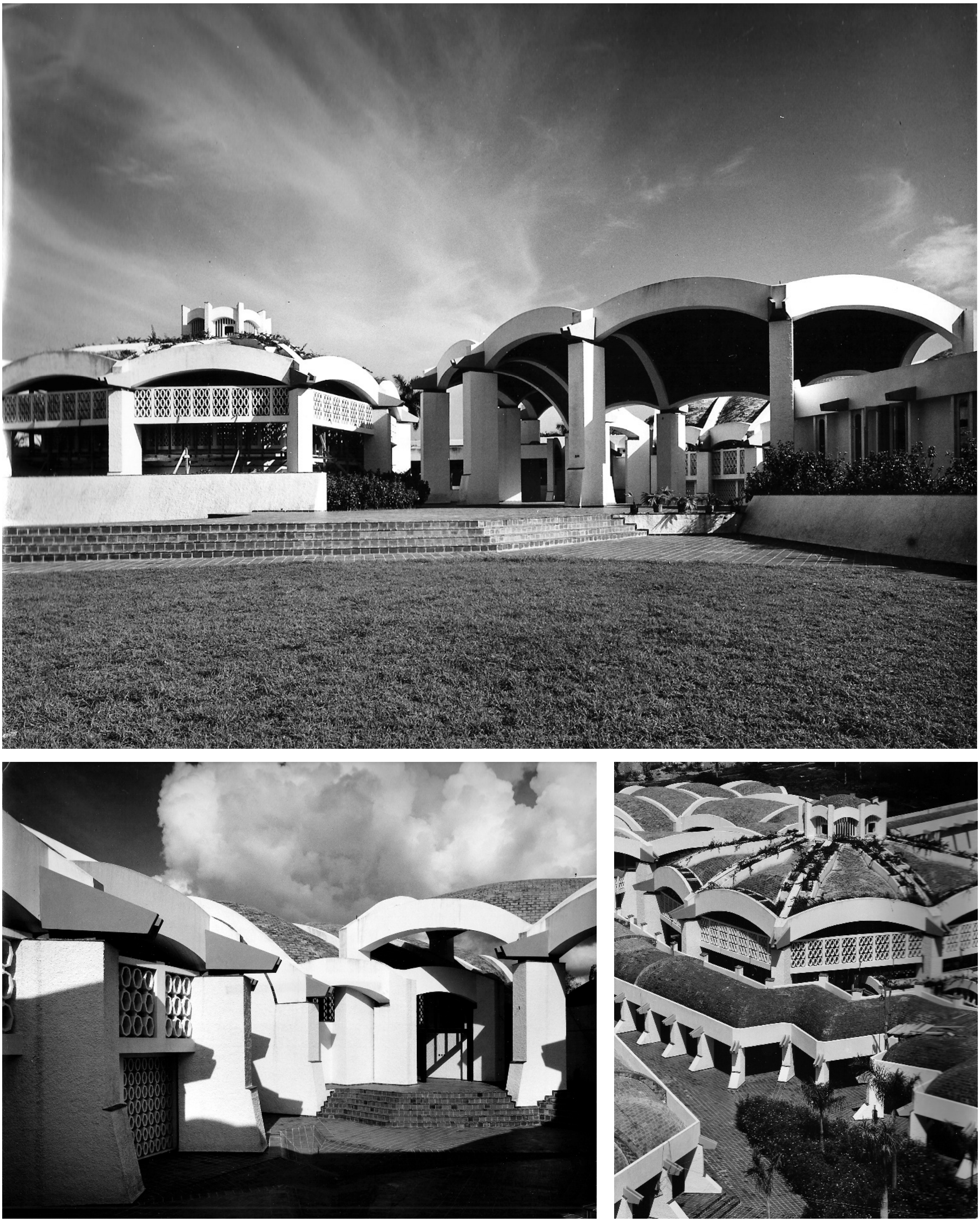


Figure 62 - The School after completion. Photos by P. Gasparini (ISA archive).

Other projects

Between 2000 and 2005 the whole School of Modern Dance has been restored. Within this context, some in-depth diagnostic investigations were carried out, highlighting a situation of material degradation. The main issues identified were:

- intrusions of arboreal formations at the extrados of the vaults;
- significant material degradation of the outermost layer of the ceramic tiles;
- strong aggression of the atmospheric agents resulting in bricks erosion and coving.

The intervention focused on:

- renovation of the covering structures finishing (terracotta tiles covering the domes);
- total remake of skylights, windows and doors;
- renovation of plasterwork;
- replacement of the old electrical and sanitary systems.
- placement of additional buttresses on the barrel vaults of the connective paths in order to strengthen the structure, containing the consistent lateral thrusts.

Figure 63 - Renovation of the coverings (ISA archive).

The School of Modern Dance today

Figure 64 - Current views of the School of Modern Dance (2019-2020).

Figure 65 - Main criticalities affecting the building (2019-2020).

State of repair and current issues

Thanks to the maintenance works, and to the constant use, the building appears to be in a good state of repair.
The most significant deterioration phenomena currently concern the masonry and the roofs, and they are connected to problems that are intrinsic to the architectural design. The fact that the tiles composing the eaves are not jutting enough to grant a correct outflow of rainwater and the peculiar shape of the walls are the main causes of the plaster finish's leaching (Figure 65 - middle).
Rainwater has an even stronger impact on the reinforced concrete beams that frame the buildings and the covered connective pathway, which completely lacks protective elements.

Moreover, the outermost layers of tiles of the vaulted covering are starting to show some decay. In particular, during the on-site investigations carried out in 2019, it has been possible to notice the uplift of consistent portions of clay tiles, as illustrated in Figure 65 (top, right). Limited humidity stains and efflorescence also started to appear at the vaults' intrados, highlighting the mediocre efficacy of the 2000-2005 restoration intervention (Figure 65 - top and bottom, left).

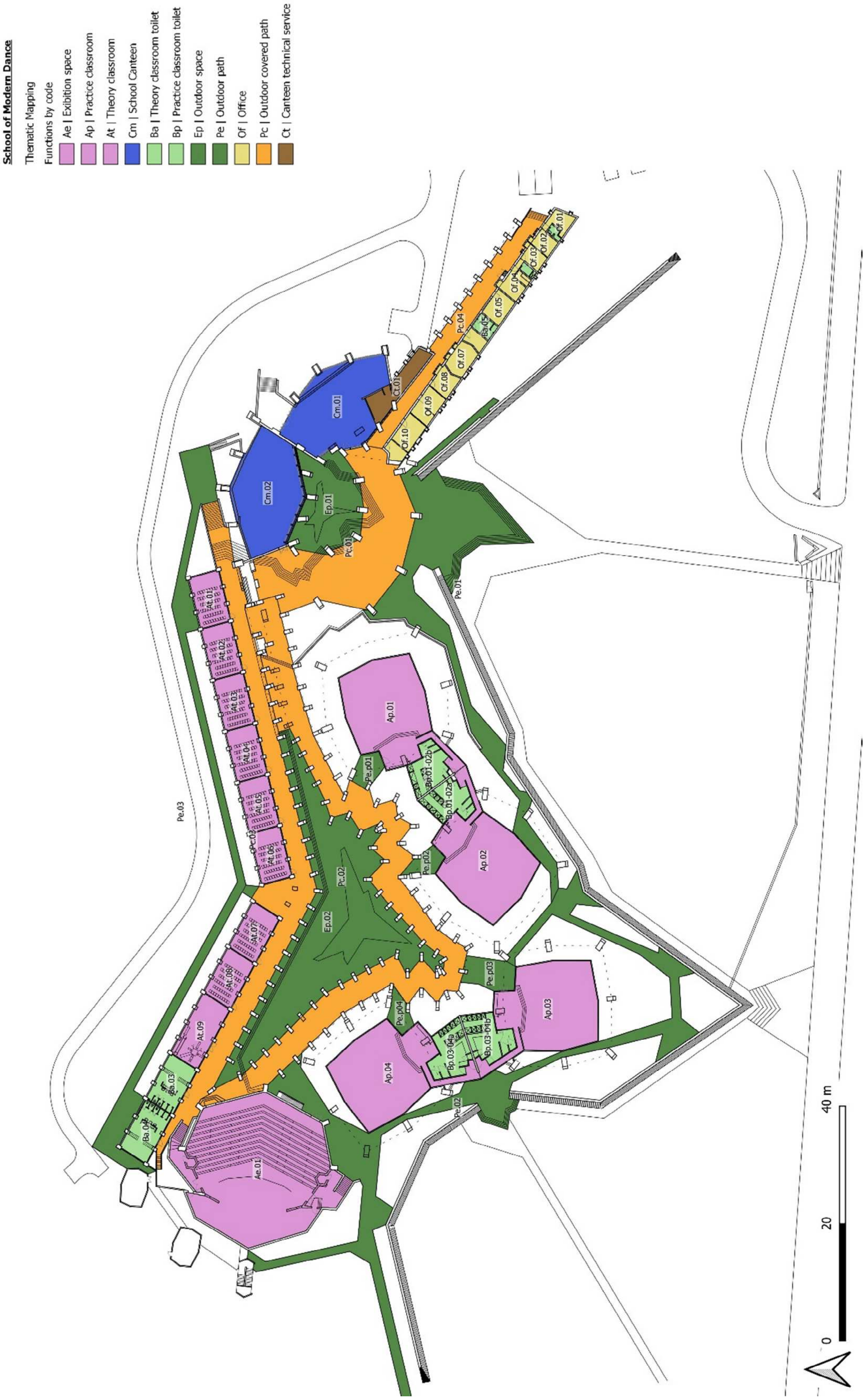


Figure 66 - School of Modern Art: intended use according to Ricardo Porro's original design.

Use

	Area [SQM]	%
Building footprint	4550,94	-
Didactic spaces	2047,94	45,00
Auxiliary spaces	612,67	13,46
Connective spaces	1525,14	33,51
Technical rooms	365,19	8,02
Specific functions	0,00	0,00
Outdoor spaces and paths	2187,94	-
Used *(w/o connective spaces)*	3025,80	100,00
Dismissed *(w/o connective spaces)*	0,00	0,00

Table 5 - Use distribution within the School.

Code	Original function	Current use
Ae.01	theater	not used
Ap.01 → 04	practical classroom - studio	practical classroom - studio
At.01 c	theoretical classroom	theoretical classroom
Cm.01	library	canteen
Cm.02	cafeteria	practical classroom - studio
Of.01; 0f.02 → 10	office	office
Of.02	concierge	office
Bp.01-02a; 01-02b; 03-04a; 03-04b	toilet - for the practical classroom	toilet - for the practical classroom
Ba.01; 01	toilet	toilet - office
Ba.03; 04	toilet	toilet - classrooms
Ct.01	warehouse - library	service space - canteen
Pe.p01 → 04		covered path (entrance to the pactical classrrom)
Pc.01		covered path - entrance
Pc.02- 03		covered path - practical classrooms
Pc.04		covered path - offices
Ep.01; 02		external paved space
Pe.01 → 03		external path

Table 6 - Chart comparing the functional distribution according to the original masterplan to the current use situation.

The School of Modern Dance, fully completed and already functioning in 1965, has always been used according to its original didactic purpose. Being included in the ENA, the school is dedicated to middle-high students.

Figure 67 - On top: a dance class in the ‘60s (left - photo by Paolo Gasparini) and a dance class in the ‘1990s (right - photo by Hazel Hankin). On the bottom: a dance class today (2019).

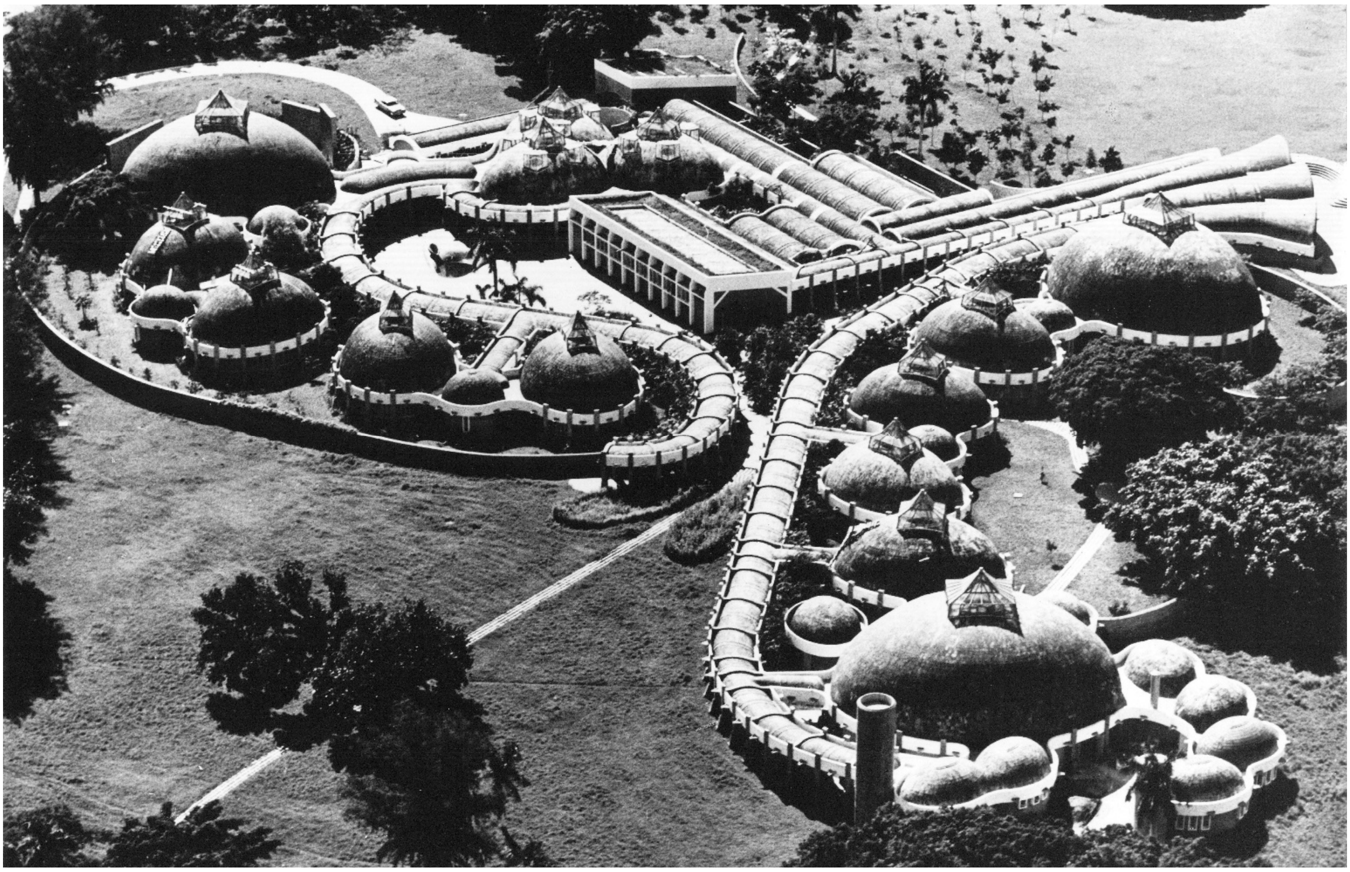


Figure 68 - Aerial views of the School of Plastic Arts in 1965. Photo by P. Gasparini (ISA archive).

1.3.5 School of Plastic Arts

Year of construction: 1961-63

Architect: Ricardo Porro

State of completion: completed

Original use: School of Plastic Arts

Current use: Faculty of Visual Arts (ISA)

Figure 69 - Location within the Schools' campus.

"...I wanted to seek an expression of an architecture for the people and to delve into the eternal problems of the human condition. The School of Plastic Arts is the expression of beginnings - the beginnings of my creative life and he beginning of the Revolution...(...) Sensuality and Sexuality are noted everywhere. (...) I tried to make an arquitectura negra, a city seized by a negritud that had never before had a presence in architecture.(...) The whites profited from this sensuality and over time produced a more modified barocco criollo. What came was a miniaturised , simplified and sweetened barocco form. So this calm and sensual Cuban baroque from the eighteenth and nineteenth centuries arrived in the twentieth with an explosion, an apotheosis. I believe that this was very correct evolution for Cuba. In Cuba this baroque is fully expressed. It is also that which I wished to express in my School of Plastic Arts..."[35]

[35] Ricardo Porro commenting on the School of Plastic Arts (from Loomis 1999).

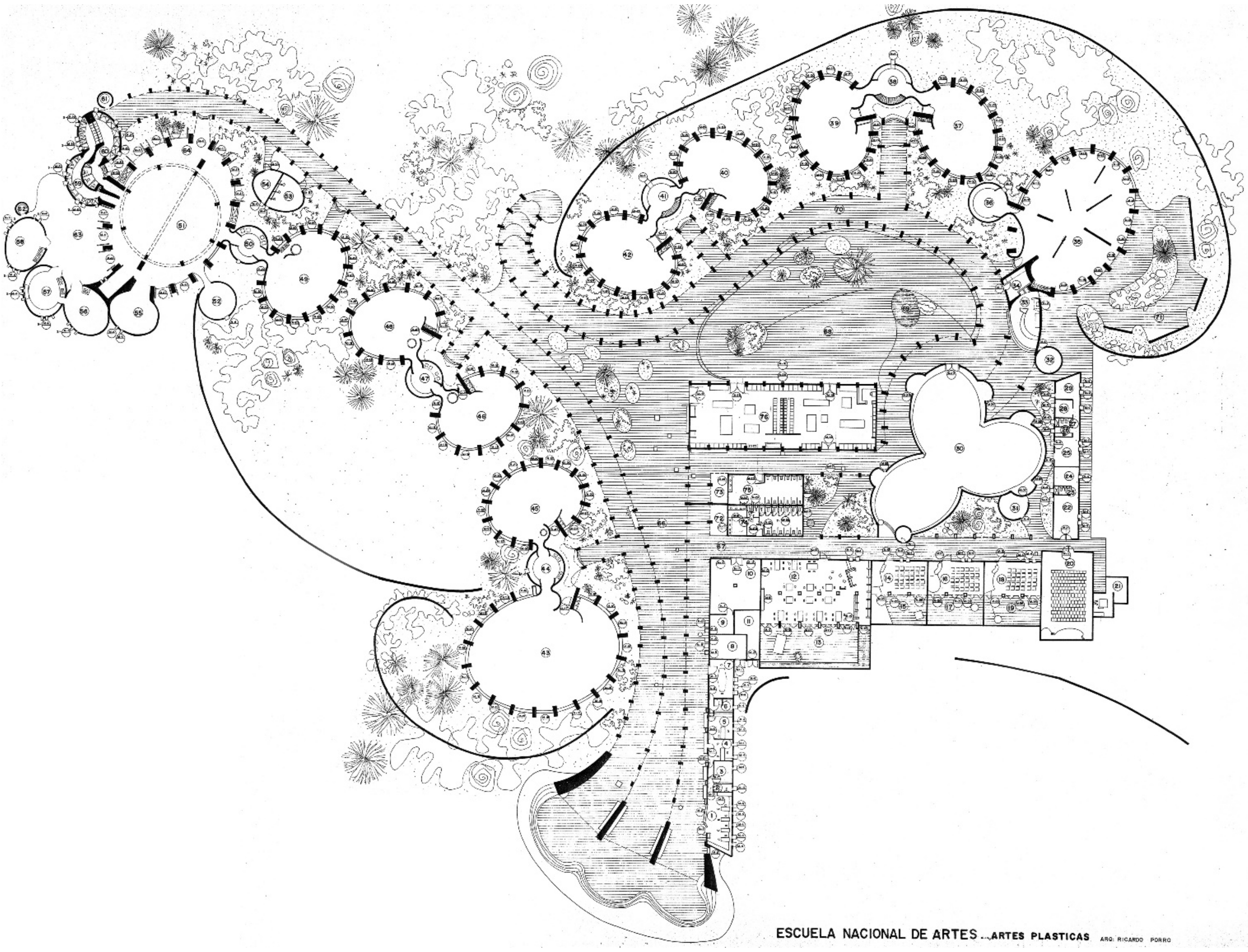


Figure 70 - Original masterplan of the School of Plastic Arts by Ricardo Porro. (ISA archive).

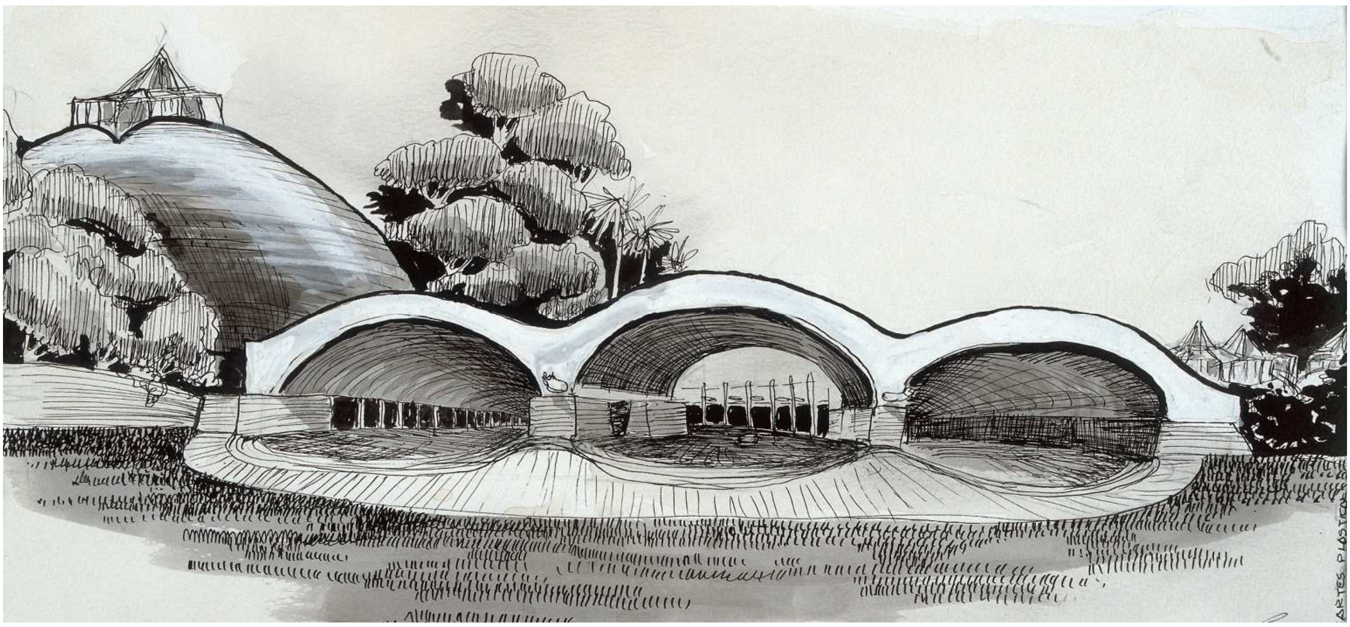


Figure 71 - Ricardo Porro (1962): sketch of the main entrance to the School (ISA archive).

The School of Plastic Arts is located in front of the entrance of the former Country Club, on the northern part of the site. The original program foresaw ten studios and additional exhibition spaces, offices, and theoretical classrooms. As in the School of Modern Dance, the School of Plastic Arts forms were determined through a spatialized symbolic representation. However, here the figurative iconography engaged issues of gender and culture that would prove controversial.

Porro sought to address identity issues through an architectural synthesis of Cuba's multicultural heritage, which he defined as a hybrid of patriarchal Spanish baroque culture and nurturing matriarchal African culture, both mediated by the sensuality of the tropics. The issues that Porro had first raised in his article "*El sentido de la tradición",* finally developed into formal imagery.

"The Revolution had been for me a cataclysm, and a very good one at that. I now wished to refute both architecture's and my own family's aristocratic past. I wanted to seek an expression of an architecture for the people and to delve into the eternal problems of the human condition. The School of Plastic Arts is the expression of beginnings — the beginning of my creative life and the beginning of the Revolution. In the moment that I conceived the School of Plastic Arts I was interested very much in the problem of tradition. Cuba is not Catholic. Cuba is a country where the African religion has more force than the Catholic. So I tried to make an arquitectura negra*, a city seized by a negritud that had never before had a presence in architecture. While it had been given a presence in the paintings of Lam, to draw from Cuba's African culture in architecture was a radical step"*[36].

Porro's poetically interpretative reading of Cuban history provided a theoretical framework for a formal elaboration of cultural themes heretofore unknown in Cuban architecture. The schools' plan evokes an archetypal African village, creating an organic urban complex of streets, buildings, and open spaces. The studios, oval in plan, are the basic cell of the complex. Each of them was conceived as a small arena theatre with a central skylight to provide zenith lighting. The studios are organized along two curving colonnaded paths. Lecture rooms and offices are accommodated in a contrasting block-like plan, that is partially wrapped by and engaged with the colonnaded path. The cupolas over the studio pavilions bear reference to both Borromini and the female breast. A triple domed exhibition space is accessible from the central square. Classrooms and administration offices are hosted inside a contrasting rectangular block.

Porro's desire to create an architecture that was evocative of the female body was in part a response to the poem Eupalinos of Paul Valery, in which Eupalinos, an architect, decides to build a temple based on the proportions of a beautiful young girl he met in Corinth. Ideas of gender and ethnicity converge in the curvilinear forms and spaces of the Plastic Arts school, which are intended as an evocation of negritude as well as of female nurturing and sensuality. For Porro, sensuality was not just a condition of negritude or gender but also a condition of generic

[36] Ricardo Porro interviewed by John Loomis, taken from Loomis 1999.

erotic nature of the tropics that invited open expression of sexuality. He brought together these readings of the building with the phrase: "*La Escuela de Artes Plasticas es la ciudad que se convierte en Eros*".

Three seemingly catalan vaults leading to three diverging colonnaded paths can be accessed at the entrance. The central path, however, ends unexpectedly, compelling one to choose one of the flanking paths.

The curving paths deny the visual orientation common to a linear perspectival organization. Following this *paseo arquitectónico* is a disorienting experience since the visitor constantly feels lost. Arrival at the main plaza is indirect and comes as a surprise. Here one encounters Porro's most overt and literal reference to the body and sexuality, a fountain in the form of a papaya, a fruit with distinct sexual connotation in the Caribbean, filling a pool surrounded by limp phallus-like drains. Here, at the journey's culmination, the erotic is no longer suggestive but representationally explicit. But beyond the erotic episodes, it is the organic spatial experience of Porro's choreographed *paseo arquitectónico* and the magic realist sensation of disorientation formed through plastic manipulation of Catalan vault that makes this complex distinctive[37].

[37] The description is based on John A. Loomis, *Revolution of forms*, 2011, pp. 57-60.

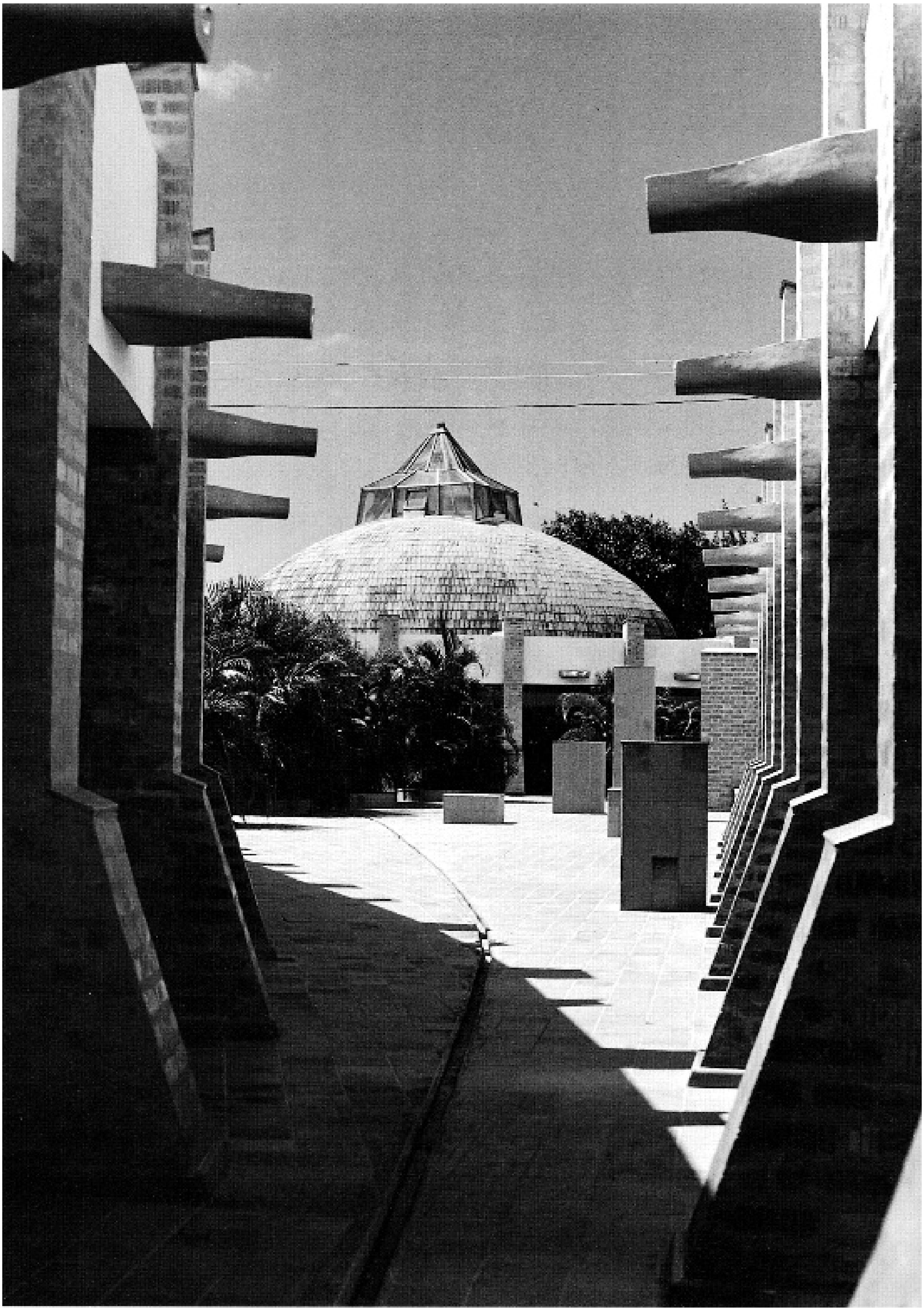
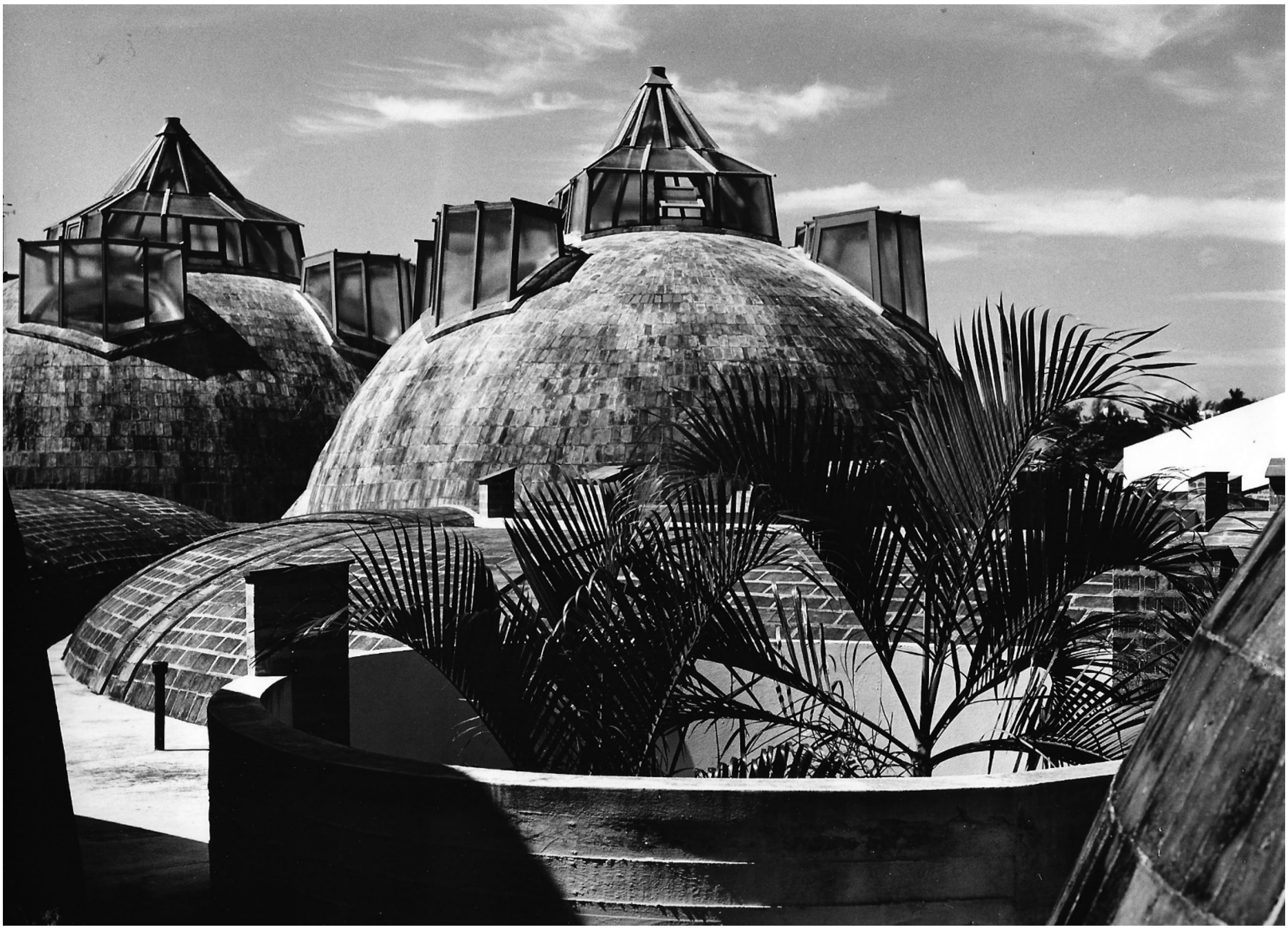


Figure 72 - The School in 1965. Photo by P. Gasparini (ISA archive).

The School of Plastic Arts in 1965



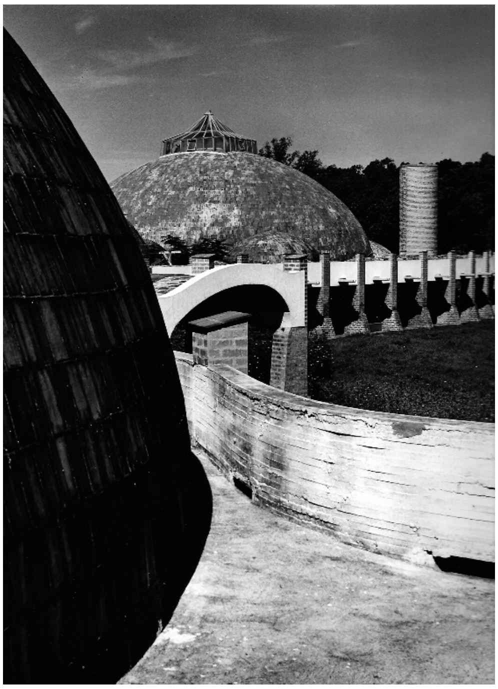


Figure 73 - The building after completion. Photos by P. Gasparini (ISA archive).

Figure 74 - Restoration occurred between 2000 and 2005. On the top: insertion of a concrete core to strengthen the pillars.

Other projects

Between 2000 and 2008, the building has undergone restoration works that mostly focused on the reinstatement of finishing materials (terracotta tiles covering the domes) and the total remake of skylights, windows, and doors. The operations, promoted by the Cuban Government, were led by Universo Garcia Lorenzo and started with an investigation of the building and an assessment of its state of repair. This resulted in a topographical survey of the building and several technical reports regarding the chemical characterization of the building materials, the main structural problems, and the environmental issues.

One of the most controversial interventions concerned the brick pillars supporting the covering domes of the open corridors. The diffused presence of cracks led to a quite invasive strengthening intervention, as a concrete core was inserted in the buttresses, as shown in Figure 74 (top).

Some studies run both before and after the intervention asserted that the cracks were caused by settlement, and therefore, they would not have compromised the building's stability. Several cracks developed a few years after the construction consequently to the natural settlements of the structures which, because of their own geometrical conformation, are subject to consistent strong thrusts.

Unfortunately, most of the operations ended up causing further deterioration phenomena connected to the choice (and sometimes even the incompatibility) of the employed materials. Indeed, the new terracotta tiles replacing the original ones already show signs of detachment.

The bricks employed to repair walls after the construction of the reinforced concrete buttresses have suffered severe deterioration due to their faulty composition. The renewal of the skylights has partially modified the domes' original shape as a new profile has been inserted where the clearstory touches the roof. This element, employed to prevent water infiltrations, has proven inefficient, and it has caused further damage to the lower structures.

Figure 75 - The School in its current state.

Figure 76 - Main criticalities detected (2019-2020).

State of repair and current issues

The School of Plastic Arts currently appears to be in a quite good state of repair. The building, completed and already functioning in 1965, has always been used according to its original didactic purpose. From 1965 to the beginning of 2000, the structures have preserved well thanks to constant use and maintenance.

The rainwater drainage system, gutters, and roof pipes require a general cleaning in order to remove the consistent quantity of leaves that have obstructed them, but they overall are in good shape. The electrical and sanitary systems are well functioning and there is a good illumination system that grants the use of the building during the evenings.

Currently, the most compelling issues to solve are connected to the attenuation of the decay of the building materials employed during the restoration process and the preservation of the original structures that still are in good state of conservation.

Despite the recent restoration intervention, many of the building's masonry pillars and walls are affected by coving, probably caused by both the low quality of the bricks and exposure to weathering (Figure 76 - bottom).

The outermost layers of clay tiles on the vaults are detaching from the substrate, as can be observed in Figure 76 (middle). This is also due to the poor quality of the materials employed during the restoration, with particular reference to the mortar.

The aforementioned problems, regarding the school's roofing, resulted in consistent water infiltration phenomena highlighted by the diffused presence of humidity stains and efflorescence at the intrados of the domes and vaults (Figure 76 - top).

Getty Foundation

Figure 77 - Intended use according to Ricardo Porro's original design.

	Area [SQM]	%
Building footprint	6573,88	-
Didactic spaces	3396,85	51,67
Auxiliary spaces	121,85	1,85
Connective spaces	2354,06	35,81
Technical rooms	701,11	10,67
Specific functions	0,00	0,00
Outdoor spaces and paths	3303,88	-
Used *(w/o connective spaces)*	3453,11	82,04
Dismissed *(w/o connective spaces)*	755,83	17,96

Table 7 - Use distribution within the School of Plastic Arts (original arrangement).

Code	Original function	Intermediate Project	Current use
Ae.01	exhibition gallery	exhibition gallery	exhibition gallery
Ap.01	workshop - ceramic art	practical classroom	workshop - ceramic art (2^ year)
Ap.02	workshop - environmental design	practical classroom	workshop - ceramic art
Ap.03	workshop - sculpture	practical classroom	workshop (1^ year)
Ap.04	workshop - sculpture	practical classroom	workshop (4^ year)
Ap.05	workshop- clay models	practical classroom	workshop - sculpture
Ap.06	workshop- foundry (arena)	practical classroom	workshop- foundry
Ap.07; 09; 10	workshop - paintings	practical classroom	workshop (5^ year)
Ap.08	workshop - paintings	practical classroom	workshop (3^ year)
Ap.11	workshop - paintings	practical classroom	workshop (4^ year) and professors' room
Al.01a; 01b; 01c	workshop - printing arts	workshop - printing arts (woodcut)	workshop - printing arts (woodcut)
Al.02a	photography area and toilet	workshop - photography	workshop - photography
Al.02b	dean and administration office	administration	Department of Theoretical Studies on Art.

Al.02c	secretary of the dean and toilet	administration	Department of Theoretical Studies on Art.
At.01a; 01b; 02: 03; 04	classroom	classroom	classroom
At.05	conference room	classroom	Teatro "El ciervo encantado". NON UTILIZZATO
At.01c; 01d	classroom	computer lab	computer lab
Of.01	professors'room	administration	Faculty of Visual Arts - meeting room
Of.02	teachers' secreatary	administration	professors'room
Of.03	teachers' secreatary	administration	Faculty of Visual Arts - secretary of the dean
Of.04	office of the deputy dean	administration	Faculty of Visual Arts - dean
Of.05	meeting room	meeting room	Faculty of Visual Arts - teachers' secretary
Tp.0102; 0304; 0506; 0708; 0910; 11a; 11b; Tt.a	warehouse	warehouse	warehouse
Tp.06b	workshop - molding and casting	service space - foundry	workshop - molding and casting
Tp.06c	workshop - molding and drying	service space - foundry	workshop - molding and drying
Tp.06d	workshop - lost-wax casting	service space - foundry	workshop - lost-wax casting
Tp.06e	workshop - electrolysis and coating	service space - foundry	workshop - electrolysis and coating
Tp.b	warehouse	technical room	service space
Tp.c	fuel tank	fuel tank	fuel tank
Tp.d	water tank	water tank	water tank
Ta.01; 02; Tp.a; Tp.06a	switch cabinet	technical room	technical space
Td.01	toilet	warehouse	warehouse
Td.02	Art History Department		
Td.03	Art History Department	reception desk	reception desk

Td.03a	Art History Department	warehouse	warehouse
Pf.01	classroom	hallway	hallway
Pc.a; b; 0106; p0106; 0711; p0711; Pd.01; 02	covered path	covered path	covered path
Ba.01; 02; 03; 04	toilet	toilet	toilet
Ep.11	outdoor patio - painting	outdoor exhibition space	outdoor exhibition space
Ep.0105; 06		external workspace	external workspace
Ea.01; 02; 03; 04; Ep.01	outdoor patio	outdoor patio	outdoor patio

Table 8 - Chart comparing the functional distribution according to the original masterplan, the intermediate project situation and to the current use situation.

Current use

Fully completed by 1965, the building has always been used for its original didactic purposes. Today it hosts the Faculty of Plastic Arts (ISA). The three-foiled space facing the central piazza often hosts small expositions cured by local students displaying their work.

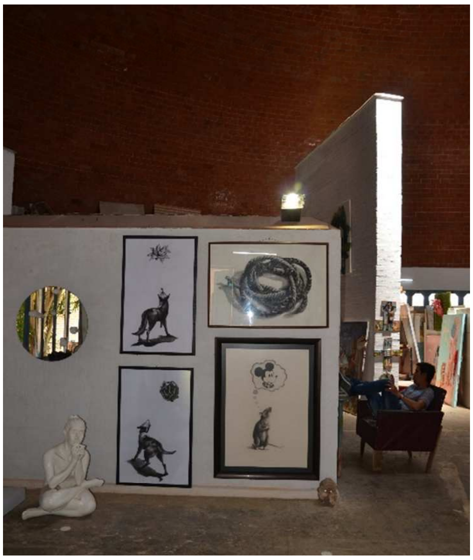


Figure 78 - On top: painting atelier in the '60s (Photo by Paolo Gasparini). On the bottom: painting atelier in 2010 (left - photo by Hazel Hankin) and a painting atelier today (right - 2019).

1.3.6 Other on-campus buildings

In addition to the five iconic architectures previously described, the School complex includes a few other auxiliary pavilions that were either pre-existent or built after 1965 to fulfill the ISA's mutated necessities. Such buildings (pinpointed in the map below - Figure 79) are strictly complementary to the scholastic activities and thus have to be taken into account in order to correctly assess the overall functional arrangement of the National Schools of Art. To complete the School complex description, the following paragraph offers a brief overview of each building, mostly focusing on the matter of current use.

Figure 79 - Auxiliary buildings currently existing within the National Art School's complex.

1. **Dorms**
2. **School library and maintenance warehouses**
3. **Rectorate building (former Club House)**
4. **Cafeteria colonial**
5. **Casa colonial**
6. **School of music (ENA - Middle level)**
7. **Casa de protocolo (Facultad de Artes de la Conservacion del Patrimonio Cultural)**
8. **Casa nel bosque**
9. **School of Theater**
10. **Facultad de los Medios de Comunicacion Audiovisual - FAMCA (presentlty out of ISA Campus)**

1. Residential building (dormitory)

Year of construction: 1978

Architect: Josè Mosquera

Area (tot): about 9.000 sqm (five levels)

Original use: Dormitory

Current use: Dormitory

The residential building, positioned halfway between Garatti's School of Music and Porro's School of Plastic Arts, was built using precast concrete on a design by architect José Mosquera. The building's linear extension and regular features - clearly referable to Soviet influence - strongly contrast with the schools' sinuous shapes. The dormitory was added to the complex in order to guarantee the possibility to study at the ISA also to the students who live too far away to afford to travel back and forth on a daily basis. Its massive and rough appearance reflects the functional approach adopted by the architect, whose intent was merely to provide a much needed service. As predictable, the final result fostered debates and collected heavy criticism.

The building is fully occupied and extensively used. Indeed, despite the small dimensions, each room hosts about four students. While the entire four levels of the structure host the dorm rooms and bathroom facilities, the ground level provides social interaction and recreation spaces. Since the building stands on pillars, the ground floor configures as a covered pathway, alternating closed rooms dedicated to services/stairs and small plazas where students can gather together.

Figure 80 - The ISA dormitory designed by Jose Mosquera in its current conditions (2019).

2. School library and maintenance Warehouses

Located nearby the rectorate building, a precast concrete warehouse hosts the Schools' library and storage space. Since the typical high moisture of tropical climate is not very suitable for paper book preservation, the library is one of the few spaces on-campus using air-conditioning. Indeed, the presence of several dehumidifiers guarantees the persistence of the book heritage of the Schools. The library is divided in three naves: the central one is dedicated to consultation and study, the left one hosts the offices, while the books' deposit occupies the right one.

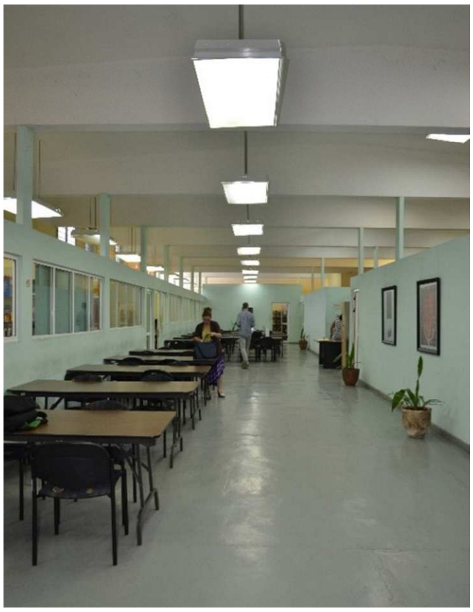


Figure 81 - External and internal view of the library of the School complex (2019).

3. Rectorate building (former Club House)

Year of construction: ante 1911

Architect: Luis Echevarria

Original use: Club house

Current use: Headquarters of the ISA, School of music, school's canteen

	P -1	PT	P1	TOT	%
Canteen	241	37	0	278	4,13
Connective spaces	565	446	400	1411	20,95
Conference hall	0	492	0	492	7,31
Classrooms (Music)	674	0	524	1198	17,79
Offices	132	97	488	717	10,65
Services and storage	286	48	70	404	6,00
Technical rooms	593	23	5	621	9,22
Dismissed	510	864	240	1614	23,96
TOT	**3001**	**2007**	**1727**	**6735**	**100 %**

Table 9 - Use distribution within the Rectorate Building (current situation).

The current rectorate building is the result of more than 100 years of transformations. The first available picture of the current rectorate dates back to 1911, and it shows the original farmhouse of *Finca Loca*, the volumes of which vaguely match today's South wing of the rectorate.

Today, the rectorate building hosts mainly two functions: the ISA music school and the ISA schools' administration. Indeed, Garatti's School of Music was never completed, and what remains after years of decay cannot be used for teaching purposes. The music school activities have been using most of the rectorate building, waiting for a dedicated space to be built, while a small portion of the didactics takes place in other places outside the ISA campus. The north wing is composed of two levels, and it presents strong signs of decay. Its spaces are nevertheless used for music education and offices in the absence of a better alternative. Some technical installations are also present in the lower level. The East wing is directly accessible from the entrance hall. At the ground level it is composed of three large spaces that are currently unused and are undergoing renovation works. The upper level is equally inaccessible and under renovation. We find technical and service spaces at the lower level, while below the terrace classrooms for the music school and some department offices are found.
The south wing is characterized at the ground level by a large hall, with movable partitions, used for performances and surrounded by the covered porch. Service spaces to the performance hall are also present. At the upper level, where a recent renovation has been almost completed, the administration offices are present, as well as two rooms dedicated to music laboratories. At the lower level, we find the canteen's large space, two large classrooms of the music school and various service spaces. The west wing is currently unused at the ground level and at the lower level. It shows signs of decay, and renovation works would be needed to make the spaces usable. Only the upper level is currently in use, hosting some musical teaching spaces[38].

Figure 82 - View of the rectorate building from the park (2019).

[38] F. Taravella, *Teaching the Arts beyond Modern Architecture. Adaptive reuse of Havana's former Clubhouse as a contemporary school of music*, master thesis. Supervisor: Prof. Davide Del Curto, Politecnico di Milano, 2020.

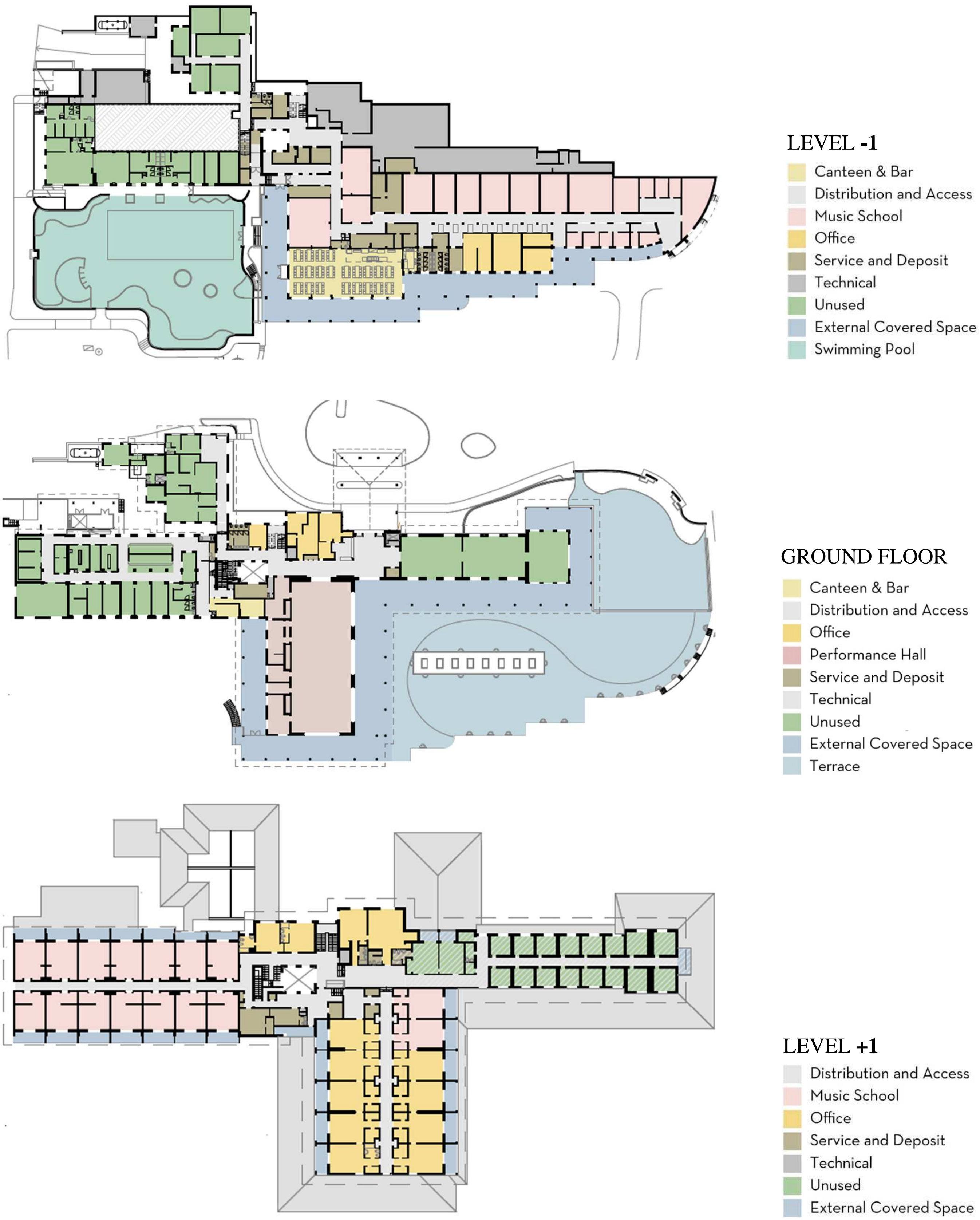


Figure 83 - Current use of the rectorate building (from Taravella 2020, tavv. 6-7-8).

4. Cafeteria colonial

Located between the Rectorate building's main entrance and the School of Plastic Arts the *Cafeteria colonial* represents a meeting spot for the students of the Schools.

Figure 84 - View of the cafeteria (2019).

5. Casa colonial

The small building, situated near the schools' campus's main entrance, was originally intended as the caretaker's house. Today it hosts a few dance classes.

Figure 85 - View of the Casa colonial (2019).

6. School of music - Middle level

Year of construction: 2000

Architect: Universo Garcia Lorenzo

Area (tot): 14.814 sqm

Original use: School of Music - Medium level (ENA)

Current use: School of Music - Medium level (ENA)

In 2000 architect Lorenzo Garcia Universo designed a new building to host the ENA's School of Music. The building is made of precast concrete, and with its 14.814 sqm construction area appears rather large. The classrooms are arranged around an internal patio.

In 2007 the School went through a refurbishment including:

- repairs to the hydro-sanitary and electrical installations;
- renewal of carpentry, covers, painting;
- renovation of the kitchen facilities and canteen.

Overall, the building appears to be in pretty good conditions.

Figure 86 - School of music (ENA) in its current conditions (2019).

7. Casa de protocolo - Facultad de Artes de la Conservacion del Patrimonio Cultural

The Conservation Faculty is one of the latest additions to the educational offer of the ISA. Since its establishment, the course of study has quickly grown and keeps expanding.

Classes are held in the building known as the *Casa de protocolo*, which stands uphill, on the east end of campus. Some of the external spaces surrounding the building are also used for laboratory activities.

However, the structure's dimensions and quality are not completely suitable with the increasing number of registrations and courses to be taught.

Figure 87 - The faculty of conservation today (former *Casa de protocolo*).

8. Casa nel bosque

Due to the proximity to the former *Casa de protocolo*, the building currently offers additional spaces at the disposal of the faculty of conservation.

Figure 88 – View of the *Casa nel bosque* (2019).

9. School of Theater

Since Gottardi's School of Dramatic Arts was never completed, the ISA had to find a different space to hold drama classes. The selected building is located close to the Gottardi's school, near the edge of the campus.
Although spaces are rather small, the building is in a good state of repair.

Figure 89 - The building currently used as the School of Theater (2020).

9. Facultad de los Medios de Comunicacion Audiovisual - FAMCA (presentlty out of ISA Campus)

The *Facultad de los Medios de Comunicación Audiovisual* - FAMCA is currently housed in two residential buildings located in the Miramar district, between 3 and 14th street. This degree course was recently established and completes the educational offer of the ISA with some courses related to new media, such as cinema, television, radio, web and social media. The buildings have a net usable area of approximately 400 square meters and house some classrooms for lessons, two recording studios and other common areas. This venue was leased by ISA due to the lack of suitable spaces in the "iconic" buildings within Playa's main campus. Considering the topicality of these subjects and the great interest on the part of the students, FAMCA represents an evident demand for new spaces.

Figure 90 - FAMCA building in Miramar neighborhood.

Figure 91 - FAMCA building in Miramar neighborhood (back, classroom, staircase).

1.3.7 Materials and techniques

Before proceeding to a description of the five iconic buildings that are the subject of the present conservation plan, it seems appropriate to spend a few words on the common criteria that guided the five buildings' design and construction. Although each architect was in charge of one (Gottardi) or two (Garatti, Porro) schools, the three designers had established a few shared principles to follow in order to guarantee homogeneity to the complex, which, after all, aimed at being a unitary complex. Quoting an interview with Ricardo Porro:

“Nos reunimos y discutimos la forma de construcción que utilizaríamos. Se nos pidió que no usáramos ni acero ni hormigón, sino materiales y mano de obra artesanales. Yo quería que hubiera ciertas normas comunes a todas la escuelas: el sistema constructivo, la libertad formal y el empleo de los mismos materiales y después cada cual haría lo que creyera conveniente”[39].

According to Porro's words, the common ground had thus to be in the constructive system, in formal freedom and material choice. Regarding the latter item, it should be noted that the conditions imposed by the US embargo significantly weakened the Cuban economy, causing shortages of construction materials. On top of that, Cuba itself had limited local natural resources. As a direct result, given the difficulties encountered to obtain steel and cement to make reinforced concrete, the decision was to build the Schools with locally-sourced bricks and ceramic tiles. In particular, to convey the idea of novelty and freedom, the construction system to be adopted was catalan vaulting. As a matter of fact, this technique allowed maximum freedom in the organization of the spaces (with a clear reference to the ideals of the early Cuban Revolution), while the use of bricks was an allusion to the land, to the landscape, to the local building tradition, to a specific *"genius loci"*.
In this regard, a certain convergence with the thought of Ernesto Nathan Rogers appears evident. Indeed, in the same years, he theorized a modern architecture that was rooted in tradition and local specificity.

The Catalan vault, or *boveda catalana*, is typically a thin vault structure, built using thin tiles with no use of fixed scaffolding, as its strength comes from its very shaping. In general, the Spanish term *boveda catalana*, refers to the lightness and flexibility of this element, which is usually composed of five layers of tiles, positioned either by the head or - sometimes - by the side. The terracotta tiles are positioned in at least two layers - one is laid orthogonally, and the other diagonally - held together by consistent layers of mortar. The construction process sees the use of removable scaffolding, shaped after the curvature of the intrados. Once done, the scaffolding can be removed and place elsewhere to proceed with the construction.

[39] Quoting Ricardo Porro. Taken from Pizarro Juanas, 2012, p. 193.

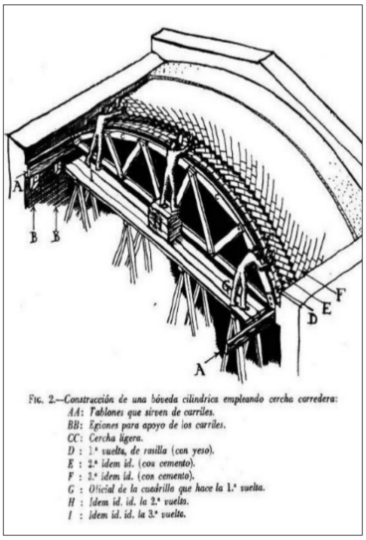


Figure 92 - On the left: Illustration of the construction process of catalan vaults (from L. Moya Blanco, Bovedas Tabicadas, Ministerio de la Gobernacion - Direccion generale de Arquitectura, 1947, p. 20) . On the right: Guastavino's "Rib and Dome system" (from J. Parks, A. Neumann, The old world builds the new, Biblioteca Avery, 1996).

Figure 93 - One of Gumersindo's training sessions. Photo retrieved from ISA archive.

The structural behavior is that of a monolithic structure, characterized by little thickness and weight, as well as by great flexibility in movement and shape. These particular features allow catalan vaulting to be also employed to cover large spans. However, it is crucial to maintain the displacement of the tiles' joints, shifting them while overlapping layer to layer.

The *Boveda Catalana* or *Tabicada*, was largely used in Spain, although its origin is generally attributed to the ancient vernacular architecture of the whole Mediterranean area (examples of Catalan vaults can be found in North Africa, Spain, and Italy). The technique was rediscovered in the XX century by Antoni Gaudí, who adopted it in 1899 for the construction of the Schools of the Sagrada Familia in Barcelona.

However, while in Spain the *Boveda Catalana* was undoubtedly full of meaning in terms of cultural identity[40], it was unknown in Cuba. Exported to the US by Guastavino at the end of the XIX century, thin vaulting landed in Cuba in the '60s thanks to a mason named Gumersindo, an expert constructor coming from Spain who offered to teach this technique to Cuban construction workers.

It should be noted that people working at the Schools' construction site were not only professionals but also young architecture students who voluntarily offered their help, in a perspective of inclusion and cooperation aiming to suppress hierarchies. All of the workers were involved in the whole process embodying the Revolution's utopian equality spirit.

"The workers' reaction was interesting. I remember when I first took the plant and the model to explain the project to them. I really wanted them to be an active part of what they were building and, with the social change brought about by the Revolution, they could think that the school they were building was for theirs; it was not like before that what they built was only for the rich. Their participation and enthusiasm were very important. There were not only close relationships between designers and builders, but also with the new generation of art students who were present from the beginning. All participated in the shaping of the new program and the effective and concrete construction of the Schools. A strong bond had been created between designers, workers and students, and together we participated in the construction, offering help both in the creation of a wall and in the excavation for the foundations. Voluntary work was, at that moment, something spontaneous, without obligations"[41].

Given the little expertise of many of the workers and the unprecedented use of catalan vaulting, the construction followed a traditional and empirical method. To test the strength of the thin vaulted structures, load tests were carried out on models. However, the mistrust towards the building technique and the project's overall relevance lead the MICONS to impose several changes and structural reinforcements, fearing the structures' quick failure.
This fervid and chaotic situation finally brought to the actual construction of the Schools, which - although partially unfinished - were officially inaugurated in 1965.
Since then, no one seems to have given second thoughts to these architectures' structural features, whose deceptive appearance ostentatiously refers to the pure catalan vaulting technique.
As will be further explained in Action 2[42], a pivotal point of the analyses has thus been to clarify the actual construction system employed to build the schools. In fact, before Princeton University started its researches in 2016, the common belief (trusting appearances and the very architects' words) was that the five School were entirely built using masonry and Catalan vaulting:

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[40] Architects of the "Catalan Modernism", such as Muncunill, Doménech and Montaner, Puig and Cadafalch largely adopted the Catalan Vaulting technique in their designs.
[41] Loomis 1999, p. 66.
[42] See *2.3 The construction process.*

"The distinct layered pattern illustrated in Figure 94 *is one of several details that caused scholars to assume thin-tile vaulting was used as the main structural system of the Ballet School. The edge's visible layers of mortar and tile layered edge are normally a definitive characteristic of thin-tile vaulting. However, the results of fieldwork conducted in November 2016 (by Princeton University - ed.) combined with access to the original construction photographs by Jose Mosquera, practically contradicted this assumption. […] Upon closer inspection of one of the pendentives of the Dance Pavilion, exposed reinforcing steel can be seen, which confirms that reinforced concrete is present in parts of the structure. In fact, the black tile outlines visible on the newly discovered concrete layer were probably added after the spalling had occurred to maintain the uniform surface appearance of the structure. The hole due to spalling is about three-inch deep confirming that the structural element is built of concrete. In addition, on top of the concrete a mortar layer is visible as well as only one layer of tiles. This indicates that first concrete element was built, then, once the concrete was hardened, mortar is used to carefully cover the element with the tiles. Mr. Mosquera confirmed the use of reinforced concrete within the domes of the school and supported his statement with the photographs. In particular, he explained that for reinforced concrete elements, first the wooden formwork would be built, then the layer of ceramic tiles would be carefully laid onto the forms, covering the bottom and the sides, then the rebars would be placed, and finally the concrete would be poured. Once the forms removed, the appearance of the bottom of reinforced concrete elements would be neat and indistinguishable from the appearance of thin-tiled vaulting structure"*[43].

Figure 94 - The seemingly catalan vaults of Garatti's School of Ballet.

[43] I. Douglas, R. K. Napolitano, M. Garlock, B. Glisic, *Cuba's National School of Ballet: Redefining a structural icon*, "Engineering Structures", vol. 204, 2020.

These observations, collected by Princeton's research group, refer exclusively to Garatti's School of Ballet and represent the outcome of a rather quick on-site inspection that occurred in 2016. Even though Princeton scholars' analyses pointed in the right direction, the limited time and resources they had at the time did not allow further investigations. They thus concluded that the School of Ballet included both reinforced concrete elements and catalan vaulting in a *"joint composition that enabled architectural grandeur while maintaining structural reliability"*[44].

Picking up from there, within the Keeping It Modern grant initiative, the described topic was further examined, leading to an even better understanding of the structural arrangement of the domes of the School of Ballet, but also of the other Schools. As a matter of fact, a correct assessment of the schools' behavior and conditions could not overlook the in-depth analysis of their actual construction system. Indeed, the presence of true catalan vaults on the site proved to be even more limited than expected, as most of the bearing elements of the five buildings appear to be made of reinforced concrete (externally covered with clay tiles/bricks). A possible cause of the shift between the original designs and the realized architectures could be found in the fact that not being accustomed to thin-tile construction techniques, the builders of the Schools chose a safer path and deferred to working with reinforced concrete, to which they had prior empirical knowledge and construction exposure.

Despite the mutated constructive system, the architects managed to convey the message of freedom and revolution they originally sought. The dominant role of vaults and domes is clear at first sight, and the instant formal impact of the architectures is not at all diminished by its being made of concrete rather than catalan vaulting.
In fact, as foreseen, roofing takes primary importance in the project of the National Schools of Art. Coverings were not conceived as the mere horizontal projection of the building but as three-dimensional spaces with their own peculiarities and functions. They configure as outdoor rooms, paths, landscape viewing sites. Especially in the Schools designed by Vittorio Garatti, the walkable roofs develop in continuity with the ground, becoming an additional floor to be used to stroll, dance, play while contemplating the tropical landscape, but also the architecture itself. The three architects created a true "architectural promenade", which, alternating spaces to experience, rest, meet, observe, and dialogue, fulfills the schools' social function.
Overall, the layout of the schools recalls the structure of a city, composed by small units connected by streets, covered routes and rest areas. In this regard, Porro suggested an interesting comparison with Venice: *"…traté de hacer un edificio que fuera feminidad, pero también (porque yo venía influenciado de lo que era el urbanismo de Venecia), que fuera ciudad, pero una ciudad que se convierta en Eros, una ciudad que fuera amor"*[45].

[44] Ibidem.
[45] Pizarro Juanas, 2012, p. 181.

1.3.8 The tropical park and the Quibù river

The tropical park surrounding the Schools also constitutes an essential asset to preserve. Indeed, nature was always considered by the three architects as both a source of inspiration and an element to be integrated into the design. The five buildings appear perfectly blended with their natural environment: a green park crossed by the Rio Quibù. The land is undulated, and the schools' buildings have been graciously adapted to the terrain, following its winding course. Originally, the buildings were only connected by a perimetral ring road. The currently present internal routes were recently created.

The park has been subject to a consistent redevelopment project starting from 2007. The main operations carried out included:

- Protection activities against Rio Quibù frequent floods, such as cleaning, extraction, and transport of sediments, construction of retaining walls and of a perimeter containment channel;
- Construction of three bridges (2 vehicular and 1 pedestrian) to cross the Quibù River.
- Realization of 3.66 km of vehicular vials and 2 km of pedestrian paths between the schools.
- Creation of 10 parking areas (distributed over the site to serve the different functions), covering an area of about 1500 sqm;
- Repairing of the asphalt of the peripheral vials;
- Installation of the perimeter fence surrounding the park. A hedge of *bougainvillea* (8000 plants) and *cardona* (4800 plants) were planted to guarantee further protection from intrusion.
- Construction of the *Garitas*: new controlled gateways to directly access each one of the School buildings from the outside;
- Setting of outdoor lighting: 5.2 km of vehicular roads and pedestrian paths were provided with lighting, as well as the 3.5 km of the peripheral roads of the schools.
- Maintenance of green areas and new plantings (for the reforestation of the Quibú River 6.000 new trees were planted);
- Rearrangement of the landscape.

It should finally be noted that the tropical park constitutes a natural reserve and is characterized by an extremely rich biodiversity, both in terms of flora and fauna (Figure 95). While representing a surplus-value, this feature underlines the necessity of an all-embracing management plan, fostering the conservation of the iconic architectures of the Schools and preserving and enhancing the precious environment surrounding them.

Figure 95 - The tropical park of the Schools with its fauna and flora (photos by Tamara Gispert Galindo).

1.4 Functional analysis

The National Schools of Art were originally built to host five faculties: Modern Dance, Ballet, Plastic Arts, Music, and Dramatic Arts. Each building was studied and designed in order to provide suitable spaces for the teaching and practice of these disciplines. However, when the construction site shut down in 1965, only two Schools out of five were completed, leading to an indispensable reassessment of the overall organization. The lack of maintenance through the years has worsened this situation, as less spaces are now available for use, due to their critical state of repair.

Today the *Universidad de las Artes de Cuba* (ISA) offers six different majors which are: Music, Visual Arts, Dance, Dramatic Arts, Conservation and Restoration, Visual Arts and Communication.

Since the constant and proper use of a building is essential to grant its preservation over time, the development of a preservation plan necessarily needs to take into account the current situation of the Schools of Art also on a functional level, in order to identify strengths and weaknesses of the current administration. This analysis will set the basis to outline a new and more efficient management model.

To uphold the peculiar character of the buildings, which are strongly representative of a specific historical moment, the most suitable solution seems to keep their original academic function, although improving the quality of the offered services, reshaping the Schools organization on the basis of the current educational offer. In order to achieve this goal, the first step has been to map the intended uses of the spaces, highlighting their possible discrepancies with the actual use. Interviews with the ISA's rector and the faculties' presidents were also conducted to understand better how the Schools work (schedules, number of students enrolled, etc.) and to gather information about potential educational demands (suitability of the spaces, number of classrooms etc.). The frame of requests emerging from the aforementioned activities represents the key to correctly address the functional issue, offering directives on how to re-organize spaces and uses accordingly to current requirements.

Since about sixty years, the Schools' construction, the educational offer, and social context have undoubtedly and consistently changed. In this regard, a point of strength is the growing interest in arts and culture shown by Havana's community over the last few years. The analysis of the urban context helped defining new activities to enhance the National Schools of Art and, viceversa, removing those that are superfluous. For an instance, it could be useful to evaluate the actual fruitfulness of the establishment of a School of Ballet, especially since the Cuban National Ballet School - which is one of the biggest and most valued ballet schools in the world - is just a few miles away, in *Habana Vieja*.

As the architects already envisioned in their original plans, the Schools could benefit from evening openings that would both provide entertainment to the local community and grant the use of the Schools to the fullest. This kind of operation would require the drafting of a Business Plan to evaluate the impacts and the profits of this action. Further considerations can be made about the park; one of the main concepts of the Schools design was to fully integrate architecture with nature, yet - for safety reasons - the former golf club does not seem to be easily accessible to Havana's population. Perhaps a greater openness of the park to the public could increase the dynamism of the complex, helping its preservation at the same time. Nonetheless, students' security should also be guaranteed, especially since the ENA students are mostly minors.

1.4.1 The Instituto Superior de Arte (ISA)

Bringing together arts under the same roof was an essential component of that ideal that initiated the process leading to the construction of the National Art Schools of Havana. The architects decided to build five separate buildings, but the importance of exchange between the arts has never been left aside.

On the ashes of the *Escuela Nacional de Arte (ENA),* the *Instituto Superior de Arte (ISA)* was established on September 1st, 1976 by the Cuban government as a university level school for the arts. In its original structure, three schools were present: Music, Visual Arts, and Performing Arts. On the other hand, the ENA continues to exist targeting younger students (high school level) and offering courses of study in Dance and Music[46].

However, since teaching methods continuously evolve, the schools' educational offer kept changing, resulting in the current arrangement. Today the ISA comprises six faculties: the four original ones (*Arte Teatral, Arte Danzario, Artes Visuales, Musica*) and two additional ones dedicated to the Arts of Audio-visual Communication Media (FAMCA - *Facultad Arte de los Medios de Comunicación Audiovisual*) and the Arts of Preservation of Cultural Heritage (*Facultad de Artes de la Concervación del Patrimonio Cultural*). The former was established in 1989, while the latter in 2018 as a replacement of the previous *Centro de Estudios sobre Conservación, Restauración y Museologia* (2012).

More in-depth, the mentioned majors include the following courses of study:

- *Dramatic Arts*: performance, scenic design, dramaturgy, theatrology:
- *Dance:* ballet, contemporary dance, folklore;
- *Audio-visual communication media*: direction, editing, photography, production, sound;
- *Visual Arts*: painting, sculpture, graven, restoration;
- *Preservation of Cultural Heritage*: conservation and restoration, museology;
- *Music*: saxhorn, singing, choir, lyrics, clarinet, composing, composing and bassoon, composing and violin, double bass, choral conducting, choral conducting and singing, choral conducting and musicology, orchestra conducting, orchestra conducting and violin, orchestra conducting and cello, musical sound direction, musical sound direction and trombone, bassoon, flute, guitar, lute, musicology, musicology and musical sound direction, oboe, percussions, piano, piano and clarinet, piano and musicology, piano and violin, saxophone, saxophone, and musicology, Cuban tres (three-course chordophone), trombone, trumpet, tuba, viola, violin, cello.

The marked artistic talent of the Cuban population and high demand for the teaching of artistic disciplines, brought to the establishment of ISA's detachments among the island. In particular, one is located in Camagüey, one in

[46] The on-campus building hosting the ENA are Gottardi's School of Modern Dance and the more recent School of Music by architect Universo Garcia Lorenzo (2000).

Santiago de Cuba and one in Holguín. ISA offers both pre-degree and post-degree courses, as well as the possibility to choose between day (CP - *Curso Diurno*) or night school (CPE - *Curso por Encuentros*). Further opportunities, such as post-graduate specialist training and professional updating, might become available within the next few years. The table below summarizes the ISA's functional structure, reporting the number of students enrolled in each faculty.

ISA - Havana main campus			
Major	**Day School**	**Night School**	**Total**
Dramatic Arts	82	105	187
Dance	73	104	177
Audio-visual communication media	91	55	146
Visual Arts	65	82	147
Preservation of Cultural Heritage	59	47	106
Music	234	145	379
SUBTOTAL	**604**	**538**	**1142**
ISA - Camaguey			
Major	**Day School**	**Night School**	**Total**
Dance	--	40	40
Audio-visual communication media	--	29	29
Music	--	28	28
SUBTOTAL	**--**	**97**	**97**
ISA - Holguin			
Major	**Day School**	**Night School**	**Total**
Audio-visual communication media	--	59	59
Music	6	34	40
SUBTOTAL	**6**	**93**	**99**
ISA - Santiago de Cuba			
Major	**Day School**	**Night School**	**Total**
Dramatic Arts	--	37	37
Dance	--	38	38
Music	--	3	3
SUBTOTAL	**--**	**78**	**78**
TOTAL	**610**	**806**	**1416**

Table 10 - The majors taught at the ISA (Havana and detachments) and corresponding number of enrolled students (Academic Year 2019-2020).

As deducible from the table, today ISA hosts about 1400 students coming from all the provinces of the island. Among these, 593 come from Havana, 118 from Holguin, 110 from Camaguey, and 88 from Santiago De Cuba. There are 24 international students.

The headquarters hosts 1142 students, of which 604 enrolled in day courses and 538 enrolled in individual courses. The teaching of disciplines introduced in the 1960s involves about 900 students, of whom about half attend day courses:

- Music: 379 students enrolled (234 day courses; 145 individual courses); 40 musical specializations are foreseen;
- Theater: 187 students enrolled (82 day courses; 105 individual courses);
- Dance: 177 students enrolled (73 day courses; 104 individual courses);
- Visual Arts: 147 students enrolled (65 day courses; 82 individual courses).

As for the disciplines that were introduced later on, the FAMCA - located in a building outside the perimeter of the park - has a total of 146 students, of which 91 enrolled in day courses and 55 in individual courses. The specialization in cultural heritage conservation, which includes methodological insights and practical workshops in various fields (restoration of canvases, archaeological finds, photographs), involves a total of 106 students, of which 59 enrolled in day courses and 47 attending individual lessons. The didactic activities of the Heritage Faculty take place in one of the buildings on the park's perimeter.

ISA has three other offices in the area, in Camaguey, Holguin, and Santiago de Cuba, which carry out exclusively educational activities through meetings and count 274 total members. The ISA branch in Camaguey offers training in the fields of dance (40 students enrolled), communication and new media (29 students), and music (28 students); the members are 97 in total. The Holguin office has 99 members and offers courses in music (40 members), communication and new media (59 members). The ISA headquarters in Santiago de Cuba has 78 members, including 37 students of theater arts, 38 of dance, and 3 of music.

ISA's training activities involve a total of 703 teachers, of which 226 are structured (32.1%). Indeed, most of the lessons are held by artists who carry out professional activities and who can transfer their experience to students.

From the number of both enrolled students and course of study offer, it is evident that music is by far the largest faculty within the ISA. Nevertheless, there is no specific building for the teaching of music classes as the existing dedicated spaces are currently located in a rectorate building wing. Besides the fact that such rooms are not very suitable for this specific use, student practicing generates discomfort to the administrative personnel working in the offices nearby. Moreover, since spaces are limited, many students have to find other places to rehearse and often use the available spaces located within the abandoned Schools of Music, Ballet, and Dramatic Arts, with possible safety risks. Thus, the functional analysis proved fundamental to highlight (and subsequently try to address) all the issues concerning use (or lack thereof).

Although the original masterplans from the 1960's illustrate the intended function of nearly every single room of the five buildings, due to dismissal, transformations, and evolution of the educational offer, today, these drawings do not appear accurate anymore. For this reason, the first task of the functional analysis consisted in a precise mapping of the current uses of the five buildings, as well as of other auxiliary buildings that are present on-campus (e.g., rectorate building, dormitory, library etc.)[47]. Indeed, in order to provide a thorough evaluation of the current use situation, it was essential to have a global overview of the site rather than limited to the five iconic architectures. To achieve this result, a meticulous visit of the spaces composing each on-campus building was conducted. With the help of local personnel (e.g., students, professors, deans), it was possible to pinpoint all the functions that are currently installed within the buildings. On the same occasion, a general assessment of the spaces was also carried out, allowing further considerations in compatibility between spaces and functions. In fact, spaces' suitability is an aspect that needs to be taken into account when developing a management plan that aims to suggest an improved functional distribution.

Moreover, interviews with the deans of the different faculties were set up in order to gather specific requirements. This resulted extremely useful, as in their supervising role, they were able to highlight existing criticalities while pointing out possible future developments based on the current educational trend.

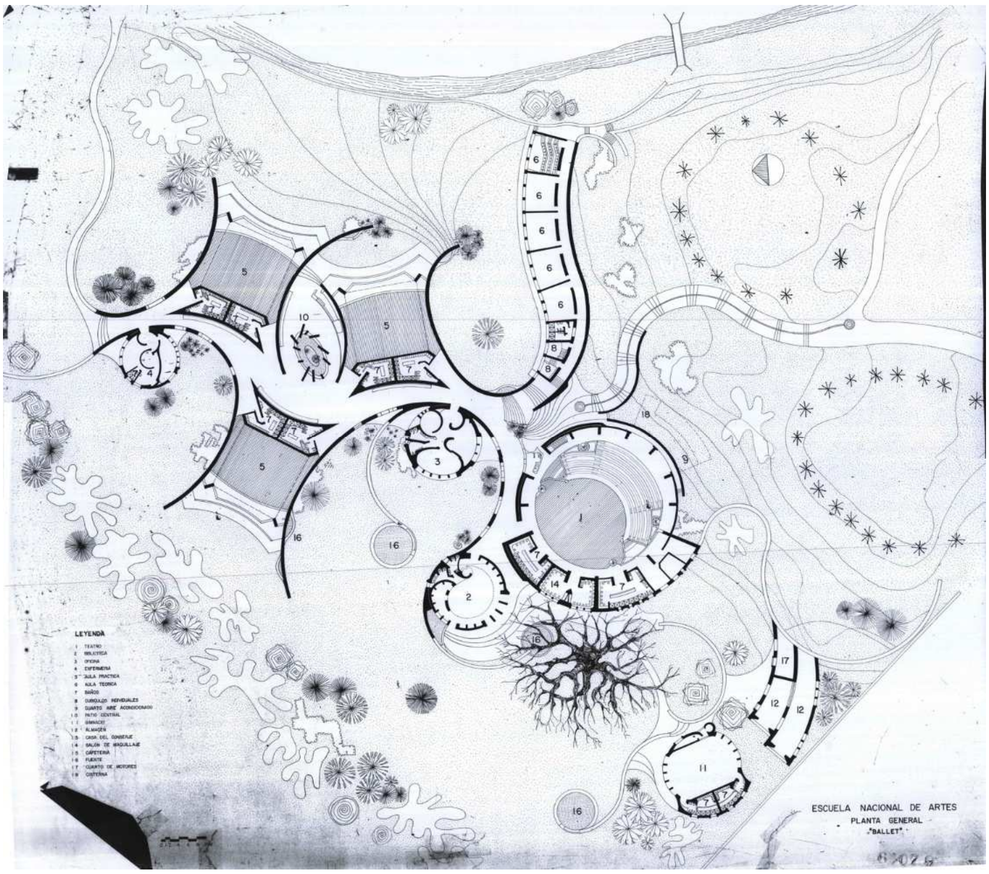

Figure 96 - Original masterplan for the School of Ballet with intended functions distribution (Image from ISA archive). Key: **1** - Theater; **2** - Library; **3** - Offices; **4** - Infirmary; **5** - Dance Pavilion; **6** - Theoretical classroom; **7** - Restrooms; **8** - Individual classrooms; **9** - Technical room (air conditioning) ; **10** - Central Patio; **11** - Gym; **12** - Storage *(never built)*; **13** - Janitor's house; **14** - Dressing rooms; **15** - Cafeteria; **16** - Fountain; **17** - Engine room *(never built)*; **18** - Tank.

[47] For a complete list of the auxiliary building, see paragraph 1.3.6 Other on-campus buildings.

1.5 Photographic campaigns

1.5.1 Photography as a tool for knowledge

From the ‘60s till now, the National Schools of Art have been the subject of more or less structured photographic campaigns. As a matter of fact, the fascinating unfolding of the five architectures encourages the attempts of both professionals and amateur photographers to capture the beauty of these organic shapes.
The possibility to compare historic and current images can indeed provide a large amount of information, as underlined in the following paragraphs.
The photographic materials collected throughout the Keeping It Modern initiative illustrate the main phases of the life of the Schools, from the building site to the present time. The main campaigns are summarized below, making a distinction between authorial campaigns and documentary campaigns.

1.5.1.1 Authorial campaigns

The first, and probably most complete, photographic survey of the building is the one carried out by Italian photographer Paolo Gasparini in 1965. Italian-born photographer Gasparini has extensively documented the Central American context since the 1960s.
The campaign interested each of the five schools to illustrate the newly built revolutionary architectures accurately. To do so, the shoot tries to describe the pavilions at different scales, starting from aerial views of the buildings in their entirety to end with detailed photographs.

A further photographic campaign on all of the five schools was carried out in the 90’s by American photographer Hazel Hankin. Her work has been partly published and appears - among other publications - in John Loomis’ *Revolution of Forms*.

“I first saw these neglected masterpieces in the mid-1990s. Their dilapidated condition was heartbreaking, but their astonishing beauty, mystery and sensuality captivated me utterly. Falling in love with their shapes and forms, the integral landscape, ant the lovely light, I embarked on an interpretative photo essay I hoped might capture something of the evocative atmosphere I responded to so deeply”[48].

As stated, her work is “interpretative” more than it is descriptive. Indeed, the photographs she took in 1994 and 1997 have a certain artistic vibe and clearly aim to narrate the schools highlighting their flaws as well as their irresistible vital rhythm. The photographer counterposes the Schools' abandonment designed by Vittorio Garatti and Roberto Gottardi to the inhabited Schools by Ricardo Porro in an alternation of silence and sound, stillness, and movement (Figure 97).

[48] https://www.hazelhankin.com/galleries/cuban-art-schools, accessed on 2020/11/25.

Finally, the most recent authorial campaign (to the best of the authors' knowledge) is the one commissioned in 2010 by John Loomis in view of the publication of the second edition of his book *Revolution of Forms* to Dieter and Theresa Janssen. In this case, the focus was on Vittorio Garatti's Schools of Ballet and Music. The outcome is yet different from the previous campaigns as it favors architectural details to general overviews. Moreover, contrary to Gasparini's and Hankin's work, Janssen opted for color photography instead of black and white, making the architectures more real and possibly closer in time.

These images, spreading worldwide, contributed to increase the fame of these architectures and their designers, offering a chance to observe the spaces and the architectural choices that made these buildings an icon of the Cuban Revolution.

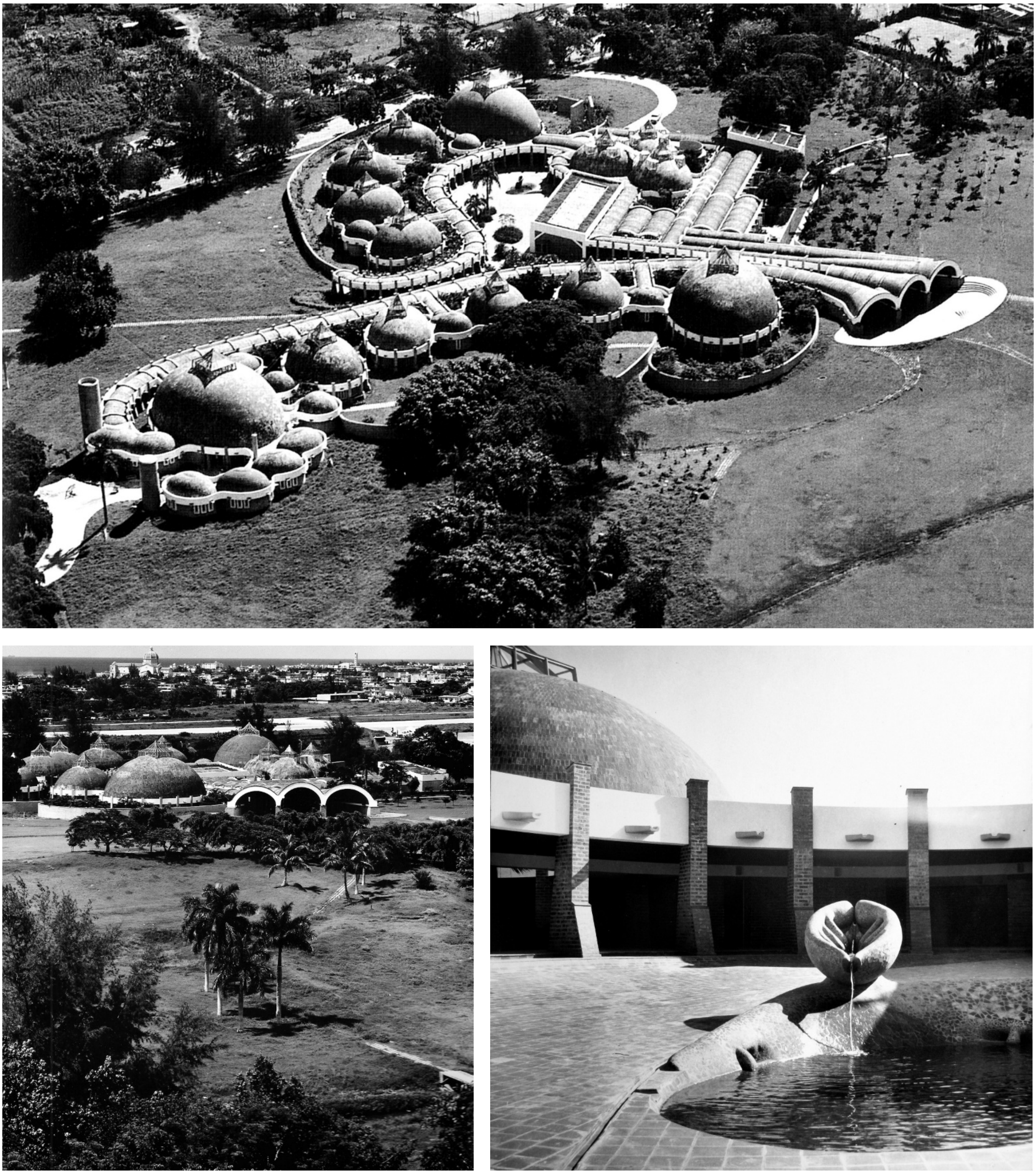

Figure 97 - The School of Plastic Arts in 1965. Note the gradual approach to the building. Photos by Paolo Gasparini (ISA archive).

Figure 98 - On the top - left: students in the plaza of the School of Modern Dance. On the top - right: view of the School of Dramatic Arts. On the bottom: the main entrance to the School of Ballet. Photos by Hazel Hankin (2010).

1.5.1.2 Documentary campaigns

Alongside the more qualitative authorial campaigns, many other surveys have been carried out over time.

Between 1961 and 1964 Josè Mosquera documented the construction site, mainly the School of Ballet, offering precious insights about the building process. These documents dispelled major doubts concerning the use of reinforced concrete within the structure of the School of Ballet.

Between 2000 and 2005, Universo Garcia Lorenzo took a consistent number of pictures to document the School of Modern Dance restoration activities and on the School of Plastic Arts.

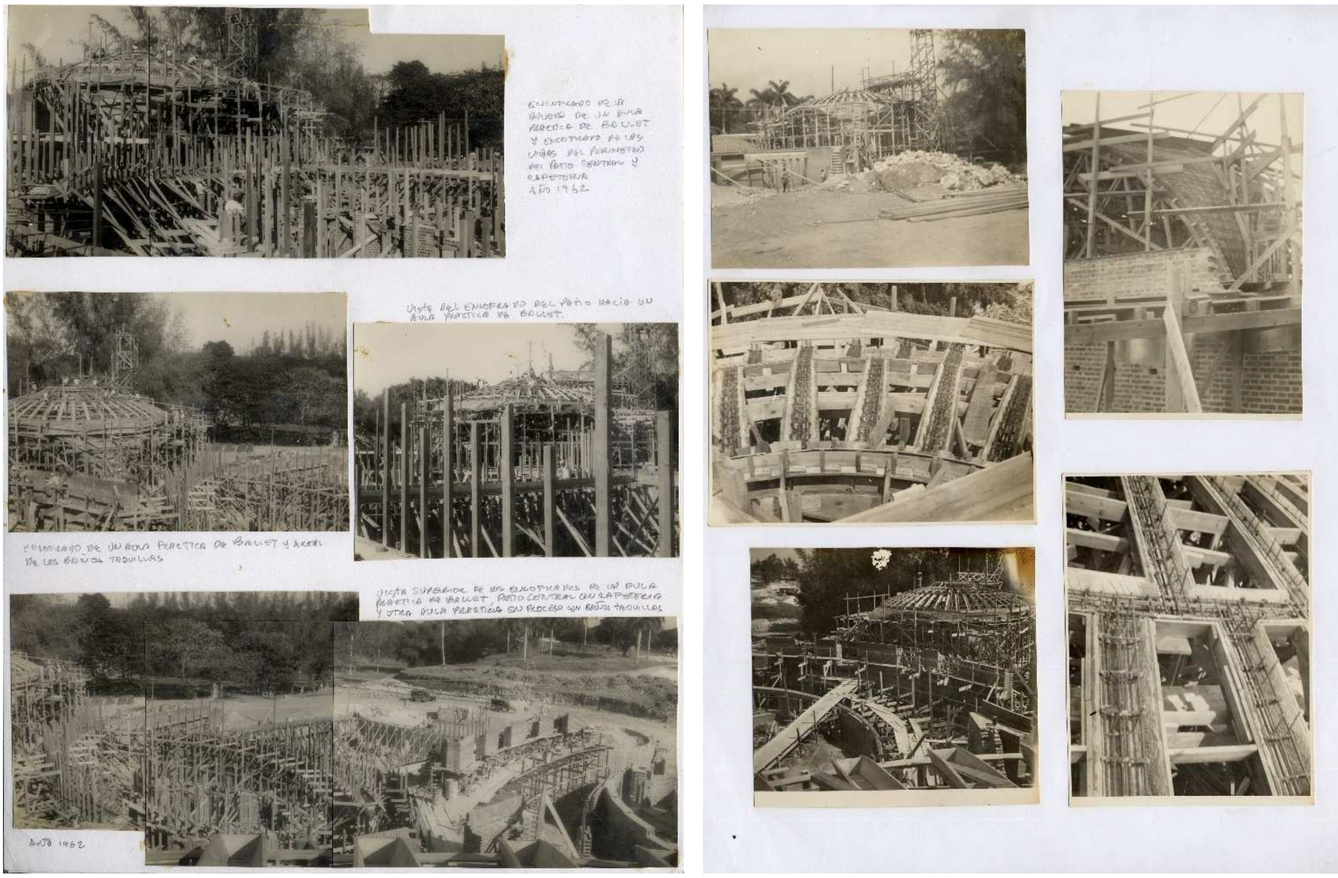

Figure 99 - Two pages from José Mosquera photographic album (1961-1964).

The systematic photographic campaigns carried out annually or biennially by Vittorio Garatti and his co-workers since the ‘1990s, when the architect was finally readmitted in Cuba, documents the state of the constructions and some extraordinary events, such as particularly heavy floods (Figure 100).

The outcome is extremely interesting, as from the sequence of images it is possible to immediately detect the unceasing transformations of the architectures and their relationship with the surrounding environment (Figure 101).

Figure 100 - The School of Ballet flooded on the occasion of different on-site inspections: 2005 - 2006 - 2007 - photos stored in the ISA archive; 2019 - photo taken within the Keeping It Modern Initiative.

Figure 101 - The *paseo arquitectonico* of the School of Ballet during different on-site inspections: 1965 - Photo by P. Gasparini; 90’s and 2007 - photos stored in ISA archive.

Figure 102 - Comparison of different satellite maps of the school of ballet collected from the historic series of Google Earth.

As can be observed, the appearance of the park has changed over the years. A sequence of satellite images outlines the trends of growth or decreasing of the vegetation (Figure 102).

For the preparation of the Conservation Management Plan, each on-site inspection has been thoroughly documented.
A concise selection of photographs illustrating on-site activities conducted during the four missions to Havana is offered in the following pages (Figure 103, Figure 106).

Figure 103 - Representative images of the first field trip to Havana, occurred in January 2019.

Figure 104 - Images taken during on-site activities in June 2019.

Figure 105 - Photos documenting the diagnostic analyses performed on the School of Ballet in November 2019.

Figure 106 - Photographic documentation of the latest mission occurred in February 2020.

1.5.2 1965 vs 2020

Beyond descriptive and illustrative intentions,
photography appears as a method to look at and depict places,
objects, the faces of our time, not to catalog or define them,
but to discover and build images
which are also new possibilities of perception[49]

Thus, the challenge we set ourselves to recount once again Garatti's Schools, this time through our current gaze. The photographic campaign was intended to revive the 1965 campaign and the subsequent campaigns that took place up to the early 191990s. Basically, the aim was to compare the schools' current appearance, resulting from decades of abandonment, with the image of the Schools in the 1960s, showing the irremediable changes that affected and the buildings and the landscape.
As in Ghirri's statement, photography can build images that open new perceptions. Perhaps this is the chance to suggest a new gaze at the Schools.

Therefore, retrieving visual representation […]
as an instrument of relationship with the world and the environment,
can have a great cultural weight and prove truly effective.
[…] the need not so much to regain possession of the environment,
but to install once again a relationship to the environment as a whole.[50]

Intending to reproduce the same shots from 1965, the camera operator sought the same photo framing while considering the inevitable differences related to the lenses and camera parts. The lenses that were used at that time were fixed focal lengths (prime lens). Instead, the camera operator used two variable length lenses cameras (Nikon D5000 and SONY ILCE-7M3). In addition to the inevitable dissimilarities owed to the use lenses and camera sensors (SONY ILCE-7M3 camera has a full-frame image sensor, Nikon D5000 camera has a 23,6 × 15,8mm CMOS sensor) that are different from the ones used in 1965, there are also differences related to light. Indeed, we did not get to know the period of the year and the time of the day when the historical pictures were taken. Nonetheless, the results proved acceptable for the purpose we aimed at when replicating these shots.

[49] L. Ghirri, *La fotografia: uno sguardo aperto,* 1984.
[50] L. Ghirri, *Lezioni di fotografia*, eds. G. Bizzarri e P. Barbari, Quodlibet compagnia extra, 2009.

Figure 107 - School of Ballet by architect V. Garatti. n.d. author Lorenzo Carmellini vs 2020.

A first concerns the School of Ballet. The photo in Figure 107 was taken on February 21, 2020, at 5:10 pm with a SonyILCE-7M3 camera with FE 16-35 mm F4 ZA OSS lens, focal length 32 mm, exposure 1/500 sec, f/4, ISO 125. The comparison between the two pictures highlights the state of decay and abandonment currently affecting the School of Ballet. It is also possible to notice the complete disappearance of the medio-punto window frames, designed to block the tropical sun while guaranteeing air circulation. A diffused detachment of the outermost layer of clay tiles regards both the Dance Pavilion's pendentive and the extrados of the seemingly Catalan vaults covering Garatti's *paseo arquitectonico*. The growth of weeds and shrubs worsened the situation, contributing to the structure's decay.

Figure 108 - School of Ballet by architect V. Garatti. 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

The second scene that was chosen also concerns the School of Ballet. It was immortalized with a Nikon D5000 camera with 18 - 55 mm f /3.5 - 5.6 lens, focal length 24mm, exposure 1/100 sec, f / 8, ISO 200.

The picture, overlooking the cafeteria patio, is taken from the inside of the School and, as in the previous shot, it reflects the School's current abandonment.

The wooden window frames that are visible in the background are now completely gone. Exposure to weathering resulted in soiling affecting both brick pillars and concrete elements. The vegetation completely invaded the paved patio, burying the round fountain that can be seen in Gasparini's photograph.

The historical picture here portrays an interesting and peculiar architectural feature of the project. Indeed, the fountain located in this patio, while contributing to the building's temperature regulation, aimed at offering a pleasant perception to the user, providing him with a space of undeniable quality. The depicted patio was originally intended to be the school's main recreational point, where students could hang out while enjoying products from the cafeteria. The image on the right brings us back to reality, showing an abandoned - and yet fascinating - space.

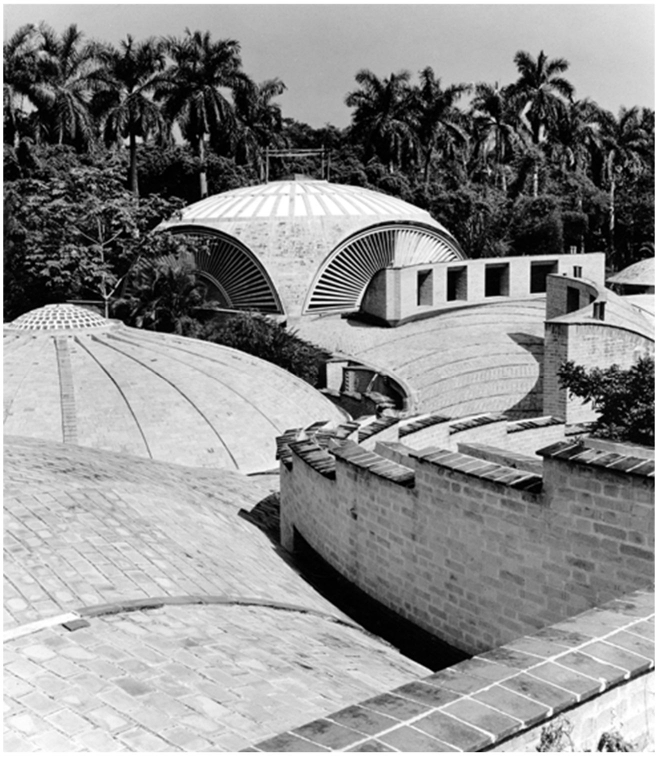

Figure 109 - School of Ballet by architect V. Garatti, 1965 (ISA archive. Author: Paolo Gasparini) vs 2020.

Figure 109 is the last image that was selected among the shots from the School of Ballet. It was taken on the morning of February 20, 2020. In order to reproduce the 1965 shot, the camera operator used a Nikon D5000 with 18 - 55mm f/3.5 - 5.6 lens, 24mm focal length, 1/500 sec exposure, f/9, ISO 200. As in previous cases, the comparison between the two images recounts a history of slow pillaging and deterioration, which resulted in the complete removal of the wooden jalousie of the Dance Pavilions' arched windows. Vaults and domes diffusely lost portions of the clay tile covering, and vegetation attempts to grow in mortar joints, producing further damages.

All things considered, despite the neglected appearance of the building, its actual state of repair is rather good. Vittorio Garatti conceived the School of Ballet has an architecture blending with nature. Indeed, the shape of the Dance Pavilions' domes retraced the foliage of the surrounding *algarrobo* trees. Today, even though the vegetation in the background looks thicker, one can grasp this intended design as a symptom of a true insertion in the context of architectural forms. The dome portrayed in the left image, deprived of doors and windows, conveys a sense of even greater lightness than originally intended.

Figure 110 - School of Music by architect V. Garatti, 1965 (ISA archive. Author: Paolo Gasparini) vs 2020.

Figure 107 is the first shot concerning the School of Music. The photo was taken with a Nikon D5000 camera with 18-55 mm f/3.5-5.6 lens, 24 mm focal length, 1/400 sec exposure, f/10, ISO 200. The image represents the covered external path connecting the spaces located on the upper level of the *gusano*. The changes between 1965 and today are evident, as the vaults covering this portion of the corridor disastrously collapsed. Damages extended to the flooring, where tiles are completely missing. The spatiality and rhythm we witness in the image on the left are long gone and can only be imagined thanks to the remaining vertical elements.

Figure 111 - School of Music by architect V. Garatti, 1990s vs 2020.

A further shot of the School of Music aims to portray the changes occurred on the curved concrete beam-planters completing the classrooms' vaulted roofs. The photo was taken at 04:04 pm on February 21, 2020, with a Nikon D5000 camera with 18 - 55 mm f / 3.5 - 5.6 lens, 24 mm focal length, 1/125 sec exposure, f / 13, ISO 200.

The comparison between the two shots displays the poor state of repair of the building material, which, having lost part of the concrete cover now presents widespread oxidation of the rebars.

On the other hand, it is possible to notice a greater attention to the upkeep of the green areas: in the early 90's shot the vegetation takes over the built spaces that are not in use. In the 2020's shot the lawn is perfectly mowed and

kept away from the architecture to protect it from humidity. The window frames, partially present in the photograph on the left, today appear are completely gone.
Compared with the current one, the image on the left offers a chance to reflect upon the implication that architecture dismissal entails over time: progressive deterioration of materials and structures, loss of details and technological finishing elements.

Figure 112 - School of Music by architect V. Garatti, 1965 (ISA archive. Author: Paolo Gasparini) vs 2020.

The last photograph that was chosen for the photography campaign on the School of Music was taken on February 21, 2020, at 12:20 am with a Sony ILCE-7M3 camera and FE 16-35mm F4 ZA OSS lens, focal length 23 mm, exposure 1/1250 sec, f / 4, ISO 125.
The first difference that can be observed from the comparison between the two shots (in addition to the exposure), is the complete loss of the brick shutters. Such elements were originally designed to project a pleasant alternation of lights and shadows on the masonry of the classrooms' plain wall, also resulting in improved climatic conditions. The deprivation of door and window frames is also evident. Unlike Figure 107, both the vaults and the floors seem to be in a fair state of repair.
The complete photographic campaign is reported in the following pages.

Figure 113 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

Figure 114 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

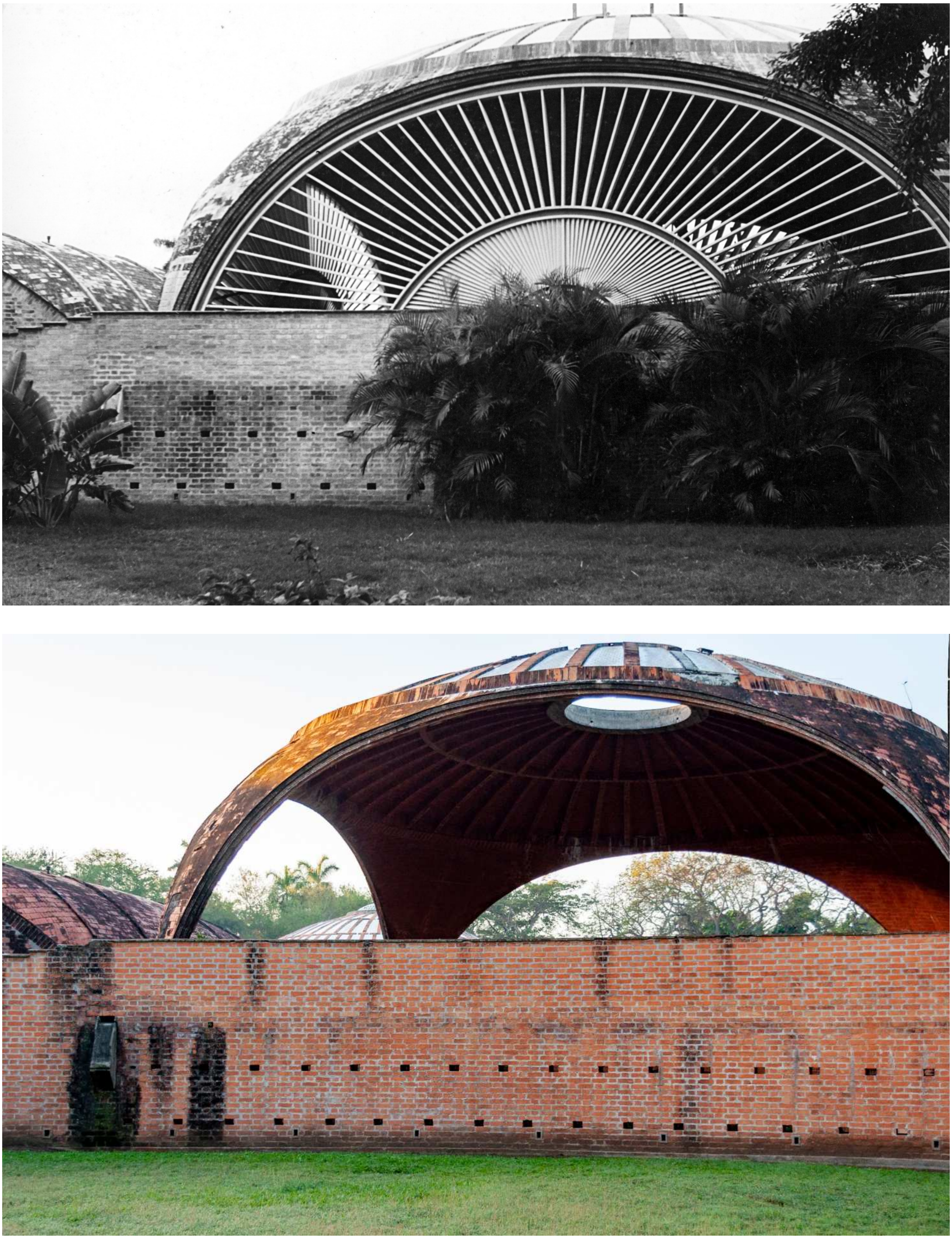

Figure 115 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

Figure 116 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

Figure 117 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

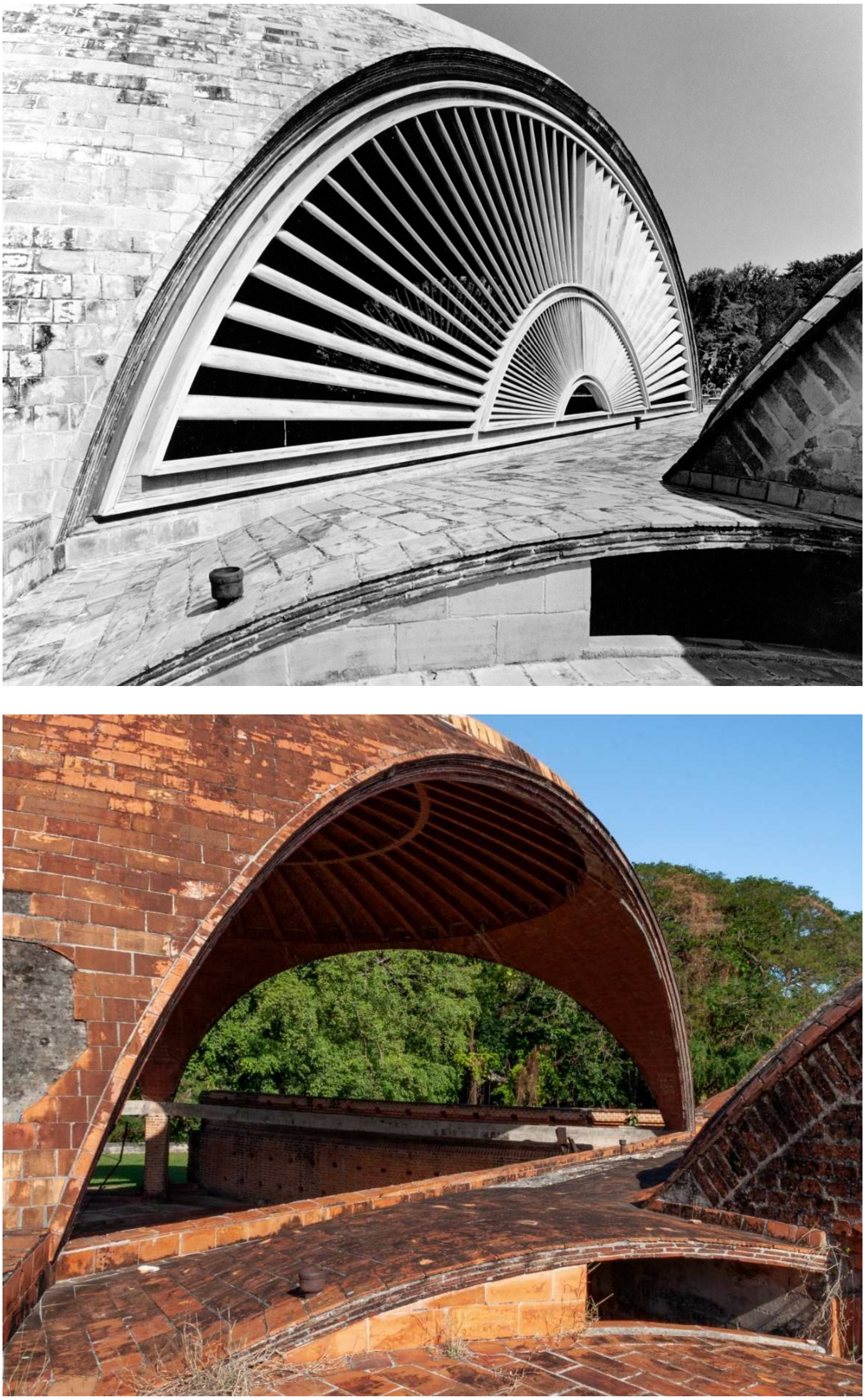

Figure 118 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

Figure 119 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

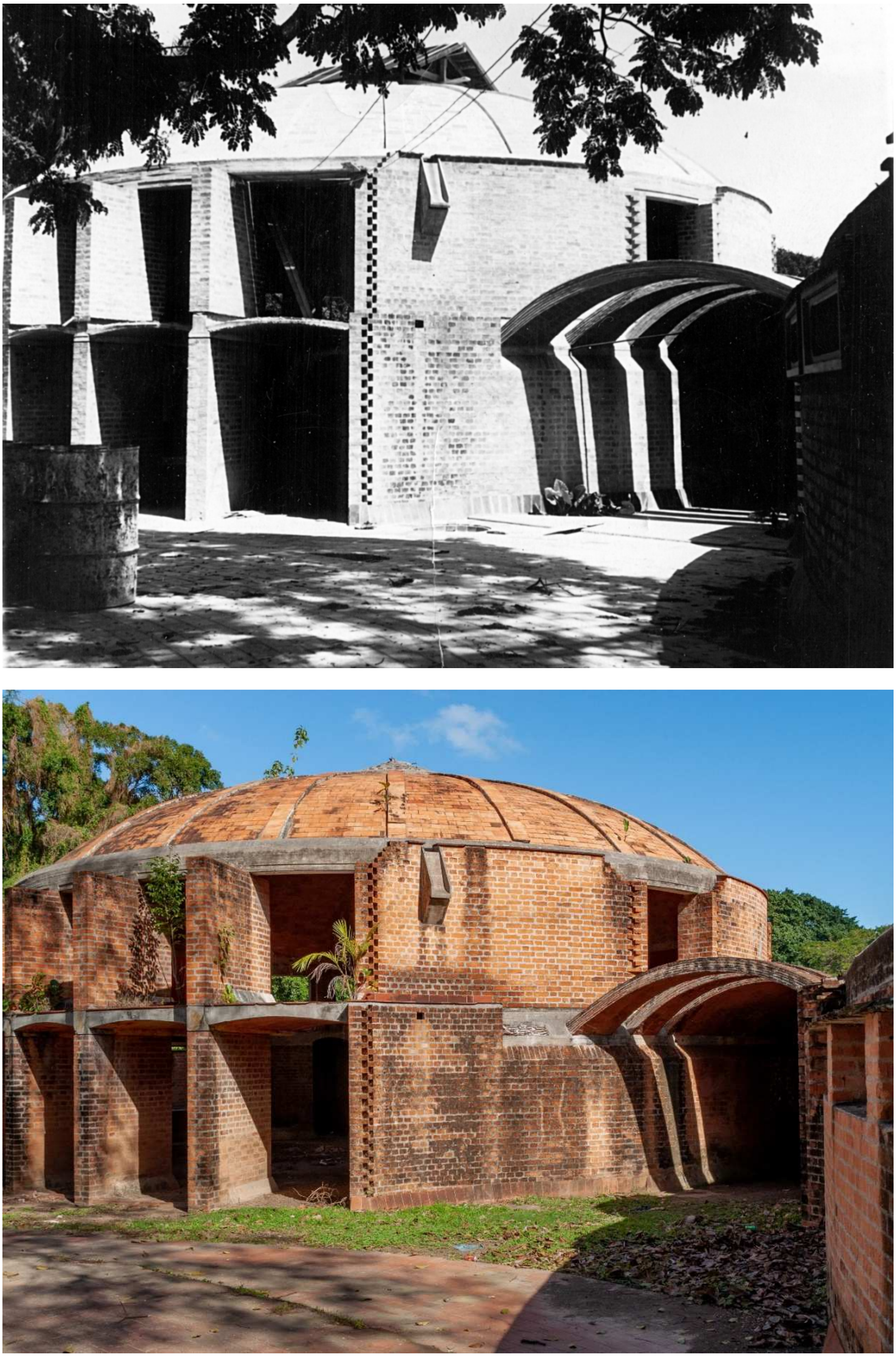

Figure 120 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

Figure 121 - 1990s vs 2020.

Figure 122 - 1990s vs 2020.

Figure 123 - 1990s vs 2020.

Figure 124 - 1990s vs 2020.

Figure 125 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

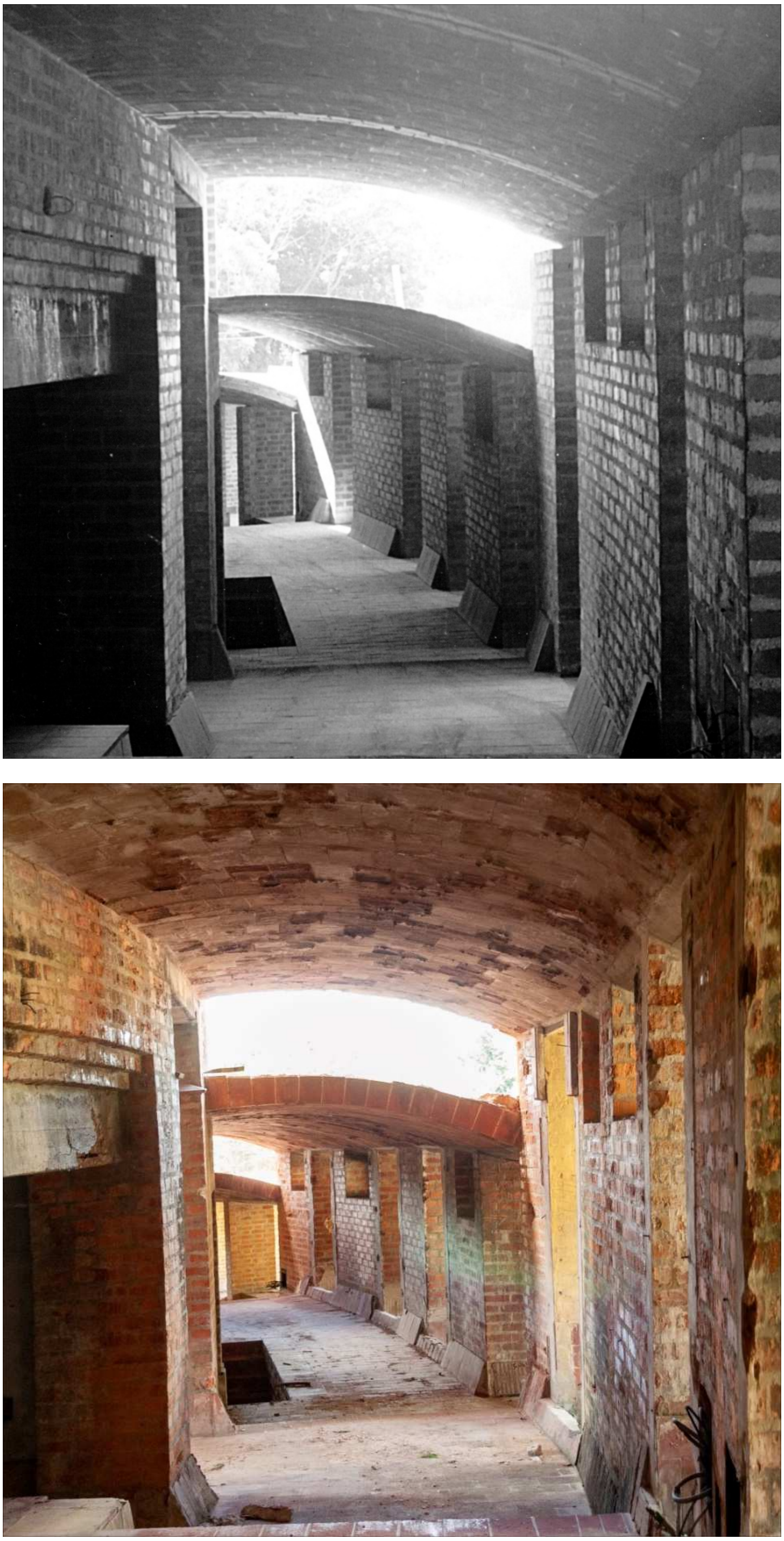

Figure 126 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

Figure 127 - 1965 (ISA archive, author: Paolo Gasparini) vs 2020.

Figure 128 - 1990s vs 2020.

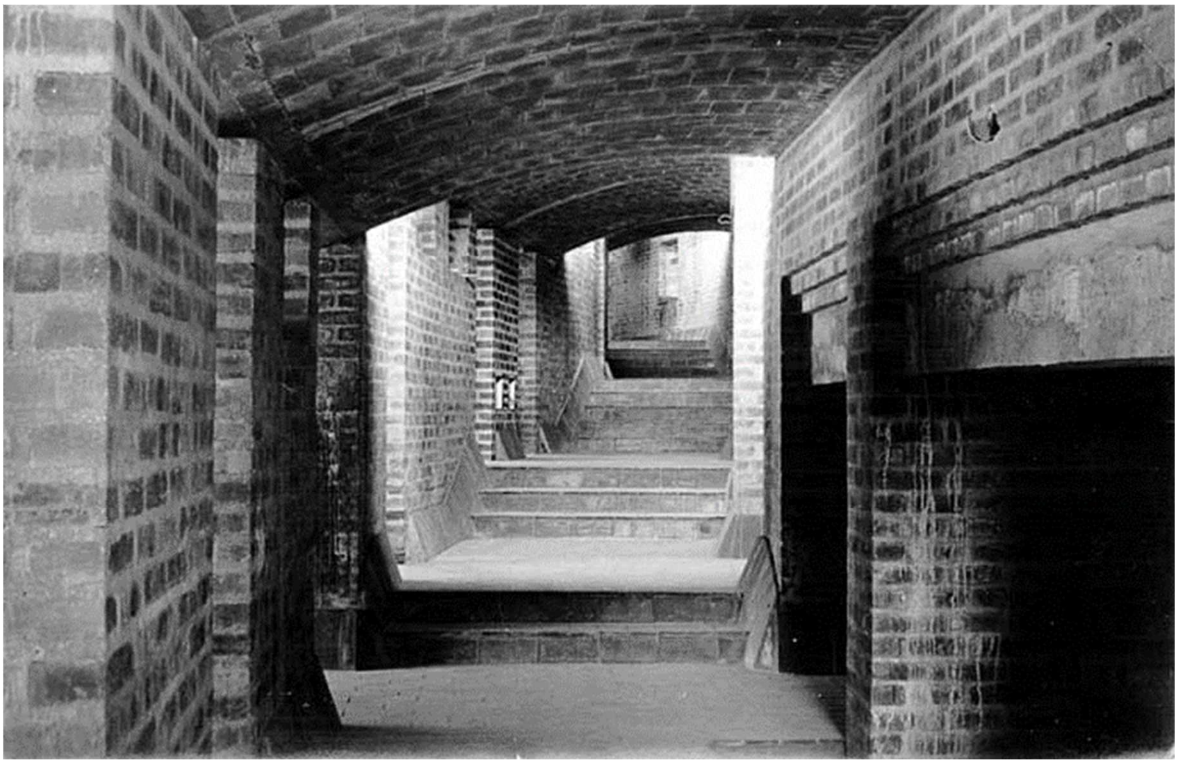

Figure 129 - 1990s vs 2020.

Figure 130 - 1990s vs 2020.

1.5.3 A school for artists

The photographic campaigns carried out over the years mostly aimed at capturing the beauty of the iconic architectures of the Schools, offering fascinating glimpses of the buildings and their sinuous shapes, the alternating of lights and shadows, the ruin following abandonment. Indeed, these aspects are crucial in order to provide an efficient documentation of the architectural features of the spaces, of their quality, as well as of their state of repair. Although the outcome proved to be truly representative of the five pavilions' essence, after visiting the Schools' campus, we felt like something was accidentally left out.

The romantic feeling instilled by the ruins' view ended up overshadowing - at least in the pictures - the unfailing dynamism of these architectures. Far from standing still, the five buildings (even the dismissed ones) represent the populated daily activities setting.

Within a system of undefined spaces, which blends together the indoor and the outdoor, the natural and the anthropological, students of art are pushed to explore, to find their own preferred spot on campus. As a matter of fact, it is completely common to find artists who set their studios inside the unused classrooms of the three Schools that were never completed and that currently stand in precarious conditions.

In this context, it seemed beneficial to promote a further photographic campaign to uncover human presence animating architecture and portray a School that, according to the original plan, is entirely devoted to art. Musicians, dancers, painters, sculptors, actors alternate on the scene of the organic pavilions, performing, socializing, and relishing the tropical park's view.

In order to convey the point of view of an artist, a former student of the Schools was appointed as the photographer. Osmara Alberteris Canizares, who graduated from ISA in 2016 with a degree in set design and is currently teaching at the Faculty of Dramatic Arts, seems the perfect fit. Her outstanding pictures, reported in the following pages, truly capture the complex nature of the buildings, which - shaped on the movements of performing bodies - are indissolubly linked to human presence.

Alberteris' work has been partly exhibited during the XXII Milan Triennial occurred in 2019. She was also awarded the Eliana Lissoni photography prize (5° edition, 2019).

Figure 131 - Ileana. Photo by Osmara Alberteris (2019).

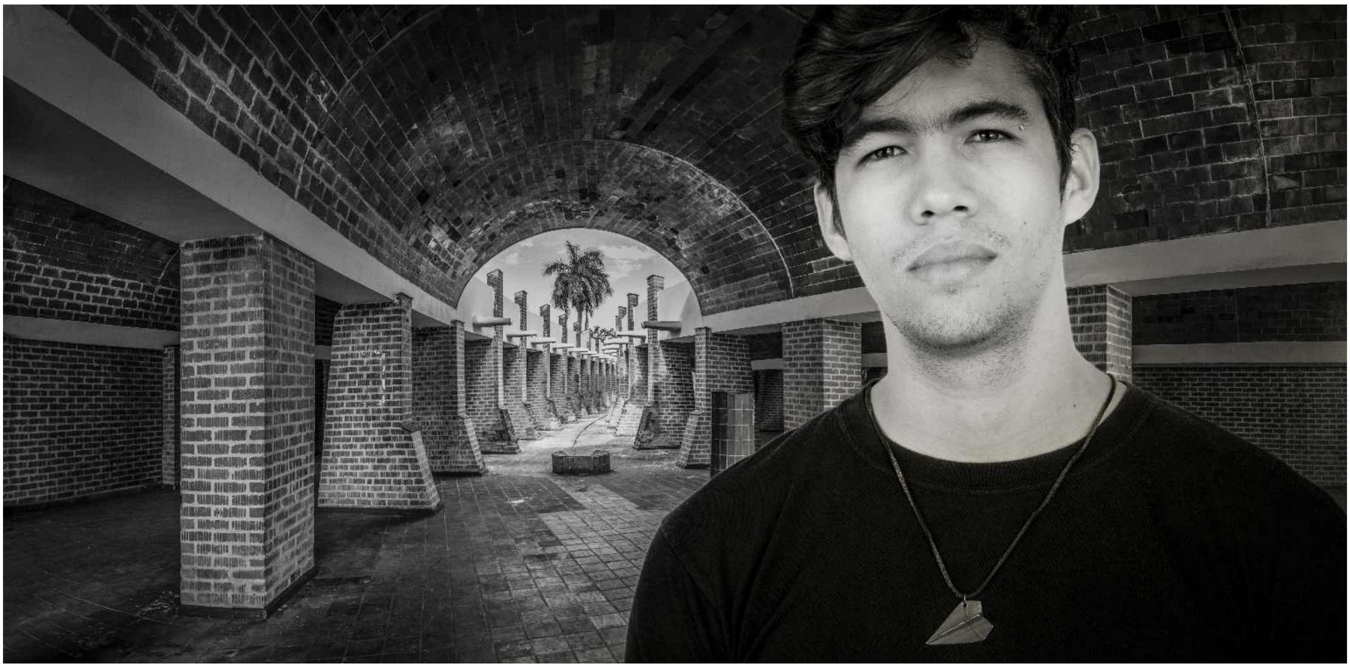

Figure 132 - Disbel. Photo by Osmara Alberteris (2019).

Figure 133 - Alejandro. Photo by Osmara Alberteris (2019).

Figure 134 - Antonio. Photo by Osmara Alberteris (2019).

Figure 135 - View of the interior of one of the minor pavilions of the School of Ballet. Photos by Osmara Alberteris (2019).

Figure 136 - A dancer performing upon the walkable coverings of the School of Ballet. Photo by Osmara Alberteris (2019).

Figure 137 - A dancer performing at the School of Ballet. Photo by Osmara Alberteris (2019).

Figure 138 - Amanda. Photo by Osmara Alberteris (2019).

Action 2

Conservation and restoration activities

Action 2: Conservation and restoration activities

2.1 Prior knowledge

2.1.1 State of the art

2.1.1.1 Literature study

When Fidel Castro and Che Guevara appointed Ricardo Porro to design the National Art Schools of Havana, they were not merely thinking about a physical building, nor complex of buildings. In their minds, the schools were to embody an ideal: the newly conquered freedom and the atmosphere of hope and inspiration that followed.

It was quite an extraordinary time in Cuban history, and Ricardo Porro, Vittorio Garatti and Roberto Gottardi were more than willing to identify themselves with the revolutionary spirit and to create the unimaginable. The outcome was so good that the Schools, for the longest time, were seen rather as a reminder of the ideals that generated them then as an educational institution. This was actually the very reason why three of the five buildings were never finished: around 1965 works abruptly terminated due to shifts in the political and social climate.

Although the most evident revolutionary feature of the National Art Schools lies in their sinuous shapes and vaulted roofs, it is clear that the three architects also pondered which constructive system was the most fitted to represent the novelty. The choice of employing catalan vaulting was in fact highly meaningful as, on the one hand, it would have allowed to prove true independence, exploiting locally - sourced materials as adobe bricks and tiles instead of importing them[1]. On the other, it would have related the new Cuban era to the Hispanic and Mediterranean culture, rather than to the United States'.

Moreover, this building technique would have guaranteed maximum flexibility in space organization, and perfect adherence to the countless curves foreseen by the architects' original drawings.

At first it was indeed officially decided to use tile vaulting as the primary structural system for the five schools, as emerges from Ricardo Porro's words:

«Nos reunimos y discutimos la forma de construcción que utilizaríamos. Se nos pidió que no usáramos ni acero ni hormigón, sino materiales y mano de obra artesanales. Yo quería que hubiera ciertas normas comunes a todas la escuelas: el sistema constructivo, la libertad formal y el empleo de los mismos materiales y después cada cual haría lo que creyera conveniente»[2].

However, this building technique was not familiar to Cuban masons. They hence sought help from a catalan collegue who immigrated to Cuba and was restoring the roof of a convent. It has been said that his name was Gumersindo, but there is no written record of him to be found, and the whole story seems to intertwine with legend.

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[1] Note that right after the revolution the US placed an embargo on Cuba which decreased access to important construction materials such as concrete and steel.

[2] R. Porro, *Arquitectura: hallar el marco poético: Entrevista con Maria Elena Martin Zequeira*, in *Revolución y Cultura*, n° 5, 1996, p. 46. The quote would translate as follows: *«We gathered and discussed which construction system was to be used. We were asked us not to use either steel or concrete, but artisanal materials and manpower. I wanted certain features to be common to all the schools: the constructive system, formal freedom and the use of the same materials, other than that, each one of us would have done what they saw fit».*

Nevertheless, pictures retrieved from Jose Mosquera's albums show a series of attempts made to test catalan vaulting on a small scale as well as to teach the technique to local manpower (Figure 1).
Today we know that things must not have gone according to plans, and a few drastic changes were made along the way. Even though hidden beneath one or more layers of clay tiles, the bearing structures of the five schools are in fact made of reinforced concrete and there is not much that can be referred to as catalan vaulting. This shift might have occurred due to safety reasons: both the architects and the masons were fairly young at the time and did not have enough experience to guarantee the good outcome of the project. Perhaps the wide span of the vaults acted as a deterrent, leading the designers to set aside the architectural grandeur in favor of structural reliability.

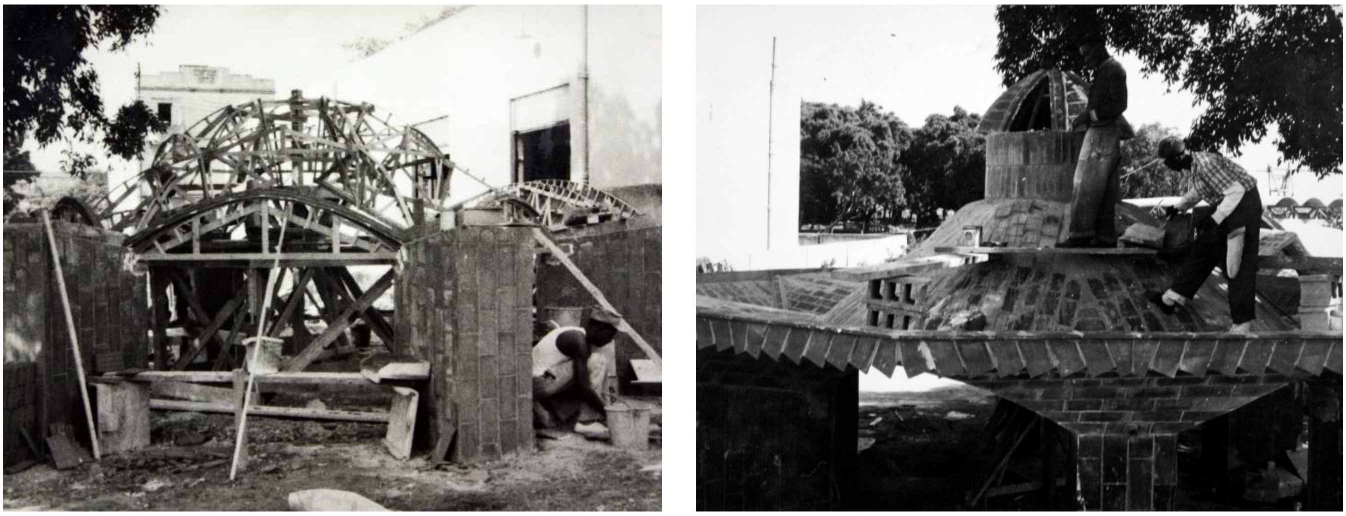


Figure 1 - The school initiated by Gumersindo to teach to local manpower the catalan vaulting building technique. The caption written by José Mosquera next to this set of pictures is: «*Banco de pruebas. Escuela para aprender la tecnica constructiva*». Pictures date back to a period comprehended between October 1961 and February 1962 (ISA archive).

An explanation as to why no one seems to have noticed - at least until recent years - the true nature of this structures can be found in the prolonged pre-eminence of formal aspects over constructive ones. Before the studies conducted by Princeton University in 2016, literature had mostly focused on architectural and cultural features, leaving aside any structural consideration.
The most accredited (and perhaps the only) theory regarding the constructive system of the schools was in fact that of John Loomis. While it does not claim to be an engineering text, Loomis' *Revolution of forms*[3] is probably the most relevant publication issued on the National Art Schools, as it has the great merit of having introduced these marvelous architectures to the world. The book was released in 1999 and, since then, global interest towards the school complex has significantly increased resulting both in multiple efforts to preserve the structures and in their official classification as Cuban national monuments.

[3] J. A. Loomis, *A Revolution of Forms. Cuba's Forgotten Art Schools*, Princeton Architectural Press, New York 1999.

While describing the five sinuous buildings and the fascinating landscape of the former golf club, Loomis reports that tile vaulting was used extensively in the structures[4]. This belief was probably the result of the architects' telling combined with the deceptive appearance of the five buildings. Attached to their original idea and to what it stood for, the three architects seem to have chosen to conceal the extensive use of concrete refining the structures as if they were in fact catalan vaults. This is particularly evident in the School of Ballet, where the side finishing of arches and domes consists in alternating layers of tiles and mortar.

Despite the inaccuracy of the theory, due to the extensive influence of Loomis' book, other scholars ended up assuming that thin tile vaulting comprised the main structural system of the schools' vaulted roofs. Eventually, this assertion also caught the attention of the engineering community, leading the Department of Civil and Environmental Engineering of Princeton University to seize the opportunity to further examine this ancient technique that still eludes modern analysis methods.

2.1.1.2 Princeton University's latest findings

In 2016, basing on information made available by previous studies, Princeton University's professors Maria Garlock and Branko Glišić[5] included the National Art Schools of Havana among the case studies to be examined by students within the course *CEE463 - A Social and Multi-dimensional Exploration of Structures*. Each edition of the course had had a different theme, and the topic selected for the Fall 2016 semester was, in fact, *Creativity in Cuban Thin Shell Structures*[6].

As one of the main objectives of the course was to teach the multi-dimensional aspects of structural engineering[7], many different activities were carried out throughout the semester, including a field trip to the location of the analyzed structures.

It was exactly adopting the proposed holistic approach that Isabella Douglas, one of the students at the time, shed light on some forgotten structural features of the School complex, concerning in particular Vittorio Garatti's School of Ballet.

Although Douglas initially assumed the structural system of the building to be a rare example of catalan vaulting, fieldwork conducted in 2016 suggested otherwise. Despite the misleading appearance of the vaults, diffusely showing alternating layers of clay tiles and mortar, the degradation of the structure provided new insights concerning the constructive system of the vaulted roofs. Indeed, where the tiles delaminated, it was possible to notice concrete spalling, as well as exposed steel reinforcing.

[4] «In creating this dynamic special experience, Garatti pushed the structural potential of the Catalan vault farther than had any of the other projects» - Loomis 1999, p. 105.
[5] Both Professors work in the Department of Civil and Environmental Engineering.
[6] Further information is available at https://cubanshells.princeton.edu/.
[7] *«The course approaches structural engineering as a holistic discipline, teaches a sense of scale, and makes the student reflect on the constructability aspects of design, on aesthetic and on the technical, social and environmental context of engineering works»* - retrieved from the description of the course available at Creativity in Cuban Thin Shell Structures web site (see previous footnote 2).

On-site observations were then confirmed by architect José Mosquera, who took active part to the construction of the National Art Schools as a young student of architecture. His telling, as well as the invaluable photographic records regarding the construction site he provided, had a key role in redefining the structural interpretation of the Ballet School's domes. Piecing together data collected on-site with information retrieved from original architectural drawings, historic pictures and interviews with members of the design and construction team, Douglas (re)discovered the presence of a reinforced concrete grid-shell system underneath the adobe tile cladding of the domes. Such finding significantly altered the engineering understanding of the structure, leading the student to deepen the knowledge of the building by developing a bachelor thesis[8] on the topic.

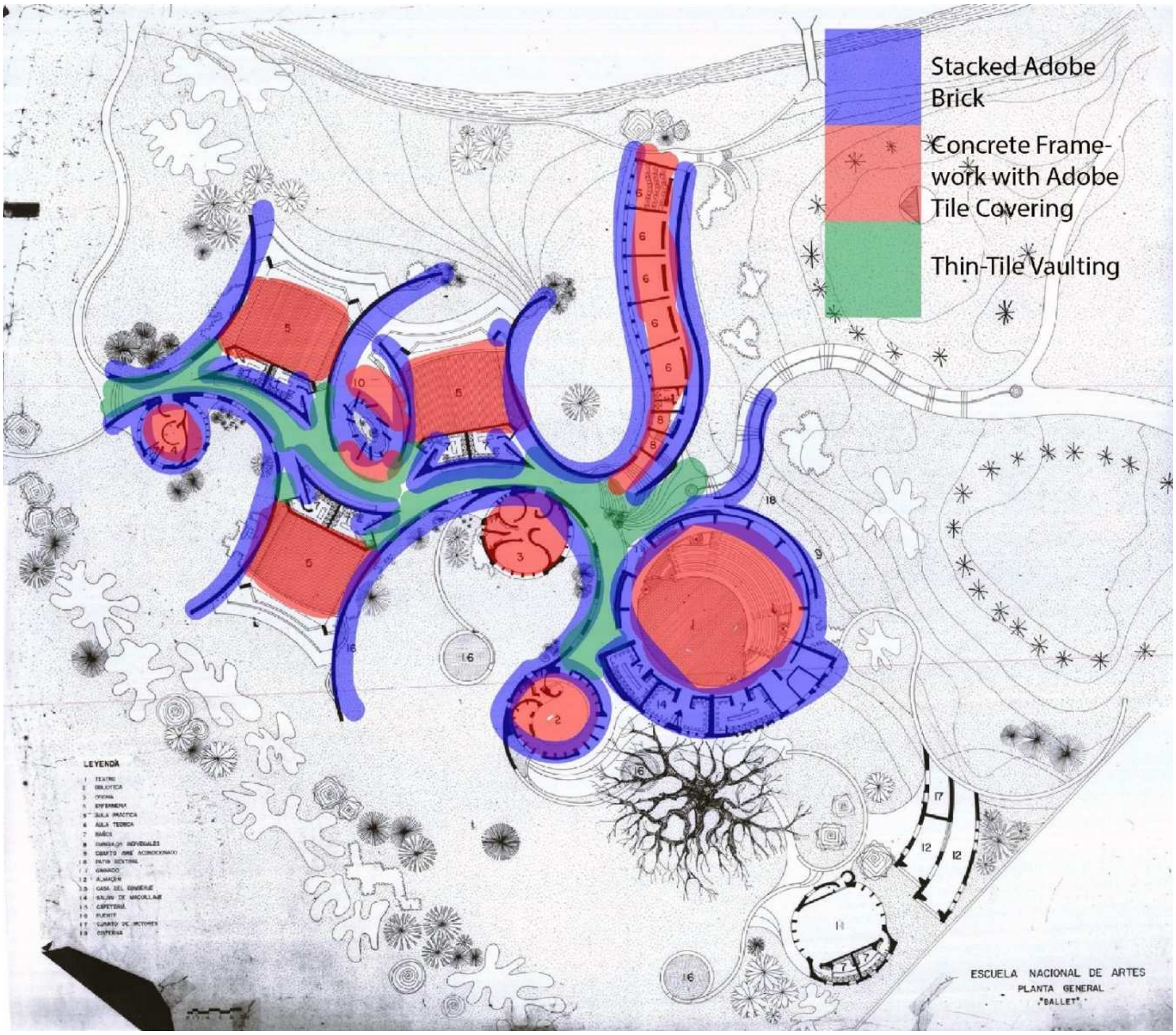


Figure 2 - Architectural plan of the School of Ballet with structural system types superimposed (image taken from Isabella Douglas bachelor thesis)

[8] I. Douglas, *Cuba's National School of Ballet. Redefining a Structural Icon*, Princeton University, April 17, 2017. Advisors: Dr. Maria Garlock, Dr. Branko Glišić.

The main objective was to replace the existing theory that catalan vaulting was used exclusively in the construction of the School of Ballet, whereas it is in fact incorporated with other techniques, into a heterogeneous structural system (Figure 2). To prove her point, while also providing a more thorough comprehension of the global structural behavior of the building, Douglas carried out some preliminary structural calculations:
«Based upon this findings, structural analyses of the domes were made using three techniques: membrane theory, graphic statics, and finite element analysis. Results point to the conclusion that the concrete, not the tiles, form the main structural system»[9].

2.1.1.3 Aim of the research
Although Princeton's research proved revealing and essential in order to conduct further studies, a few aspects were expressly neglected due to lack of information. Access to the Schools site is indeed limited, and, in November 2016, Princeton crew had the chance to spend only half day on-site, which, of course, was not enough to allow a complete and accurate survey of the School of Ballet. However, the students managed to take a good number of pictures and data, focusing at first on the global level, and then taking detailed measurements of representative structural elements. Nonetheless, the absence of precise data regarding global geometries, key structural dimensions and systems, as well as materials properties resulted in significant approximation and potential uncertainties.
Regardless of the reliability of the structural evaluation carried out by Isabella Douglas, the importance of her study lies in the observations concerning the constructive system employed for the domes. Also, by highlighting the weaknesses in her work, Douglas has provided our group with a precise state of the art, even pointing out those aspects that needed further attention and verification. Afterall, as she states, *«the true power of this method is that with the discovery of each new piece of evidence comes the opportunity to refine the global engineering community's understanding of the design of this structural icon»*[10].
Accordingly, the goal of the present research has been to fit more pieces into the puzzle, following the path that had already been partially traced out by Princeton's Department of Civil and Environmental Engineering. The final aim has hence been to gain a thorough knowledge of a selection of domes within the School complex, evaluate their current state of repair and structural conditions, and identify possible criticalities and risks in order to foster a better and targeted preservation strategy.
The work, carried out by Princeton University (Department of Civil and Environmental Engineering) and Parma University (Department of Engineering and Architecture) started exactly at the ending point of Douglas thesis, taking up the suggestions given by former Princeton's student and her advisors.

[9] I. Douglas, B. Glišić, M. Garlock, *A structural Evaluation of Cuba's National School of Ballet*, in *Creativity in Structural Design*, Proceedings of the IASS Symposium 2018, July 16-20, 2018, MIT, Boston, USA.
[10] I. Douglas, R. Napolitano, M. Garlock, B. Glišić, *Reconsidering the Vaulted Forms of Cuba's National School of Ballet*, in R. Aguilar et al. (Eds.), *Structural Analysis of Historical Constructions*, RILEM Bookseries 18, pp. 2150-2158, 2019.

Such recommendations can be summarized as follows:

a) Conduct an accurate survey of the structures in order to obtain all necessary information regarding the geometry of the vaulted roofs, as well as their dimensions.
b) Carry out laboratory testing of material properties to improve the precision of computational models.
c) Perform magnetometry testing to confirm the diameters and position of rebar.

In addition, being granted access to further historic documentation coming from both Vittorio Garatti's and José Mosquera's archives[11], it has been possible to clarify the stratigraphy of the main constructive elements of the domes, redefining - once more - this structural icon.

2.1.2 The first site visit

An early on-site inspection occurred between January 27th and February 5th, 2019. It was essential to get in touch with the local context. The chance to meet the people working and studying at the Schools, to get an overview of Cuban culture, and to physically experience the architectures gave us a more precise idea of the available resources, and thus helped to better plan the following steps.

During the trip, a lot of time was dedicated to introducing the local community to our project. Great effort was put into communication with the Cuban Ministry of Culture (being the schools a National Monument) and with the staff of the ISA. Both institutions have responded enthusiastically, showing great interest toward the initiative, and even offering to actively cooperate exchanging information and expertise with us. The involvement of Cuban professionals had always been one of the final goals of the research, also considering that in the long term, they are the ones that will be in charge of the preservation and management of this monumental site. In this case however, the collaboration has exceeded the initial expectations, granting us access to data that we might not have gathered otherwise. If the MinCult has facilitated us by streamlining bureaucratic procedures, the professors teaching at the ISA - and, in particular, those from the Faculty of Heritage Preservation[12] - worked alongside us throughout the project.

However, the most important objective of the visit was to finally gain a true sense of the place, understanding the real dimensions of the site as well as of the single buildings and their reciprocal relationship. Walking from one school to the other we better understood the global organization of the complex and got the chance to reflect upon some preliminary criticalities, among which the considerable size of the former golf club, and of the single schools. To face this challenge without losing perspective, it was finally decided to operate on two different scales:

- a global one (comprehensive of the whole site);

[11] Collecting and cataloguing such historical records was one of the goals of the present study. For further information see the general report, Chapter 1.
[12] *Facultad Artes de Conservación del Patrimonio Cultural.*

- and a local one (single buildings). Working mostly on the smaller scale, our workgroup has focused on two specific case studies, aiming at proposing a *modus operandi* to be later applied to other buildings of the complex by local professionals. The pavilions to be analyzed were selected by taking into account several different aspects spacing from architectural significance to the question of current use.

After carefully pondering pros and cons of each building, the School of Ballet was identified as the most suitable combination of strengths and weaknesses. This structure is highly iconic and interesting in structural terms, as shown by previous Princeton studies. Data availability was in fact a decisive criterion, considering both the most recent information gathered by Isabella Douglas and the historical records stored in Vittorio Garatti's and José Mosquera personal archives.

The involvement of former members of the Garatti Committee in the project guaranteed easier access to the materials that have been produced by the architect over the years. Such documents are - for the greater part - still stored at its firm in Milan, and they were hence relatively easy to consult.

Another aspect that was carefully considered is that the School of Ballet has never been in use, which, on the one hand means that, due to lack of maintenance, its state of repair is not optimal. On the bright side however, it granted full accessibility to the site without interference with scholastic activities, as would have happened in the case of the School of Plastic Arts and of the School of Modern Dance.

Within the School of Ballet, structural analyses have been conducted on the Choreography Theater, which has the largest dome of the whole complex, and on one of the three smaller Dance Pavilions (it should however be noted that the three mentioned Pavilion domes show the same geometry and constructive system; thus, they have the same structural behavior).

A few preliminary observations were also made on Garatti's School of Music, as well as on one of the small domes of the School of Plastic Arts, which has been studied mostly because of poor microclimatic conditions.

Figure 3 - Orthophotograph of the School of Ballet. Circled In red the two analyzed domes: BA.2.14 - Choreography Theater and BA.3.59 - Dance Pavilion.

2.2 On-site analyses and capacity building

Once acquainted with the site and with the resources at our disposal, we could verify the actual feasibility of the necessary on-site investigations. We were hence finally able to schedule a series of operations on the field, in order to obtain all the required data to provide an accurate and thorough analysis of the selected structures.
The activities were carried out during three different missions to Havana[13], thanks to the support of AssoRestauro, who supplied the technical staff and instrumentation. Investigations were combined with capacity-building activities resulting in a set of workshops addressed to local students, professors and professionals.
On-site investigation therefore had a double purpose:

- the collection of useful data to deepen knowledge of the Schools and develop the CMP;
- the transfer of technical expertise to local colleagues who will be in charge of future preservation activities.

The main idea is hence to provide the ISA with a comprehensive toolkit to take good care of their monumental buildings. The following paragraphs quickly summarize the steps we followed in order to meet these two goals.

2.2.1 Geometric survey

(June 2019)[14]

As pointed out by Princeton University's previous studies, there was no reliable survey describing the geometry and dimensions of the Schools. The very first activity planned was hence a laser scanner survey to obtain 2D drawings and 3D models to be used for the structural analyses. The results have indeed highlighted the existence of some evident deformations in the Dance Pavilion, which have been thus confirmed by the numerical analysis[15].
While Andrea Garzulino (Politecnico di Milano) took care of a territorial survey of the whole school site, *Zenith Ingegneria* and *Restaura y Proyecto Companies* (which are both AssoRestauro associates) dealt with the detailed surveying of two domes of the School of Ballet. For such activities, a high-density three-dimensional acquisition method was chosen to record all the data useful for the structural analysis and the definition of the intervention project on three selected portions of the schools. Specifically:

- a classroom from the School of Plastic Art,
- one of the three Dance Pavilions of the School of Ballet
- and the Choreography Theater of the School of Ballet (Figure 4).

For this type of survey, two terrestrial laser scanners (Z+F IMAGER 5010c and FARO Focus S350) were used to meet the needs arising from the different types of data to be recorded. Indeed, the focus was in parallel on the detailed acquisition of the geometric information concerning the schools (through the Z+F laser scanner) and of the geometric information concerning the connection of the schools with the entire area (using the FARO laser scanner).

[13] The missions occurred in June 2019, November 2019 and February 2020. For a synthesis see Annex 2 A of this report.
[14] For the complete report of the activities of Geometric Survey see Annex 2 B, attached to the present report.
[15] The analysis of deformations and the matching results of FEM analysis are described in Chapter 2.4 of this report

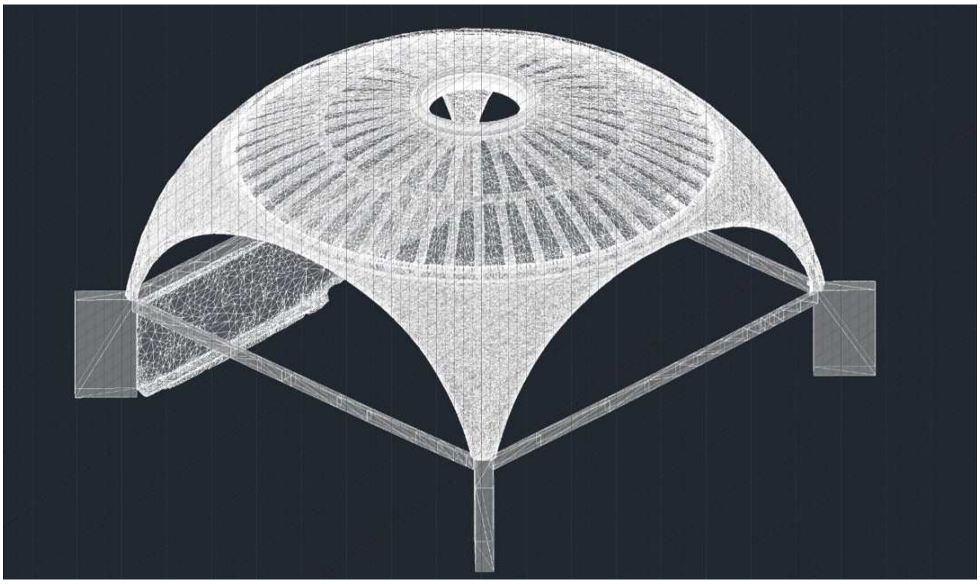


Figure 4 - Three-dimensional model of the Ballet School surveyed space (Zenith Ingegneria - Assorestauro associate).

2.2.2 Material sampling

(June 2019)[16]

During the June mission, samples of the different building materials employed in the construction of the Schools have been collected. Focusing on the previously selected case studies, sampling has been carried out on bricks, mortars, concrete and ceramic tiles.

The sampling has been operated by Eng. Giorgio di Ludovico (employed at *Tecnova Group* - Assorestauro associate), who was also involved in the capacity building activities. Laboratory analyses were then performed by *Mapei*, who provided our team with the chemical characterization of the different materials.

The acquisition of precise information regarding materials composition is essential in order to evaluate their quality, as well as their compatibility with substances that might eventually be used in restoration interventions.

2.2.3 Thermographic surveys

(June 2019 - February 2020)[17]

Two campaigns of thermographic survey were performed in June 2019 and in February 2020. The main purpose of the first (carried out by Giorgio di Ludovico from *Tecnova Group*) was to detect local phenomena of decay e.g. infiltration, moist humidity, rising damp, delamination affecting the structures. The purpose of the second (operated by Luca Valisi from *Politecnico di Milano*) was to detect the presence of a concrete structure hidden under the

[16] A complete report concerning the sampling occurred in June 2019 is attached to the present report in Annex 2 C. Results of laboratory analyses performed by MAPEI can be found in Annex 2 F.
[17] The thermographic survey occurred in June 2019, operated by Tecnova Group is described in Annex 2 C, operated by Politecnico di Milano is described in Annex 2 D.

brick-masonry skin of the iconic buildings. This followed the preliminary outcome of the "thin shell structures" by Princeton University[18].

A total of four buildings have been inspected. In detail:

- School of Ballet,
- School of Music,
- School of Dramatic Arts,
- School of Modern Dance,
- School of Plastic Art.

Active thermography utilizes external heat source to cause a change in the thermal profile in the investigated structures: heat is absorbed by the masonry, to be later released from the surface. However, because of different properties of the materials, the heat release is not simultaneous, allowing to identify discontinuities and anomalies within the structure. This method can be used to detect delamination, cracks, masonry arrangement below plaster, and it can hence be very useful when conducting structural analysis.

In this particular case, thermography has proven essential in order to understand the structural organization of the domes of the School of Plastic Art, which, like the ones of the School of Ballet, are supported by a reinforced concrete grid-shell framework (Figure 5).

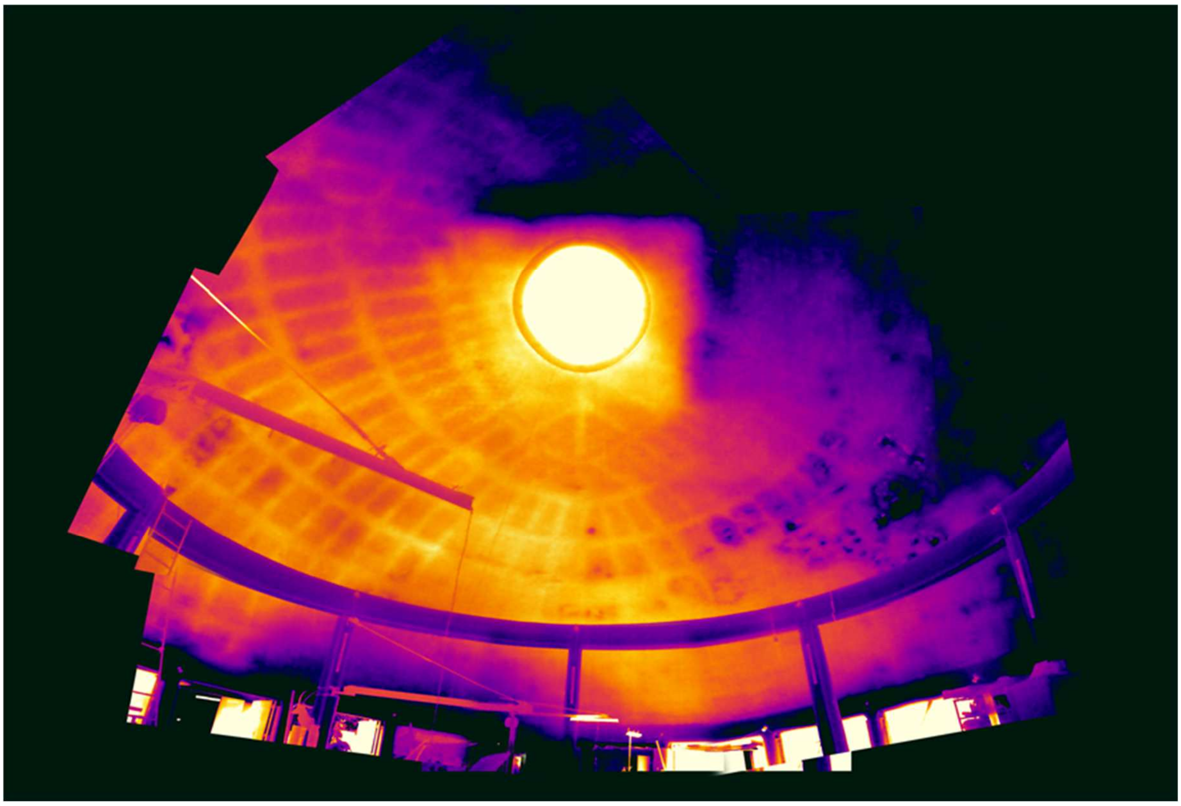


Figure 5 - Thermography of the School of Plastic Arts, intrados of the dome of the Foundry. 19th Feb. 2020, 1.00 p.m. Range: 28.5-30.4°C, Air: 29.1°C, 67.0% (Luca Valisi - Politecnico di Milano).

[18] Douglas, I., Napolitano, R., Garlock, M., Glisic, B. (2020), Cuba's National School of Ballet: Redefining a structural icon.

2.2.4 Mapping of deterioration and crack paths

(June 2019 - November 2019 - February 2020)[19]

During June, November and February fieldwork, the team has collected data regarding the current state of repair of the two selected domes (School of Ballet - Choreography Theater and Dance Pavilion). The acquired information has then been organized and reported into drawings summarizing the deterioration patterns affecting the domes.

A general survey of the structures of the School of Music has also been carried out. Indeed, throughout the last year, University of Parma's student Giuseppe Abbattista has been working on his master thesis, proposing a restoration project for Vittorio Garatti's School of Music. He thus proceeded to a survey of the state of repair of the structure and to the study of its structural system[20].

Such activities have been extremely useful in order to suggest the most suitable conservation activities and to better interpret the structural behavior of these buildings.

2.2.5 Structural diagnostics

(November 2019)[21]

During November on-site inspection (November 17th-22nd), the research group from Parma University, along with Engineer Cristiano Russo (SPC s.r.l.- Assorestauro associate) performed some non-destructive diagnostic tests with the dual purpose of:

- Verifying the current conditions of the structures through visual inspection and preliminary qualitative analysis;
- Assessing the quality of the building materials, especially focusing on reinforced concrete.

The inspection has also allowed to clarify some aspects regarding the structural organization of the analyzed domes that were still unclear, due to lack of documentary information.

Performed tests include:

- Pacometer testing: employed to locate rebars inside reinforced concrete elements and determine their approximate dimensions;
- SON-REB testing: it has been performed on all the accessible concrete elements in order to evaluate the strength of the material. The results have confirmed the excellent quality of the concrete, which had already been assumed after a preliminary visual inspection. The strength values resulting from the SON-REB testing range from 40 MPa to 60 MPa, which is surprisingly high, given the historical time and the inexperience of many of the masons working at the construction site.

[19] The crack pattern analysis is summarized in the descriptive worksheets (Annex 2 I) of each dome while a complete report of these activities (and drawings) is reported in Annex 2 F.
[20] See Annex 2 F.
[21] A detailed report of the activities carried out during November 2019 mission is reported in Annex 2 G.

- Dynamic testing: some dynamic tests (one for each dome) have been performed in order to obtain further information to calibrate the FEM models.

2.2.6 Pilot site: the conservation of exposed concrete structures

Due to the extensive presence of reinforced concrete within the Schools complex, the conservation of concrete surfaces constitutes a crucial topic when reasoning on the meanings of buildings and the acceptable margin of transformation associated with the CMP drafting.

There are relatively few structural elements in the five schools where reinforced concrete is left exposed. Indeed, in most cases, the structure is, covered with a layer of bricks (or tiles), plaster, or covering paint. Moreover, the different features and issues of the few exposed elements make the hypothesis of a typical surface treatment strategy, to be declined in different situations, largely impractical. In the various cases, specific interventions will therefore be defined, starting from a careful analysis of the elements and the context.

These investigations must include a preliminary diagnostic campaign aimed at evaluating the characteristics and state of conservation of the concrete (characteristics of the mixtures, thickness of the concrete cover, depth of the state affected by carbonation processes) and of the reinforcements (number and dimensions, corrosion, reduction of the section).

The generally good state of repair of the elements suggests an adequate water/cement ratio and careful preparation. The high level of constant environmental humidity and the absence of temperature range can be considered protective factors for the conservation of the material.

As part of the Keeping It Modern project, a diagnostic campaign was carried out on three concrete samples[22]:

- concrete from the tie-rod of the School of Ballet's Dance Pavilion;
- concrete from the ring beam located at the base of the dome of the Choreography Theater of the School of Ballet;
- concrete from one of the pendentives of the Dance Pavilion of the School of Ballet;

The study aims to verify the typology of the materials employed in the construction of the Schools and define the most suitable products/systems to be used in possible maintenance activities and restoration interventions.

For this purpose, the evaluations mostly concerned the content of soluble salts, the mineralogical composition (by means of spectroscopic analysis such as XRD - X-Ray diffraction), the quantitative and qualitative presence of hydrate compounds (through "thermal analyses").

The samples have been sprayed with a 1% phenolphthalein solution in ethanol to evaluate the carbonation phenomena. The surface turns red if the reagent detects the presence of $Ca(OH)_2$, which means that the $pH > 10{,}2$ (alkaline material, the rebars are protected from corrosion); on the contrary, the color remains unchanged if the $pH < 8{,}6$. This means that the concrete, due to carbonation phenomena, has completely transformed into $CaCO_3$.

[22] See *Annex 2 E Chemical analysis of building materials. Sample analysis report.*

The test performed on the three samples highlighted that the carbonation phenomenon has wholly affected the samples, but there are no soluble salts (chlorides, sulfates, nitrates). Very different types of binders, inert, and inert binder ratio are detected.

In such a diversified scenario, it is not possible to formulate universal solutions.

The most significant and challenging theme is undoubtedly that of the restoration of the School of Music's exposed concrete fronts (Gusano), which, by extension and diffusion of degradation phenomena, represents a topic of investigation both from a technical and a design point of view.

During the research, some materials and intervention techniques were then tested through a study site to identify some possible action lines. In addition to the visual checks, some effectiveness checks were carried out with a portable instrument that allowed the main parameters to be checked.

In order to verify the technical feasibility of the interventions, the study site was conducted in close collaboration with local companies and workers, in a logic of comparison and exchange of experiences.

2.2.6.1 Use and conservation problems of exposed concrete in the schools

In the schools, the use of exposed concrete is somewhat limited. In the Ballet School, the concrete structure can be seen in the Choreography theater (Ring beam at the base of the dome, top oculus and mezzanine slab), in the Dance Pavilions (tie-rods and top oculus) as well as in the perimeter curb of the patio and internal walkways. The concrete of the architraves and gargoyles of the library, offices, and infirmary is also on-sight.

Overall, the material appears to be relatively compact, and the signs of the formwork used for the casting are visible. There are limited shortcomings.

On the other hand, the state of conservation of the dance pavilions' beams is more critical, showing widespread lacks and detachments. The thinness of these elements and their exposure to atmospheric agents accelerated the material's carbonation processes with consequent loss of the concrete cover's protective characteristics against the metal reinforcements.

Corrosion processes, which are known to involve a significant volumetric increase, led to the detachment and expulsion of the cortical layer, progressively exposing new portions of the material to atmospheric agents' action and thus causing a reduction in resistant sections. A similar phenomenon occurs in the same classrooms' porticoed elements, where the concrete cover is now almost entirely absent.

In Roberto Gottardi's School of Theater, all the reinforced concrete perimeter curbs are left exposed. Along the external elevations and the walkways, the material appears compact, and the signs of the formwork can be identified. Despite exposure to atmospheric agents, the elements appear to be in a good state of repair;

There is a widespread blackening due to biological agents (probably an algal patina). Some punctual detachments can be observed due to the reinforcements' corrosion with consequent expulsion of the concrete cover, located in the percolation points of rainwater.

The curbs are covered with a layer of covering paint gray in color, probably acrylic, and show no evident damages in the interior.

Figure 6 - School of Ballet, elements in exposed concrete.

Figure 7 - School of Theater, rehearsal room.

Figure 8 - School of Theater, external walkway.

In Roberto Porro's schools (Plastic Arts and Modern Dance), all the internal and external structural elements in reinforced concrete (i.e., arches, curbs, gargoyles) are covered with a white paint similar to the one that covers the plasters.

This covering coating makes the surface uniform and hides any traces of production but at the same time contributes to the good conservation of the elements, acting as a protective layer. Some cracks or limited phenomena of expulsion of material are observed at points of discontinuity, stagnation of rainwater, or the presence of higher plants' root systems. On the other hand, algal patinas are widespread.

Figure 9 - School of Modern Dance, External façade.

The School of Music is the one that has the largest amount of exposed concrete surfaces: the curved façades towards the Rio Quibù are marked by a succession of reinforced concrete "tubs", which form the terminal part of the vaults. On the extrados, these elements are covered with brick elements and form external walkways. The surface is rather compact and devoid of visible aggregates, but the formwork's very evident signs give a material texture to the surface.

The state of conservation is rather critical. The humid points are those where the most significant percentage of detachments, cracks, and deficiencies occur, namely: the top area, exposed to the action of rainwater, and the lower area, where there are the holes that allow the runoff of rainwater. Over time, metal gargoyles were added to direct the water flow to the ground and avoid percolation on surfaces. The accumulation of materials along the walkway and the deterioration of the pavement have, however, caused the gargoyles to be blocked and water to stagnate on the extrados.

More than the absence of coating on the front, the loss of the coating on the extrados favored the corrosion of the reinforcements and the consequent loss of even significant parts of the material. Therefore, the flooring re-development will have to be addressed as a priority, as part of overall planning that will have to cover all the elements that make up the prospect, starting with the windows.

2.2.6.2 School of Music: the pilot site

The pilot site took place during the mission of February 2020 (13/02/2020 - 18/02/2020). The site's choice was made in collaboration with ISA, in particular with the director of the *Facultad de Artes de la Conservación del Patrimonio Cultural (CECREM),* Silvia Ramirez Paseiro. The upper-level tub was selected as the action area, in correspondence with the classrooms granted for use by some school students.

The selected area has good accessibility and conservation conditions that can be considered representative of the entire building.

Figure 10 - School of Music, area of intervention.

Phases of intervention

The first phase of the intervention consisted of removing the deteriorated material until the solid and resistant substrate was reached. All the operations to remove the deteriorated material were carried out until the complete uncovering of the reinforcements to ensure the additions' better adhesion.

In some cases, the chance of making regular shape integrations was tested, making cuts with angle grinders, also in order to ensure better adhesion of the patch.

Figure 11 - Deteriorated material removal.

Figure 12 and Figure 13 - Cuts with angle grinders.

Subsequently, surface deposits were cleaned with a dry sandblasting machine (IBIX System). The most appropriate inert material and the service pressure were evaluated during operation.

Figure 14 - Cleaning operation.

A crucial point was the choice of materials to be used.

The use of cycles on the market, consisting of protective treatment, repair mortar, and coating, gives excellent guarantees in terms of ease of use, durability, and uniformity of interventions. However, the market in the Cuban context for restoration materials is very limited.

Therefore, it was decided to operate with a cycle of products supplied by the MAPEI company, which has distributors on the local market.

The tested intervention cycle includes:

- Treatment of protective irons with a re-alkalization protective treatment by applying one-component anticorrosive cementitious mortar (Mapefer 1K MAPEI) with a brush. The application of the product guarantees a Ph > 12, and therefore the conditions of passivation. Two layers of product were applied by brush.
- Implementation of the additions with fiber-reinforced mortar (Mapegrout T60 MAPEI). After applying the mortar, the surface was smoothed with a spatula with a few small-grain aggregates to make the final effect more similar to the existing surface. Patches of different shapes, regular and not, have been made.
- Finishing with semi-covering acrylic paint (Colorite Beton MAPEI). The product was applied by brush in three different dilution ratios to indemnify the best coverage level and match with the concrete color:
  1. a solution in 25% water;
  2. a solution with 50% water + color in tempera (turned out to be the best solution);
  3. a solution in 50% water.

Figure 15 - Treatment of protective irons.

Figure 16 - Fiber-reinforced mortar addition

Figure 17 - Finishing with semi-covering acrylic paint.

Figure 18 - Three finishing color tests.

The proposed cycle allows excellent adhesion of the additions to the surface and protects the reinforcements from corrosion. The dark color and the different textures of the fiber-reinforced mortar require the application of a covering colored finish on the entire surface, including both the integrated portions and those still in good condition. The appropriateness of this treatment must be evaluated both from a technical and conceptual point of view.

From a technical point of view, the application of a finish, albeit in solution, can have a protective function and can therefore help slow down the carbonation processes. Simultaneously, the presence of a film negatively affects the vapor permeability of the material. This characteristic must instead be maintained to allow evaporative cycles, especially in an environment with high humidity.

The compatibility of an intervention that involves an important transformation remains open, covering a surface designed to be left exposed with a finishing layer. However, the treatment does not involve a thickness such as to hide the signs of the formwork and the main irregularities of the texture. Obviously, it involves greater chromatic uniformity and a "flattening" of the elevation image. To overcome these critical issues, an integration treatment can be thought of that allows greater consistency in color and texture with the existing one not to require the affixing of a covering film over the entire surface. Therefore, the additions could be made with two different materials: with a commercial fiber-reinforced mortar in contact with the reinforcements and up to 1-2 cm from the surface (with a mortar similar to the existing one in the cortical part). The 2-phase structuring would optimize the intervention because it would benefit from the technical qualities in terms of performances and durability of commercial products, guarantee the maximum aesthetic compatibility of the additions, and avoid the reduction of permeability resulting from the affixing of a film.

In defining the intervention cycle, applying a non-covering water repellent product on the untreated areas can be evaluated after cleaning and removing the biological patinas.

This assessment must take into account multiple parameters, including:

- product effectiveness, in terms of reducing surface absorption and reducing the diffusion of biodeteriogens;
- variation of the surface permeability to water vapor;
- chromatic variations and "wet effect" on the surface;
- duration and times of product re-application. In this respect, the ease of access is a positive element.

A similar solution was tested and proposed as part of the drafting of the Conservation Plan for the University Colleges of Urbino by Giancarlo De Carlo (Keeping It Modern Grant 2015).

In the same research, various morphologies were also evaluated for the implementation of the integrations and precisely:

- additions of irregular shape, flush with the surface of the existing material, without evident edges;
- additions of regular shape, in relief concerning the existing surface;
- additions of regular shape, flush with the surface of the existing material.

Several options were also evaluated concerning the repetition of the signs of the formwork:

- application of boards to reproduce the surface of the formwork;
- no trace, sponging of the surface to bring out the aggregates;
- making horizontal marks at the joint between the boards.

In that context, the theme of the conservation of exposed concrete surfaces was of primary importance, given their extension and the care given by De Carlo to their design and restoration. De Carlo himself had proposed to make the integrations with a regular shape, in relief to the surface and with a different texture, to identify them as "additions", successive layers linked to the inevitable passage of time.

In the long history of planning and redesigning the Schools, only Roberto Gottardi thinks of an intervention, not completed, which borrows architectural restoration tools.

In the Music School, the realization of a non-mimetic intervention would activate interest in the different life stages that *Gusano* has gone through overtime, despite the failure to complete and use it for teaching activities. Therefore, it is a question of highlighting the potential that this building can express, not necessarily as a School of Music.

The appropriateness of this choice will, in any case, be assessed, also taking into account the number, location, and size of the additions to be made and the choice of materials, as well as the overall redesign of the elevations. Finally, the interventions must be carried out in successive phases, ensuring a uniform result both in aesthetic and qualitative terms, in the hypothesis that the recovery of the *Gusano* takes place in successive stages, even involving different subjects.

During the pilot site, two protective products were also tested, applied by brush on a surface in good condition, and cleaned with a dry sandblasting machine:

- IBIX Biocare Essenzio, a biocide product based on natural extracts;
- IBIX Biocare I-Protect AS, water-repellent impregnating agent for surfaces.

The two products have been diluted in a ratio of 1: 4 to create a light protective surface film. IBIX Biocare Essenzio was also tested on a surface affected by algal colonies, cleaned with mechanical tools and water.

Finally, the interventions' effectiveness was verified with portable instrumentation for rapid on-site diagnostics (IBIX Mobile Lab).

Five test points were identified:

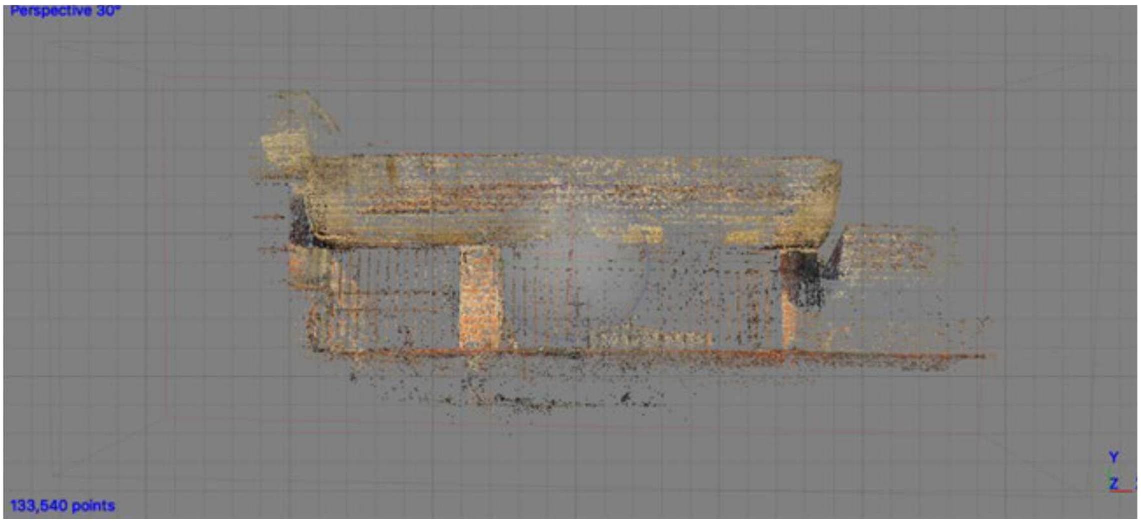
- Sample 1 (surface with cleaning treatment at the point of surface runoff);
- Sample 2 (surface with a cleaning treatment and IBIX Biocare Esenzio, at the point of surface runoff);
- Sample 3 (dry sandblasting cleaned and protective)
- Sample 4 (dry sandblasting cleaned);
- Sample 5 (untreated surface - control point).

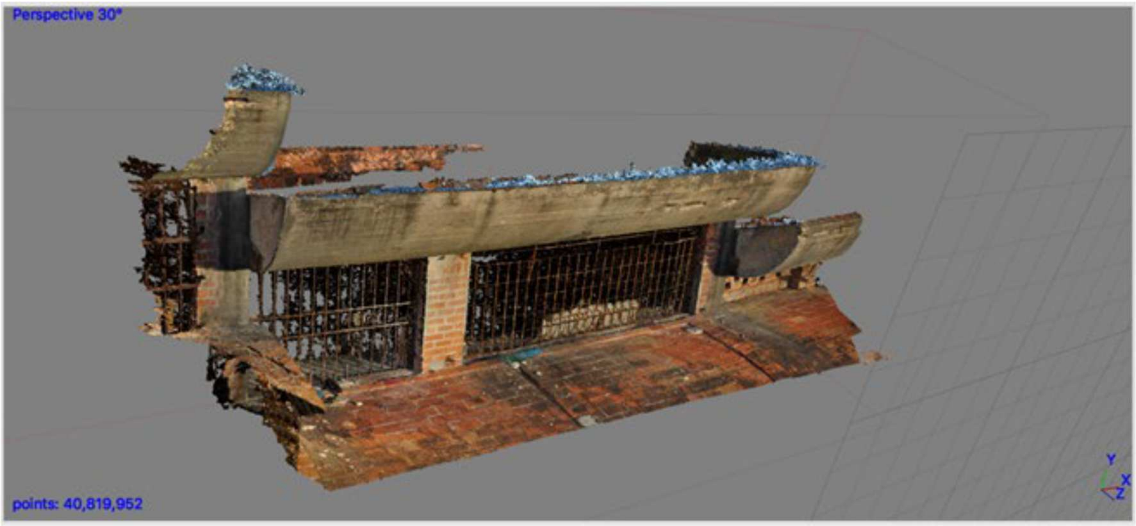
Two primary analyses were carried out with the portable laboratory on all samples: surface observation under the light microscope, min. 10X, max. 150X magnification and low-pressure water absorption so that the results could be compared on the different surfaces sampled. In addition, two measurements were carried out on sample 1 before the protective operation, with the different instruments present in the Mobile Lab: Pyrometer to measure the environmental parameters and electromagnetic induction contact hygrometer to obtain information on the water level.

The activities carried out were documented through photographic reports. To better evaluate the intervention, two three-dimensional photogrammetric models were created before and after the intervention.

Figure 19 - IBIX Biocare Essenzio application.

Figure 20 - Rapid on-site diagnostics (IBIX Mobile Lab).





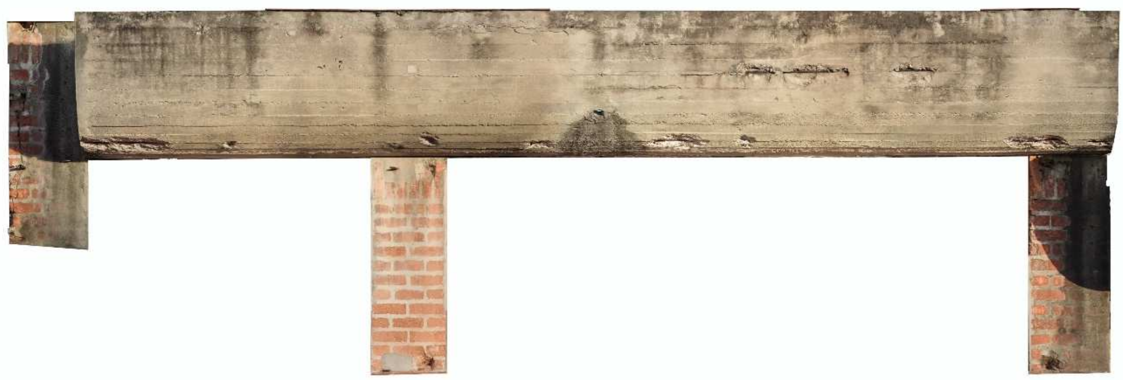


Figure 21 - Three-dimensional documentation before the intervention (point cloud, 3D-model, and orthoimage).

Figure 22 - Orthoimage of the final result after the intervention.

2.3 The construction process

The large amount of data collected during the on-site activities, as well as records emerged from archival research, brought us to the necessity of working through a lot of information. The primary goal was to analyze the new findings in order to clarify doubts regarding the constructive system of the two domes. A second was to systematize the results, making them easily available to whomever will need them in the future. This aspect is indeed relevant, as it guarantees the possibility to keep implementing this study: by supplying future professionals with a solid set of information, we prevent them from starting from scratch once again, while fostering progress.

We therefore attempt to reconcile data resulting from the fieldwork with the records emerged from the archives, both drawings and pictures showing the 1960's construction site. As a result, we can adjust the hypothesis previously formulated by Princeton University, highlighting an even greater use of reinforced concrete than expected[23].

It should be noted that the study of historic documentation is not at all secondary in structural analyses. In fact, the reading of the deformation and cracking data cannot find a certain interpretation without taking into account all those events that have shaped the building overtime, starting from its very construction. This philological work brought us to a satisfying level of certainty regarding the different constructive elements of which the domes are comprised, resulting in an overall more accurate structural analysis.

The following paragraph aims at illustrating the different phases of the construction of the domes of the Choreography Theater and of the three Dance pavilions. In general, the criteria employed to build the School of Ballet are quite consistent among the different domes, the main idea being to use clay tiles as formworks where to directly pour the cement. However, due to some differences in geometry and dimensions, the structures maintain a few specific features, that will be further analyzed in the following paragraphs.

As mentioned, the main sources of information concerning the building site were the photographs taken by Vittorio Garatti and José Mosquera during the construction site and today part of the ISA archive[24], which carefully documented nearly all phases of the construction.

2.3.1 Centering

As shown by the pictures above, the first step towards the construction of the domes of the School of Ballet was to build the timber scaffoldings and centering.

[23] Note that Princeton's former student Isabella Douglas was not able to consult Vittorio Garatti's materials, which have proven essential to better define the constructive system of the analyzed domes.

[24] Cuban architect and construction worker who took part to the construction of the National Art Schools as a student. In particular José Mosquera cooperated in the construction of Vittorio Garatti's School of Ballet and School of Music.

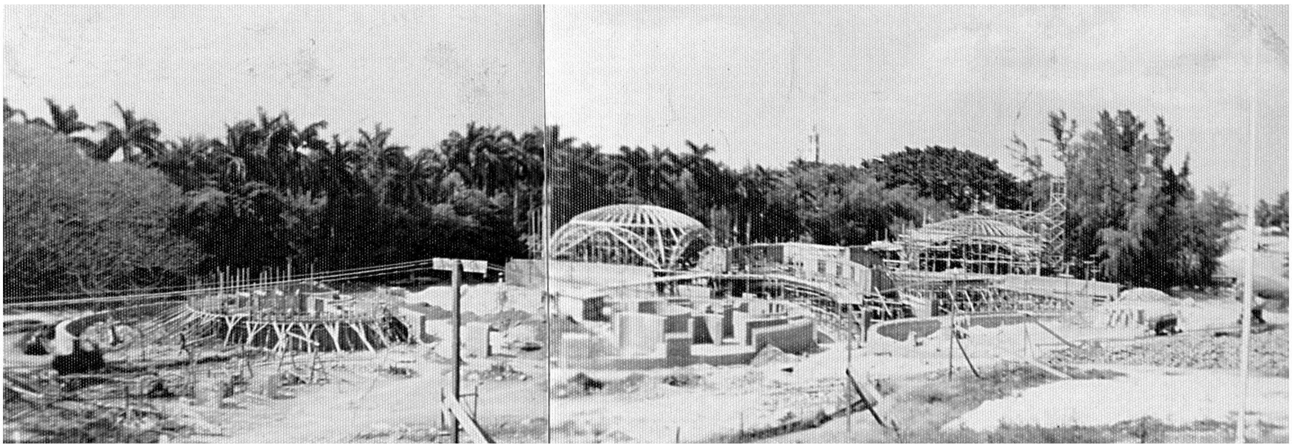


Figure 23 - View of the School of Ballet during construction: wooden centering of the Dance pavilions (ISA archive).

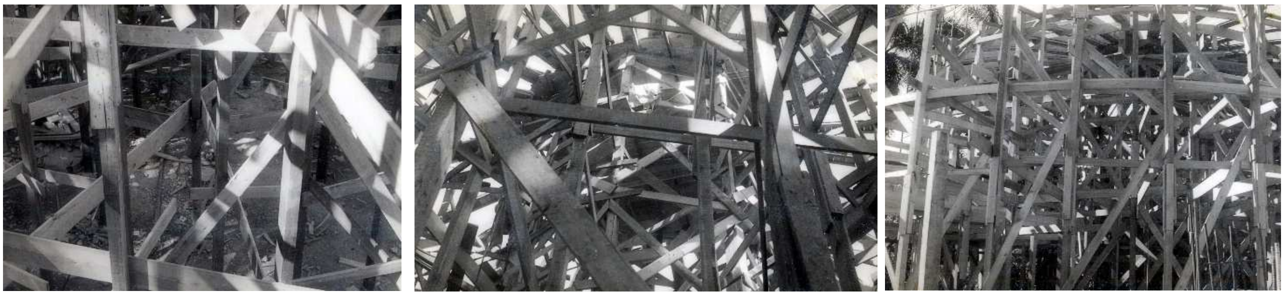


Figure 24 - View of the wooden scaffolds and centering of the dome of the choreography theater (ISA archive).

Such elements are essential in order to correctly shape arched vaults and domes, acting as temporary structures upon which the stones, bricks (or clay tiles in our case) are laid during construction. Due to the significant span of the domes, the wooden frameworks employed for the School of Ballet appear quite large and complex.

2.3.2 Formwork

Once created a firm support with the correct geometric features, the construction workers built a series of formworks where to pour the concrete. As a matter of fact, the latter represents the predominant constructive system employed in the construction not only of the School of Ballet, but - as proven by thermal imaging - of each one of the five National Art Schools.

Although different as for dimensions and shape, the domes of the three dance pavilions and the dome of the choreography theater are comparable, and possibly built with the same criteria and method. Both domes are composed of a ribbed spherical cap on the top and of a continuous base (an annular sector for the choreography theater, four pendentives in the case of the practice rooms).

The grid-shells - both for the choreography theater and for the practice rooms - have been built by lining the inside of the previously prepared wooden formworks with clay tiles. This way, once the concrete had set, it was possible to dismantle the wooden formworks, leaving the clay tiles in plain sight and the concrete hidden underneath.

Vittorio Garatti allowed us to understand - at least for the most part - the sequence of operations carried out to complete the structures.

By laying the clay tiles over the wooden centering, the construction workers created the curve intrados of the pendentives/annular sector, which also acted as formworks for the following concrete casting. The on-site investigations and micro-destructive testing have verified that the intrados of the pendentives of the practice rooms is composed of at least three layers of clay tiles. However, the fact that the Ferro-scan system employed to search for rebar within the pendentives was hardly able to detect any iron[25], suggests that the clay tile layers could be even more (at least four layers of 1,5 cm thick tiles and three 1-1,5 cm layers of mortar). If the construction system employed to build the ribs and rings of the grid-shells was not particularly complex, the one developed for the pendentives of the practice rooms and the annular sector of the choreography theater was rather unusual.

As for the annular sector of the choreography theater, at least two layers of clay tiles are at the intrados. This has been observed both by performing some micro-destructive testing and by analyzing the pictures shown below: the clay tiles at the intrados of the dome (Figure 27, right, as we see it today) are horizontally laid while the building-site picture (Figure 27, left) shows tiles that are alternatively laid horizontally and vertically. Such difference proves that at least two the clay tile layers compose the intrados of the crown sector of the choreography theater.

Figure 25 - Choreography Theater: Lining of the wooden formworks with clay tiles (ISA archive).

[25] The employed Ferroscan has a maximum detection depth of about 10 cm.

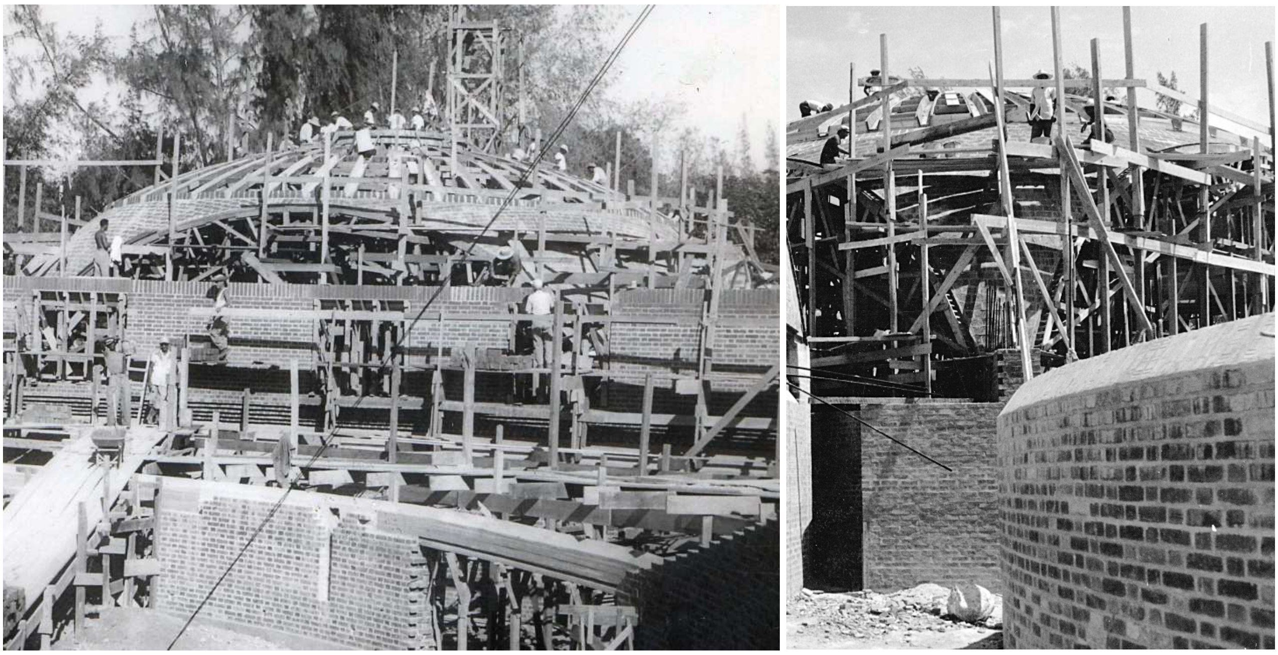


Figure 26 - Dance pavilion: layering of the clay-tile formworks for the construction of the pendentives (ISA archive).

The resulting thin shells, still supported by scaffoldings and centering, were hence meant to be a sort of mold to shape and hide the concrete at the same time.

Figure 27 - Choreography Theater: clay tile formwork of the annular sector of the dome (the photo on the left is taken from the ISA archive).

2.3.3 Reinforcing bars

Once the clay-tile formworks were ready, the construction workers laid and connected the iron reinforcing bars. As can be noticed from Figure 28 (left), the rebars designed for the rings and ribs of the grid shell also protrude vertically, indicating the intention of connecting them to a further reinforcing system to be added above.

With regards to the pendentives of the practice rooms, the building-site pictures (Figure 28, right) allow us to say with certainty that there is a reinforcing net. Although existing in Vittorio Garatti's original designs, the rebar of the pendentives could not be detected by the Ferroscan survey performed during November mission. As mentioned above, the employed instrument has a maximum detection depth of about 10 cm, thickness that can easily be reached considering the several layers of tiles composing the intrados. The existence of a connection between the pillars and the pendentives is also proved by the building-site pictures; the highest portion of the masonry pillar (base of the pendentive) is made of concrete, and the iron bars sticking out are meant to be connected to the reinforcement of the pendentive.

A few other observations can be made regarding the reinforcing system of the choreography theater. As a matter of fact, even though the grid shell of the main dome was built in the very same way of the ones covering the practice rooms, the annular sector below is quite different from the pendentives described above. The rebar of this concrete ring (also referred to as "crown"), consists in the extension of the iron bars of the main ribs of the grid-shell, connecting the upper spherical cap to the ring beam located at the base of the dome. Although this arrangement was not detected by the Ferroscan survey operated in November 2019 (only performed at the extrados of the dome), the picture above (Figure 30) suggest it. In addition, the crown at the base of the Choreography Theater was reinforced with an iron grid, rather similar to the one positioned in the pendentives of the Dance Pavilion. According to Garatti's drawings, another grid should have been located inside the crown, on the extrados side. The presence of this second grid was verified by the Ferroscan, which detected the presence of iron bars running in two directions with a spacing of approximately 25 cm.

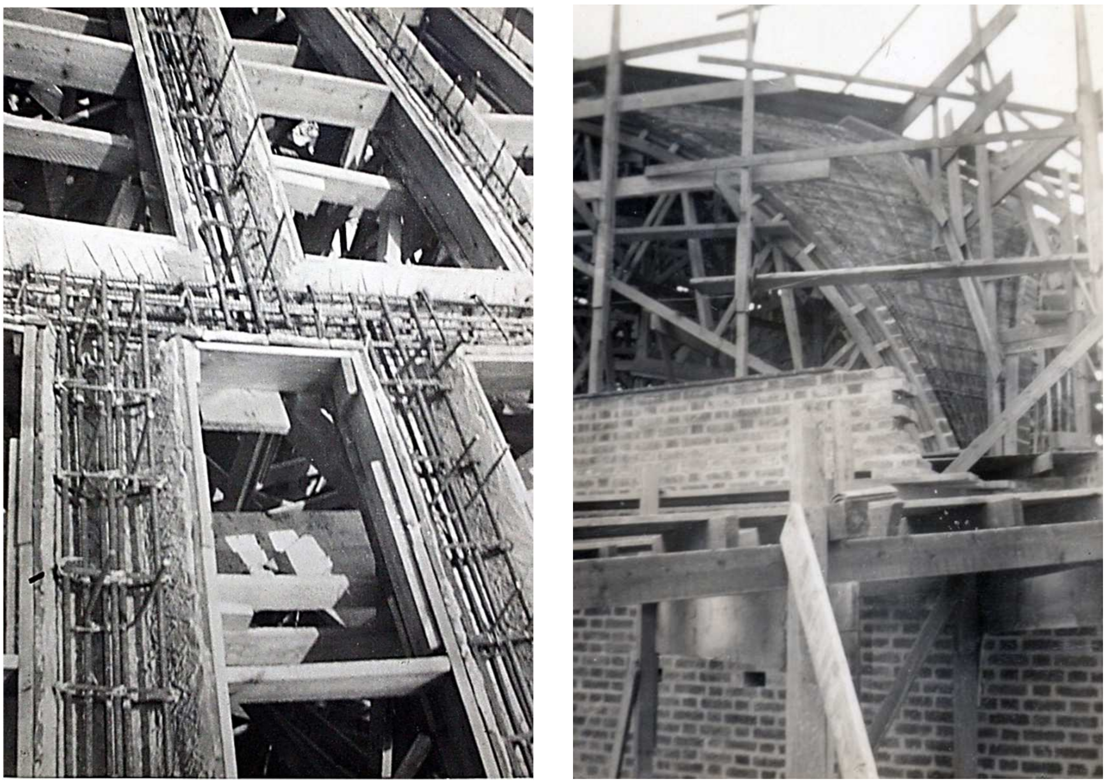


Figure 28 - Dance pavilion: positioning of the rebars. Left: view of the grid-shell. Right: view of one pendentive (both images are taken from the ISA archive).

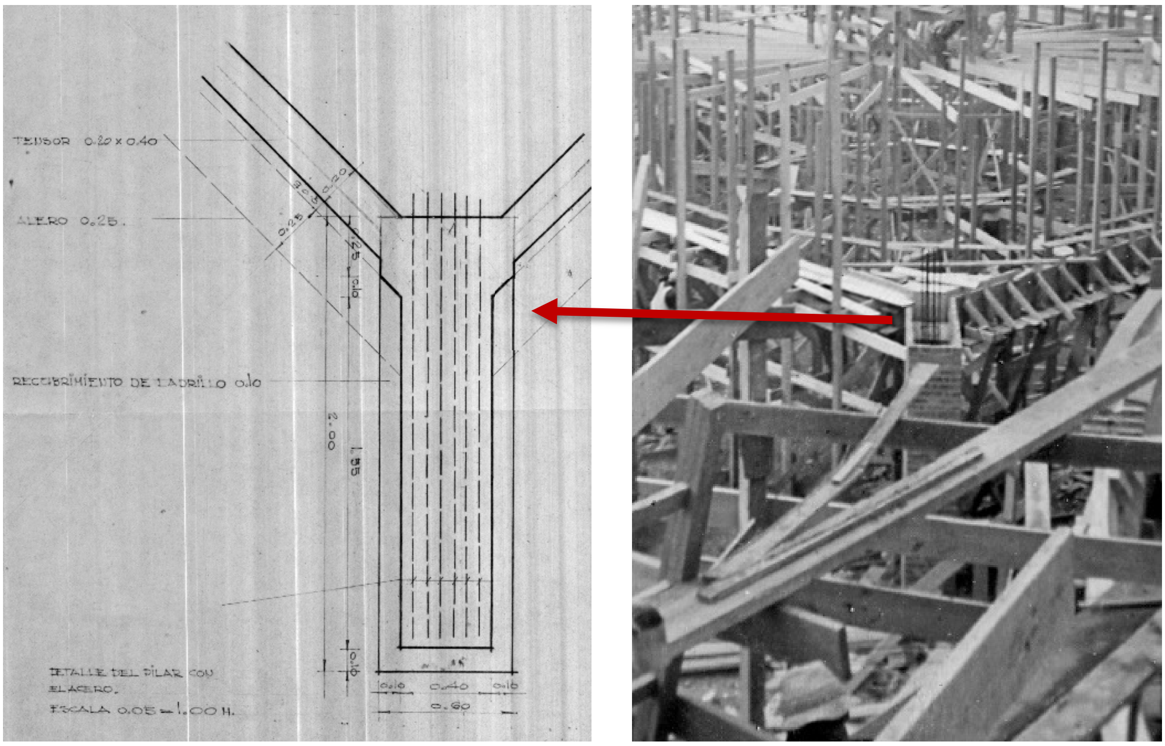


Figure 29 - On the left, the original design of the concrete block located at the top of the pillars. In the middle, a picture from the construction site showing some iron bars jutting from the pillar (images taken from the ISA archive).

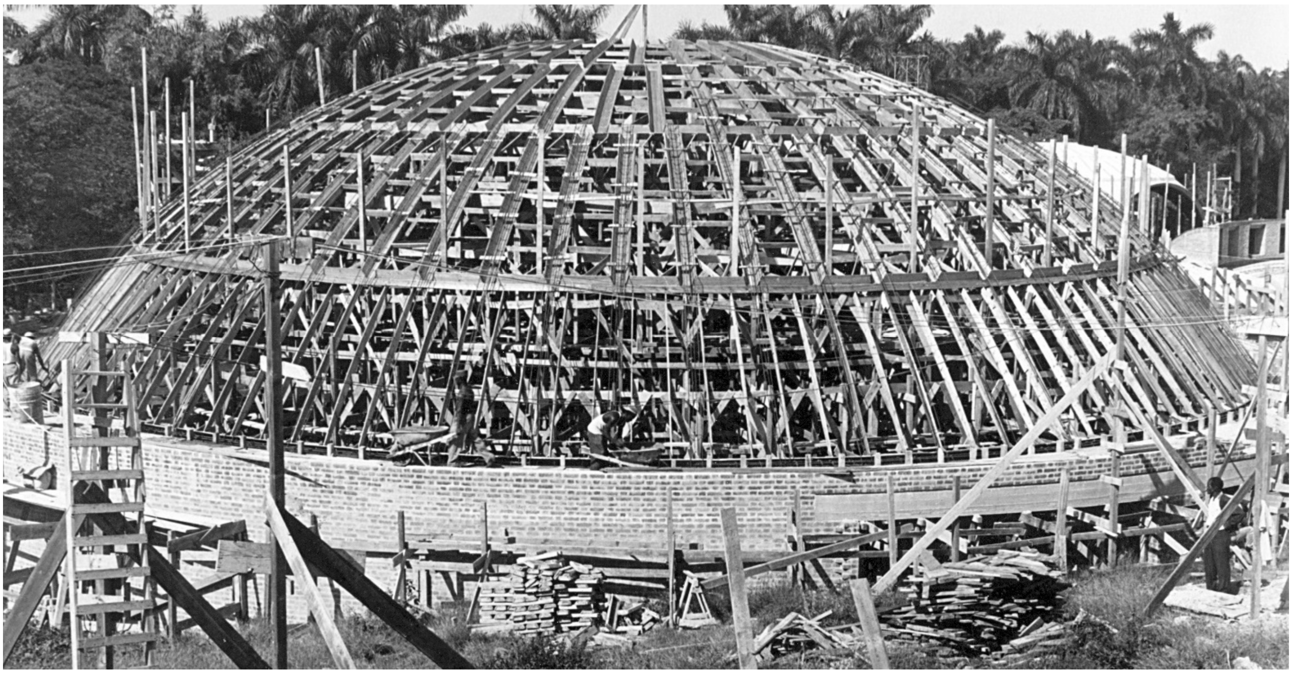


Figure 30 - Choreography Theater: formworks and rebar arrangement (ISA archive).

2.3.4 False catalan vault

Once the grid-shell was ready, it was time to fill in the voids between the ribs. Using the same approach that had been adopted until then, the architects decided to use thin clay tile layers to close the gaps. In this way, the impression we get looking at the intrados of the domes, is that of a structure entirely made of masonry. However, as also shown by the original drawings, the idea was once again to employ the clay tiles to both create the mold for a further concrete layer casting and, at the same time, hide it from the sight.

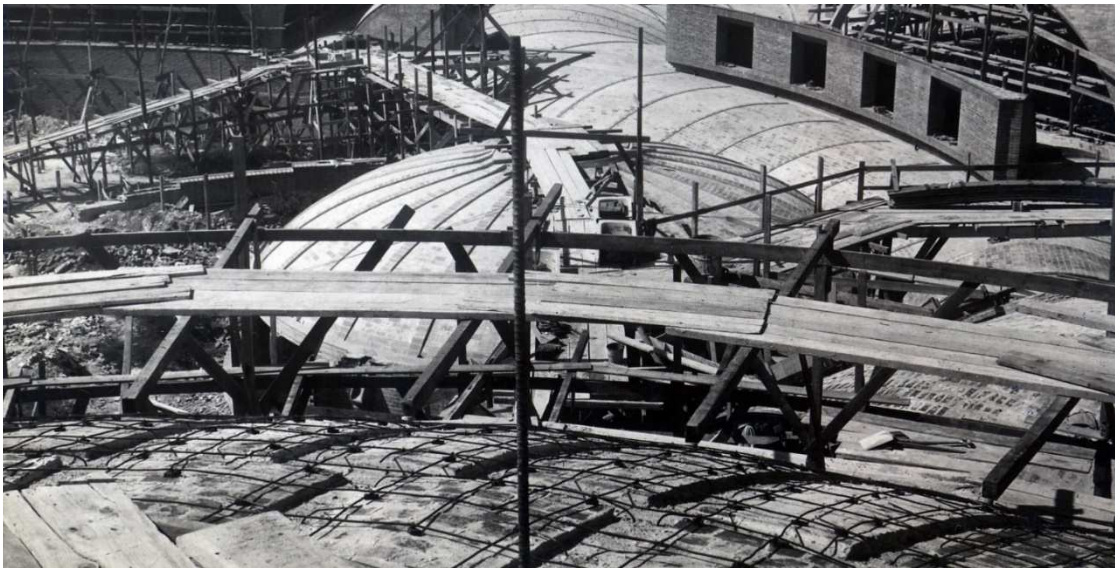


Figure 31 - Choreography Theater - view of the “catalan vaulting” filling the voids between the ribs (ISA archive).

Figure 31 shows the choreography theater once completed with tile vaulting. A reinforcing iron net has been laid out, secured to the structure by anchoring it to the masonry vaults. The original drawings suggest the clay tile layers composing the vaults to be two, but we don't have further verifications in this regard.

Although the only picture regarding this phase portrays the choreography theater, it seems reasonable to think that the same technology would have been employed in the dance pavilions as well. A hint at this possibility is given by the rebar arrangement we have already observed in the previous Figure 28 (left), where in addition to the longitudinal bars and stirrups employed in the ribs, we see some sort of brackets that were probably designed to connect the grid-shell to a further concrete element to be positioned above.

Figure 32 shows the Dance pavilion after the second concrete casting, which covers the entire spherical cap creating a smooth and continuous shell. The picture clearly shows the true nature of the domes of the School of Ballet: structures that, despite a masonry appearance, are entirely made of reinforced concrete.

Figure 16 shows the dome at the end of the construction process, with the scaffoldings being dismantled. It can be seen as the top has been completed with a ceramic coating. Brick tiles were used to coat the pendentives, rings, and ribs, that is the reinforced concrete structure. White tiles were instead used to cover the false catalan vaults, that is the gaps between ribs and rings.

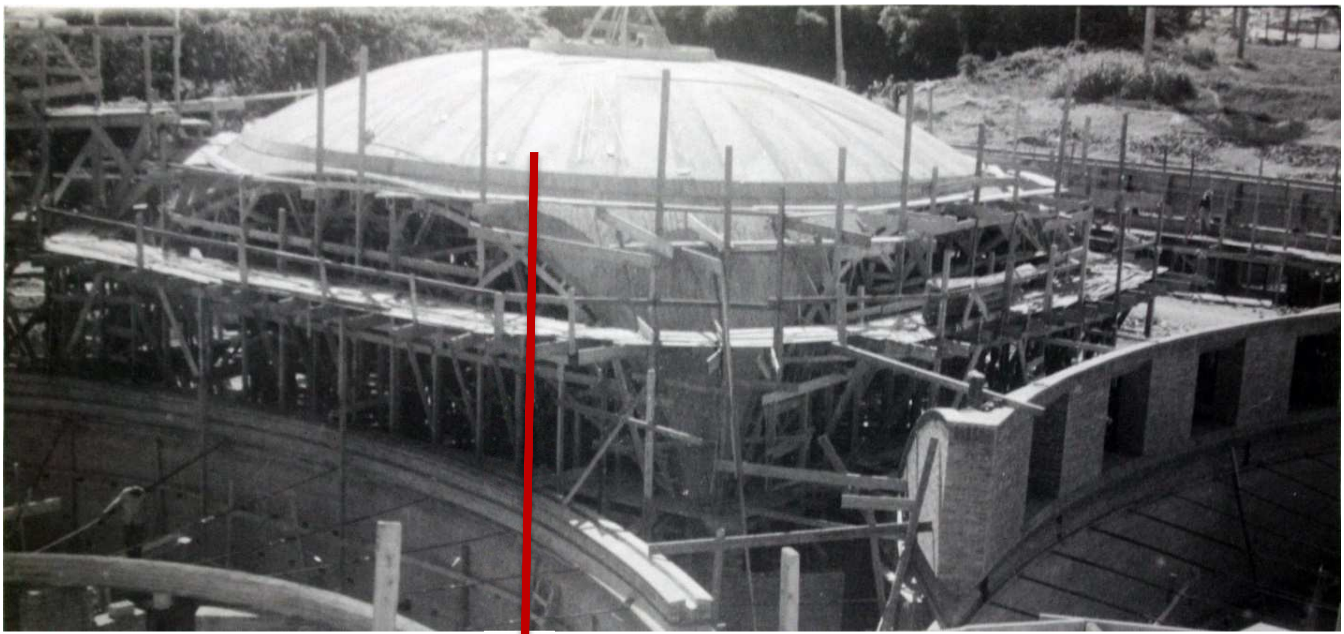


Figure 32 - Dance pavilion: view of the dome after the second concrete casting (ISA archive).

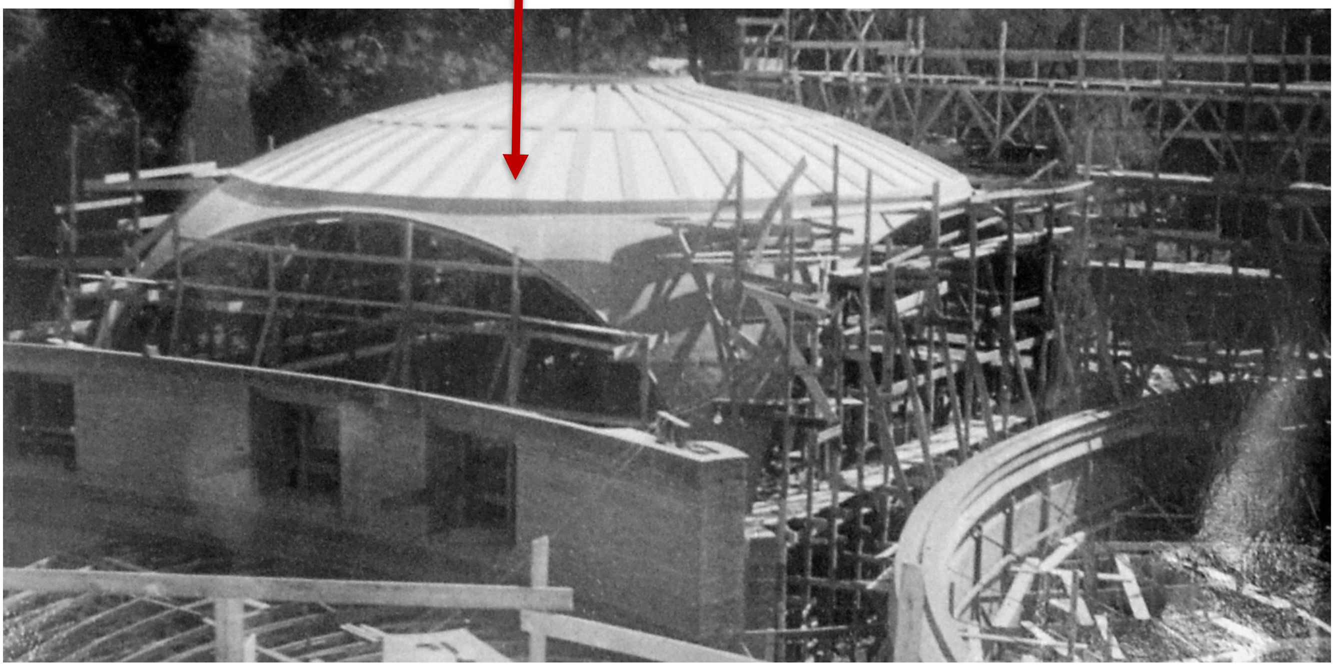


Figure 33 - Dance pavilion 59 after completion (ISA archive).

2.3.5 Finishing

As consistently done throughout the whole construction process, the last phase of construction consisted in the covering of the reinforced concrete structure with clay tiles. At the extrados, Vittorio Garatti retraced the internal grid-shell using different color tiles (the spherical cap is covered with white tiles, while the ribs and rings are plain clay tiles).

The only concrete elements that were always meant to be in plain sight are, in the Dance pavilions, the top oculus and the tie-roads at the base of the pendentives, in the choreography theater the top oculus and the ring beam located at the base of the dome. Beside these few exceptions, the rest of the structure had a deceptive appearance that led many scholars to believe that the main constructive technique employed in the School buildings was catalan vaulting.

Figure 34 - Current view of the three dance pavilions.

Today, due to disuse, poor maintenance and continuous exposure to weathering, the structures of the School of Ballet are slowly deteriorating, uncovering their real constructive system and giving us the chance to truly study and understand the structural behavior of this nonetheless beautiful architectures.

2.4 The two domes: structural survey and current state of repair

The two domes under study have been investigated in detail[26], in order to carry out a reliable structural analysis, through which to obtain an evaluation of the current structural efficiency and to put forward some hypotheses on correct conservation strategies (and possible strengthening). Below is reported a brief description of the structural organization of the two analyzed domes (the Choreography Theatre and the Pavilion dome of the Practical Room), considering and comparing:

- the data of the previous documentary analysis[27];
- the main results of the investigation process (both through direct inspections and with limited test materials);
- their structural survey (with the analysis of the main cracks, deformations and damages).

Final aim of the investigation carried out was to clarify some aspects still unclear on the real structural organization of the domes, focusing in particular on some structural elements not adequately documented until now.

In particular:

- for the Choreography Theatre (dome 14)
    - o the circular crown at the base of the dome (the lower part between the ribbed structure and the lower circular reinforced concrete beam)
    - o the consistency of the 16 masonry pillars at the base of the main circular ring and of the mezzanine
    - o the consistency of circular reinforced concrete beam at the base of the dome
- for the Dance Pavilion (dome 59)
    - o the structural organization and the state of repair of the pendentives
    - o the state of the 4 tie-beams at the base of the dome
    - o the consistency of the 4 masonry pillars at the base of the pendentives.

Moreover, some investigations on the quality of the materials (by limited tests) have been carried out in order to better evaluate the real consistency of the structural elements and to reliably model their mechanical characteristics in the FEM model subsequently performed by Princeton University group[28].

For clarity, hereafter the data are organized by structure, trying to underline - for each one - the most significant results obtained[29].

[26] In addition, some investigations and a general structural survey (with the mapping of damage) have been carried out also on the School of Music, whose detailed results are reported in Annex 2 F (Master Thesis in Architecture by Giuseppe Abbattista, Parma University, 2020).
[27] See previous Chapter 2.3. The construction process of this report.
[28] As can be seen in the following Chapter 2.5. Structural Analysis of this report, the information gathered on the materials allowed a significant improvement of the FEM model reliability, clarifying some points of the previous models (Douglas, I., Napolitano, R., Garlock, M., Glisic, B., 2020).
[29] The structural survey of the two domes, and the analysis of the state of repair is synthesized in Annex 2 I.

2.4.1 The Choreography Theatre

The dome of the Choreography Theatre (Figure 35), built to host performances of the ballet students, is by far the largest structure within the complex. With a diameter of approximately 30 m, its dome covers an area of about 290 m^2, containing the stage and the seating steps which could seat up to two hundred people. The Choreography Theater was conceived by Garatti as a study space, where the very audience became part of the scene. The absence of pre-established separations between the dancers and the spectators provided maximum freedom, allowing to reorganize the set in the most suitable way for each different show. Access to the theater is located on the mezzanine floor, which basically consists in a continuous annular walkway that runs around the entire hall without interruptions. Five spiral metallic staircases lead from the mezzanine to a higher circular gallery designed to place the lighting system. A spectacular suspended ladder connects the gallery level to a further utility level, located just under the skylight at the top of the dome (Figure 35, right). The dressing rooms for the artists, utility rooms and storage rooms were situated around the stage, hidden to the sight by a curtain of shutters that could be opened to access the performance area directly.

When in 1964 the building site had to shut down due to the tightening of the embargo against Cuba, the choreography theater was uncompleted. Just like the whole School of Ballet, it was briefly used by the National Circus, and then definitively abandoned.

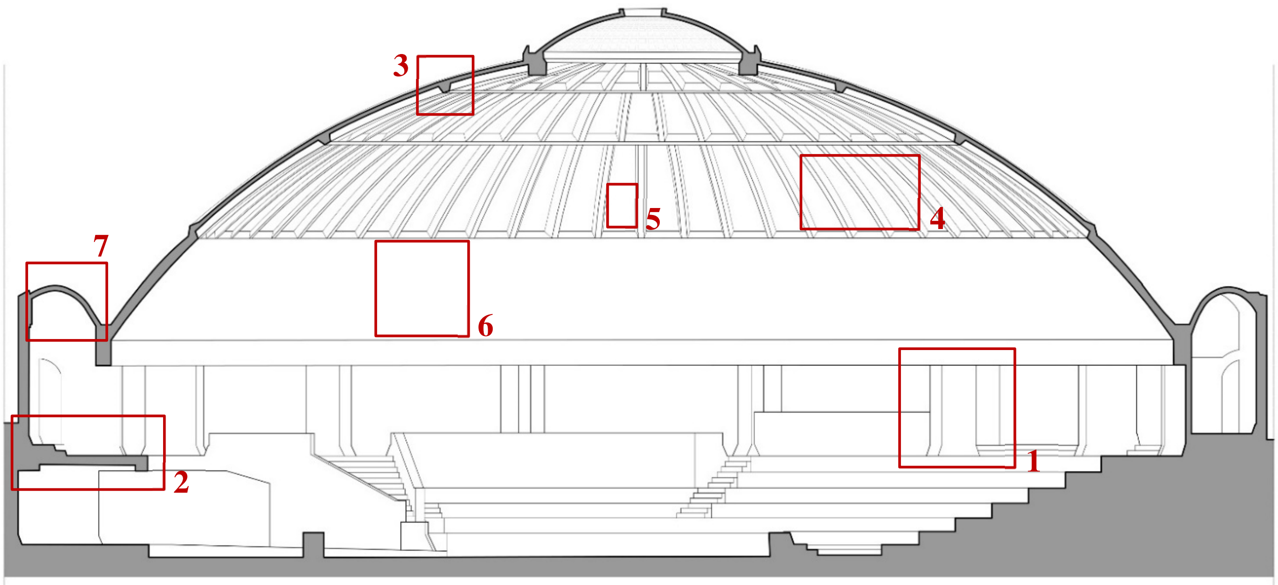
Figure 35 - View of the Choreography Theatre: extrados (left) and intrados (right).

2.4.1.1 Structural organization and consistency of the main structural elements

The dome of the Choreography Theater is a spherical cap which covers a span of approximately 30 meters, about 9 meters high. The structure comprises seven main elements, as indicated in Figure 36[30].

The dome stands on a reinforced concrete ring beam (ø 30.20 m) supported by 16 radial brick pillars. Looking at the dome (either at the intrados and at the extrados) it is possible to clearly identify two different sectors:

- the lower one, plain and homogeneous, to which we will refer as “crown”, is a spherical segment made of reinforced concrete covered by clay tiles which lays upon the above-mentioned concrete ring beam (element 6 in Figure 36);
- the upper one consists of a grid-shell framework composed of 5 rings and 16 main continuous ribs, running from the crown to the top oculus (element 4 in Figure 36). Each of the resulting 16 slices are stiffened by intermediate ribs. The interstitial space between the ribs is filled with what - at casual sight - appears to be catalan vaulting (5 in Figure 36); it has however been noticed that this is not exactly the case. Both the rings and the ribs have been built by pouring cement inside wooden formworks internally covered with tiles. Due to their inaccessible position, the number, dimension and location of rebar inside these elements has not been verified directly, although several pictures from the building site seem to confirm the arrangement illustrated in the original drawings by Vittorio Garatti[31].



1 | Pillars
2 | Mezzanine
3 | Rings
4 | Ribs
5 | False catalan vault
6 | Crown
7 | Perimetral vault

Figure 36 - Outline of the main constructive elements composing the Choreography Theater.

[30] Each element has been individually studied on the basis of historical records and on-site analyses and is exhaustively described in the descriptive worksheet of the Choreography Theater, reported in Annex 2 I.
[31] As reported in the previous Chapter 2.3 of this report.

A circular oculus is located at the zenith of the dome, granting light to enter the theater from above. The concrete ring around the oculus has a diameter of 5.60 meters and is covered by a domed skylight made of concrete and glass blocks.

All around the perimeter of the main dome, runs a secondary vault - “almost catalan vault” - covering the annular hallway of the Choreography Theater at the mezzanine level (element 7 in Figure 36).

As already said, there were a few unclear aspects that could only be clarified with the help of some instrumental testing. In particular, for the Choreography Theater, four questions had remained open:

a) the constructive system - and thus the stratigraphy - of the circular crown at the base of the dome;
b) the consistency of the 16 masonry pillars supporting the lower concrete ring;
c) the consistency of the mezzanine;
d) the consistency of the reinforced concrete ring beam at the base of the dome.

We can also add a fifth issue, regarding the stratigraphy of the:

e) “false Catalan vault” which fills the interstitial spaces between the concrete grid-shell framework of the upper dome, which is not directly inspectable but whose consistency can be further clarified through some historical-geometrical considerations.

Crown

If the upper part of the dome is visible and its structural organization is well documented by the original drawings by Vittorio Garatti - which had shown a good fitting with the historical pictures of the building site - some uncertainties are still present regarding the hidden structure of the circular crown below this grid.

In particular, analyzing the original drawings by Garatti (Figure 37, on the left), it seems that the 16 main continuous ribs of the upper grid had to prosecute also in the crown, which was represented in section (always in Garatti drawings) as an armed concrete layer (Figure 37, on the right), without further specifications.

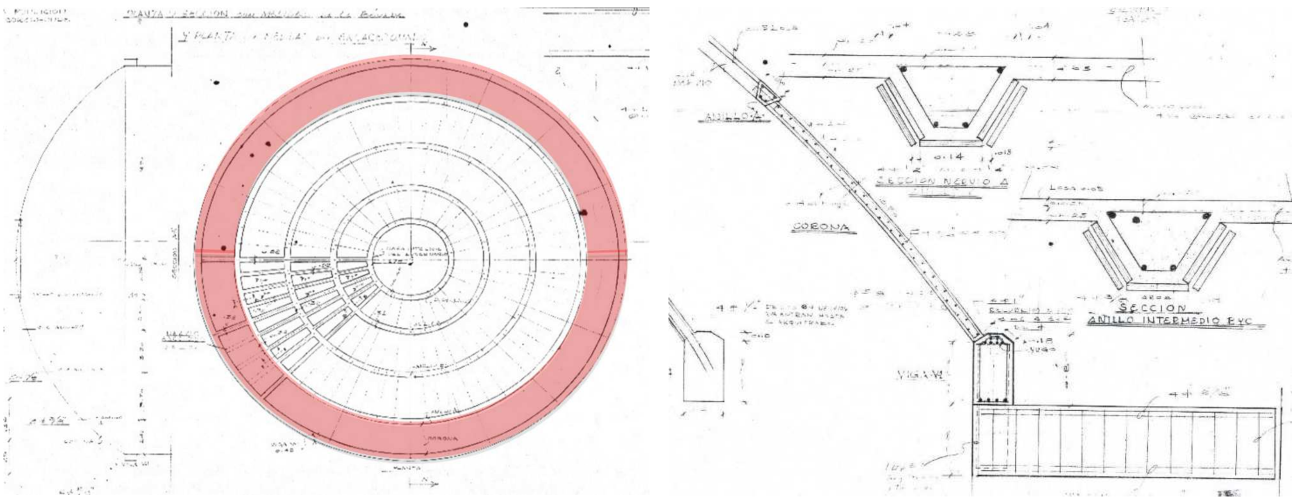


Figure 37 - Original drawings of the circular crown of the Choreography Theater by Vittorio Garatti (ISA archive)

Some pictures taken during the construction site - previously reported (Figure 30 and Figure 31) - and the original drawings by Garatti, suggest that:

- rebars are extended from the ribs through the crown, connecting with the rebar of the ring beam at the base of the dome with no distinction between the steel bars descending from the 16 main ribs and the secondary ones (Figure 30);
- Horizontal bars (may be organized in a grid) are represented in the section of the crown (Figure 36, left) but no photos were found concerning the outermost grid reported in the original design.

In order to verify the adherence of the real structure to the original design, some pacometric tests have been performed at the extrados of the crown, as illustrated in Figure 38[32].

The test indeed detected a 25 x 25 cm grid under the surface, showing good consistency with the analyzed drawings. However, no anomalies emerged in correspondence of the ribs, as the mentioned grid seem to run homogeneously along the spherical sector.

The SON-REB test executed in proximity of rib 1 (SR-1 in green in Figure 38, right) indicated a resistance value of concrete of approximately 40 MPa. As well known, SON-REB test allows to better estimate the mechanical characteristics of concrete, considering the opposite reaction of Sonic test and sclerometer test to some defects in concrete response. Although a direct investigation is needed in order to have a precise value of the material real resistance (coring with laboratory mechanical tests) the use of combined method SON-REB permits to estimate, with a reliable approximation, the "quality" of the concrete (its homogeneity and resistance). In particular, in all the concrete structures of School of Ballet we have found values around 45-50 for the rebound index - sclerometer tests, and velocity of around 3500-3800 m/s in the sonic tests. As before, see Annex 2 G for detailed description of the results.

Finally, information regarding the stratigraphy of the crown have been obtained by observing the historical photographs[33] (Figure 27): at least two layers of clay tiles at the intrados acted as a formwork for the casting of the curved concrete slab, while at the extrados the crown is covered with a single layer of clay tiles.

By fitting together all the collected data the stratigraphy reported in Figure 39 has been hypothesized as the most reliable, with few uncertainties e.g. the exact number of clay tile layers at the intrados, which could be more than two, and the rebar arrangement on the intrados side.

[32] See Annex 2 G for detailed report on test performed (report by Eng. Cristiano Russo).
[33] See previous Chapter 2.3. The construction process of this report.

Figure 38 - The pacometer tests performed on the extrados of the Choreography Theater.

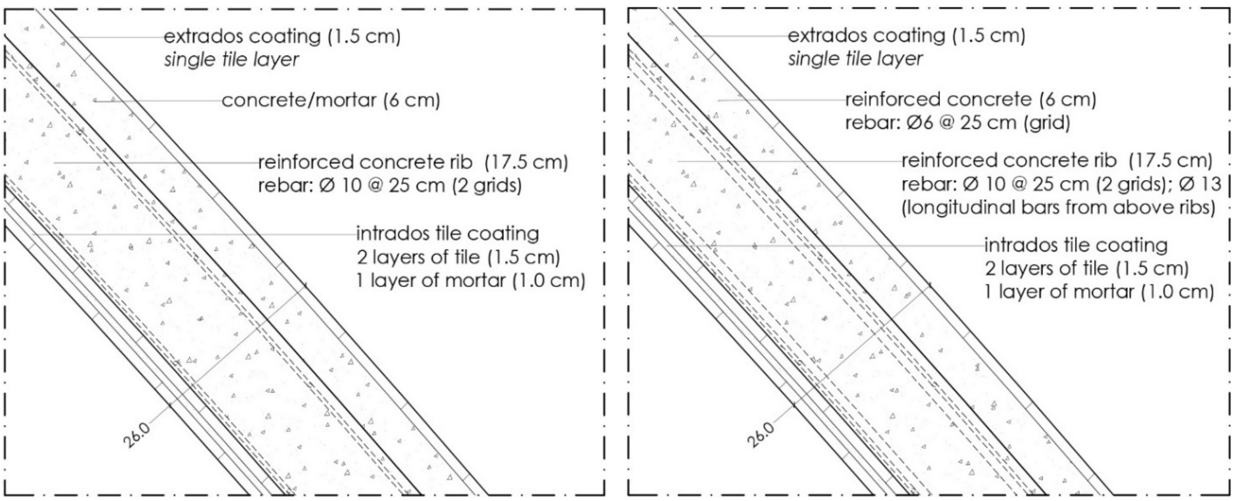


Figure 39 - Stratigraphy of the crown located at the base of the Choreography Theater. On the left: main rebar arrangement; on the right: rebar arrangement at ribs continuation.

Pillars

The ring beam at the base of the dome lays on 16 masonry pillars located on the mezzanine level and partially supported (in false) by 16 other pillars at the ground level. Such pillars stand on a reinforced concrete base - about 20 cm high -covered with clay tiles. Although the original drawings by Garatti (Figure 40, left) foresaw a reinforced concrete core in the pillars (20 x 40 cm, 1 m high) the tests performed on the structures have not confirmed this structural organization (Figure 40, right). Moreover, the construction site photographs don't show the presence of a reinforced concrete core for the pillars, at least for those located at the mezzanine level (Figure 41). Anyhow - given the dimensions of the pillars and the surveyed crack pattern under the ring beam - the hypothesis of a complete masonry structure is fully reliable.

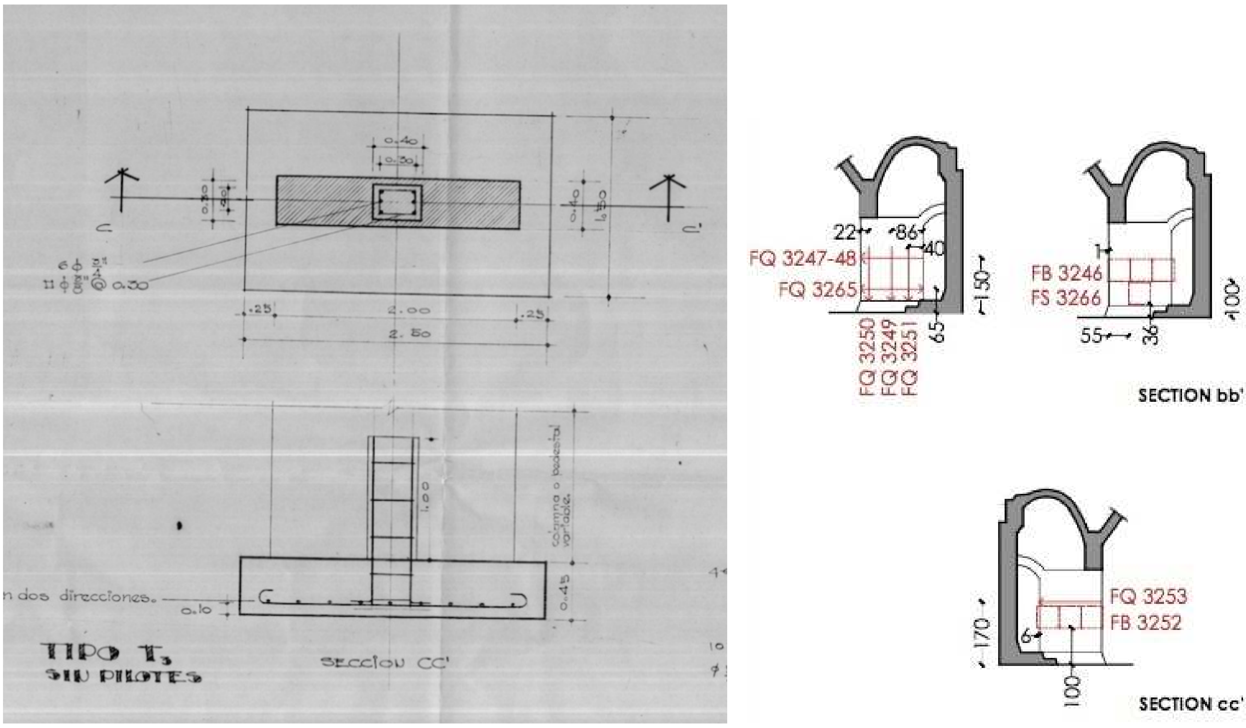


Figure 40 - The original drawings of the pillars (on the left - ISA archive) show the presence of a reinforced concrete core inside the masonry (20x40 cm, 1m high). On the right, the position of the tests carried out on the pillars.

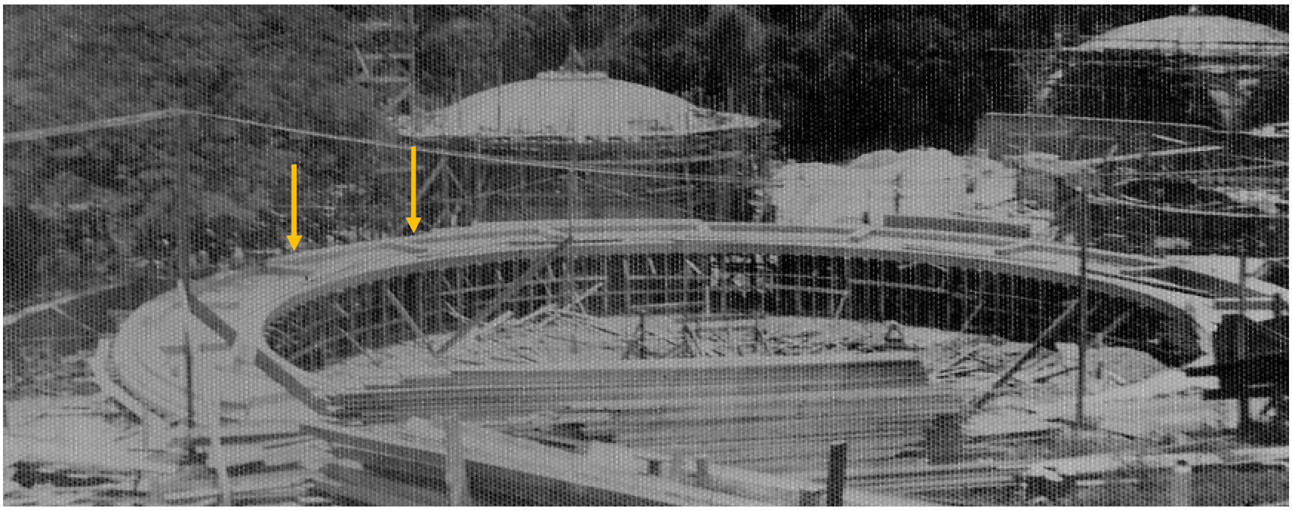


Figure 41 - The Choreography Theater during construction of the mezzanine level. The configuration of the pillars' base does not seem to indicate the presence of a reinforced core into the masonry pillars (ISA archive).

Mezzanine

Some pacometer tests have also been performed on the mezzanine slab, in order to verify its consistency with the original design by Vittorio Garatti[34]. A quite large number of tests (position plotted in Figure 42) allowed to verify the presence of reinforcing bars, organized as reported in the following schematic drawing (Figure 43).

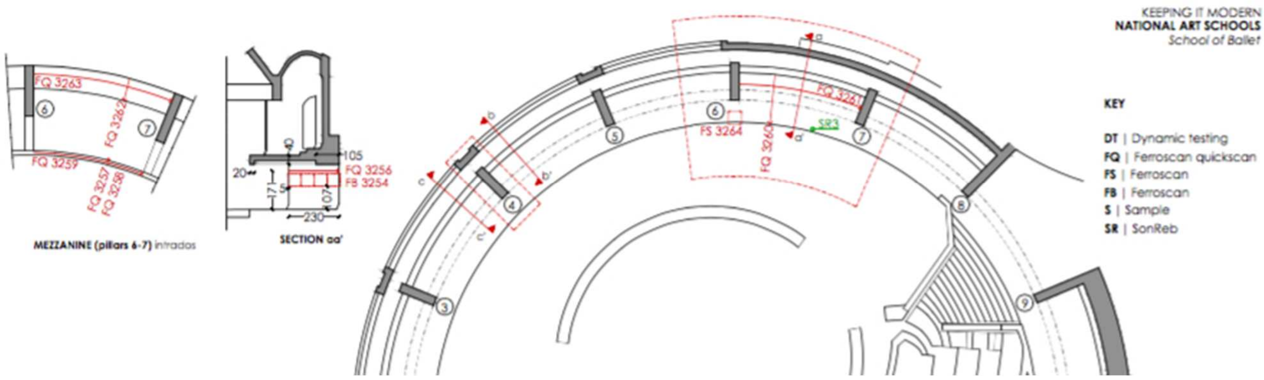


Figure 42 - Position of the tests performed on the mezzanine (from FB3254 to FS3264) nearby the pillar n.6.

[34] The photographic albums did not include any picture concerning this particular element; thus, for the mezzanine we don't have any "historical" data.

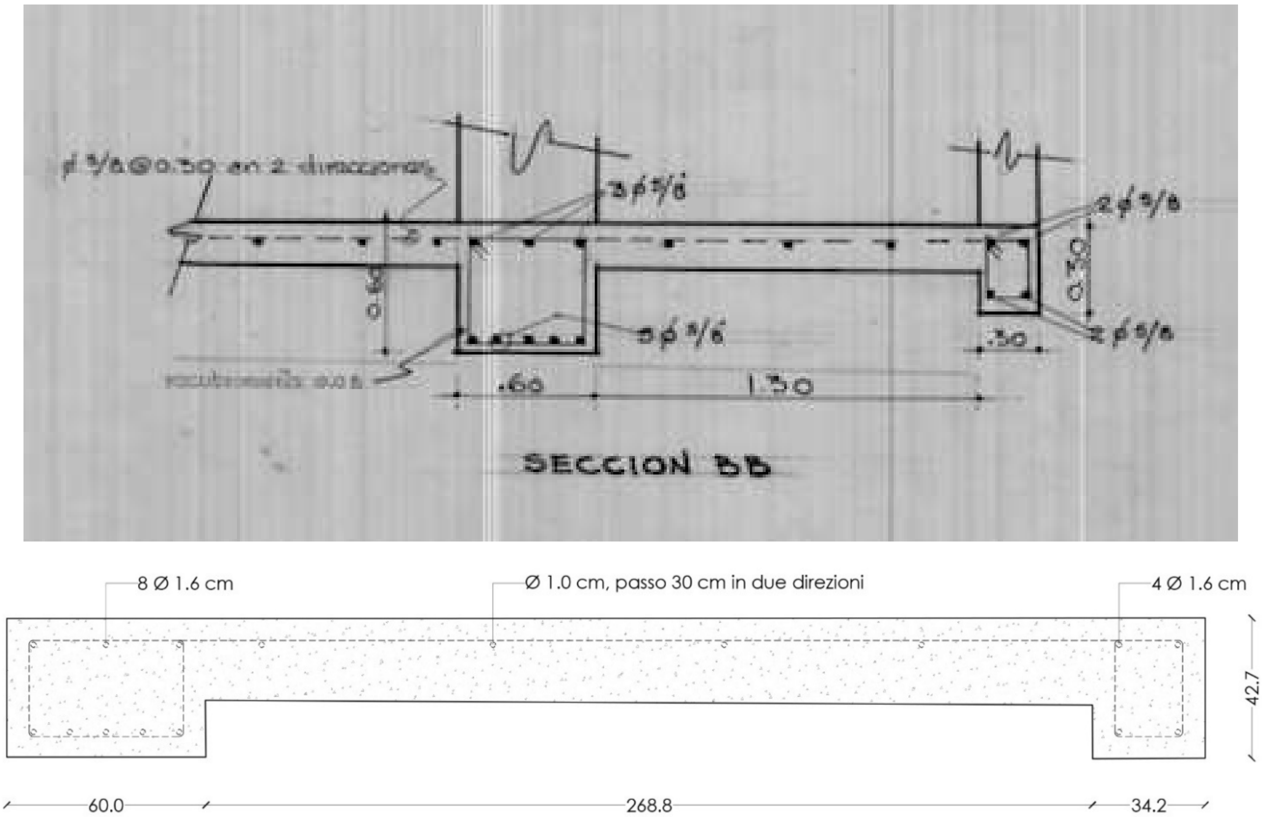


Figure 43 - The structural organization of the mezzanine. Above, the original design by Vittorio Garatti (ISA archive), below a drawing summarizing the results of the on-site surveys.

Ring beam

The reinforced concrete ring beam (ø 29.80 m, section 71x46cm), located at the base of the dome, shows a diffuse presence of soiling, moisture stains, percolation and biological colonization, especially on the outer surface, which is more exposed to weathering (as can be seen in the following paragraph, Figure 49 right). Despite this general decay, the concrete is in exceptionally good conditions, probably due to the very high quality of the original manufacturing. The most significant results came from SON-REB testing, which once again highlighted the outstanding strength of the concrete. The average resistance value was estimated to be of approximately 60 MPa[35].

In order to verify the adherence of the real construction with the original drawings, some pacometric tests have been performed, which has allowed to reliably reconstruct the most probable position of the bars inside the circular beam (Figure 43, right).

As for the connection between the pillars located at the mezzanine level and the concrete ring beam above, some information emerged from the archival materials. In particular, a drawing by Vittorio Garatti (Figure 44, left) indicates the presence of a reinforced concrete block located at the top of the pillar to join it with the ring beam. In the lack of direct investigations possible, some information can be obtained by a few pictures from the building site

[35] See Annex 2 G for details.

(Figure 45) which show some hollow spaces at the top of the pillars, suggesting the possible function of the outermost layer of bricks as a formwork for the above-mentioned reinforced concrete connection.

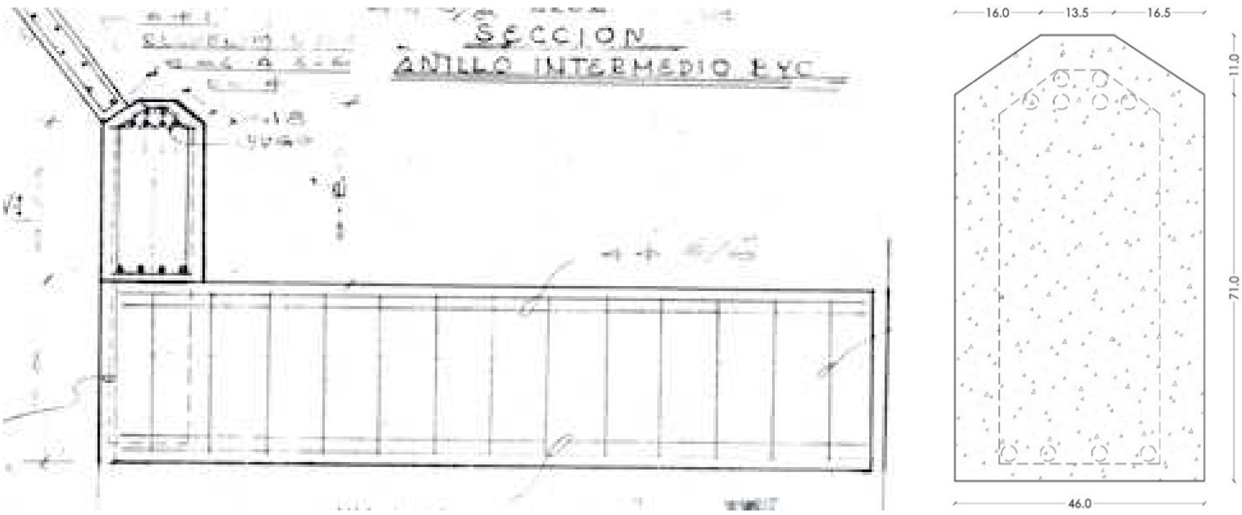


Figure 44 - The structural organization of the circular lower beam as indicated in the original design (left - ISA archive); drawing of the beam resulting from the on-site surveys (right).

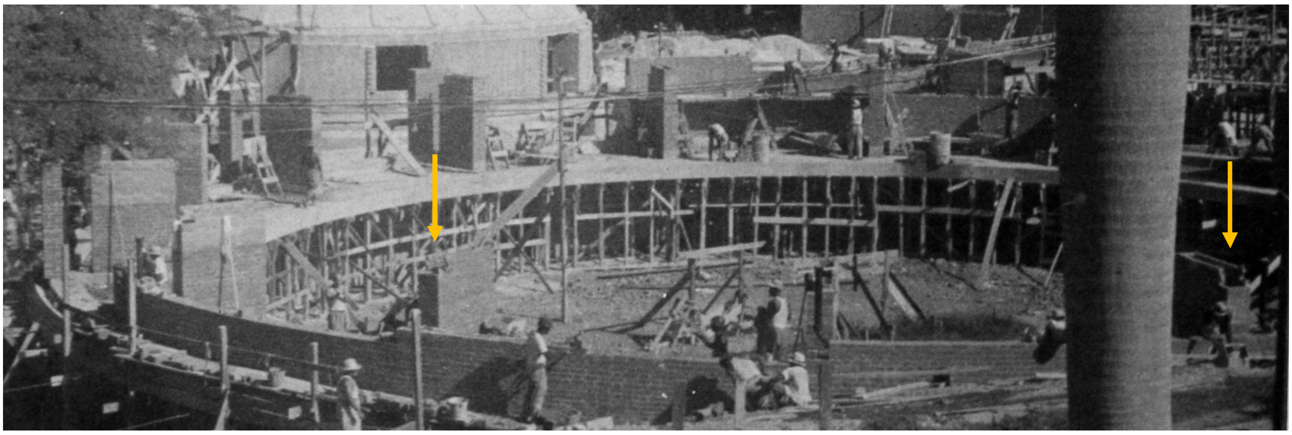


Figure 45 – Picture from the construction site showing the empty brick formworks at the top of the pillars on the mezzanine level (ISA archive).

False catalan vault

A further interesting finding of the present research regards the “catalan vaults” filling the interstitial spaces between the concrete grid-shell framework of the upper dome. Given the position of this element, a direct inspection was not possible, but, also in this case, pictures of the construction site allowed to partly clarify the most reliable stratigraphy of the vaults.

Figure 46 shows the presence of a reinforcing iron grid at the extrados of the “Catalan vault”, which actually transforms it into a mixed masonry-concrete structure, whose most probable stratigraphy is reported in the same figure (right).

There are still a few uncertainties regarding the effective number of tile layers located at the intrados: however, Garatti indicated, in its original drawings, two layers for the intrados, and one single layer of white ceramic tiles for the coating.

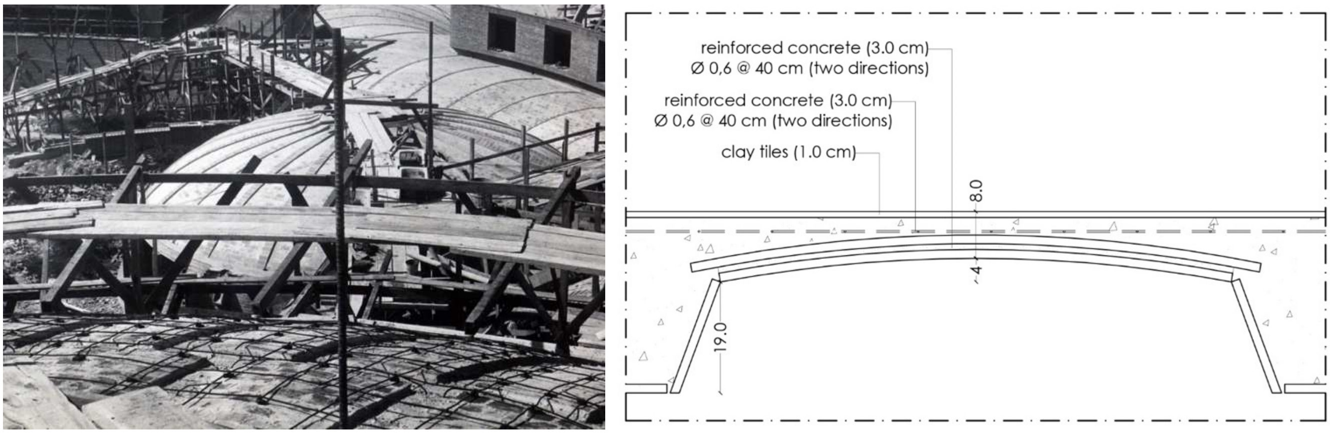


Figure 46 - On the left, construction site picture (ISA archive) showing the reinforced grid above the “false Catalan vault”, whose stratigraphy is represented on the right.

This new piece of information is very relevant to the structural interpretation of this building, but it is even more relevant when we come to consider the significance that catalan vaulting seemed to have in the original plan. Although not diminishing at all the architectural value of these incredible buildings, the observed abundance of concrete use seems to collide with the principles stated by the architects when starting their designs. As anticipated, such revolution in the structural organization was probably the result of a certain incompatibility between the utopic ideas of the architects and their material feasibility. In the end, the compromise was to maintain the imagined appearance while using safer and more tested constructive methods and materials.

Dynamic tests results

Finally, in order to have some further indications for a better calibration of the FEM model of the dome, a dynamic test has been performed, by positioning a velocimeter on the extrados of the dome (near the rib n.1).
Analyzing the spectrums and the corresponding peaks along the cross direction, it is possible to notice two trends of values: one has frequencies between 8 Hz and 11 Hz, and the other with lower frequencies, from 1 Hz to 2 Hz. The maximum span is 518.29 Hz, as recorded in acquisition 13, with a frequency of 10.31 Hz.
Frequencies calculated along the vertical direction are comprehended between 25 Hz and 30 Hz. The maximum span is 574.29, as recorded in acquisition 8, with a peak frequency of 28.31 Hz[36].

[36] See Annex 2 G, pp. 93, 97-100.

Current state of repair and damage analysis

The lack of use and maintenance suffered during the last decades left its mark on the theater which nowadays lays in an advanced state of decay. Surprisingly enough however, despite the long abandonment, at a first (qualitative) glance, the global conditions of this dome do not seem to be particularly worrying from a structural point of view.

As a matter of fact, the main issues appear to be the direct result of the absence of an appropriate system of protection against water. Despite humidity is a relevant problem, it does not seem to have seriously compromised the structural elements of the dome, which doesn't present, up to now, severe damages, significant cracks or deformations. So far, moisture seems to have mostly affected the surface of the dome (both internally and externally), resulting in biological colonization and efflorescence (Figure 47).

In particular, shrubs have been growing into the interstices between the extrados tiles lifting them up and causing their partial or total detachment from the lower layers (Figure 48).

This phenomenon has been exposing the structure to weathering leading to further water infiltrations. Passing through the layering of the dome, moisture generated saline efflorescence and humidity stains on the inner surface, as well as on the pillars and on the concrete ring beam. Moreover, due to the lack of covering of the top oculus and to the frequent floods of the Rio Quibù, the floor of the theater is almost constantly wet. This condition has been fostering the development of bio-deterioration agents, such as moss and lichens, which can be diffusely found both on the ground and on the ring beam at the base of the dome (Figure 49). What is more worrying are the corrosion phenomena that have been observed on the mezzanine reinforced concrete slab, as well as the presence of some minor cracks on the masonry pillars, owed to the load of the dome above it.

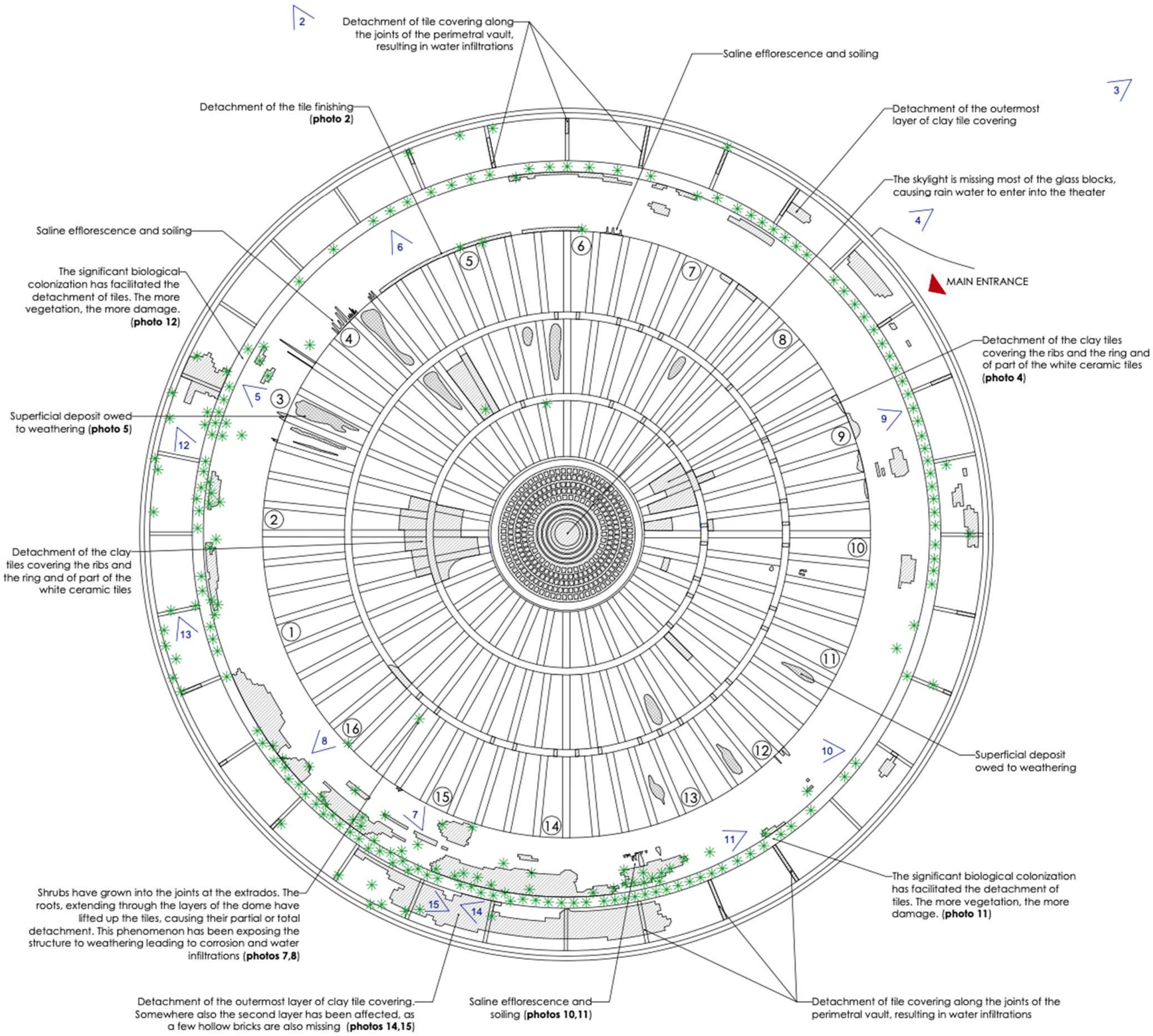


Figure 47 - Plan view of exterior damage which shows the extreme amount of biological damage in the lower left: a tree leans over the dome in this location, which may be encouraging further plant growth.

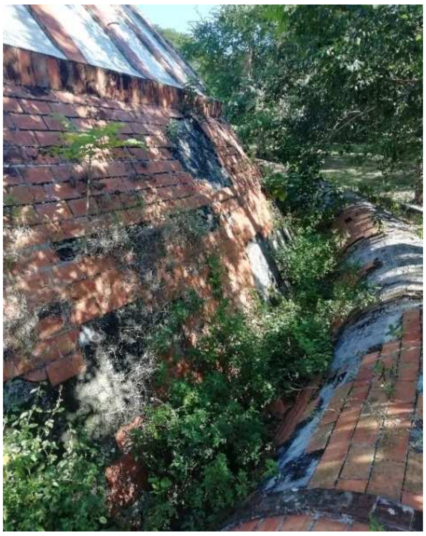



Figure 48 - View of the extrados of the dome of the Choreography Theater affected by the diffused presence of vegetation.


Figure 49 - View of the intrados of the dome (left) affected by moist stains, soiling, efflorescence and biological colonization, particularly evident on the ring beam (right).


Figure 50 - On the left, corrosion phenomena of the bars in the mezzanine beam (due to water infiltration). On the right, the trace of a thin presso-flexion crack on the pillar, under the ring beam (for the load of the dome).

Although as of today the situation does not look too alarming, it should be noted that, in the long term, it could represent a potential threat for the preservation of the structure, and it thus needs to be kept under control if not solved.

The fact that the above-mentioned issues have only marginally impacted the dome can be partly justified with the very high quality of the building materials employed[37]. As for the reinforced concrete elements we have indeed detected a homogeneous, compact, high-strength concrete reinforced with improved adherence bars. The SON-REB testing has indicated strength values that range between 40 and 60 MPa[38] for all the concrete elements composing the dome structure. The masonry walls (and especially the pillars) also appear very well fabricated, with solid good manufactured bricks arranged with very resistant cement mortar.

2.4.2 Dance pavilion

Although structural analysis has only concerned dance pavilion n°59, within the School of Ballet there are in total three dance pavilions analogous in terms of geometry, dimensions and structural systems[39]. These three spaces were designed to allow students to rehearsal in the most suitable way. The whole building actually aims at reflecting the dynamic movements of the dancers, which have inspired the curved walls and the domes, characterized by different heights and spans. As Vittorio Garatti once stated:

«I wanted the school to be extremely dynamic, in part as a response to the dynamism of dance. But I wanted the school to be dynamic not only because it was a ballet school, but because it was to be a vision of our future. Dynamic, at the same time expressing freedom, open in all directions where you could come and go as you wished»[40].

This attempt emerges clearly from the configuration of the dance pavilions, whose borders are imperceptible creating a sort of undefined space. The curved dome has a span of about 16 m, covering an approximately squared area of 270 m^2. The structure looks extremely light and gracious, although originally their appearance was quite different. Where today we only see four large arches, there once were beautiful wooden windows accurately realized by local craftsmen.

Also, while today the pavilion develops on a single level, the original drawings show four little overhead metallic balconies, located at the base of the pendentives, designed so that the professors could better oversee the class.

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[37] This has been confirmed both by qualitative observations as well as by the SON-REB tests performed on the concrete in November 2019, reported in Annex 2 G (report by Eng. Cristiano Russo - SPC Srl, pp. 5-6, 30, 40, 65).

[38] Although the concrete strength detected by the SON-REB tests is often higher than 40 MPa, for precautionary reasons, in the structural analyses we will use this value, which approximates the actual average value by default. This will increase the safety factor.

[39] Actually, on-site investigations focused on all 3 domes and determined that they have similar level and mode of damage; for this reason, the following description of damage and the proposed interventions can be approached similarly for all 3, though the work during the interventions will of course reveal the invidualities of each.

[40] Loomis 1999, p. 97.

Just like the Choreography Theater, the dance pavilions were never completed or used. Since the construction stopped in 1964 they have been in a state of complete abandonment.

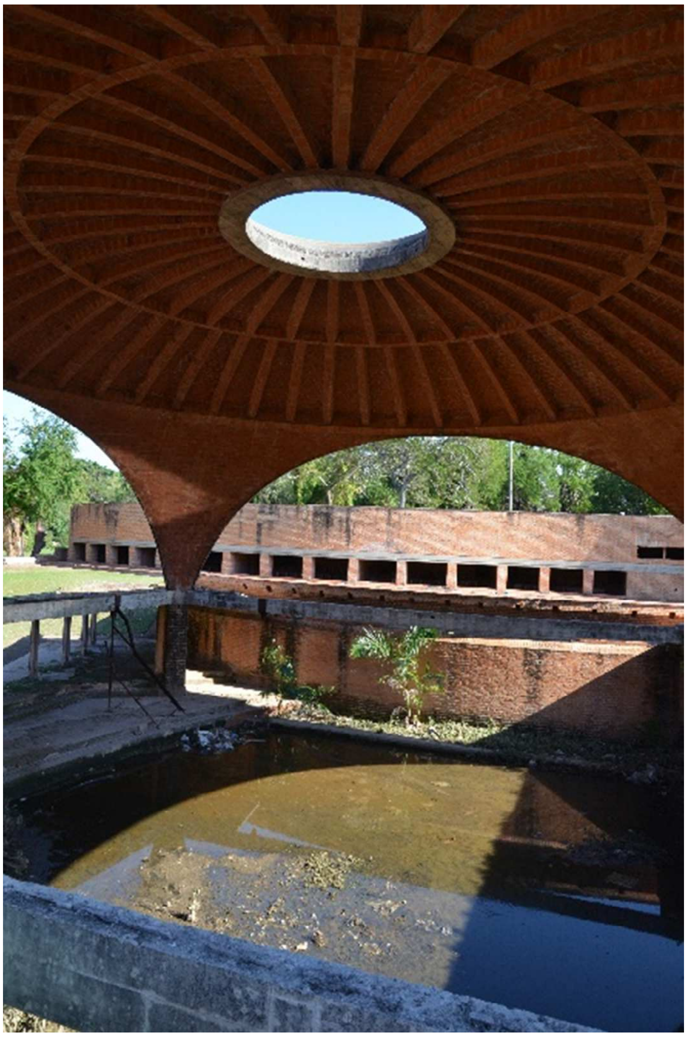

Figure 51 - View of the Dance Pavilion’s extrados (left) and intrados (right).

2.4.2.1 Structural system and consistency of the main structural elements

Structurally, the dance pavilion is composed by the constructive elements schematically reported in Figure 52, which have been carefully studied in this research[41].

The dome has a span of approximately 16x16 meters and is about 7 meters high.

Just like in the Choreography Theater, the load bearing structure of the dome consists in a grid-shell framework made of reinforced concrete covered by several layers of thin tiles. The grid is composed of 3 rings (top ring: ø 3.00 m; middle ring: ø 10.00 m, lower ring: ø 16.00 m, element 3 in Figure 52) and 80 ribs, 16 of which are continuous from the oculus to the lower ring (element 4 in Figure 52) while the remaining ones have only a stiffening role.

The cap stands on four pendentives (element 2 in Figure 52) which transfer their load (and thrust of the lateral arches) on four massive angular masonry pillars (base: 60x200 cm, element 1 in the drawing). Moreover, four reinforced-concrete beams (section: 20x40 cm) connect pendentives at their base, seemingly acting as “tie rods” for the dome (element 6).

As for the previous dome, also in this one the interstitial voids between the ribs are filled with “false catalan vaults” (element 5 in the same figure).

A large oculus located at the zenith of the dome allows light to enter from above. The skylight that was supposed to cover the hole was never built, leaving it completely open.

Despite some geometrical differences, even important, the construction process is substantially analogous to that of the Choreography Theater: basically, the intrados clay tile layers work as formworks for the concrete elements.

Following the same approach adopted in the previous case, in the following paragraphs the main results obtained during the fieldwork are summarized, trying to underline some aspects still unclear. In particular focusing on:

a) the structural behavior of the pendentives;
b) the consistency of the 4 masonry pillars supporting the pendentives;
c) the current conditions and the real structural role/efficiency of the four concrete tie-beams at the base of the dome.

As for the Choreography Theatre, another important issue has regarded

d) the real consistency and the most probable stratigraphy of the “false Catalan vaults” which fill the interstitial spaces between the concrete grid-shell framework of the ribbed cap, also in this case not directly inspectable.

[41] All detailed information regarding each single structural element are reported in the worksheet arranged for the dance pavilion and Annex to this report. See Annex 2 I.

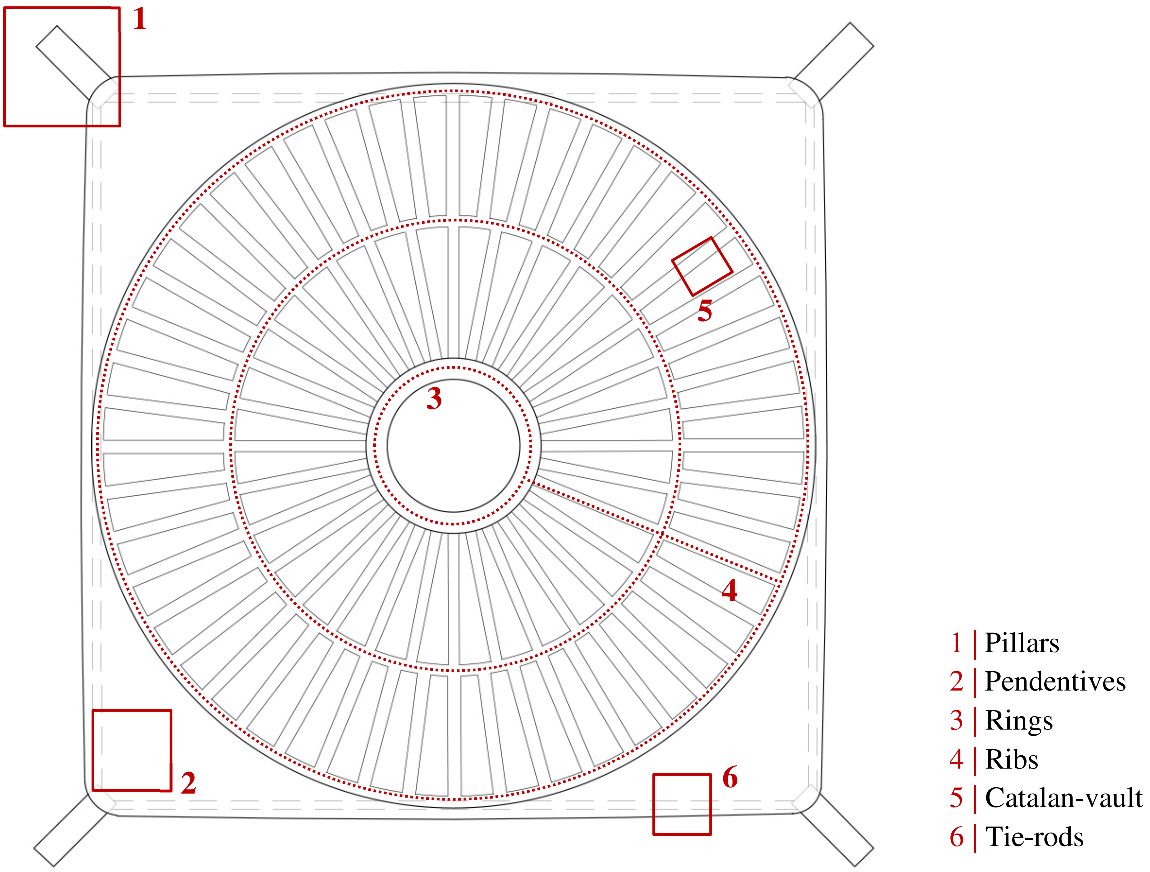

Figure 52 - Outline of the main constructive elements composing the Pavilion Dome of Practical Room (BA.3.59).

Pendentives

Despite the deceptive appearance of the pendentive's side finishing (Figure 53, left), which seems to suggest a catalan vault making, recent studies carried out by Princeton University led to a complete review (in 2016) of the existing theories regarding the construction process of the School of Ballet and, in particular, on the real stratigraphy of the four pendentives which support the ribbed cap, which, according to Douglas' observation, should hide an armed concrete structure.

Furthermore, the original drawings by Vittorio Garatti prescribe a reinforced concrete slab inside the pendentives, hidden from sight by clay tiles (Figure 53, in the middle). Moreover, one of the building site pictures preserved by José Mosquera seems to prove a substantial consistency between the drawing and the actual construction, with a grid of reinforcing bars positioned inside of the clay tile formwork (Figure 53, right).

Although these evidences seem to reliably confirm the presence of an armed concrete slab inside the pendentives, we have to underline that the pacometric tests carried out during the on-site inspection of November 2019 did not detect any iron presence inside these elements[42]. The probable explanation of this lack of evidence is the limited inspection range of the employed instrumentation, which only scans up to a depth of approximately 10 cm.

Since from Mosquera's photography we can see that the rebar is located at the intrados, it was rather predictable not to encounter iron presence while scanning the extrados. It has to be noted that no reinforcements were detected while scanning the intrados surface either, but this fact can be explained supposing that the thickness of the tile layers at the intrados exceed 10 cm[43]. Only a georadar inspection could definitely clarify this aspect, showing the actual arrangement of the rebar.

Regardless, we can say that the bar position at the intrados is not really effective in this structure, given that intrados is subjected to compression, while actually the maximum tensile stress occurs at the external side of the solicited section. This predictable mechanism is evidenced, in our case, by the crack pattern surveyed on the pendentives (Figure 61), which actually show a delamination process at the base and a large zone of external brick layer detachment (as fully described in the following paragraph) exactly at the hinge level, approximately at 30-40° on the impost plane (where also the FEM model has shown the maximum deformation and stress[44]).

In order to assess the quality of the materials, some SON-REB tests have been performed at the base of the pendentives [45] (Figure 54, right) and the results have confirmed what already stated for the quality of the material used, which appeared homogeneous, compact, high-strength concrete (maybe reinforced with a folding grid of improved adherence bars) whose resistance can be reliably estimated around 50MPa, thus extremely good.

[42] See Annex 2 G (report by Eng. Cristiano Russo - SPC Srl), pp. 66-69, 71.
[43] During the on-site inspection it was possible to count at least three layers of tiles alternating to layers of mortar, but it is very well possible for layers to be four. Indeed, each layer (either tile or mortar), measures approximately 1.5 cm. To reach a total of 10 cm there need to be at least seven layers (four of tiles and three of mortar).
[44] See Chapter 2.5 of this report and Annex 2 H for details.
[45] See Annex 2 G (report by Eng. Cristiano Russo - SPC Srl), pp. 66, 72.

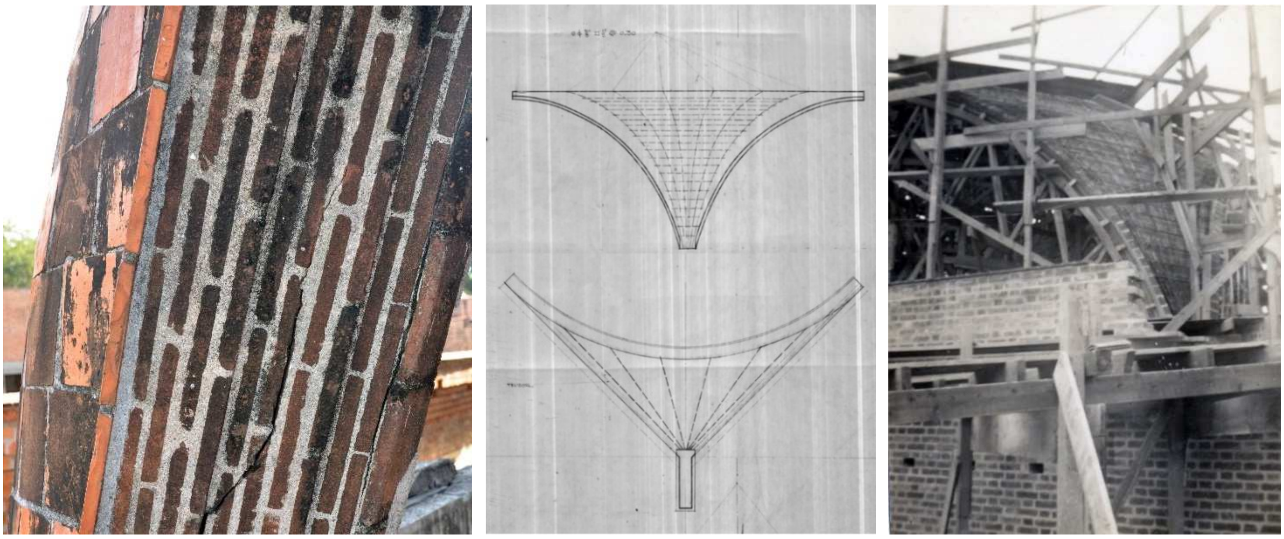

Figure 53 - On the left, the side of the pendentive simulating the catalan vaulting technique. In the middle, original drawing by Garatti illustrating the intended arrangement of the rebar (ISA archive). On the right, a picture of the construction site showing the positioning of the concrete reinforcement (ISA archive).

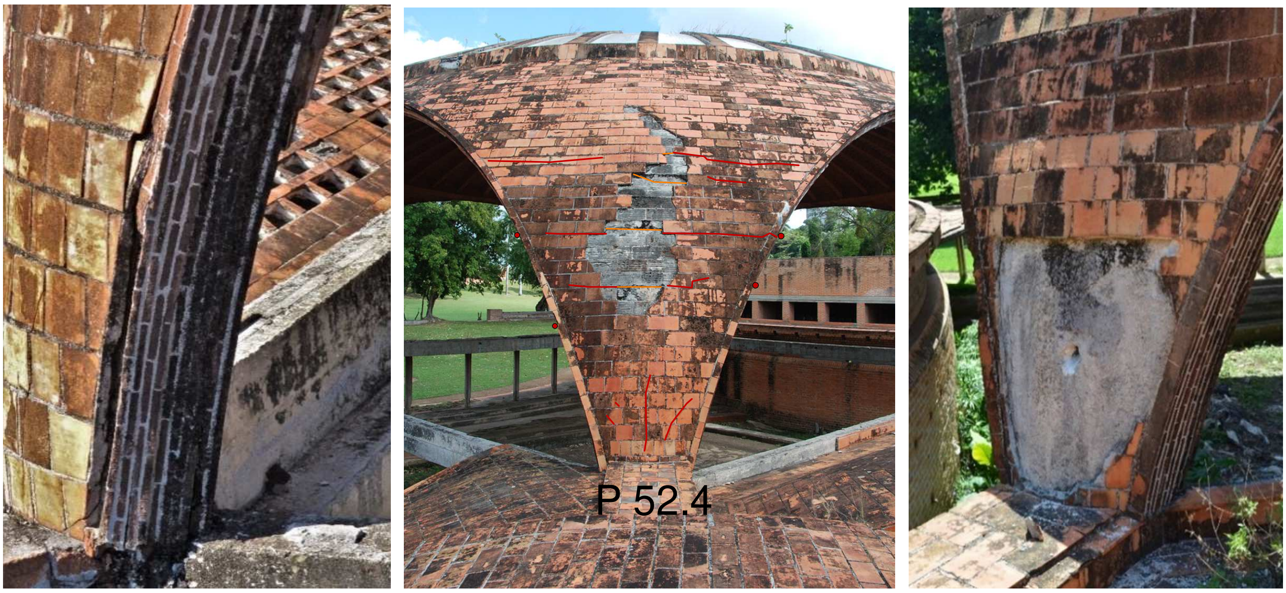

Figure 54 - Cracking and tile detachment at the extrados of the pendentives, approximately at the hinges zone. On the right, the zone of pendentives without bricks, where SON-REB tests have been performed.

Pillars

Four masonry pillars are located at the corners of the pavilion to support the four pendentives of the dome. According to Vittorio Garatti's original drawing, while the lower part of the pillars was to be entirely made of bricks, the top portion would have hidden a reinforced concrete block, constituting the base of the pendentives (Figure 55, left).

This arrangement, which would have guaranteed the connection between the pillars and the pendentives, seems to be partially proved by a few pictures from the building site (Figure 55, center), showing some vertical iron bars emerging from the pillar. Direct observations carried out on-site also support this scenario (Figure 55, right): where the covering clay tiles have detached from the upper surface of the pillars, we can see a block of concrete hidden by bricks on the sides.

Also in this case we have to note that the pacometer tests performed did not clearly detect any iron presence, leading to believe that the reinforcing bars are located at least 10 cm below the outermost surface[46].

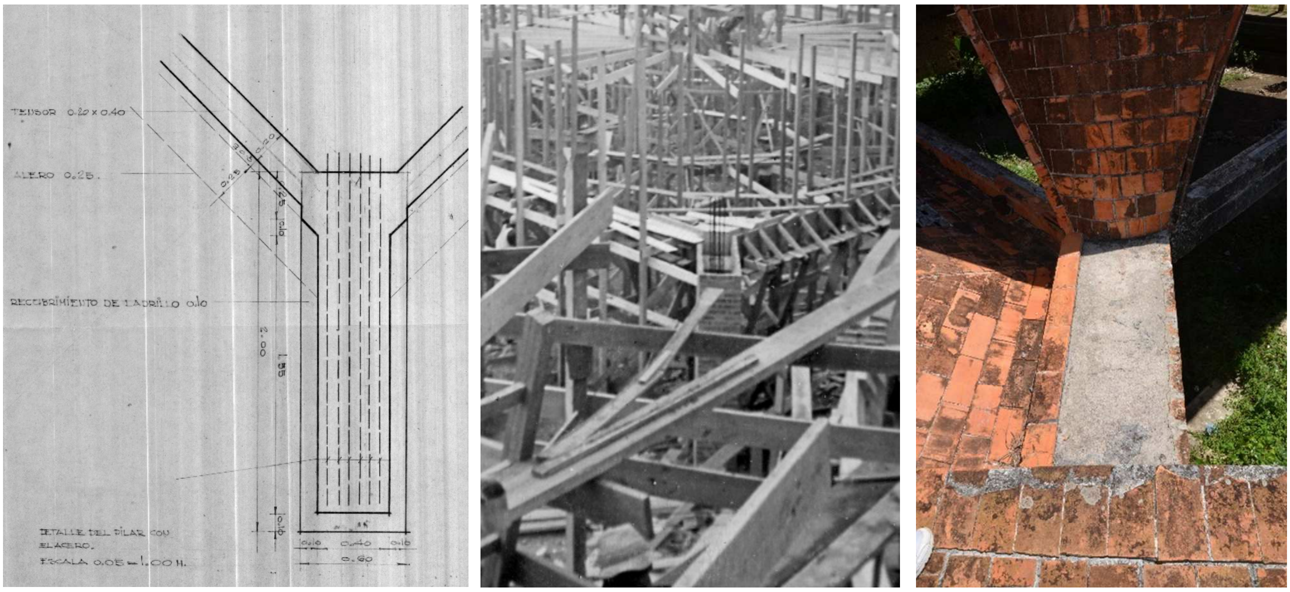

Figure 55 - On the left, the original design of the concrete block located at the top of the pillars (ISA archive). In the middle, a picture from the construction site showing some iron bars jutting from the pillar (ISA archive). On the right, a recent picture of the top of the pillars. Notice that, once again, the external layer of bricks acted as a formwork for the concrete.

Tie beams

A critical issue affecting this dome is the severe deterioration of the four reinforced-concrete beams (section: 20x40 cm) connecting the pillars at the base of the pendentives and seemingly acting as tie rods.

The laser scanner survey carried out in June 2019 has highlighted a significant deformation of these elements. The deflection of about 4-5 cm measured at mid-span can however be easily attributed to the dead load of the beam

[46] See Annex 2 G (report by Eng. Cristiano Russo - SPC Srl), pp. 66, 70, 80-82.

itself and does not seem to be excessively worrying. Nevertheless, this deformation (together with some vertical tension cracks visible at the top of the beam, near the pendentives) seems to exclude any proper tensional work carried out by these elements, thus refuting, at least in the "normal state" of the structure, their function as "tie rods" for the thrust of the dome. This limited structural function has been underlined also by the results obtained by the FEM analysis, which have shown a substantial primary bending behavior for the ties[47].

Conversely, the state of decay of the materials really requires some attention. Due to long-term exposure to weathering, the beams have suffered a diffuse loss of the concrete cover, which has largely started to fall down, leaving the underneath iron bars exposed to corrosion phenomena (Figure 57, right). Spalling is also consequence of corrosion in rebars and some section loss at several supports was observed.

Pacometer tests have been performed in order to detect the position of the bars inside the beam, even though the loss of the concrete cover allows to notice a consistence presence of iron bars by sight. Strangely enough, the ferroscan device has not detected any bars at the analyzed location[48].

As could be predicted by visual inspection and given the current state of deterioration, the quality of the concrete resulted a little lower than the others. SON-REB testing highlighted a strength value of around 40 MPa[49], which, however, can still be considered a rather good resistance.

We have to underline that the support structure (the tie beams and pillars) of the dome is not an isolated system, but connects to masonry walls around the classroom perimeter, either directly or via reinforced concrete "struts" which double as support beams for the hallway roof (Figure 58, right). Due to the high stiffness of the walls and the damage to the struts, it appears that the auxiliary structures do provide some lateral support to the pillars and we can say (as confirmed by the FEM analysis) that undamaged walls, due to their high stiffness, may even contribute more resistance than the tie beams to the thrust of the dome.

A further contribution to the stability of the dome might have come from the metallic structures originally designed by Garatti to allow dance teachers to overlook the class during practice (Figure 56). Indeed, each concrete tie-rod (except for the one laying on the plain brick wall of the changing rooms) was supported by two metallic tubular pillars[50] (Figure 57). Each pillar is provided with a ladder leading to the small angular balconies located at the four corners of the pavilion. While the main purpose of these elements was to address a functional issue, it is likely that they also had an impact on the structural behavior of the dome. In particular, the tubular pillars, significantly reducing the span between the main brick pillars, might have had positive effects in terms of deflection. Also, the triangular balconies on the corners, improving the connection between the tie-rods probably had a stiffening effect on the structure, contributing to the counteraction of the horizontal thrusts.

[47] See Chapter 2.5 of this report and Annex 2 H for details.
[48] See Annex 2 G, pp. 66, 75-78, 85-87.
[49] See Annex 2 G, pp. 66, 84.
[50] Note that most of these elements have been removed over time: the remaining metallic pillars look rather damaged and deteriorated, while the balconies completely disappeared.

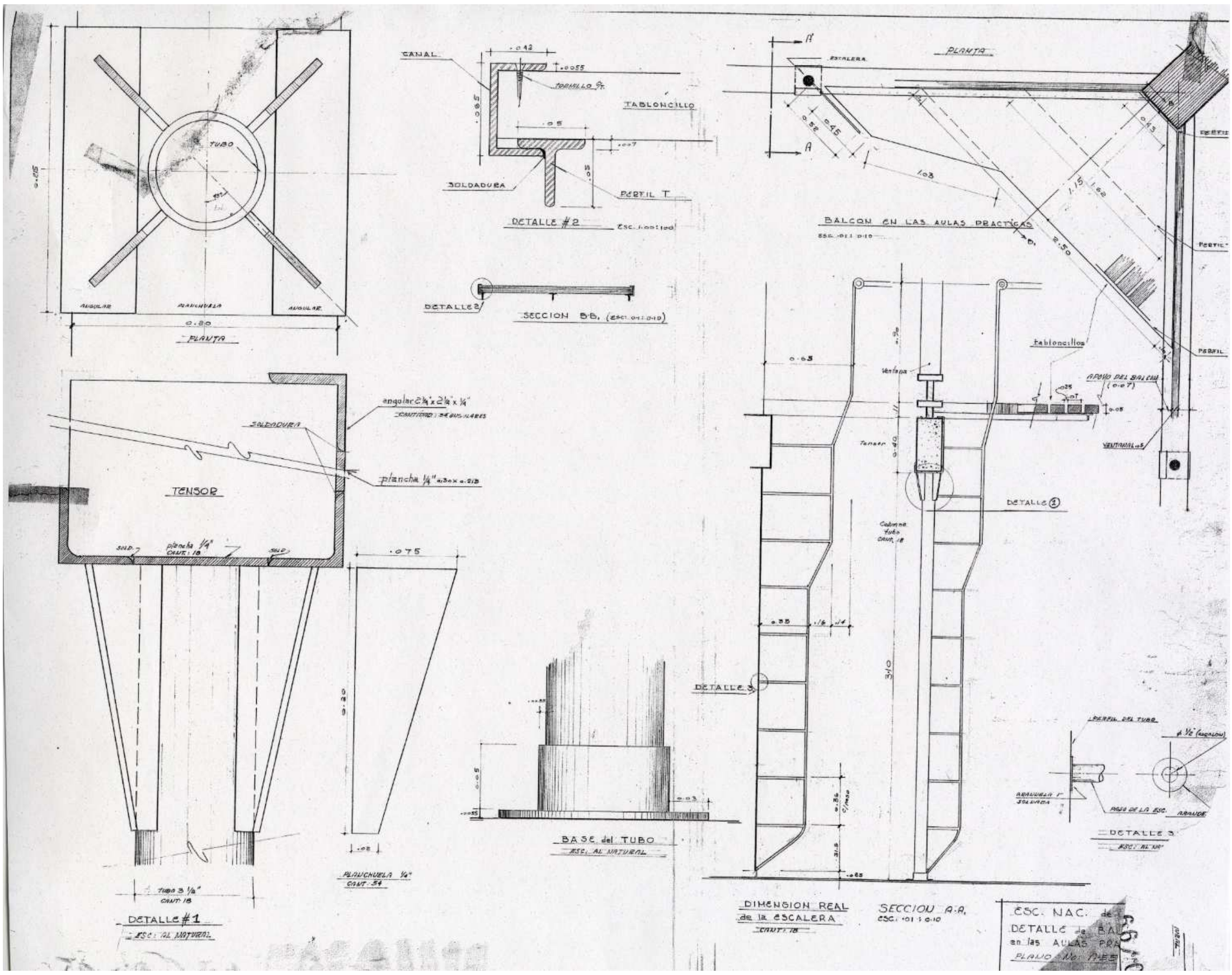

Figure 56 – Original drawing illustrating the details of the metallic pillars and balconies (ISA archive)


Figure 57 - On the left, view of one of the metallic pillars located nearby the corners of the pavilion. On the right: diffused loss of the concrete cover resulting in rebar corrosion.

Figure 58 - On the left, the inflection of one of the tie beams, with evident loss of materials at the bottom in the middle span (bending behavior). On the right: overview of dome and the auxiliary support structures surrounding it.

False catalan vault

With regard to the tile vaults filling the voids of the grid-shell framework, we can reasonably assume that they were built similarly to the ones in the Choreography Theater. We therefore hypothesize that they comprise a certain number of clay tile layers at the intrados (probably two), a curved reinforced concrete slab and an external ceramic tile covering.

Although this assumption is quite reasonable, considering the general construction process of the School, it should be noted that no records concerning the Dance pavilion were found on this regard. The only picture showing the reinforcing grid above the ribs and tile vaults is the one of the Choreography Theater (Figure 46).

2.4.2.2 Dynamic tests results

A local dynamic test has been performed by positioning a velocimeter at the extrados of one of the pendentives of the dome, placing the acquisition unit inside a small recess owed to a previous concrete sample[51].

Analyzing the spectrums and the corresponding peaks along both the radial and the cross direction, the frequency peaks locate within two different ranges: the first one goes from 2 Hz to 3 Hz, the second from 8 Hz to 10 Hz. For both directions the maximum span corresponds to acquisition 24. Along the vertical direction the maximum span of the frequency peaks has been calculated for acquisition 24, with a frequency value of 8.25 Hz.

[51] See Annex 2 G, pp. 94, 101-102.

2.4.2.3 Current state of repair and damage analysis

As stated before, the Pavilion Dome BA. 3.59 Practical room is similar, for the main aspects of structural system to the previous analyzed Choreography Theatre, in particular for the ribbed cap which, besides the dimension, finds the main difference in its base: four pendentives instead of a continuous annular crown.

As in the previous one, humidity and biological colonization, which affect both the intrados and the extrados of the dome and the pendentives are two significant issues. However, since the dance pavilions are more exposed to weathering than the Choreography Theater, the resulting effects appear amplified.

Vegetation has grown into the interstices of the roof tiles or between the ribs of the dome's joints, causing the detachment of the superficial layer in large zones (Figure 59), especially, as stated before, at the base of the pendentives (Figure 60). This degradation phenomenon can lead to structural disease in the long term, exposing the structure to weathering (thus leading to corrosion of rebar and significant reduction of section).

Figure 59 - Detachment of extrados tiles owed to vegetation growth.

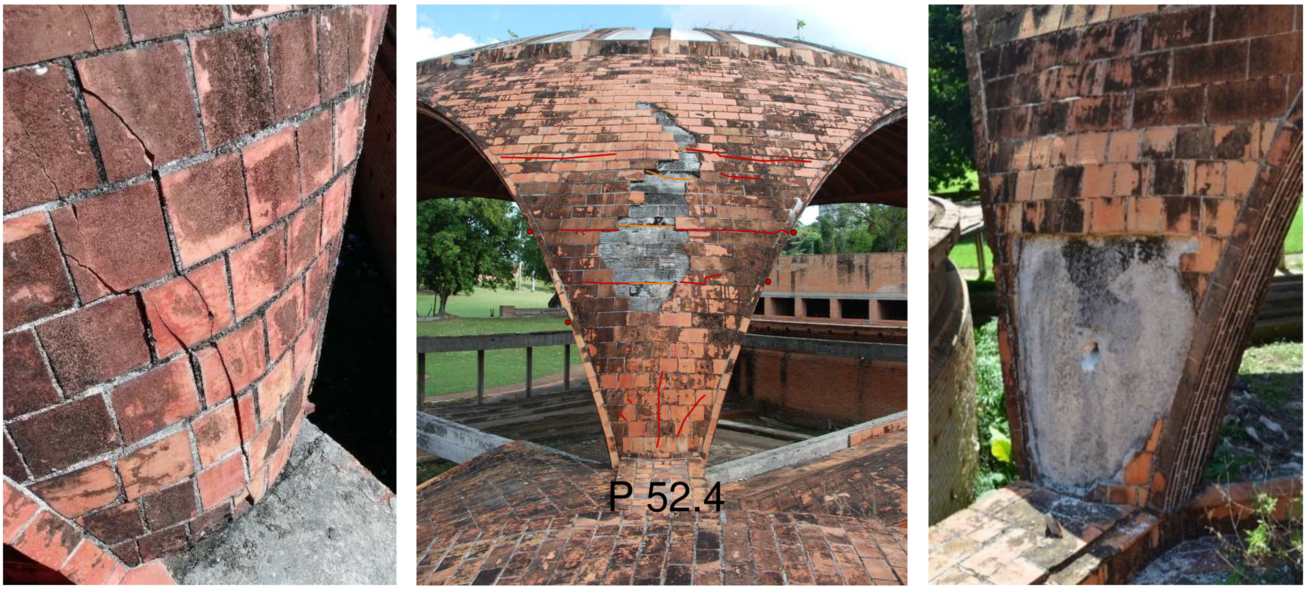

Figure 60 - Cracking and tile detachment at the extrados of the pendentives.

At the intrados of the dome, there is a widespread presence of moist stains and efflorescence, which are particularly concentrated:

- at the attachment of the superior ribbed cap to the circular ring (Figure 62, left);
- over the four arches (at their apex and at the hinges, as shown in Figure 63);
- at the base of the pendentives (Figure 64, left);
- and, generally, on the four tie-beams at the base of the structure (Figure 64, right).

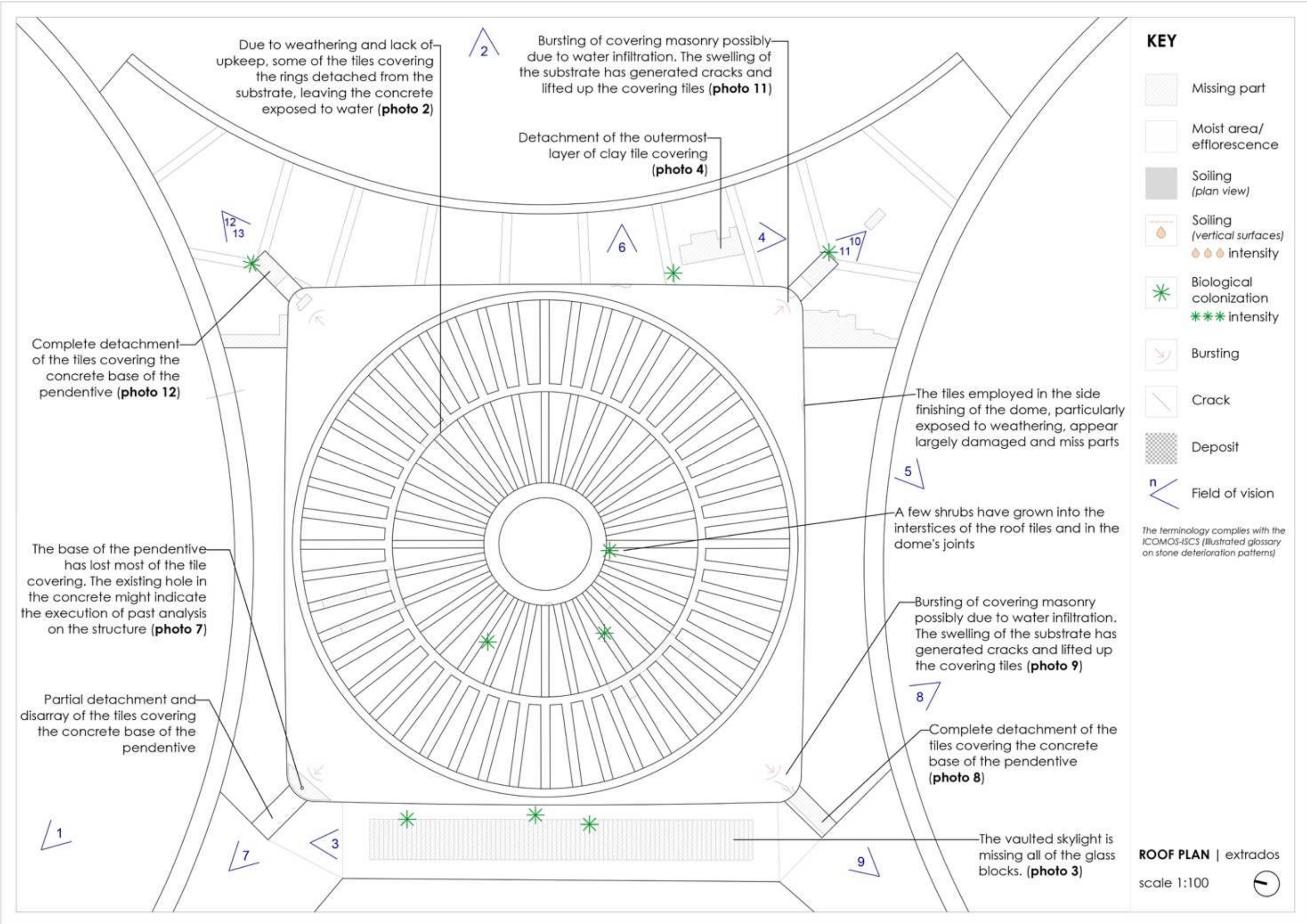

Figure 61 - Mapping of the damages and deteriorations surveyed on the extrados of the Pavilion dome. A detailed survey of damage and decay is reported Annex 2 F of the present report.


Figure 62 - Moist stains and efflorescence at the intrados of the dome, concentrated on the attachment between the ribs and the annular ring/pendentives; on the right, the percolation on the hinges.


Figure 63 - Damage and degradation in arch near apex (right) and at the hinges (left).


Figure 64 - Damage and degradation at the base of the pendentives (at the intrados) and decay of the tie beams (with loss of material and corrosion of the bars).

We have to underline that the surveyed phenomena are not simply classifiable as "superficial decay or deterioration" problems; conversely, they reveal regions of high stress, indicating the critical elements whose further degradation can definitely compromise the structural efficiency and the integrity of the dome. Virtually, as shown in the following[52], these "decay phenomena" anticipate and show, in the real structure, the stress and strain patterns of the FEM model, addressing our attention to some main structural issues further studied and clarified in the following structural analysis.

For clarity, the principal observed cracking and deterioration phenomena are hereafter summarized, according to members and trying to anticipate some structural interpretation.

The first concern is about the pendentives which represent the most critical elements, both in terms of structural importance as well as damage. In virtue of the same repeated structural scheme in the three pavilion domes, a comparative investigation of damage has been carried out (February 2020 by Princeton University) on all twelve pendentives, allowing to detect a common (as expected) mechanism of damage evidenced by:

- cracking in the tile extrados and side layers and, where visible, in the concrete, as well as delamination of the tile layer from the interior concrete section;
- tile loss in at locations of the critical stress zones (extrados of the pendentives, around the hinges of the arches) (Figure 64, center);
- cracking and spalling on the inner, lower face of the apex of the arched opening, indicating the presence of tensile stress (Figure 63)[53].

The second significant damage is the severe deterioration of the reinforced concrete beams at the base of the dome, which show a consistent deflection (maximum at midspan), coupled with a diffuse loss of the concrete cover. Of course, since left exposed, the steel bars reinforcing the beams are starting to corrode, adding risks related to section reduction. If no measures are taken, in the long run the situation is destined to keep worsening.

[52] See Chapter 2.5. Structural analysis and in particular Annex 2 H. FEM analysis of the two domes.
[53] The largest tension cracks appeared to occur at two locations, which divided the arch into approximately into thirds. also shows and tile degradation and delamination near the arch apex. These phenomena are fully compatible with the well-known arch damage mechanism.

2.5 Structural analysis

On the basis of the collected data it has been possible to proceed to the structural evaluation of the two domes described. To do so, two methods have been combined: numerical analysis (finite element models FEM, carried out by Princeton University) and some simplified stability assessments (Parma University), considering the elements involved and trying to define a "safety index" for each of them and for the whole domes.

The aim of these analyses was to further clarify the structural behavior of the 'improved Catalan vaults', in order to set up a reliable strategy of conservation.

First, starting from a recovery of empiricism used at the time of construction, a preliminary static analysis of the main constitutive arches of the two domes is proposed, by means of the well-known Mery's graphic method. Moreover, the integrated historical and structural study has allowed to definitely clarify the technique used at time of construction, enabling to properly judge the role of reinforced concrete into the (improved) 'Catalan vaulting system', not so far completely investigated. The results are then compared to those obtained by the FEA models of the domes, which have confirmed and further clarified some aspects still unclear: as stated before, the precision survey (laser scanner[54]) and the (even limited) tests carried out on the materials, have led to a significant improvement of the previous structural analyses of these two domes.

Indeed, the adopted procedure hereafter described highlights the fundamental role of an integrated study (historical and structural) in considering the real structural behavior of monuments which allows to reliably construe the present decay in order to properly intervene for future conservation.

2.5.1 Choreography Theater

2.5.1.1Graphic method (Mery's approach and the hypothesis of masonry dome)

"*Arch is nothing else than a force caused by two weakness*" said Leonardo da Vinci, even before the fundamental Hooke's theory which related the shapes of an arch and of a *catenaria*. Based on literature data and, in particular on the historical approach, developed by Méry in the XIX century on the arch collapse mechanism, it is possible to define the extreme position of the line of thrust, which determines the critical points of the structure. Indeed, the minimum and the maximum values of the thrust locate the position of the cracks and the hinges in which the collapse mechanism begins.

This theory still holds for the domes. A dome, in fact, can be imagined as composed by a series of arches, which could be obtained by slicing the structure along meridian planes. Two opposite slices form an arch and they work together by compression, making the most of the mechanical properties of the masonry. Therefore, it is possible to draw, for the dome, the same line of thrust which was previously identified as the basis of the collapse theory on the arches. In this way, it is easy to identify the specific equilibrium state in compression, at which the dome is safe.

[54] See Annex 2 B of the present report.

According to the aforementioned historical method, the dome of the Choreography Theatre has been firstly investigated by using some simplifications: firstly, starting from the symmetry of the structure, the dome is converted to an arch, taking advantage of the empiric-experimental knowledge on dome mechanical behavior (Figure 65).

In particular, considering the structural organization of the dome, this simplified calculation has been referred to 1/16 of the dome, corresponding to each continuous rib and to relative supporting pillar.

The graphic results have been then compared to the reference to a simplified arch, which reaches its stability through the solution of the three equilibrium equations. This procedure has allowed to obtain the radial thrust force of 1/16 of the dome, in order to evaluate its primeval assessment, in a qualitative way before the more advanced finite element analysis. Actually, it was also aimed at verifying the reliability of a conceivable first design - by Vittorio Garatti - of a "masonry" dome (catalan vault type) with this geometry.

In Figure 66 a scheme of the arch which synthetizes 1/16 of the dome is represented.

The slice is subdivided into 14 elements used for the Mery's graphic method, whose self weight is reported in the following Table . In this table, the different values of specific weight, referred to each element, are specified, and they are proportionally obtained from the material characteristics (respectively for masonry and reinforced concrete) inserted in the successive numerical model.

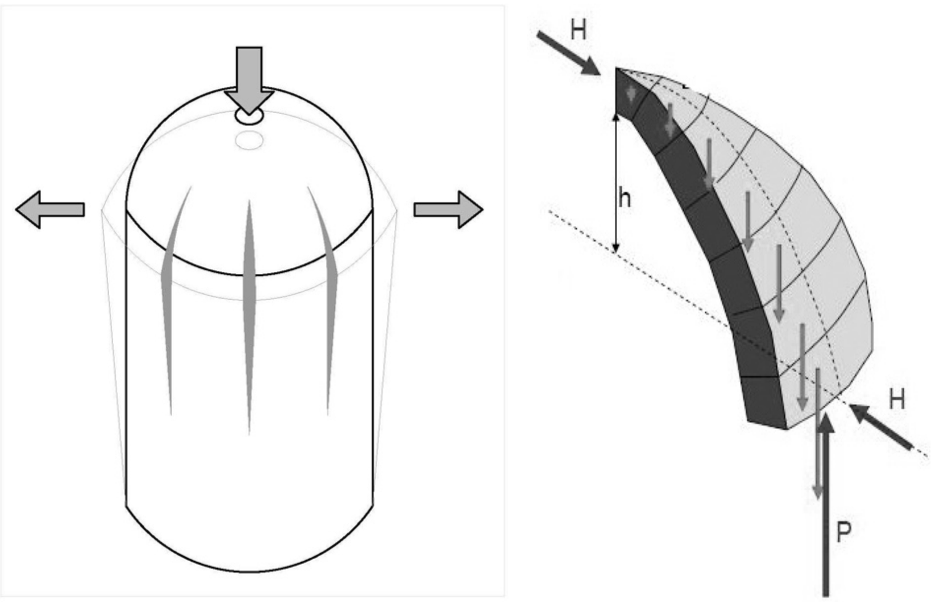

Figure 65 - On the left, the damage mechanism typical of (masonry) domes; on the right the macro-elements calculation in the simplified analysis as "arches" with Mery's graphic method and in the equilibrium approach.

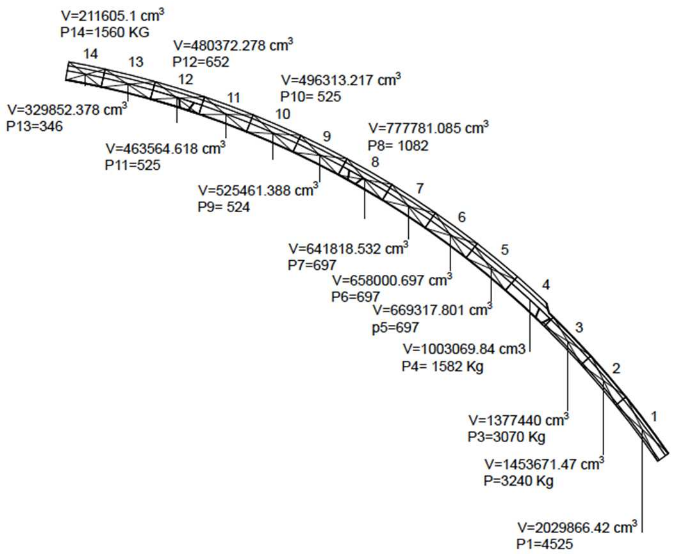

Figure 66 - An "arch-slice" of the dome, which simulates the behavior of the continuous ribs. The arch is divided in 14 elements, whose volume (V) and weight (P) are reported in the figure, for the successive Mery's graphic analysis.

Table 1 - Weight of each element constituting a 1/16 slice of the dome, as reported in the Mery's method

ELEMENT	VOLUME (cm3)	VOLUME (m3)	SPECIFIC WEIGHT (kg/m3	WEIGHT (kg)
1	2029866.42	2.02986642	2229.09	4524.759951
2	1453671.5	1.45367147	2229.09	3240.368127
3	1377440	1.37744	2229.09	3070.441131
4	736837.5	0.736837517	2147.8	1582.6093
5	324312.6	0.324312568	2147.84	696.5715973
6	324313.2	0.324313207	2147.8	696.5729697
7	324314.5	0.324314488	2147.8	696.5757211
8	502201.6	0.502201608	2155.2	1082.331366
9	243242.9	0.243242896	2155.2	524.2305313
10	243247.3	0.243247344	2155.2	524.2401175
11	243254.4	0.243254417	2155.2	524.255361
12	301684.8	0.301684761	2163.0	652.5375318
13	160166.9	0.16016687	2163.0	346.4374325
14	211605.1	0.211605144	2163.0	457.6972928
1/16 DOME	8476158.7	8.5	2170.59	18619.63
ENTIRE DOME	135618539.4	24.5	2170.59	297914.055

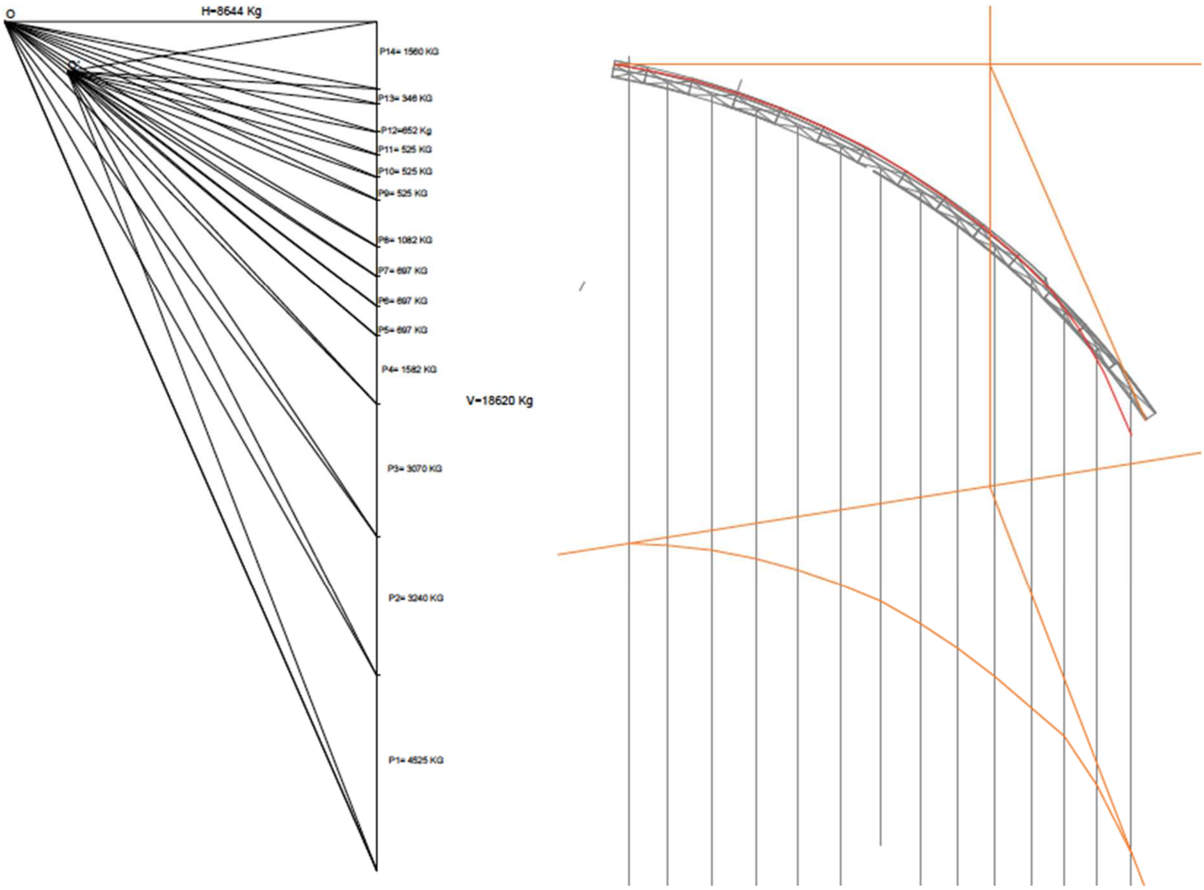

Figure 67 - On the left, the two polygons of forces with the fictitious pole (O') and the real one (O) from which the inclination of the line of thrust inside the dome can be obtained (right).

Figure 67 (on the left) the two polygons of forces are drawn (respectively referred to the two poles: the fictitious, O', and the real one, O) and on the right, the line of thrust inside the dome is finally plotted. From the figure, it can be seen that the dome - with the only gravitational load - almost entirely contains the line of thrust inside its section, thus partially confirming what assumed by previous studies[55] and also anticipating the results of the numerical model (presented hereafter) which substantially found the dome compressed[56].

[55] I. Douglas, *Cuba's National School of Ballet. Redefining a Structural Icon*, Princeton University, April 17, 2017. Advisors: Dr. Maria Garlock, Dr. Branko Glišić.
[56] A complete report is in the Annex 2 H.

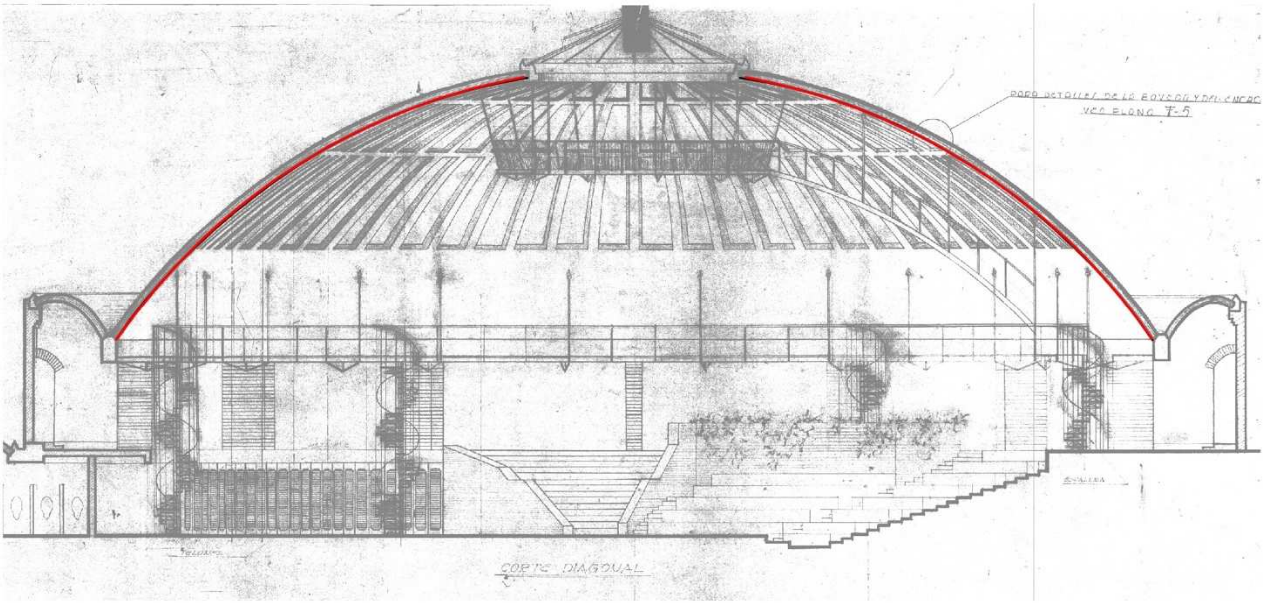

Figure 68 - The superimposition of the current dome profile (in red) obtained from the laser scanner survey, and the original curvature of the dome (in the back, original drawing by Garatti stored in the ISA archive).

Indeed, the good functioning of this vaulted system is testified by the lack of serious damages and the slight deformations of the dome, evident by the comparison between the original geometry and the last precise survey (superposed on the original drawing in Figure 68. Also the results of the numerical model have confirmed these slight deformations, thus confirming the stability of this structure.

Nevertheless, a further analysis has been made by supposing the entire section made of bricks, as the vault originally hypothesized, and the line of thrust in this case (as visible in Figure 69), is not properly contained into the vertical section of the arch, thus evidencing the inconsistency of the hypothesis of an original “pure Catalan vault” design.

However, we have to stress that, in this simplified graphic model of the "pure masonry dome" hypothesis, the confinement effect of the Catalan vaults inserted between the ribbed structure (simplified into this 1/16 slice) is not taken into account. Indeed, as in other major domes (for example in Santa Maria del Fiore in Florence[57], as reported in Figure 70, right), the radial disposition of the bricks (which has primarily a constructive and functional reason) gives to the dome an "encircling effect": the composition of the thrust forces of two consecutive arches along each parallel, could act, actually, on the inclination of the line of thrust, slightly reconducting it towards the axis of the examined arch (Figure 70) and thus making the most of compressive properties of masonry. Despite this confinement effect, after this first simplified graphic analysis, the original hypothesis of a “pure masonry dome” can be definitely discarded.

[57] Chiarugi, A., Fanelli, M. and Giuseppetti, G. 1993. Diagnosis and Strengthening of the Brunelleschi Dome. In: Proc. IABSE Symposium, Rome, 441-448; BARTOLI, G., BETTI, M., BLASI, C., OTTONI, F., COLI, M., MARCHETTI, E., AND RIPEPE, M. (2015). *Synergistic and Interdisciplinary Approaches for the Conservation of Monumental Heritage: Cupola of Santa Maria del Fiore in Florence, Italy,* in J. Perform. Constr. Facil.,10.1061/(ASCE)CF.1943-5509.0000831 , 04015091, American Society of Civil Engineers, ISSN (print): 0887-3828, ISSN (online): 1943-5509

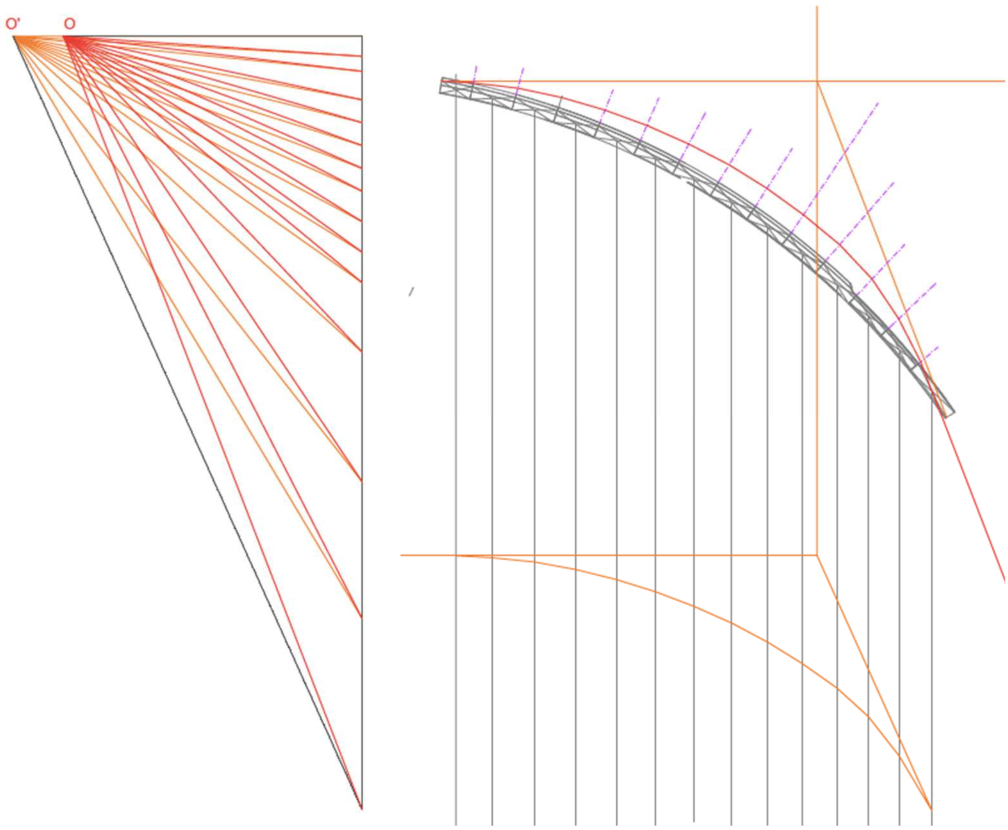

Figure 69 - On the left, the two polygons of forces with the fictitious pole (O') and the real one (O) and (on the right) the graphic construction of line of thrust in the case pure masonry (Catalan vault) dome.

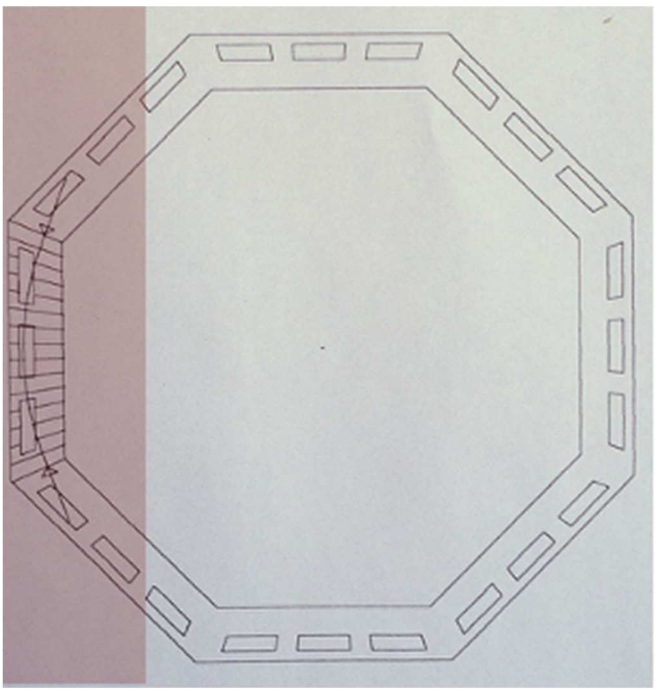

Figure 70 - Octagonal ring made by Brunelleschi in Santa Maria del Fiore dome (image by Chiarugi, 1993).

2.5.1.2 Numerical modeling by Finite Element Analysis (FEA)

Starting from the previous investigation, a FE model of the dome has been performed by Princeton University Group, with these main objectives:

- Greater understanding of the structure's behavior under normal gravity loading, trying to better clarify the interactions between the ribs and shell;
- Analysis of the dome behavior under three loading conditions:
    - Dead loading, with full gravity load of the structural components
    - Wind loading using hurricane windspeeds with return period of 700 years
    - Settlement loading of two pillars at the structure's base.

A complete description of the operations made in order to set up a reliable numerical model of the dome and the criteria used to set up a correct finite element analysis is fully reported in Annex 2 H (by Princeton University Group) attached at the end of this report. Hereafter we only summarize the main issues and the final results, which, once compared and joined to the previous qualitative structural analysis, allowed us to advance some final conclusions on the real structural assessment of the dome and to hypothesize the most reliable intervention for its strengthening (and conservation).

It's important to stress, in fact, that at the base on this and the further dome modelling, there is the idea of a continuous and rigorous comparison of the results of the numerical modelling (FEA) with the real structure evidences, in particular starting from the corroboration of damages (those obtained by the model and the surveyed ones). Only this match, and the iterative correction of any numerical model, can assure the reliability of the final results when we consider the structural analysis of such complex existing structures. Especially when, as in this case, it's not possible to dispose of a precise stratigraphy of structural elements or tested material properties (in the lack of direct destructive tests)[58].

Geometrical model and material properties

Starting from the results of the precise geometrical survey carried out during this study[59] along with the field dimensions provided, a model was constructed in the 3D drafting program Rhinoceros (Rhino) which articulated each component (ribs, rings, shell, pillars) as separate volumes (Figure 71[60]).

[58] Indeed, we want to recall that, as referred in the previous chapter 2.4, the hypotheses made on stratigraphy of each structural elements - which anyhow we demonstrated to be quite reliable - are often deducted by documental research and by a deep on-site observation and supported by indirect tests, thus limiting the direct (and invasive) inspections or (worse) destructive tests, as prescribed for cultural heritage.

[59] See Annex 2 B of this report.

[60] Even shown in the figure for clarity, the pillars and mezzanine level were not included in the FEA model -due to computational expense and insignificance. See Annex 2 H for details.

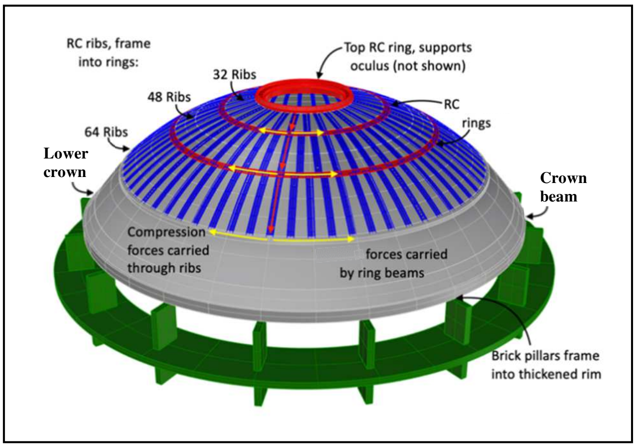

Figure 71 - On the left, Rhino model of Choreography Theater.

These volumes have been then joined together (ribs, lower crown and ring beam) for the importation of the model into FEA software ABAQUS, thus simulating the construction process of the dome, which finally resulted a concrete rib system. The reinforcement system has been defined by inserting three separate sections at precise positions, concurrent with the previous examination of the construction documents and pacometer results[61]: a rebar system for the ribs and rings, reinforcement through the lower crown (both inserted at approximately mid-height of the volumes) and tension reinforcement at the bottom of the lower ring beam (in the bottom chord of the beam) [62].
The parts imported into ABAQUS for analysis comprised the concrete rib system, rib reinforcement system, crown reinforcement, lower ring reinforcement, and the dome shell, which was embedded fully into the concrete volumes, via a system of ties between the ribs and shell layer, specifying the ribs as the "master surface" in virtue of its major stiffness[63].
In order to effectively model the concrete mechanical properties of the Choreography theater, the Concrete Damaged Plasticity (CDP) material property was implemented in ABAQUS to simulate the behavior of concrete cracking under tensile and compressive stresses. The reinforcement shells as well as the dome shell were modeled with steel rebar and idealized elastic concrete, since cracking in those regions was less critical. The structural components were assigned element types and material types as shown in and the material properties are presented in Table 3[64].

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[61] As reported in Chapter 2.4 of this report and fully described in Annex 2 G.
[62] In ABAQUS, reinforcement can be inputted as a shell layer embedded in a solid, so a shell layer was constructed in Rhino for each of the reinforcement sections: the ribs reinforcement, the crown reinforcement, and the lower beam reinforcement.
[63] The rib structure was designated as the master surface because it is the stiffer of the two structural components, and, due to the nature of the dome shell, forces are anticipated to flow from the shell to the ribs to be distributed to the supports.
[64] It was determined unnecessary to model the tile and mortar material properties in the model because at the present stage the tiles do not provide significant structural capacity, due to their scaled and cracked state. While their originally intended role could have been in part structural, due to the observed damage to tiles we conservatively assume that at present day the tiles only serve an aesthetic and protective role for the concrete underneath. Therefore, these materials are not included in the ABAQUS analysis in this work.

Table 2 - Model Element Types and Material properties.

Component	Element Type	Material	Special Module
Rib System	Deformable solid	Concrete	CDP
Dome Shell	Deformable shell	Regular concrete	Constant Reinforcement: 1.2 cm bar @ 40 cm, both ways
Ribs Rebar	Deformable shell	Regular concrete	Angular Reinforcement: Radial: 1.3 cm bar at 22.5° Circ: 1.3 cm bar at 22.5°
Crown Rebar	Deformable shell	Regular concrete	Angular Reinforcement Radial: 1 cm bar at 15° Circ: 1 cm bar at 15°
Lower Beam Rebar	Deformable shell	Regular concrete	Angular Reinforcement: Circ: 1.6 cm bar at 15°

Table 3 - Material Properties of the Abaqus Model.

Material	Density (kg/m3)	Modulus of Elasticity (GPa)	Poisson's Ratio	Yield Stress
Concrete	2400	30	0.2	40 MPa
Steel	7800	200	0.28	413 MPa

The sixteen masonry pillars evenly spaced around the circumference of the dome have been modeled as pin supports at the locations of each pillar, restraining movement in the x, y, and z directions but do not inhibit rotation in any plane. These restraints do not fully represent the actual conditions of the dome: in reality, the pillar connections provide minimal tangential constraint and provide limited radial constraints, due to the presence of the brick wall built behind the support. The depth of pillars in radial direction is very high compared with the pillar length, thus radial displacement on top of the pillar is minimal as it mostly depends on shear forces in radial direction; the mezzanine ring additionally prevents movement in radial direction of the pillars. In addition, the high stiffness of lower crown combined with the constraint of the mezzanine ring also minimizes displacements in tangential direction[65].

Applied loads: numerical analysis results

The numerical model of the dome was analyzed, as stated before, under three main loading conditions:

- Gravity loading:
- the most elementary load case (considering gravity acceleration and material densities);
- Wind loading:

[65] Future work will include modelling of the pillars which will result in more accurate boundary conditions for the dome. In terms of the actual connection point, modeling the pillars as pins at specific points is fairly conservative, since it will provide a more concentrated stress at the point itself than is expected from the 40 cm wide pillars, but it is within the acceptable accuracy in this project.

- For the hurricane loading, the calculated wind pressure applied was ±1821 Pascals on the surface of the dome (return period of 700 years for the windspeed)[66]. Wind load combined with dead load provides an extreme loading condition on the structure.
- Settlement loading.
- Due to the common flooding of the Rio Quibù and full saturation of the soil at these times, settlement is a severe risk to the structure. Additionally, some of the masonry pillars have superficial concrete damage and may need repair during the renovation of the Ballet Dome, so the maximum possible span length of the lower ring is useful to determine. For this analysis, two boundary conditions were removed, widening the space between pillars[67].

Gravity Loading

Under simple gravity load condition, the dome appears to be subjected to low stresses except at the locations where the ribs connect to the lower crown. FEA predicts minor damage at the connections between the ribs and concrete crown which is concurrent with observations of the structure that show significant efflorescence damage at these points (i.e., water infiltration in the cracks through the dome shell) as evidenced in Figure 72. This damage is the most likely a result of high stress concentrations due to force flow from an area of low stiffness (the ribs and thin shell) to an area of very high stiffness (the reinforced lower crown).

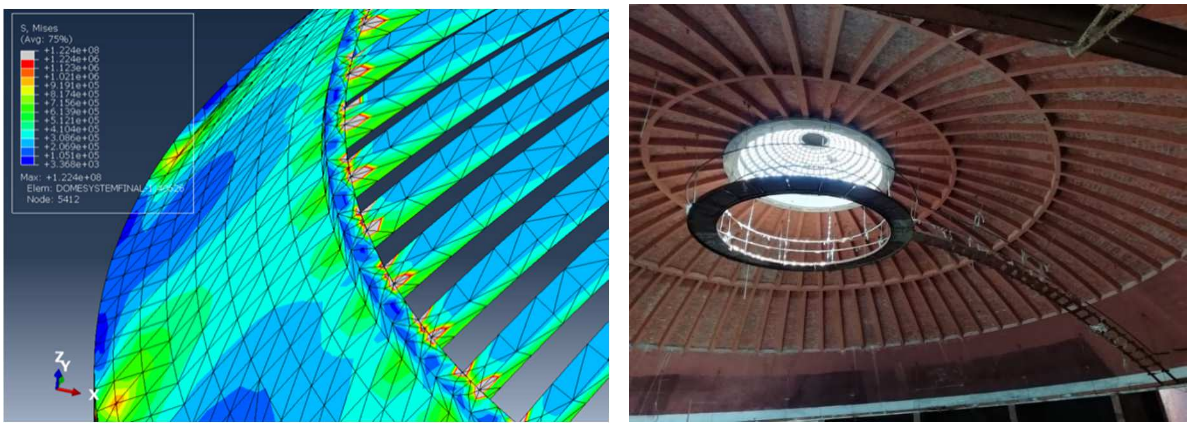


Figure 72 - On the left, Von Mises stress on dome shell due to gravity load; red-colored contours at ribs-crown connection indicate locations of potential damage. On the right Damage on dome shell due to gravity load indicated with bright and red colored areas.

It has also to be noted that, as anticipated in the previous Figure 68, the maximum deformation anticipated by the FEA model is about 0.5 mm at its most extreme point, in the center of the dome, and reducing through the outer extents of the dome. In comparison to anticipated deformations, as well as previous studies of the structure[68], this

[66] The wind pressures act normal to the shell or dome surface, as outlined by ASCE 7-10 directional procedure, with downward pressure acting on the windward side of the dome and uplift acting on the leeward side.
[67] No wind loading is added to the structure due to low probability of combined incidence, i.e., settlement is combined with gravity loads only.
[68] Douglas et al., 2020.

deformation appears to be very small but it can be explained by the high stiffness provided through modeling of the reinforcement structures, boundary conditions (pins instead of rollers), and the tied dome-shell connection (rather than simply applying a shell load to the ribs), which had not been considered in previous study[69].

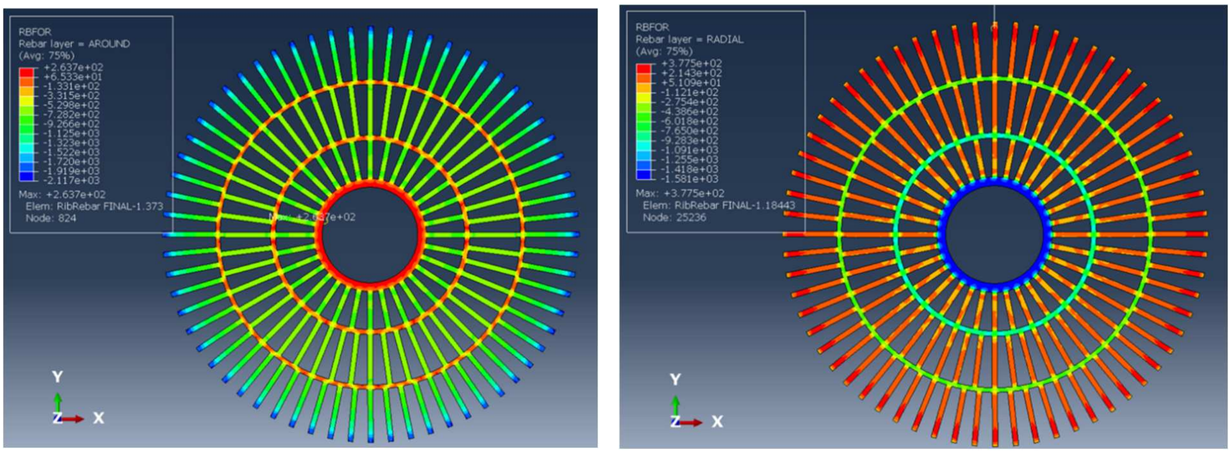


Figure 73 - Stress in rib reinforcement (on the left) and in the hoop ring reinforcement (on the right) under gravity load.

Under gravity load, both hoop rings and ribs are placed in compression, as expected based on traditional dome analysis (stresses in the rib and in the hoop ring rebar are shown in Figure 73). Reaction forces in each pin connection were roughly equal, which indicates the dome's weight is distributed equally to each of the sixteen columns, as expected, and the average forces experienced in the radial, tangential, and vertical direction are shown in Table 4.[70]

Table 4 - Reaction forces due to gravity loading.

	Magnitude of Resultant (kN)	Radial (kN)	Tangential (kN)	Vertical (kN)
Average Value	399.6	-180.0	0.0	356.8

The maximum vertical force is approximately 357 kN, acting upwards to support the dome structure as expected. The radial force of -180 kN, acting to constrain outward displacement of the structure, is more extreme than expected and shows that the outward deformation of the dome's lower ring is quite significant. Considering the immense shear force implied by the radial reaction inwards compels an assessment of the shear capacity of the pillars, further investigated[71].

[69] Additionally, high deformations are expected from time-dependent deformation effects such as creep and shrinkage which cannot be reproduced through this analysis.
[70] The magnitude of the resultant force is also displayed here, although without a direction component; this is the total load on the pillar. It is important to note that although the averaged tangential force is approximately zero, the individual values measured for tangential force (not displayed here) were the most highly variable, ranging from -1444 Newtons to 1539 Newtons. It is unclear where these forces are being created, perhaps because the radial ribs are not aligned in all places between rings; however, since the maximum individual tangential force is two orders of magnitude smaller than the radial force, this is acceptable to leave for future studies.
[71] A simplified calculation for the assessment of shear failure of the pillars is reported in the following paragraph.

Wind Loading

The original model was subjected to hurricane wind loadings as well as gravity loading. Wind loadings acted perpendicularly inwards on one half of the structure and outwards on the other, simulating the wind pressures and uplift characteristic of a severe storm. Because of the asymmetric load condition, this produced an asymmetric response in the structure as well, as shown by the Von Mises stresses (Figure 74, left) On the side with wind pressure into the structure, the Von Mises stresses are much higher because the wind loading is exacerbating the normal loading of the structure, especially near the top of the dome where the near-vertical wind pressure and gravity are combining for a maximum load. Very high stresses are observed at the boundary between the positive and negative pressures, which is possibly due to the twisting that the structure undergoes at that point. Again, as with the regular gravity loadings, the highest stresses occur where the ribs frame into the crown, with more significant damage occurring in those locations. Based on this comparison, it is possible to conclude that although hurricane loads may cause some momentary deformation of the structure, it is unlikely to cause long-term structural damage at this windspeed. Therefore, hurricane wind loads are likely well within the sustainable range for this structure.

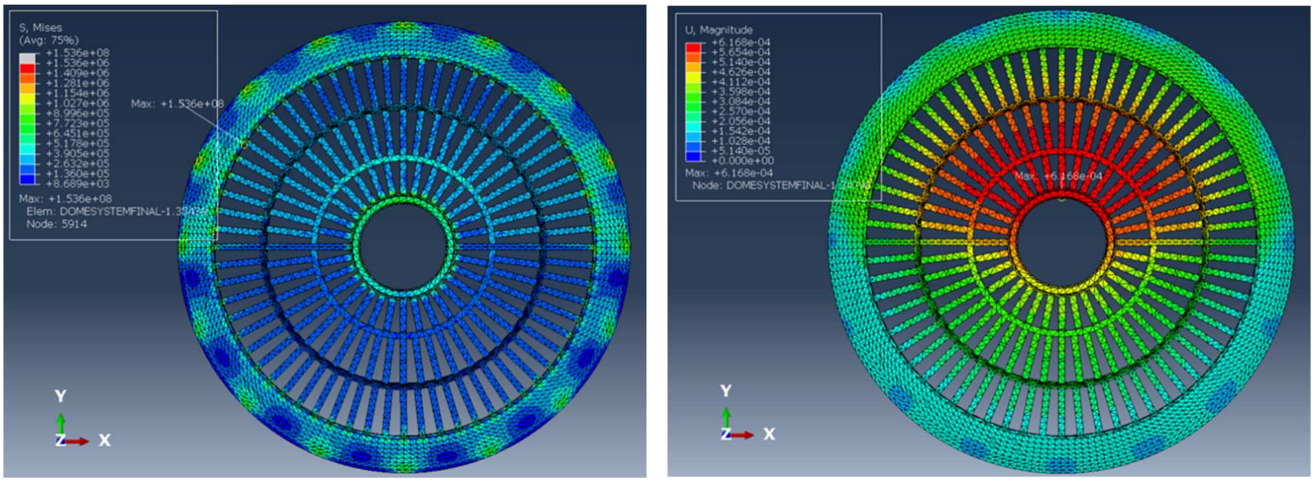


Figure 74 - Von Mises stresses (left) and displacement (right) in dome shell due to wind load and dead load.

In comparison to the gravity load model, the addition of the wind load does elicit a higher magnitude of deformation, with around 0.6 mm of deformation exhibited at maximum rather than 0.5 mm with gravity loading (Figure 74). Because this deformation was not accompanied by damage, the structural behavior in the event of a severe hurricane is much better than originally anticipated.

In order to better understand how the hurricane load changes the gravity load path as well as the shear forces experienced by the pillars, we have to stress that the support reactions from the wind loading model (reported in Table 5 for some investigated points) are not significantly higher (at least in Radial direction) than the one produced by gravity load (187 kN vs. 180 kN).

Table 5 - Reaction forces due to wind and gravity loading.

Node #	Magnitude of resultant (kN)	Radial (kN)	Tangential (kN)	Vertical (kN)
A	430	-187	0	387
B	427	-182	139	359
C	366	-171	0	324
D	427	-182	-140	360

Similar comment applies to vertical reactions. Hence, while hurricane winds may provide lateral forces on the structure, they do not greatly change the gravity load path or the magnitude of reactions. This is a reassuring result as it indicates the dome is not tipping in any way[72].

Settlement Loading

Finally, two pillars were removed from the structure to simulate settlement loading. Since two boundary conditions were removed from the model, this will be an extreme case that is not necessarily anticipated in the lifetime of the structure. This increased the span between supports from approximately 6 meters to 18 meters, tripling the free span on one side. The irregular boundary condition also produced a moment throughout the structure as gravity loads were unable to be resolved at the missing pillar. As expected, the removal of two pin supports produced irregular displacement on the structure, with the ABAQUS model showing a maximum deformation of 2 mm (Figure 75, left). Meanwhile, the deformation at the oculus ring remained similar to the gravity case at around half a millimeter. The Von Mises stress distribution in the dome also mirrors these trends highlighting the major stress:

- at the edges of the free span, likely because the moment induced in that section is most significant if the crown is considered as a beam undergoing bending;
- where the lower ribs frame into the crown above the two supports next to the longer span: because the dome is curving in this location, the induced rotation at the base of the beams creates a high stress (Figure 76, right).

[72] However, the shear reaction forces acting on the pillars are an area of some concern because the masonry columns were not designed for lateral loads, especially along the narrow axis of the column; these loads may require future analysis.

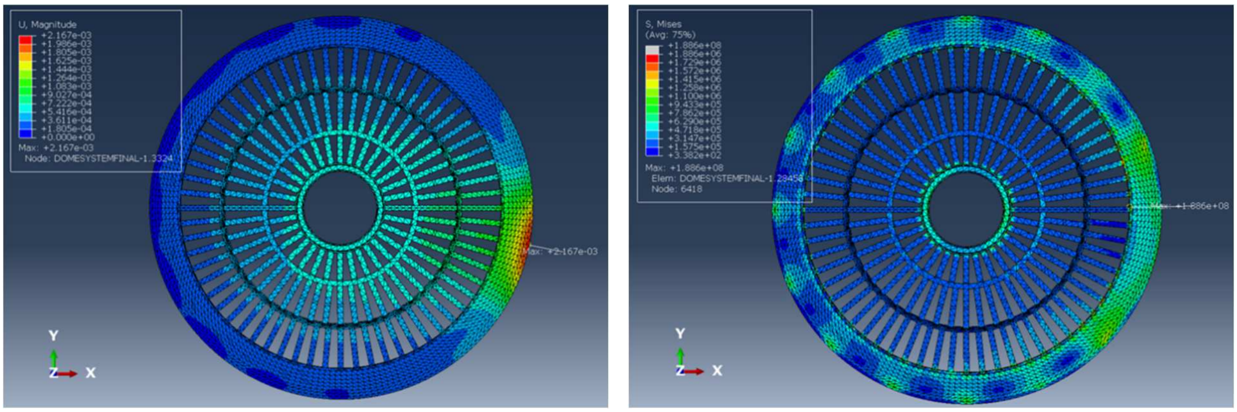


Figure 75 - Displacement (left) and Von Mises stresses (right) in dome shell due to settlement load.

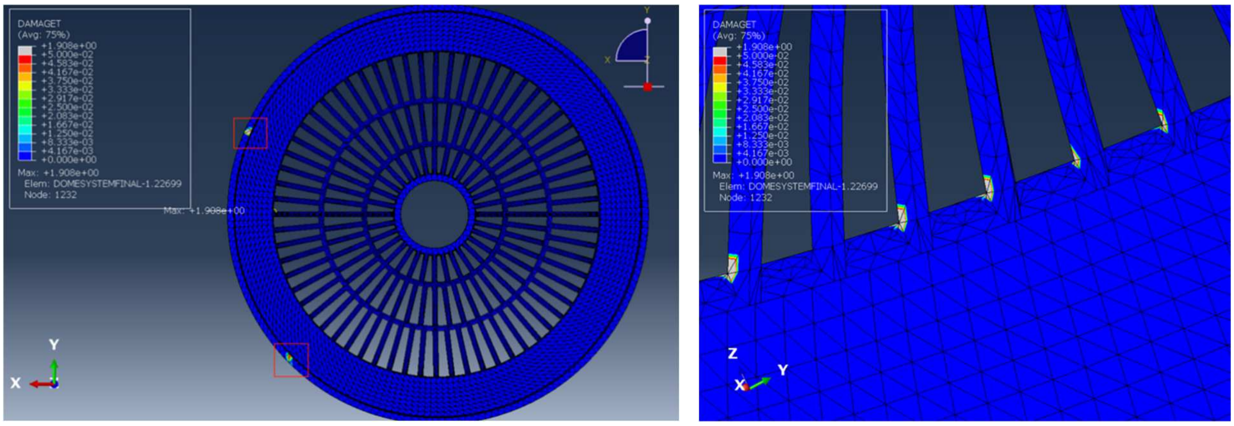


Figure 76 - Damage under settlement load. On the right it can be seen that the major damage is concentrated in the connection between the beam crown and the ribs (as in the case of simple gravity load) for difference of stiffness.

As observed in both the gravity loading and wind loading model, the beam-crown connections are again the location of highest Von Mises stress and are most likely to be damaged in the event of significant settlement.

Table 6 - Reaction forces due to gravity load and settlement.

Node #	Magnitude of Resultant (kN)	Radial (kN)	Tangential (kN)	Vertical (kN)
A1	840.5	-414.7	365.5	633.2
A2	838.1	-415.5	-359.9	632.7
Average	418.9	-196.1	0	356.7

Looking at the maximum reaction forces at the pin supports adjoining the long span (on either side of the 18-meter span, named A1 and A2 in Table 6) we can see that the magnitude of the load on either side of the unsupported span is around double the average load on all pillars, although the distribution of load is not uniform across the remaining pillars. As expected, the tangential forces are equal and opposite on both sides of the long span, reacting to pull the mass of the dome back from the unsupported edge. The fact that the tangential forces on the pillars to either side of the long span are more than half of the vertical force (around 360 KN to 633 KN) is worrying and implies a huge lateral force on the pillars to either side of the beam[73].

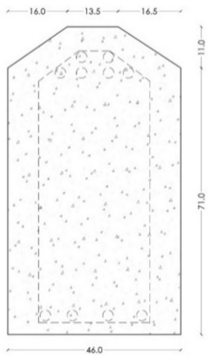
2.5.1.3 Some notes on stability assessments

Starting from the combined results of the previous graphic method and considering the maximum values obtained by the subsequent and deeper finite element analysis, some simplified calculation has been carried out in order to evaluate the assessment of the most solicited structural elements of the examined dome.

In particular, the encircling effect of the ring beam at the base of the dome has been verified by comparing its resistance to the major tangential stress to which it can be subject.

As expected, also in consideration with the surveyed condition of the ring beam and the lack of significant deformations of the dome at its base, the results are comforting in confirming the effectiveness of this hooping system, whose limit resistance is far over its maximum stress (as shown in following Table 7).

Table 7 - A simplified assessment of the circular beam work and state of stress.



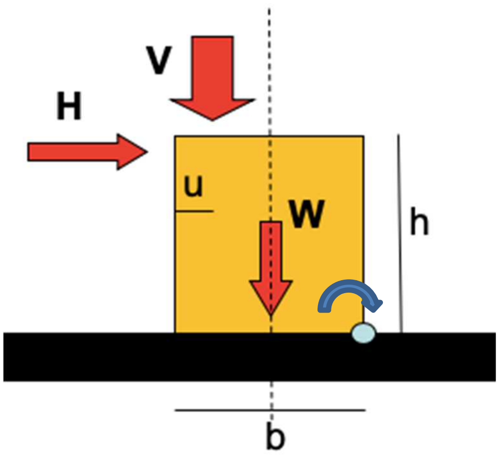
CIRCULAR BEAM		
beam section	3266	cm2
rebar diameter	16	mm
rebar section	803.84	mm2
number of rebars	8	
total rebar section	6430.72	mm2
H	221259.8937	N
tensile tension	34.40670621	N/mm2 (Mpa)
Yeld stress	413	N/mm2 (Mpa)
resistance	359.13	N/mm2 (Mpa)
safety index	**10.44**	**>>1**

As evidenced by the numerical model significant vertical and radial loads are exerted by the dome on the 16 pillars at its base, which in the FEA have been modeled as pin boundary condition for the dome.

In step with this, further investigations into the supporting conditions of the dome have been recommended by the results of the numerical modelling in order to verify possible pillar failure under eccentric loading, which may cause shear failure or tip-over.

[73] The magnitude of this load impels the need for future examination of the capacity of the pillars, verified in a simplified way in the following paragraph.

Table 8 - Equilibrium of one of the 16 pillars at the base of the Choreography Theatre, considering its possible overturning.



EQUILIBRIUM of the PILLAR		
h (height)	250.00	cm
b (lenght)	170.00	cm
t width	40.00	cm
weight distance (b/2)	85.00	cm
V dome	35000.00	Kg
H dome	18000.00	Kg
W pillar weight	3060.00	Kg
g specific weight	1800.00	kg/m3
u (distance)	20.00	cm
M rib	4500000	Kgcm
M stab	5510100	Kgcm
safety index	**1.22**	

Firstly, the possible overturning of one of the 16 pillars under the maximum radial load has been considered (in gravity and wind loading condition) by a simple application of the equilibrium approach, as represented in the following figure, whose results are plotted in the near Table 8.

As shown by the "safety index" (>1), the huge dimension of the pillars, and their structural organization in the space, counteract the possible overturning caused by the radial forces, at least in the two main load conditions (under gravity and wind action).

Therefore, the simplified assessment of the pillar under combined compressive and bending stress, under great eccentric load has been carried out in the longitudinal section.

Table 9 - Tab.4.5.III. NTC 2018 Italian Technical Law for the coefficient of reduction of resistance in case of eccentric load.

	m = 6e/t				
h_0/t	0	0,5	1,0	1,5	2,0
0	1,00	0,74	0,59	0,44	0,33
5	0,97	0,71	0,55	0,39	0,27
10	0,86	0,61	0,45	0,27	0,15
15	0,69	0,48	0,32	0,17	---
20	0,53	0,36	0,23	---	---

The results plotted in the table show an eccentricity index (m, for the Italian law) major than the limit for masonry sections (Table 9). This value, combined with the slenderness of the pillar (reported in the Table 10 as l=h/t), leads to a very disadvantageous coefficient for the reduction of compressive resistance of masonry (fi = 0.27) which significantly reduces the capacity of the pillar in supporting buckling, as confirmed by the surveyed cracks at the base of the ring beam (figure on the left of Table 10).

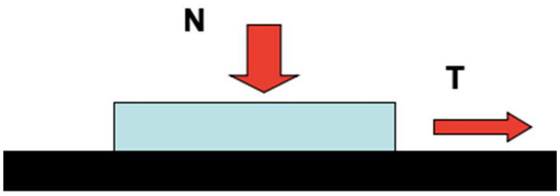
We have to underline that in this calculation the effect of the surrounding supporting structures (the vaulted corridor surrounding the dome) is neglected, thus underestimating the pillar resistance capacity.

Table 10 - A simplified assessment of the resistance of the pillar to combined compressive and bending stress.

PILLAR BUCKLING RESISTANCE		
es vertical load	59.774041	cm
(V*(b/2-u))/(W+V)		
es horizontal load	118.234367	
H*h/(W+V)		
e 1	58.4603258	cm
m=6e/t	2.06	>2
l=h/t	1.47	
fi reduction resistance	0.27	
reducted resistance	17.415	
safety index	**0.6**	

Table 11 - Simplified assessment of the possible shear failure of one of the 16 pillars at the base of the dome.

$$f_{vk} = f_{vk0} \quad 0{,}4\,\sigma_n$$



shear failure PILLAR		
fvk	123.11	N/cm2
fvko+0.4 sigma		
fvd =fvk/gamma	61.55	N/cm2
sigma n max	291.67	N/cm2
fvko	6.44	N/cm2
tau 0	9.2	N/cm2
shear stress	26.47	N/cm2
safety index	**2.0**	

Finally, the last analysis has been made on the possible shear failure of the same pillar, always caused by the radial forces acting on it. The vertical load, in this case, helps the structural element in contrasting the shear force, significantly increasing the shear resistance of the masonry (to which a percentage of compression stress is added (40%)). As can be seen by the results plotted in the following Table 11, the "safety index" for the pillars against shear failure is far major than 1, thus leading to a (simplified) positive response for its stability assessment for this damage mechanism.

2.5.2 Dance pavilion

2.5.2.1 Graphic method (Mery's approach)

As the previous Choreography Theatre, the first step in the structural analysis of the Dance pavilion dome has been the application of Mery graphic analysis method. In this case, given the geometry of the dome, the "slice" considered has been ¼ of the whole dome, including one of the four pendentives which represent the main structural element (and the most damaged one) of the dome.

Final aim of this simplified investigation was to find the extreme position of the line of thrust, checking the safety of the dome, and to determine the forces (vertical and horizontal) acting at the base of the dome, at the top of the four pillars.

Thus, according to the aforementioned historical method, the pavilion dome has been "reduced" to its diagonal arch (Figure 65) which reconducts the load of ¼ of the dome through the pendentive on the huge masonry pillar at its base.

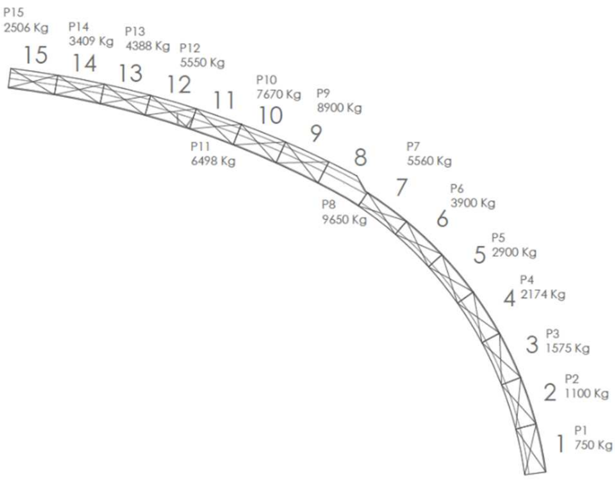


Figure 77 - The diagonal "arch-slice" representing ¼ of the dome. The arch is divided in 15 elements, whose weight (P), used for the successive Mery's analysis, are plotted in the figure.

This type of analysis is really interesting in this case because, unlike the previous analyzed dome, the Dance Pavilion shows, as stated before[74], significant deformations, especially in the pendentives (Figure 78).

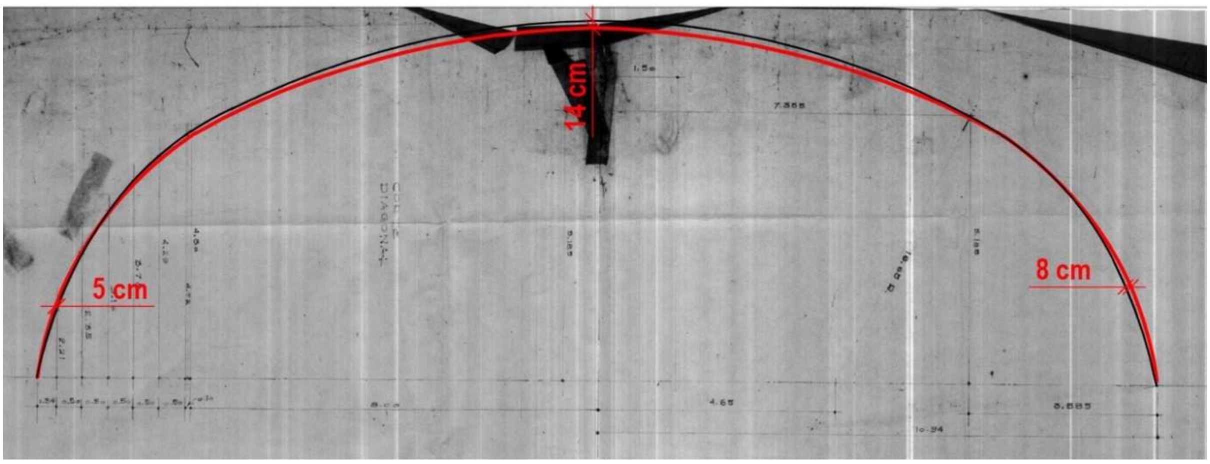


Figure 78 - The superimposition of the current dome's profile (in red) obtained from the laser scanner survey, and the original curvature of the dome (as in Garatti's original drawing, ISA archive) considering the diagonal arch (and thus, the pendentives).

[74] See previous Chapter 2.4 of the present report.

In Figure 77 a scheme of the arch which synthetizes 1/4 of the dome is represented.

The slice is subdivided into 15 elements used for the Mery's graphic method, whose self weight is reported in the following Table 12, where the different specific weights, referred to each element, are specified (proportionally obtained from the same material characteristics used in the successive numerical model).

Table 12 - Weight of each element constituting a 1/4 slice of the dome, as reported in the Mery's method (Figure 77 and Figure 79).

ELEMENT	ELEMENT AREA (cm2)	DEVELOPMENT ARCH (cm)	volume (cm3)	VOLUME (m3)	SPECIFIC WEIGHT (kg/m3)	ELEMENT WEIGHT
1	3127.2	104	325228.8	0.33	2200.00	715.50336
2	3068.5	156.0	478686.0	0.48	2200.00	1053.1092
3	2987.2	229	684068.8	0.68	2200.00	1504.95136
4	2882.9	328.0	945594.5	0.95	2200.00	2080.307856
5	2757.1	462.0	1273798.7	1.27	2200.00	2802.357096
6	2615.2	649.0	1697238.8	1.70	2200.00	3733.925448
7	2456.7	989.0	2429626.9	2.43	2200.00	5345.17907
8	3351.8	1336.0	4478018.2	4.48	2100.00	9403.838136
9	3409.2	1212.0	4131974.6	4.13	2100.00	8677.146744
10	3273.4	1087.0	3558185.8	3.56	2100.00	7472.19018
11	3153.9	956.0	3015118.8	3.02	2100.00	6331.749564
12	3051.6	841.0	2566353.6	2.57	2100.00	5389.342455
13	2966.1	684.0	2028832.9	2.03	2100.00	4260.549132
14	2897.9	544.0	1576452.2	1.58	2100.00	3310.549536
15	2847.06	407	1158753.4	1.16	2100.00	2433.382182
TOTAL 1/4 DOME					WEIGHT 1/4	64514.08132

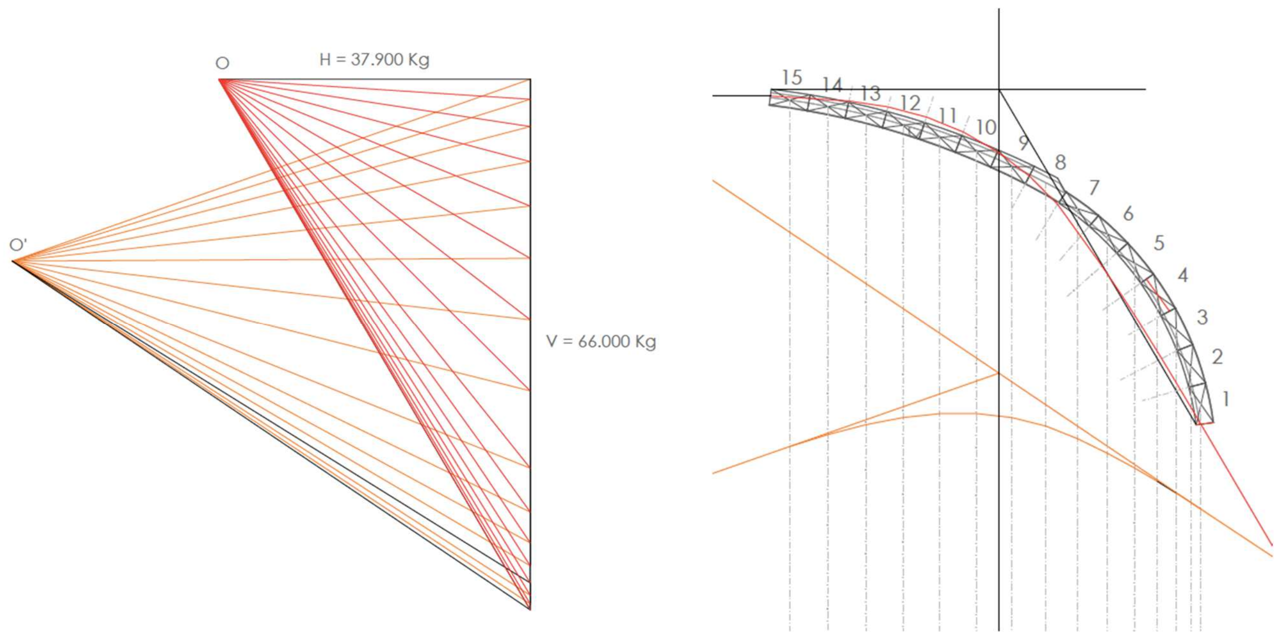


Figure 79 - On the left, the two polygons of forces with the fictitious pole (O') and the real one (O) from which the inclination of the line of thrust of the dome can be obtained (right).

This simplified construction has confirmed the deformative state of the pendentives, evidenced also by the FEM analysis and confirmed by a comparison between the laser scanner survey and the original drawing by Vittorio Garatti (as plotted in Figure 78). Indeed, as stated before (chapter 2.4 of the present report), the first one concern is about the pendentives which show deformations and about three horizontal cracks of various extent, coupled with diffuse bursting phenomena at their base, which have resulted in crack paths and tile loss, as previously described in the analysis of the state of repair of the dome.

This worrying state of damage can be confirmed in the drawing of the thrust line, which, even if considerably simplified and substantially referred to a "masonry" dome (with no tensile resistance hypothesis and completely neglecting the encircling effect of the rings), is completely outside the section in the pendentives (Figure 79, right), thus anticipating the concentration of tensile stresses in their extrados, furtherly found by the FEA.

At the end of this graphic analysis, even very simplified, it seems possible to definitely exclude the hypothesis, as in the previous case, of a “pure masonry (catalan) dome”, which, with the present curvature and thickness, especially in this case, wouldn’t be safe.

Anyhow, Mery’s method, combined with simple equilibrium approach, has allowed to obtain the radial thrust force of 1/4 of the dome, in order to investigate the activation of possible damage mechanisms in the supporting system: the huge four angular pillars and the four beams inserted at the base of the pendentives, whose function - once again - has been definitely clarified by the combined results of numerical analysis and simple equilibrium approach.

2.5.2.2 Numerical modeling by Finite Element Analysis (FEA)

Based on the previous investigations, a finite element analysis of the dome was performed by Princeton University Group. The investigation focused on the primary concerns:

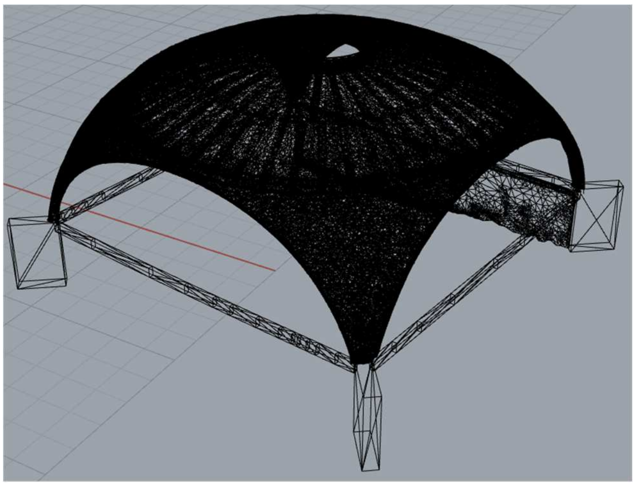
1) The performance of dome under variety of loading scenarios (dead load, live load, wind load, and differential settlement of supports);
2) The function and necessity of the tie beams;
3) The remaining strength in the pendentives.

Also in this case, as with the Choreography Theatre, a complete description of the numerical modeling process is reported in Annex 2 H (by Princeton University Group) attached at the end of this report. Hereafter we summarize the main issues and the final results, which, once compared and joined to the previous qualitative structural analysis, allowed us to advance some final conclusions on the real structural assessment of the dome and to hypothesize the most reliable intervention for its strengthening (and conservation).

Geometrical model and material properties

In order to create a 3D model of the classroom suitable for finite element analysis, a simplified, doubly-symmetric geometric model was derived from the laser scan geometry[75]. “Average” or representative cross-sections and elevation and profile curves were used to generate the idealized “undeformed” geometry, which is shown in Figure 80[76].

The structure is idealized as a continuous homogeneous solid, except for the dome which is modeled as a shell. The tile layers are not modeled separately from the underlying concrete: where tiles yet adhere to the concrete (such as the intrados of the pendentives), the tile and mortar layers are included as part of the stress-resisting cross-section[77]. For modelling steel reinforcement, ABAQUS supports the definition of steel reinforcing layers within composite shell elements as well as the embedment of steel truss elements within solids. These definitions were used to model the rebar layers in the dome shell in accordance with the construction drawings and photographs, as shown in Figure 81 (left).The meshed model is shown in Figure 81 (right).



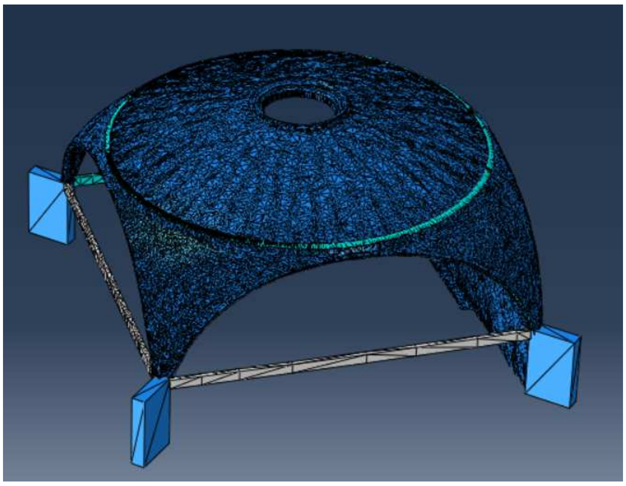


Figure 80 - Laser scan geometric (left) and meshed (right) models.

[75] See Annex 2 B of this report.

[76] Note that the geometric model does not include the “auxiliary members”, such as the perimeter walls, to which the pillars either attach directly or are connected by struts. Though these walls will provide additional lateral stiffness to the pillars, they are omitted for the analysis to first ascertain if the pillars are sufficient without them and to reduce the overall size of the model and the computational expense.

[77] Where the tiles are detaching from the surface (such as the extrados of the pendentives), they are not included in the member cross section.

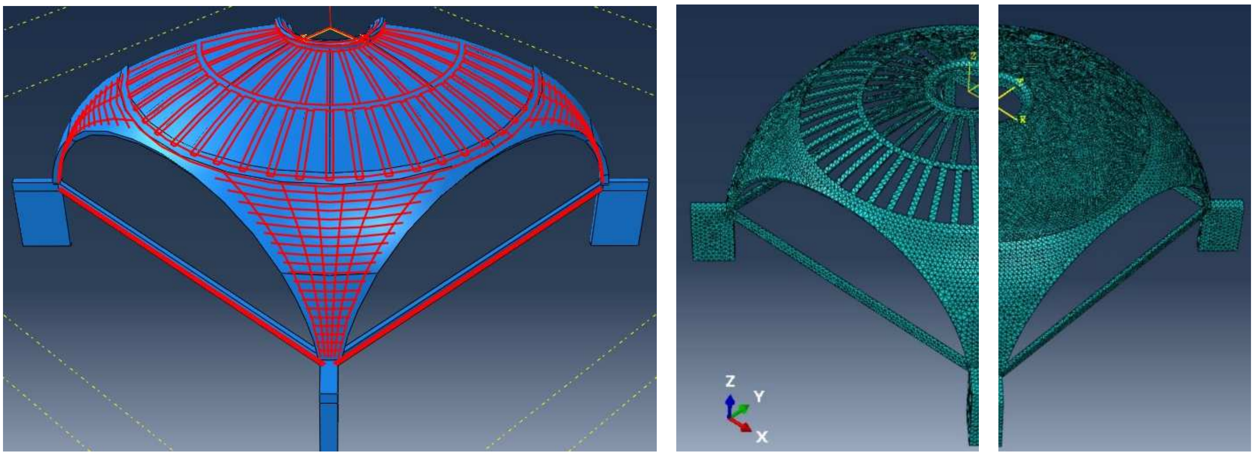


Figure 81 - Reinforcing bars and shells embedded within solid parts (left) and meshed models (center and right).

The material properties were derived from the on-site tests, where applicable, or derived from literature: a concrete strength of 40-50 MPa (3.9-4.4 MPa rupture strength) was used and a yield strength of 300 MPa was assumed for the historic reinforcing grade steel.

In order to model the damage occurring in the concrete at post-yield stresses and simulate the existing, damaged structure, a Concrete Damaged Plasticity (CDP) model was adopted in a further step[78].

Applied loads: numerical analysis results

The final goal of simulating the authentic, damaged structure was split into different phases in order to speed the analysis process. Two models have been analyzed under various loading conditions and the results are presented herein.

This two-part analysis comprises the following:

- Linear elastic model with dead, wind, and live loads and differential settlement of the pillars.
- Inelastic analysis with damage simulation (more refined mesh and CDP material model) in order to obtain a more realistic analysis of damage.

[78] CDP is a well-used and documented mechanical model that expresses the plastic strain and material damage (crushing in compression and microcracking in tension) as a degradation of the elastic stiffness from an initially linear elastic curve. Esfahani et al. (2017). For a complete description, see Annex 2 H of the present report.

Loads were selected for the analysis according to past and anticipated conditions:

- The roof live load will simulate maintenance workers and equipment for future repair activities.
- Wind pressure is a standard structural loading scenario. The applied wind loads range from 50-year to 700-year wind events. (A basic case of 1680 Pa, applied diagonally to a leeward and windward pendentive face, was used for the linear elastic analysis)[79].
- Differential settlement is considered due to the adjacent river, which is subject to seasonal floods that, not infrequently, cause water to flow through the school complex.

The magnitude of each of the applied loads is given in Table 13[80].

Table 13. Applied loads.

LOAD NAME	TYPE	VALUE (UNITS)	APPLIED LOCATION
Dead - self weight	Gravity body force	9.8•ρ N/m^3	Whole model
Gravity	Surface pressure, gravity	2390 Pa	Dome shell surface
Live roof	Surface pressure, gravity	960 Pa	Dome shell surface
Wind - basic	Surface pressure, normal	+/-1680 Pa	Dome shell, pend. surface
Wind, 50-year	Surface pressure, normal	875/-960 Pa	Pendentive surface (WW/LW)
Wind, 100-year	Surface pressure, normal	1040/-1140 Pa	Pendentive surface (WW/LW)
Wind, 700-year	Surface pressure, normal	1790/-1970 Pa	Pendentive surface (WW/LW)
Differential Settlement	Prescribed displacement	3 mm	Pillar base

For the differential settlement case, three different combinations of supports were subjected to settlement: a single support, two adjacent supports, and two diagonally opposite supports. The imposed settlements for each of these cases are described in Table 14, accompanying the given nomenclature.

Table 14 - Differential Settlement location, direction, and magnitude.

Support ID			Settlement Direction		Magnitude (mm)
DS1	Single pillar (4)		-L	Lateral	(3,3)
DS2	2 pillars (1 & 3), diagonal		-V	Vertical	3
DS2H	2 adjacent pillars (3 & 4)		-V+L	Combined lateral and vertical	(3,3,3)

[79] To determine static pressure wind loads on a structure, it is standard to follow the procedure of a design code such as ASCE 7 or EN 1991. The 50, 100, and 700-year wind loads were found using conservative simplifications that allowed these methods to be applied to the dome's irregular form.

[80] Linear elastic load combinations consisted of all possible combinations of dead load, roof live load, wind load, and differential settlement, excepting those that applied live load and wind load simultaneously.

Linear Elastic Analysis

In the following Figure 82 (left), the deformed shape of the structure under self-weight is plotted. As also observed in the site inspection, the beams have significant bending deflection. The deformed shape also shows maximum deflection in the upper dome above the arched openings (bright green-colored in the figure). This result is consistent with the laser scan model. When the wind load is applied (Figure 82, right) it slightly reduces the midspan deflection of the tie beams on the windward side of the dome, while the outward self-weight deflection of the dome is counteracted by the wind pressure on the windward side and exacerbated on the leeward side (the left, blue pendentive in the figure).

The principal stress plot for the entire structure under dead load exhibits stress concentrations at predictable locations (red zones in Figure 83 and Figure 84)[81]:

- the connections between the pendentives and pillars;
- the connection of the tie beams and pillars;
- the apex of the arches.

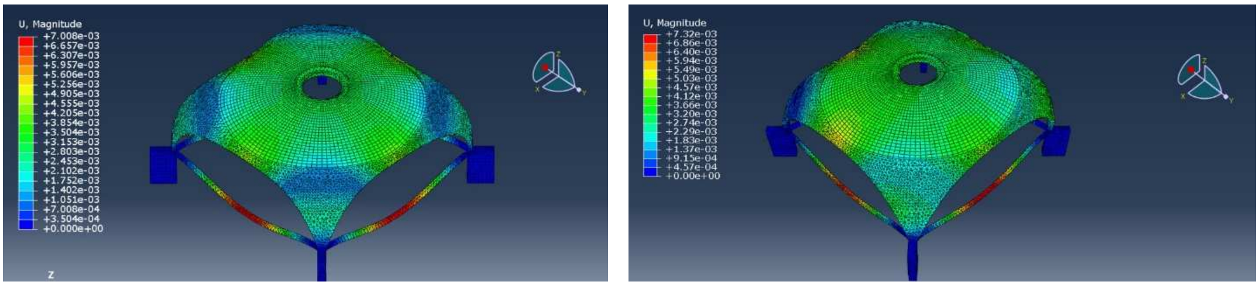


Figure 82 - Deflection magnitude in meters under dead load (left) and under wind load (right).

[81] At these locations, the principal stress is up to ten times the magnitude in other high-stress areas, such as the pendentive faces and arch apexes. This is likely due to two causes: 1) The high bending stress carried by a small section, such as typically occurs at bending member supports; and 2) an artifact of the mesh size and aspect ratio, which is larger and of poorer quality at that location.

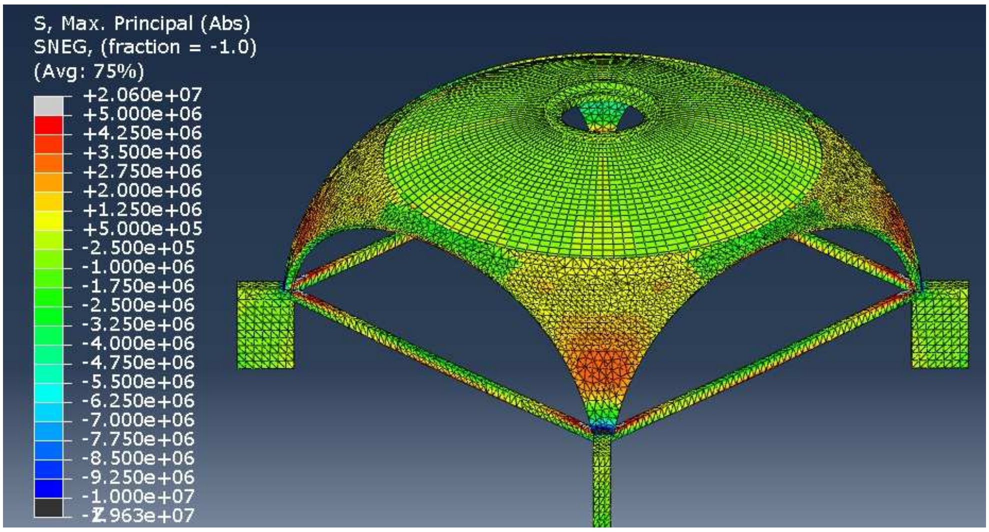


Figure 83 - Maximum principal stress under dead load for entire structure (excluding embedded reinforcement).

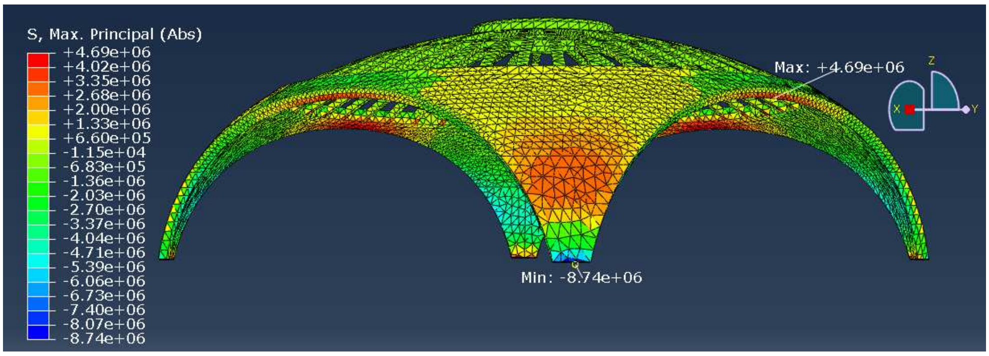


Figure 84 - Maximum principal stress in superstructure for dead load case.

Consequently, cracking is expected to occur at these locations in the model, as was visible during the site inspection.

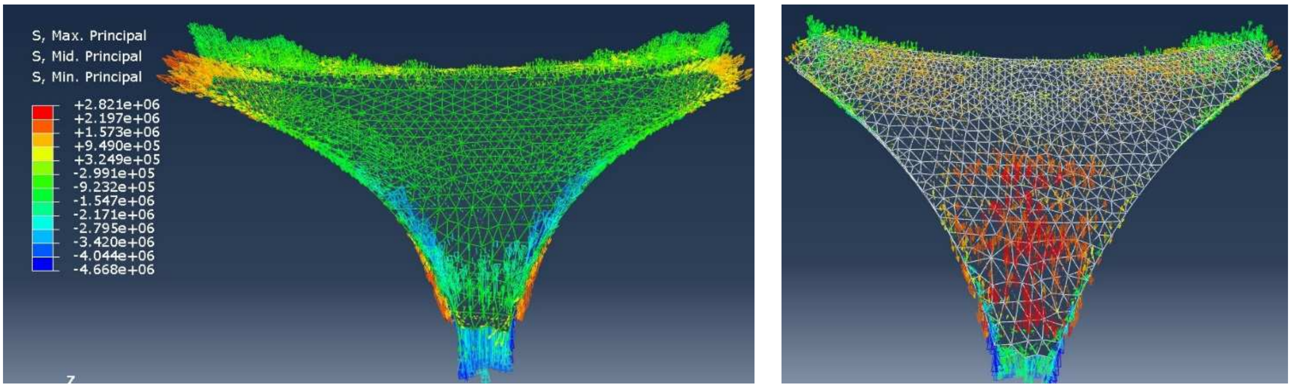


Figure 85 - Vector plot of principal stress within pendentives under dead load case (identical scale) for intrados (left) and extrados (right).

In Figure 85 is plotted the magnitude and orientation of the maximum principal stress in the pendentives, which can help in clarify their structural behavior: the maximum principal stress is directed parallel to and along the edges of the pendentive and is oriented vertically near the middle region of the pendentive. The tension and compression on opposite faces of the pendentives and arches demonstrate that the elements sustain bending stress. Moreover, the semi-vertical force vectors at the top of the pendentive have greater magnitude where the ribs frame into the pendentive.

The maximum and minimum stress results for the superstructure (shown in Figure 84) have been examined in detail, revealing that, at some location in the structure, the tensile principal stress exceeds the tensile strength for all cases. The most informative and critical cases (Table 15) were selected for deeper analysis.

Table 15 - Critical load cases.

	Load	Maximum Principal Stress		Maximum Principal Stress Location	
	Case	Tensile	Compressive	Tension	Compression
1	D	4.7	-8.7	Arch bottom	P1 base, outer face
2	D + DS	7.9	-14.5	P4 base, inner face	P4 base, outer face
3	D + Lr	5.2	-9.4	Arch apex (P4-P1)	P1 base, outer face
4	D + DS + Lr	8.2	-15.1	P4 base, inner face	P4 base, outer face
5	D + W	5.8	-10.4	P4 base, inner face	P4 base, outer face
6	D + DS + W	6.3	-11.6	P4 base, inner face	P4 base, outer face

The results of the finite element analysis for these six critical load cases have confirmed what is visualized in Figure 86 (left), which plots only one of the analyzed load cases but can be considered representative of the general results: for all cases the stress at the base of the pendentive (in 1D) exceeds the tensile strength (3.9 MPa), and in the middle region of the pendentives it exceeds the tensile strength for about half of the cases.

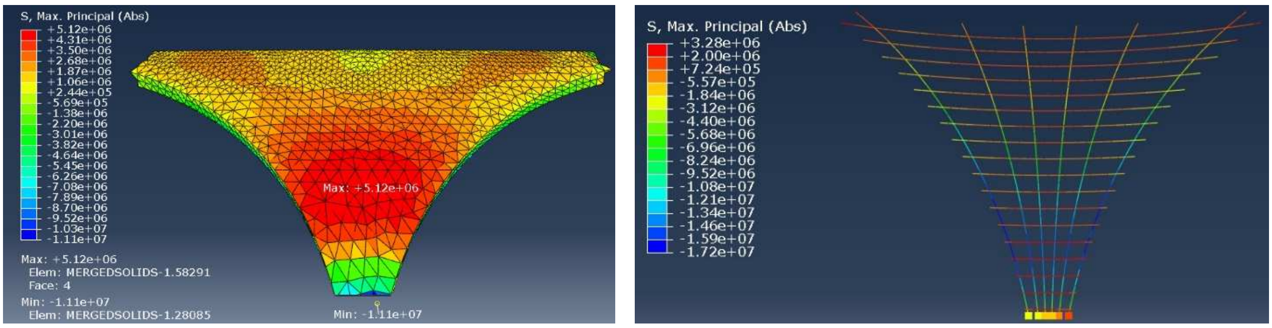


Figure 86 - Maximum principal stress under live load + settlement (left) and axial stress in pendentive rebar for dead load case (right).

The lack of tension stiffening due to the misplacement of the rebar in the pendentive cross-section - also anticipated by the graphic method results - is confirmed by the analysis results, as shown by Figure 86 (right), which displays the dead load stress results (in Pascals), with rebar compression appearing in the regions of highest concrete tensile stress.

As for the four tie-beams at the base of the dome, the finite element analysis has shown that they are not necessary for the stability of the structure under largely gravity loadings. They primarily function under bending, due to their long span and large weight, as indicated by the tension and compression on opposing faces along the beam, with the largest tension occurring at midspan (Figure 87, left).

Indeed, this result is fully consistent with the surveyed damage on these four beams: a significant deformation (deflection of about 4-5 cm at mid-span) and the loss of material in correspondence to the most stressed zones (Figure 87, right).

These data, coupled with the following assessment of the four pillars which demonstrates their efficacy in counteracting the horizontal thrust of the dome, seem to exclude any significant tensional work by these elements, thus refuting, at least in the "normal state" of the structure (dead and wind loading), their function as "tie rods" for the thrust of the dome.

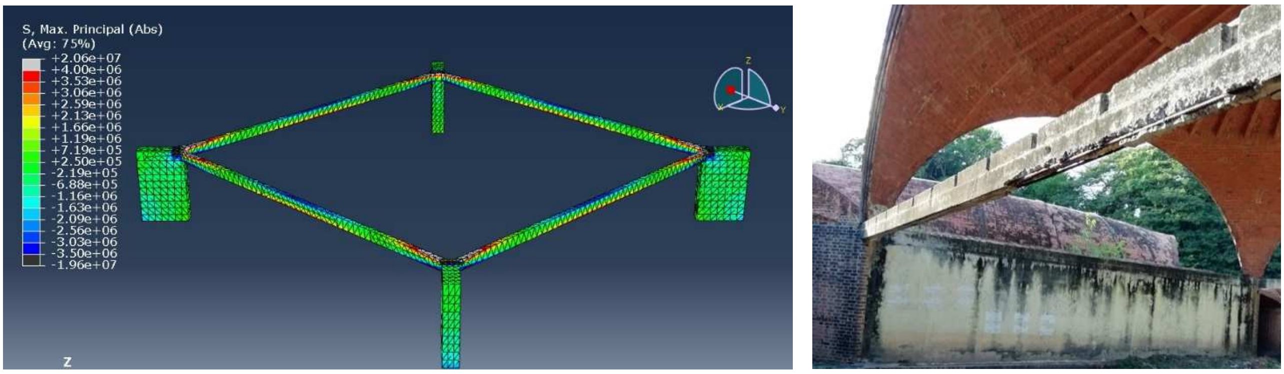


Figure 87 - Maximum principal stress in support structure under dead load (left) confirmed by the surveyed damage (right).

As for the four angular pillars, their typical reaction under the self-weight of the structure indicates that the pillars are fairly well-dimensioned for the dead loads carried, keeping the structure stable without requiring the lateral support of the tie beams (Figure 88, left).

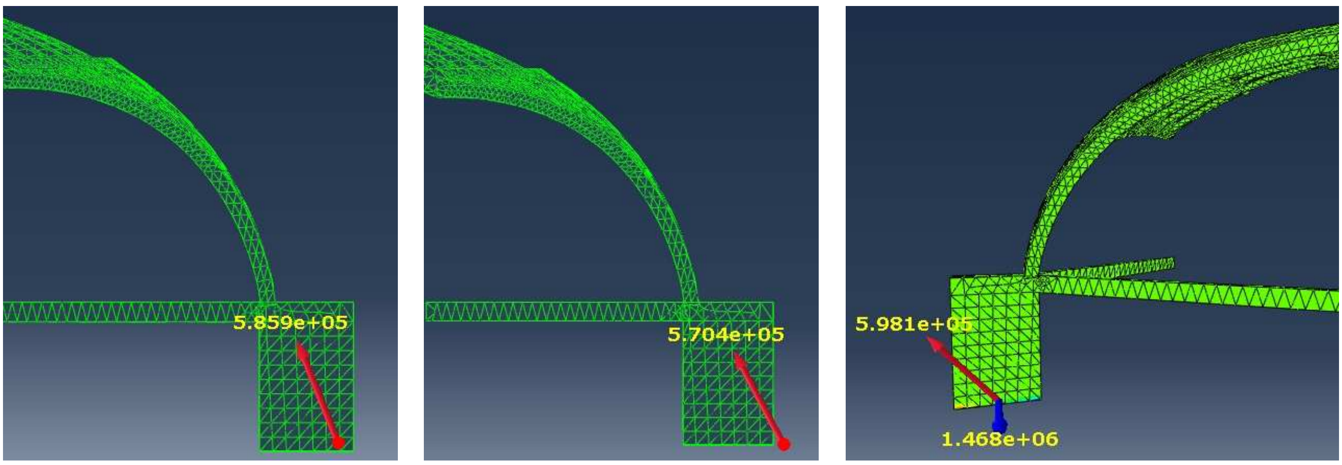


Figure 88 - Typical resultant force in pillars for dead load (left) and wind load (center) while, on the right, the resultant force (red) and moment (blue) in pillar are plotted for the most critical load case 4 (live roof + differential settlement).

Under the lateral wind load, the resultant force shifts about 0.24 meters outside the pillar cross-section (Figure 88, center), thus introducing the risk of overturning or tensile failure in the masonry pillar, which is maximum when even a small amount of settlement displacement occurs (Figure 88, right). Consequently, when a differential settlement occurs to the structure, additional lateral support is required for the pillars: in the real structure, it is either provided by the tie beams or the perimeter masonry walls to which the pillars are attached.

A simplified analysis of the pillars under the critical loads and the assessment of possible damages is reported in the following sections.

CDP Analysis

The linear elastic analyses explored the structure's behavior under various loading conditions. The CDP analyses focus on the progression of damage in models with different concrete grades, particularly under dead and wind loading, the most likely structural demands. The tensile damage plots are shown below for each of the concrete grades. For a detailed discussion of the models' performance, see Annex 2 H.

<u>CDP Model: 40 MPa Concrete</u>

For this concrete strength (40 MPa compressive strength and 3.9 MPa tensile strength), the structure fails under self-weight loading only. The damage progression from initiation to failure is quite informative, as shown in Figures 47-51 below.

[1] The tie beams and then the arch apex develop tensile cracking.

[2] The pendentive extrados, which is the tensile face, cracks under the applied self-weight. The tensile stress is then carried by the rebar at this location:

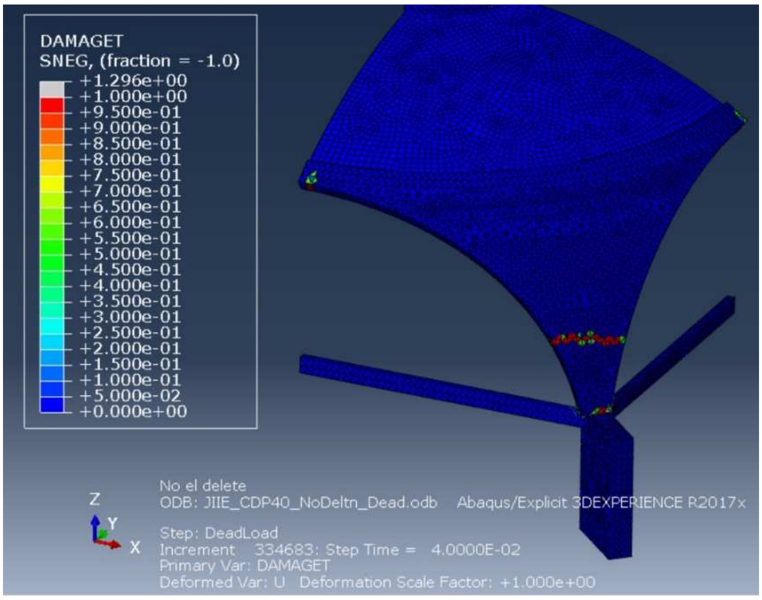


Figure 89 - Tensile damage stage 2.

[3] The pendentive crack quickly migrates across the cross-section. Cracking also develops at the third points of the arch:

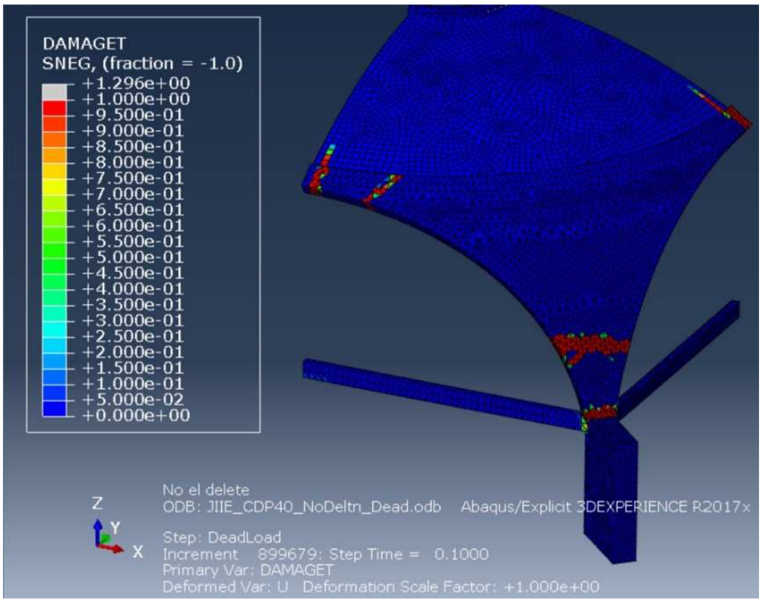


Figure 90 - Tensile damage stage 3.

[4] More cracks develop along the arch, with the pendentive continuing to deform under its self-weight:

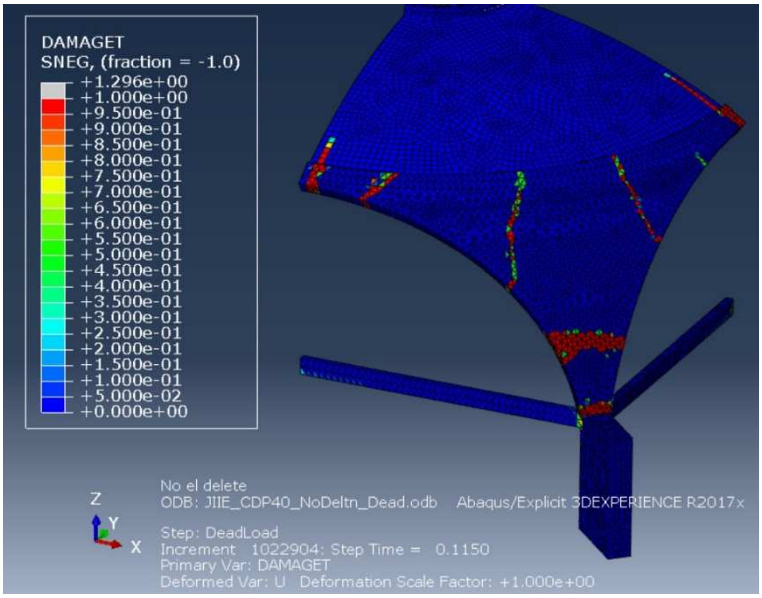


Figure 91 - Tensile damage stage 4.

[5] In the pendentive, the rebar yields in tension and the bending crack(s) continue to form. Radial cracks develop in the upper dome as the tension ring is compromised:

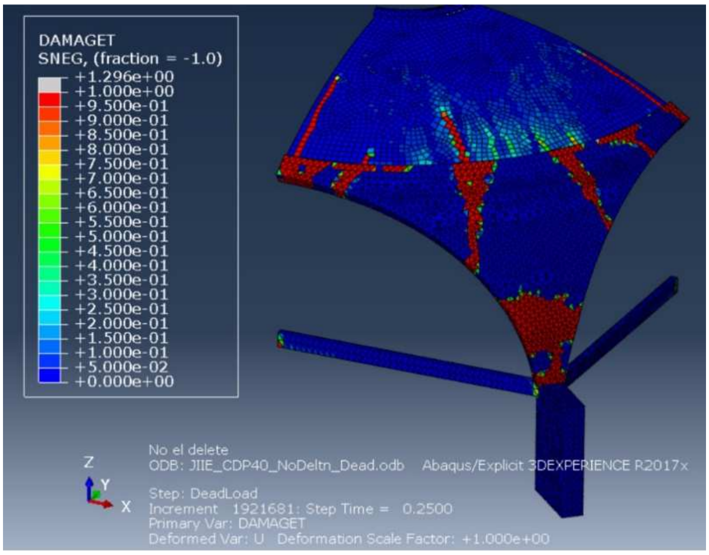


Figure 92 - Tensile damage stage 5.

[6] The radial dome cracks and horizontal pendentive cracks continue to develop until the pendentive has failed. The pendentives buckle outward and the structure collapses:

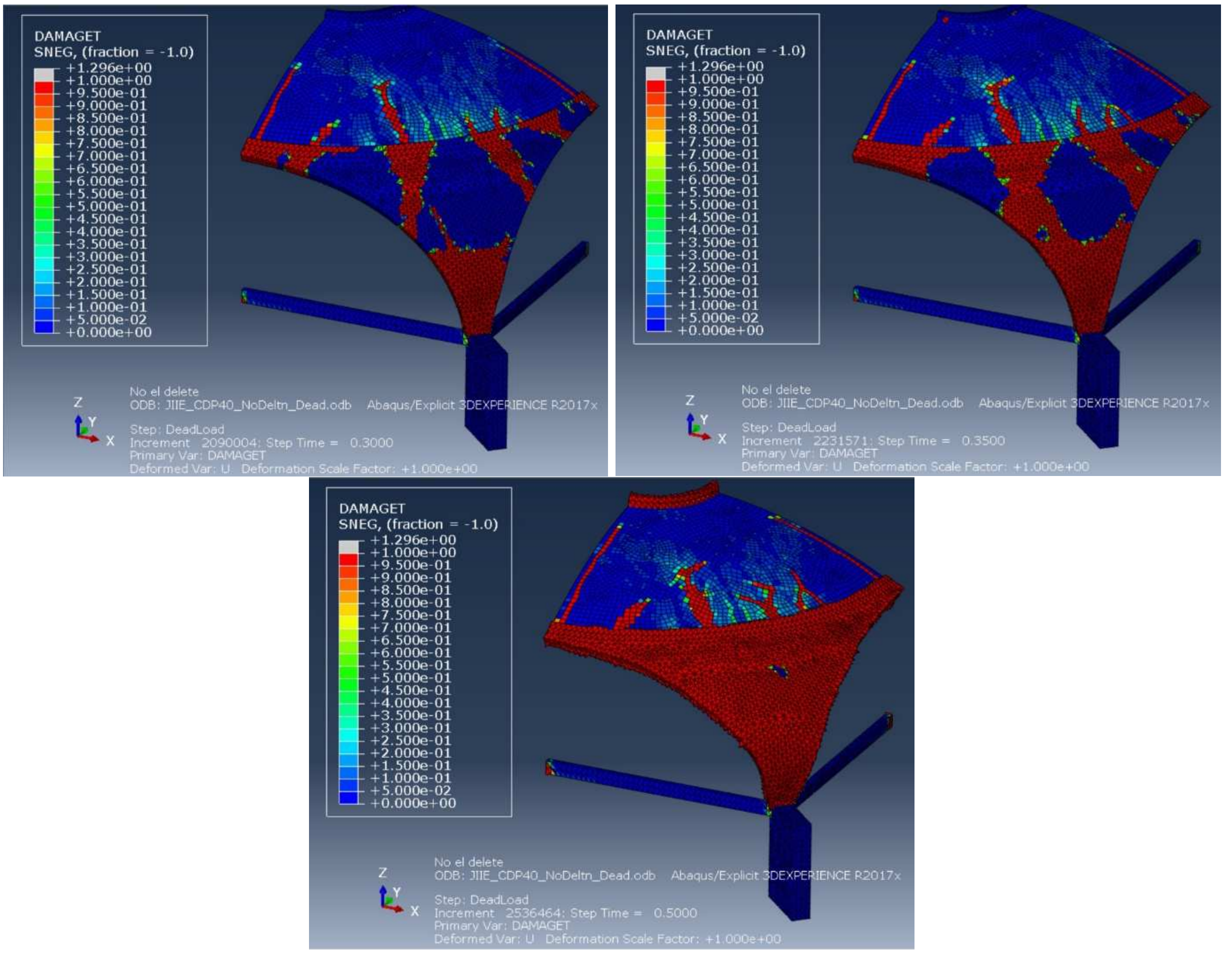


Figure 93 - Tensile damage stage 6 (failure stage).

From this damage progression, it is clear that several structural elements are critical. The pendentive rebar carries high tensile loads and, when yielded, allows the pendentive to buckle. The tension ring restrains the tensile hoop/bending stress in the upper dome. When it is compromised, the upper dome develops radial cracks which are part of the collapse mechanism.

CDP Model: 50 MPa Concrete

This model was subject to self-weight loads and wind loads ranging from 50-year wind events to 700-year (or hurricane level) wind events. With a tensile strength of 4.2 MPa, a 12% increase from the previous model, it sustained little damage other than the typical self-weight bending cracks in the tie beams. Slight arch apex cracking occurred under all wind loads but did not develop significantly.

CDP Model: 45 MPa Concrete

Current work focuses on a 45 MPa model which was created to further investigate the effects of concrete strength on the structural failure. Specifically, if the 40 MPa model fails catastrophically and the 50 MPa model is affected little by an extreme wind event.

The comparison of these three models' behavior are summarized in Table 16 below:

Table 16 - Comparison of damage levels in FE models of three different concrete grades.

Concrete Strength		Damage Description
f'_c [MPa]	f_r [MPa]	
40	3.9	Complete failure of pendentives and collapse of structure under dome self-weight.
45	4.2	Arch, pendentive, and upper dome damage (at minimum). Standard tie beam bending damage. Final behavior/safety not known.
50	4.4	Minimal tensile cracking at arch apex under self-weight + 700-year wind loads. Standard tie beam bending damage.

The process of damage development simulated by the CDP analysis, particularly the 40 MPa model, can help assess the current status of the real structure. As the real structure has tensile cracks evident at the pendentive extrados, arch apex/tension ring, and arch third points, its damage is well-progressed. Risk of failure is not imminent, according to the simulation, until the tension ring has been compromised and the vertical pendentive rebar has yielded. However, since the concrete cracking has potentially exposed the tension ring and pendentive rebar to moisture ingress, additional load may not be required to induce failure; time and degradation agents may suffice.

The CDP models exhibited damage such as that shown above: analyzed for the realistic load cases, the resulting global damage patterns correlated well to the current cracked condition of the dome, as predicted by the results of the graphic analysis and linear elastic FE analysis.

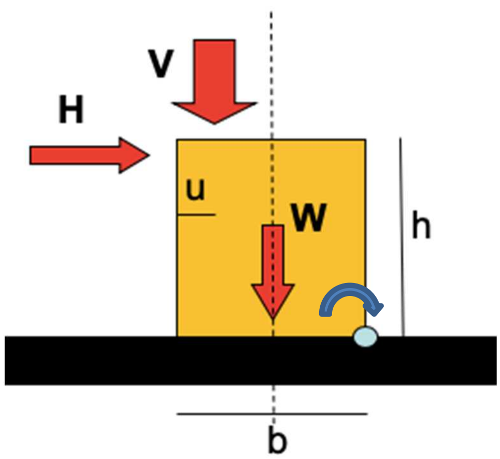
In sum, the numerical model results, particularly the linear elastic cases, show satisfactory agreement with the observed and measured behavior of the structure, thus confirming the reliability of the results, which is the first condition when dealing with existent structures, whose real material characteristics can't be defined with certainty. Due to the significant damage within the real structure, which indicates its strength lies closer to the 40 MPa model than the 50 MPa model, the structural reserve may be quite low. Additional load, support settlement, or unremedied deterioration will provide occasion for further damage to the structure, with potentially catastrophic consequences.

2.5.2.3 Pillar stability assessments

Also in this case, starting from the combined results of the previous graphic method and considering the maximum values obtained by the subsequent and deeper finite element analysis, some simplified calculations have been carried out in order to evaluate the assessment of the most demand-critical structural elements of the examined dome.

The in-site inspection, together with the finite element results, have shown that the four reinforce concrete beams at the base of the pendentives don't work - at least in "normal" condition of load - as "ties" for the thrust of the dome. Thus, considering the combined results of graphic method and finite element analysis, the stability of the four pillars has been considered, in order to verify their efficiency in counteracting the horizontal thrust of the dome. First analysis has regarded the possible turnover of the pillars under the horizontal thrust, by simple equilibrium approach. The results have confirmed what already anticipated by the FEA, showing a positive "safety index", as reported in Table 17.

Table 17 - Equilibrium of one of the 4 pillars at the base of the Dance Pavilion dome, considering its possible overturning.

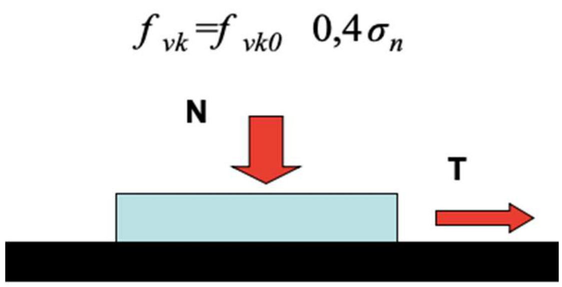


EQUILIBRIUM of the PILLAR		
h (height)	300.00	cm
b (lenght)	200.00	cm
t width	60.00	cm
weight distance (b/2)	100.00	cm
V dome	64000.00	Kg
H dome	37000.00	Kg
W pillar weight	6480.00	Kg
g specific weight	1800.00	kg/m3
u (distance)	18.00	cm
M rib	11100000	Kgcm
M stab	12296000	Kgcm
safety index	**1.11**	

The huge dimension of the pillars, and their structural organization in the space, counteract the possible overturning caused by the radial forces, at least in the two main load conditions (under gravity and wind action).

Moreover, the possible failure of the pillars for shear action has been verified. As in the previous case, the vertical load of ¼ of the dome increments the shear resistance of masonry (in the percentage of 40% of compression stress) and, as can be seen by the results (Table 18), in this case also the "safety index" for the pillars against shear failure is far greater than 1, thus leading to a (simplified) positive response for its stability assessment for this damage mechanism, at least in gravity load conditions.

Table 18 - Simplified assessment of the possible shear failure of one of the 4 pillars at the base of the dome.



shear failure PILLAR		
fvk	243.48	N/cm2
fvko*0.4 sigma		
fvd =fvk/gamma	121.74	N/cm2
sigma n max	592.59	N/cm2
fvko	6.44	N/cm2
tau 0	9.2	N/cm2
shear stress	30.83	N/cm2
safety index	**3.9**	

Also in this case, as evidenced by the finite element analysis, the most critical aspect is related to the behavior of the pillars under combined compressive and bending stress.

Considering the significant reduction of compression resistance for masonry in case of high eccentric loads (coefficient of reduction equal to 0.27, in step with the Italian Law), the Table 19 shows the pillars, which evidence a “safety index” insufficient to guarantee the stability.

Nevertheless, we have to stress that in this calculation the effect of the surrounding supporting structures (walls and floor slabs, reported near Table 19) is neglected, thus underestimating the pillar resistance capacity. Moreover, even inactive in normal conditions, we have to consider the contribution of the four tie beams in re-centering the load when possible displacements occur.

Table 19 - A simplified assessment of the resistance of the pillar to combined compressive and bending stress.

combined compressive and bending stress PILLAR BUCKLING RESISTANCE		
es vertical load	74.46	cm
(V*(b/2-u))/(W+V)		
es horizontal load	157.49	cm
H*h/(W+V)		
e 1	83.03	cm
m=6e/t	1.66	<2
l=h/t	5.00	
fd resistance	43	Kg/cm2
good mortar	1.5	
fi reduction resistanc	0.27	
reducted resistance	17.415	
safety index	**0.3**	

2.5.3 Conclusions and possible indication of intervention

2.5.3.1 Structural conclusions and possible indication of intervention on Choreography Theatre

After this combined structural analysis, some conclusions can be advanced on the stability of the Choreography Theatre dome.

As shown, in the FEA, the dome model was tested under three different loading conditions: regular gravity loading, hurricane wind loading combined with gravity loading, and settlement of two columns combined with gravity loading.

Under the gravity loading, slight deformations were observed as well as limited concrete damage at the intersection of the lower ribs and crown beam, but stresses were well below concrete strength in majority of locations, indicating that the structure is conservatively designed. Also under the hurricane wind loadings, as well, the structure was able to withstand the loads effectively although suffering more significant deformations as well as increased damage at the ribs-crown interface.

After the combined analysis (FEM analysis and graphic methods), the most at-risk parts of the structure are the connection of the outer ring of ribs and the thicker concrete crown[82]. Here, both the structural analysis and the visual inspection have evidenced the main stresses and deformation.

Moreover, considering the maximum stress highlighted by the FEA, some simple calculation have confirmed - together with the simplified graphic method - the general structural assessment of the dome which finds its critical point, in the eccentric load over the pillars at its base which simple calculation have shown

Despite this result is fully consistent with the visual inspection - which has evidenced some inclined cracks on the pillars, at the base of the ring beam - we have to underline that a failure mechanism doesn’t seem worrying, because the calculation of the effective capacity of the pillars have been reliably underestimated, neglecting the counteracting effect of the surrounding supporting structures.

Moreover, from the FEA, it’s clear that any significant settlement or removal of the masonry pillars could cause damage to the structure as well[83].

At the end of the structural analysis, it is possible to conclude that the dome of Choreography Theatre appears in good static condition, at least in case of “normal” loading (dead load and wind). More damages are predictable in case of differential settlements but, even considering the contemporary lack of two supporting pillars the dome doesn’t show failure mechanisms.

[82] Increased analysis of the connection between the lower ribs and dome crown, where moderate damage is taking place. This may include more observational studies of the damage in the dome at these locations and modeling of the dome shell as separate tiles and concrete in order to find a less conservative model.

[83] Despite no significant or failure-inducing global damage is predicted to occur in case of hurricane loading, a general inspection of the structure in the event of severe winds is recommended.

The most critical point is the lack of use and maintenance suffered during the last decades which provoked the advanced state of decay of some more exposed zones, as the direct result of the absence of an appropriate system of protection against water.

As already described, humidity is a relevant problem, and moisture has mostly affected the surface of the dome (both internally and externally), resulting in diffuse biological colonization and efflorescence, presence of vegetation on the extrados of the dome and diffuse tile loss.

This phenomenon has been exposing the structure to weathering leading to further water infiltrations.

What is more worrying are the corrosion phenomena that have been observed on the mezzanine reinforced concrete slab, which, in long period could involve also the ring beam at the base of the dome, thus compromising its structural safety.

In step with this, the interventions necessary for the conservation of this dome are not strictly "structural" but rather preventive, as:

- the impermeabilization of the extrados of the dome, with the insertion of a sheath and the repositioning of the external layer of tiles (which also the finite element model has confirmed as a "protective layer");
- hydric regulation of the near Rio Quibù, in order to avoid any settlement scenario which would provoke serious damage to the dome.

2.5.3.2 Structural conclusions and indication of intervention on the Dance pavilion dome

After this combined structural analysis, some conclusions can be advanced on the stability of the Dance Pavilion dome, considering the previous structural investigation.

The pavilion dome shows diffuse decay phenomena, caused by humidity (biological colonization, presence of vegetation, diffuse loss of tiles). This degradation phenomenon can lead to structural disease in the long term, exposing the structure to weathering (thus leading to corrosion of rebar and significant reduction of section).

As evidenced in the previous chapter, and confirmed by the FEA, these damages are not simply classifiable as “superficial decay or deterioration” issues but they reveal regions of high stress, indicating the critical elements whose further degradation can definitely compromise the structural efficiency and the integrity of the dome, which can be summarized as follows:

- <u>Pendentives high stress and deformation</u>

  Pendentives are the most critical elements, with cracking in the tile extrados and side layers and, where visible, in the concrete, as well as delamination of the tile layer from the interior concrete section. Tile loss in correspondence of the most solicited zones (extrados of the pendentives, around the hinges of the arches) and cracking and spalling on the inner, lower face of the apex of the arched opening, indicate the presence of tensile stress.

As confirmed both by on site investigations, graphic method and FEA, the faulty rebar placement (at the intrados) in the pendentives has compromised their durability and a significant portion of the cracks developed in the structure are likely due to creep under sustained dead load.

- Tension ring cracking and material loss/corrosion

  The CDP failure simulation indicates that the tension ring has significant effect on the structural integrity. The visible delamination of tile from the exterior top surface above the arches and from the inner surface at the arch apex reveals high tensile stress. There is also limited concrete or grout loss at these locations, which has in some places exposed the rebar. If allowed to develop, the continued section loss and rebar corrosion will shorten the life of the structure.
- Tie beams deflection and material loss/corrosion

  The second significant damage is the severe deterioration of the reinforced concrete beams at the base of the dome, which - despite not working in the "normal-load condition" as ties - may provide additional support to pillars in the event of differential settlement[84]. At the present situation, they show a consistent deflection (maximum at midspan), coupled with a diffuse loss of the concrete cover. Of course, since left exposed, the steel bars reinforcing the beams are starting to corrode, adding risks related to section reduction.

If no measure will be taken, in the long run the situation is destined to keep worsening.

For these reasons we suggest some interventions, which can be organized into a list of priorities based on the severity of the damage, defining the necessary interventions (to do as soon as possible) and the possible ones (which can be postponed over time).

Urgent interventions:

- strengthening of the pendentives, with the insertion of FRP reinforcement layers at the extrados (where the tensile stress is maximum), or, at least, at their base (the most solicited zones). This intervention could improve the resistance of the materials (about 10-15%) thus reducing the deformation and better supporting the existing high stress;
- This intervention has to be coupled with the impermeabilization of the extrados through the repositioning of the tiles after the insertion of a sheath beneath;
- beams repair, with the reintegration of the lost material in order to restore their resistance section and protect the rebar. The repair intervention should be better evaluated once verified the effective state of conservation of rebar (by some tests on the materials). In case of loss of resistance, an integration with iron ties (external to the section) can be hypothesized.

[84] The FEA has shown that the initial wind load (30 psf) was sufficient lateral force to require additional lateral support from either the tie beams or the auxiliary structure (masonry walls and struts) in the classroom.

- hydric regulation of the near Rio Quibù, in order to avoid any settlement scenario which would provoke - as in the previous case of Choreography Theatre - serious damage to the dome. Frequent flooding can trigger differential settlement and thus should be prevented.

Additional interventions:

- insertion of the originally drawn windows on the arches.
- After the repair of the apex of the arches, which has shown significant stress and damages, arched windows can be inserted in new materials (recognizability principle coupled with structural efficiency). The windows frame can help in supporting the arches, reducing their deformation (acting as structural centering of the arches).

The proposed interventions can assure the conservation of the dome, facilitating its reuse, which is the first guarantee of maintenance and valorization for existing structures.

2.6 Descriptive Worksheets

In order to collect and organize all the data before described, descriptive worksheet have been created. The final aim of this operation is both to increase knowledge and to enhance maintenance, preventing the complete ruin of the architectures and supplying useful details to guide possible future interventions.

Moreover, the main scope of these worksheet is to synthetize, by a numeric index, the current conditions of the structures composing the School of Arts, prioritizing interventions for their conservation. Indeed, since resources are limited, and the amount of work to be done is considerable, it is necessary to set an order that, considering several different aspects, reflects the level of risk affecting the integrity and preservation of the five buildings.

The worksheets have been structured with the purpose of being:

- Uniform: the format of the worksheet must be the same for each described structure to make both completion and easier consultation;
- Inclusive: the worksheet needs to include as much information as possible;
- Implementable: it must be possible to add further data to the worksheet, either resulting from further investigations or to record the most recent maintenance interventions;
- Accessible: the worksheet must be easily editable and accessible to different kinds of users.

With the hope that this instrument will reduce the risk of information loss, three worksheets[85] have been produced and are attached to the report[86]. The idea is that, in the future, many other worksheets will be filled in by local professionals, gradually creating a complete catalogue containing a description of each vaulted roof of the School complex.

2.6.1 Structure of the worksheets

As the first objective of the worksheets is to indicate a priority index, the cover page of the dossier briefly summarized the contents. A first table (Figure 94) provides the overall priority index - which evaluates the conditions of the whole building - and a few general data regarding the specific dome. The overall priority index represents the average value resulting from the priority indexes assigned to each individual constructive element composing the structure. It configures as a number ranging from 1 to 10 (being 1 low priority and 10 extremely urgent). A second table (Figure 95) lists all the different constructive elements. Each item is briefly described and is associated with a priority index as well. This partial index is the result of an algorithm which takes into account both the architectural value and the state of repair of the building.

[85] Two regard the School of Ballet (Choreography Theatre and Dance Pavilion), one regards the School of Music.
[86] See Annex 2 I.

Priority	
Architectural value	●●●●○
State of damage	●●●●○
Description	
Mixed structure dome: concrete framework with clay tile covering	
Use	
Original	Choreography theatre
Current	Dismissed
Maintenance	
Overall usage	Shortly as a circus school
Later interventions	None
Focus points	
Strenghts	High quality of building materials
Weaknesses	Complete lack of maintenance

Figure 94 - Worksheet: brief overview of the general conditions of the analyzed building.

3 | Rings

Description	
The bearing framework of the dome comprehends four reinforced concrete rings	
Priority	**8**
Architectural value	●●●●○
State of repair	●○○○○

Figure 95 - Summary description of the individual constructive elements composing the analyzed structure.

Architectural value comprises two criteria, namely the *consistency with the original design*, (hence the authenticity of the object) and the *technical complexity*, better explicated in the following Table 20.

The structural and conservation aspects are synthetized by the second index, the state of damage, which also takes into account the aspects related to *material decay* and those deriving by structural analysis (*structural issues)*. In the tables score attribution is better explained, textually motivating the score appointed to each entry.

The following sections in the worksheets also regard the global structure, providing information regarding its main dimensions, structural organization, building techniques and current state of damage (Figure 96).

Table 20 - Table illustrating the assessment criteria adopted to establish the priority index.

Architectural value	●●●●●
The assessment on the architectural value of the global structure, as well as of its singular components, takes into consideration two main aspects: its consistency to the original design and its technical complexity. Each field has been evaluated on a scale from 1 to 5. The number of points to be associated with the general item "Architectural value" is the result of the average among the subfields.	
Consistency with the original design	●●●●●
This item evaluates the authenticity of the object considering both its coherence with what was originally designed by the architects ("accuracy of construction") and possible later interventions which might have altered the original configuration or materials of the structure.	
Technical complexity	●●●●●
This subfield focuses on the technical complexity of the structure/element in terms of innovativeness, construction techniques and scientific interest in general.	

Table 21 - Table illustrating the assessment criteria adopted to establish the priority index

State of damage	●●●●●
The evaluation of the state of damage of the whole structure, as well as of its singular elements, takes into consideration two main aspects. On one side there is the physical decay of the building materials, on the other it is important to considerate possible structural issues that might be intrinsic of the building or developed over time. Each of these items has been evaluated on a scale from 1 to 5, considering the maximum value corresponding to high damage. The number of points associated with the general field "State of damage" is the result of the average among its subfields.	
Material decay	●●●●●
This field focuses its attention on the current condition of the building materials employed in the construction. Some of the schools have undergone restoration interventions during the years, but others have never been used nor renewed and are currently abandoned, completely lacking maintenance. The decay of the building materials might hence be owed to ageing, natural causes (biological colonization, plants growth, exposure to weathering) or human activities (vandalism, microdestructive diagnostics). Also in this case, the more decay correponds to the maximum score.	
Structural issues	●●●●●
Close attention must also be paid to identify possible structural issues. Hints can be provided by deformations and crack patterns. It is also important to verify the suitability of the dimensions of each element, in order to evaluate its effectiveness. In the lack of proper structural analysis, the index aims at synthetizea qualitative evaluation of the structural conditions of the elements (0 correponds to good conditions)	

State of repair	
	The lack of upkeep results in frequent plants growth at the extrados of the dome. Shrubs have grown into the interstices of the roof tiles or between the ribs of the dome's joints. The roots, extending through the layers composing the roof, have generated cracks and lifted up the tiles, causing their partial or total detachment from the lower layers. This phenomenon has been exposing the structure to weathering leading to corrosion and water infiltrations (as visible at the intrados).
	The joints between rings and ribs and between ribs and the catalan vault have proved to be delicate points, as they are subject to water infiltrations. Water leaks from the joints and runs along the dome creating humidity stains and saline efflorescence.

Figure 96 - Summary description of the individual constructive elements composing the analyzed structure.

A particularly relevant table is the one dedicated to the general assessment of the structure, were by comparing original drawings, construction site photographs and current state of the art, it is possible to better verify the actual consistency of the building with the architect initial idea.

A detailed survey of deterioration paths is also reported in this section, providing information regarding the current state of repair. However, since decay keeps progressing until measures are taken, the degradation mapping will need to be constantly updated. This will also help monitoring the situation, preventing major damages to occur.

The second part of the worksheet focuses on individual constructive elements, basically configuring as a collection of independent sub-worksheets. In general, each sub-worksheet supplies the same type of information listed above, although on a more detailed level. Data are organized and sorted in the same order in every dossier.

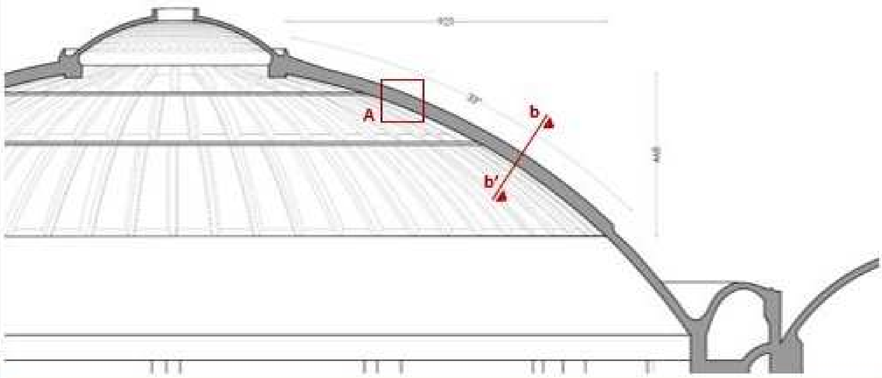
Each element is illustrated by means of a brief textual description, two larger scale drawings identifying its location within the structure and a series of small-scale constructive details indicating precise stratigraphy and rebar arrangements (Figure 97). A further table is dedicated to the state of repair of the specific element, highlighting the main issues and identifying their possible causes. At the end of the sub-worksheet there is a recapitulatory table where to assign the scores to define a partial priority index (Figure 98). The third (and final) part of the worksheet contains a chronology of the diagnostic analyses that have been carried out on the building, also recording a few specifications such as the professionals involved, the equipment employed and any possible reference to the produced results. Two further tables are dedicated to the external references and materials consulted while filling out the worksheet, and especially archival documentation, literature and technical reports.

4 | RIBS

Building Technique

The dome has a total amount of 112 ribs. However, **only 16 of them create one continual rib from the oculus to the crown**, while the others only cover a reduced span (from one ring to the next).
The ribs have been built by pouring cement inside wooden workforms internally covered with a layer of clay tiles, which hence configured as "disposable formworks". For this reason, both at the intrados and at the extrados the concrete structure appears hidden by the external masonry, composing a mixed-structure.
The number, dimension and location of rebar has not been verified directly, although several pictures from the building site seem to confirm the arrangement illustrated in the original drawings by Vittorio Garatti.

Section AA' | 1:100



Details

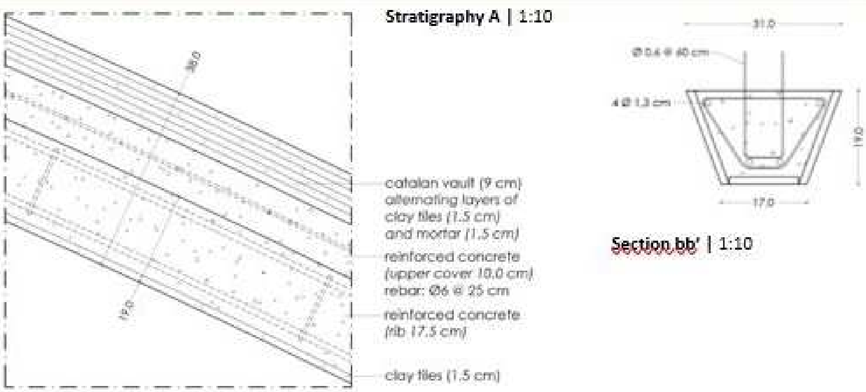


Figure 97 - Table illustrating the assessment criteria adopted to establish the priority index.

Priority		9
Architectural value		●●●●●
Consistency with the original design	The current configuration of the catalan vault is consistent with arch. Vittorio Garatti's original drawings	●●●●●
Technical complexity	Reinforced concrete ribs casted on-site by pouring cement into wooden workforms internally covered with a layer of clay tiles	●●●●○
State of repair		●●●●○
Material decay	The deterioration is punctual, mosłty related to humidity and vegetation. Water infiltration cause the decay of the clay tiles	●●●●○
Structural issues	Deformations	
	Suitability of dimensions	
	Cracks	

Figure 98 - Table reassuming the priority index.

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Action 2: Conservation and restoration activities

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Action 3

Landscape management and flood risk assessment and mitigation

Action 3: Landscape management and flood risk assessment and mitigation

Action 3 of the project is focused on the flood risk of Rio Quibù. Indeed, the sustainable restoration and revitalization plan of the *Escuelas Nacionales de Arte* site must include mitigation of the high flood risk, thus designing flood mitigation measures capable of reducing both hazard and vulnerability. Flood risk assessment and mitigation for the *Escuela de Artes* area is a primary objective of the revitalization process, as stressed by recent literature on heritage structures. Among the areas of the National School of Art that can be flooded, the School of Ballet is the major candidate to be flooded because of topography, river morphology, building location and pattern, and inadequate flood defense facilities, as experienced during the October 2007 floods.

Here, we pursued a number of tasks required for the proposed project, namely

1) Risk Assessment at the drainage basin scale;
2) Collection of hydro-meteorological data for flood hazard evaluation;
3) State-of-the-art flood scenarios;
4) Flood risk mitigation.

Risk assessment at the basin scale was basically mutuated from the available base of knowledge.

A large lack of meteo-hydrological information prevented us from being able to develop ad hoc design flood scenarios.

However, after proper discussion with personnel of the *Instituto National de Recursos Hidraulicos* INRH, we were able to work using a proper design flow scenario, produced as a basis for the design of flood countermeasures in the area of interest.

The scarce hydro-meteorological database available and reference works in the literature could be used for a qualitative benchmarking of design floods.

On-site analysis provided here much ground for flood risk assessment. Visual analysis of the situation locally, including inspection of flooded sites and flood marks, state of protection measures, and hydraulic structures, and interaction with local experts, gave us a rather clear picture of the local flood risk, so aiding numerical elaboration thenceforth.

We locally gathered hydraulic information of some flow sections of the Rio Quibù and of stream flows thereby, which, together with topographic information gathered at the fine spatial resolution, allowed us to construct a well-constrained conceptual/physical model of flood inundation of the area to be subsequently used for the conjecture of flood proofing.

Using some reference design flood scenario (for defined return periods), we were able to define flood maps, including areas, flow depth, and velocity, with decreasing frequency of occurrence, and thereby indicate a hazard level with the associated intensity of flooding (e.g., hydrodynamic pressure, etc.).

Coupling this analysis with cartographic-based assessment and local investigation, we were able to define the different levels of hazard, exposition, and vulnerability of structures in the area and thereby define a ranking of priorities for intervention.

The focus was clearly cast upon the school of ballet, but a number of other structures were labeled as weakly-to-strongly exposed to flood risk.

Based upon such, we then provided an array of possible options for flood mitigation in the area.

Based upon the available literature and internationally acknowledged standards, we defined possible, temporary, and permanent solutions that could be implemented in the area for dampening flood risk, with reference to scenarios close to events with return periods nearby $R = 100$ years the structural solutions as indicated by the INRH, namely construction of a wall surrounding the ballet school (riverside), demonstrating its efficiency against the 100 years flood. However, widening of the stream in the Country Club area as proposed thereby seems not as efficient.

Eventually, our work as here reported built a relevant base of knowledge for quantitative assessment of local flood risk in the *Escuelas Nacionales de Arte* site and provided an array of suggestions for brainstorming of possible solutions and subsequent design thereby.

Detailed design of countermeasures against flood risk clearly requires proper consideration and specific assessment locally.

However, our results here provide a robust, scientifically based tool for the management of flood risk in the area, usable henceforth for local policymakers and technical authorities.

3.1 Risk factors associated with floods in the Rio Quibù catchment

In this action, we identified flood risk factors in the Rio Quibù catchment. Using an array of information, including field surveys, collection of data, and modeling effort, we could gather, at least at a qualitative level, information on the main factors affecting flood risk in the area.

3.1.1 Field survey on critical factors affecting schools' buildings inside park area as regards flood risk and surface runoff

During June 2019, a field survey from personnel of PoliMi was specifically devoted to the assessment of critical factors and situations affecting hydraulic/flooding risk in the area.

A number of more criticalities arose during the field survey, carried out along the Rio Quibù, within the area of the schools' park, and further downstream until the river mouth. These criticalities will be briefly illustrated here and, when relevant from the points of view of risk analysis and assessment will be discussed in deeper details in the next paragraphs. Below, a list of notable points and topics, and below and a map showing their location.

A. The ruined bridge to reach Ballet building coming from music;
B. The interrupted floodwall alongside the Ballet school area;
C. The unprotected riverside alongside the Ballet school area;
D. The bridge of 15th road;
E. The external perimeter of Ballet school area just before the bridge of 15th road;
F. The bridge to reach the rectorate building at the center of the park;
G. The culvert below the way to reach the rectorate building;
H. The bridge to reach the Drama school building;
I. A hold artifact inside the Rio Quibù;
J. The road aside from the hill from upstream of the school of Ballet;
K. The soil depression inside the Ballet school area unfavorable to the outflow of water.

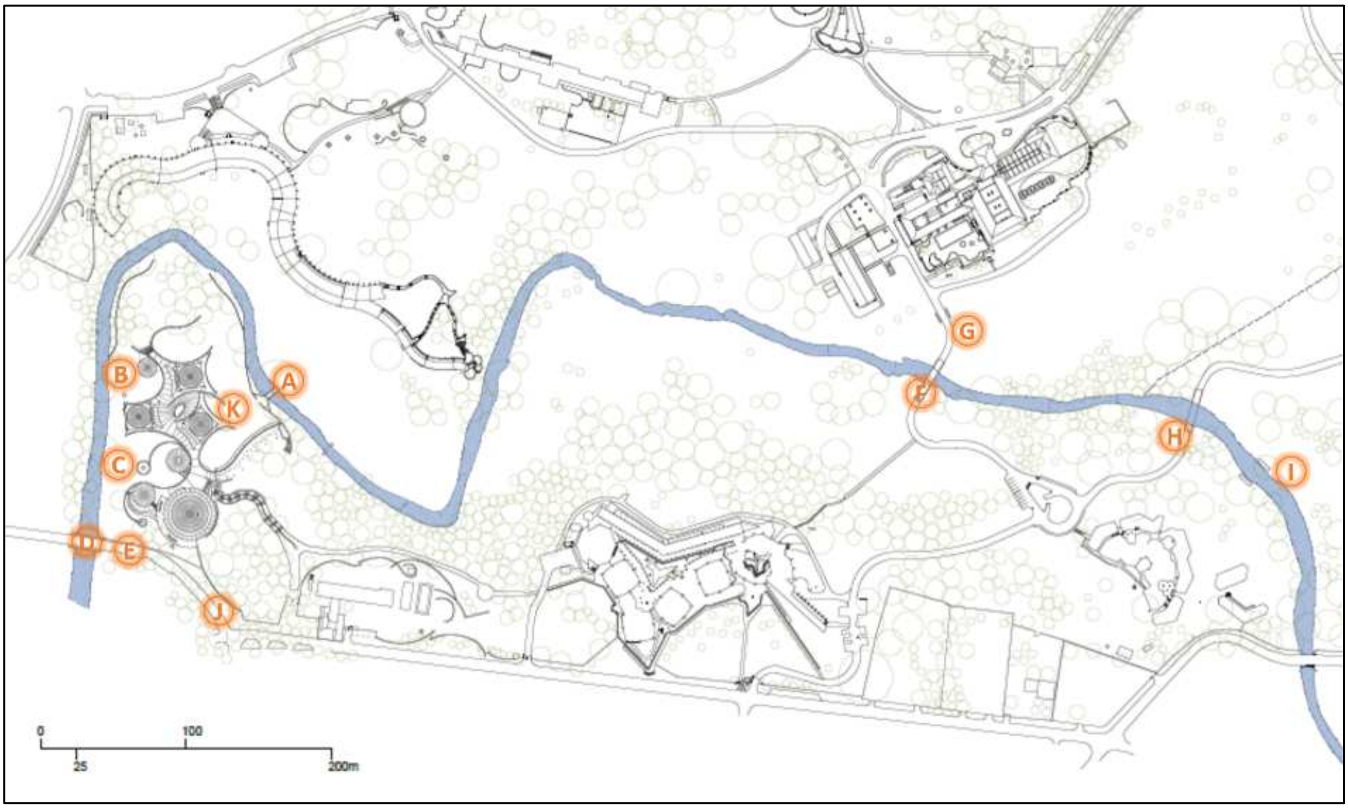


Figure 1 - First criticalities found during field survey in the Schools Park area.

Figure 2 - The ruined bridge to reach Ballet building seen from upstream - Criticality A (Bignami D.F., 2019).

Figure 3 - The ruined bridge to reach the Ballet building seen from downstream - Criticality A (Bignami D.F., 2019).

Figure 4 - The interrupted floodwall alongside the Ballet school area- Criticality B (Bignami D.F., 2019).

Figure 5 - The unprotected riverside (Ballet school area) - Criticality C (Bignami D.F., 2019).

Figure 6 - The unprotected riverside (Ballet school area) and the bridge of 15th road - Criticality D (Bignami D.F., 2019).

Figure 7 - The external perimeter of Ballet school area (inside view) - Criticality E (Bignami D.F., 2019).

Figure 8 - The external perimeter of the Ballet school area (external view) - Criticality E (Bignami D.F., 2019).

Figure 9 - The bridge to reach the rectorate building at the center of the park - Criticality F (Bignami D.F., 2019).

Figure 10 - The culvert below the way to reach the rectorate building - Criticality G (Bignami D.F., 2019).

Figure 11 - The bridge and the culvert along the way to reach the rectorate building - Criticalities F and G (Bignami D.F., 2019).

Figure 12 - The bridge to reach the Drama school building - Criticality H (Bignami D.F., 2019).

Figure 13 - A hold artifact inside the Rio Quibù - Criticality I (Bignami D.F., 2019).

Figure 14 - The road aside from the hill from upstream of the school of Ballet - Criticality J (Bignami D.F., 2019).

Figure 15 - Ballet school: soil depression and slope unfavorable to the outflow of water - Criticality K (A. Garzulino, 2019).

Overall, the findings of the survey indicate that:

- the area of the ballet school, and in general the low country club area is prone to sudden river flooding during large storms (approximately $R > 5$ years), when the Quibù river receivers large water contribution from its upstream watershed.
- likely, the area of the ballet school is also prone to local (pluvial) flooding when rainfall intensity exceeds the infiltration capacity of the soil.

The high chance of flooding is clearly visible from several shreds of evidence, including the largely damaged state of local structures, such as bridges, culverts, piles, as well as the evidence of large clusters of (dead) vegetation (woody debris, and wood jams), accumulated everywhere in the area, and clearly carried by large flows during floods. Also, the largely damaged walls surrounding the ballet school island, which was originally designed to protect the school, results in easy flooding of the Rio Quibù river.

Some structures were clearly designed to cope with flooding risk (e.g., the rectorate bridge culverts). However, while such structures can help post-flood recovery (i.e., by aiding water flow back to the river), they cannot dampen flood water effects in the area (i.e., lowering of water level) or protect the structures from water pressure whenever the flood would reach.

Also, the *puente quince* (bridge on the 15th street) may act in some circumstances as a clogging factor (especially in the presence of in-channel vegetation and/or of wood jams at the channel bottom), so helping water level rising.

Indeed, the present project for flood risk mitigation would require uplifting and re-lining of the bridge, as commented further on.

River flooding represents the main, or largest risk, in terms of flooding volumes, and accordingly, we focus here upon flood mapping in response to large storm events.

Pluvial flooding entails lower volumes, concentrated in the Southern part of the ballet school area, and in principle, it could be easily avoided by building a ditch, carrying water into the Rio Quibù river, whenever the river flow would be lower than the lawn level at the school (and being flooded anytime else).

3.1.2 Urban coverage, land-use changes, and climatic trends

Here we first gathered information on the morphology of the Rio Quibù catchment, and specifically of the elevation (i.e., using a digital elevation model DEM), necessary to provide hydrological modeling for flood assessment purpose (Bozza et al., 2016).

We used a DEM coming from ASTER-JAXA mission, with a resolution on the ground of 30x30 m^2. Second, we gathered information about critical areas within the catchment, leading to the potential hazard of overflowing of the river levees and borders.

As a basis for further deepening during a specific field survey, we have gathered information of critical sites along the Rio Quibù river, deduced from a 2006 study "Propuesta para la solución de evacuación de las aguas del Río Quibú", from the Instituto Nacional de Recursos Hidraulicos INRH.

Among others findings, the study gives indication of reference flood with given probability of 1% (return period T = 100 years), as "Actualmente el puente de 5ta Ave solo permite evacuar 36.0 m3/seg., siendo necesario la evacuación de 125 m3/seg., para una lluvia de 341 mm en 24 horas, que representa una probabilidad del 1 %."

Also, the study would provide suggestions for some possible mitigation actions and expected costs.

Further, the study provides an indication of some potential hotspots for overflow risk along with the urban trait of the river, including in the area of the school of ballet.

This available piece of information was integrated into our study, together with a direct assessment based on local surveys to document the present situation, and used for assessment of critical hotspots.

Concerning extreme rainfall (storms) in the Island, we found a study dating back to 1983 (Diaz Arenas, 1983) concerning the dynamics of tropical storms in Central America and the Caribbean, also including info on Cuba.

The study was used to recent benchmark estimates of peak floods, and relate return periods, implementing critical storm method, and derived distribution approach (Bocchiola and Rosso, 2009).

No further info was, however, available to us concerning extreme storms or recent climate trends.

Accordingly, in lack of data for extreme storm modeling in the area, and for consistency with the present state of the art, we relied on flood design (peak flows during floods) upon the available estimates from the INRH.

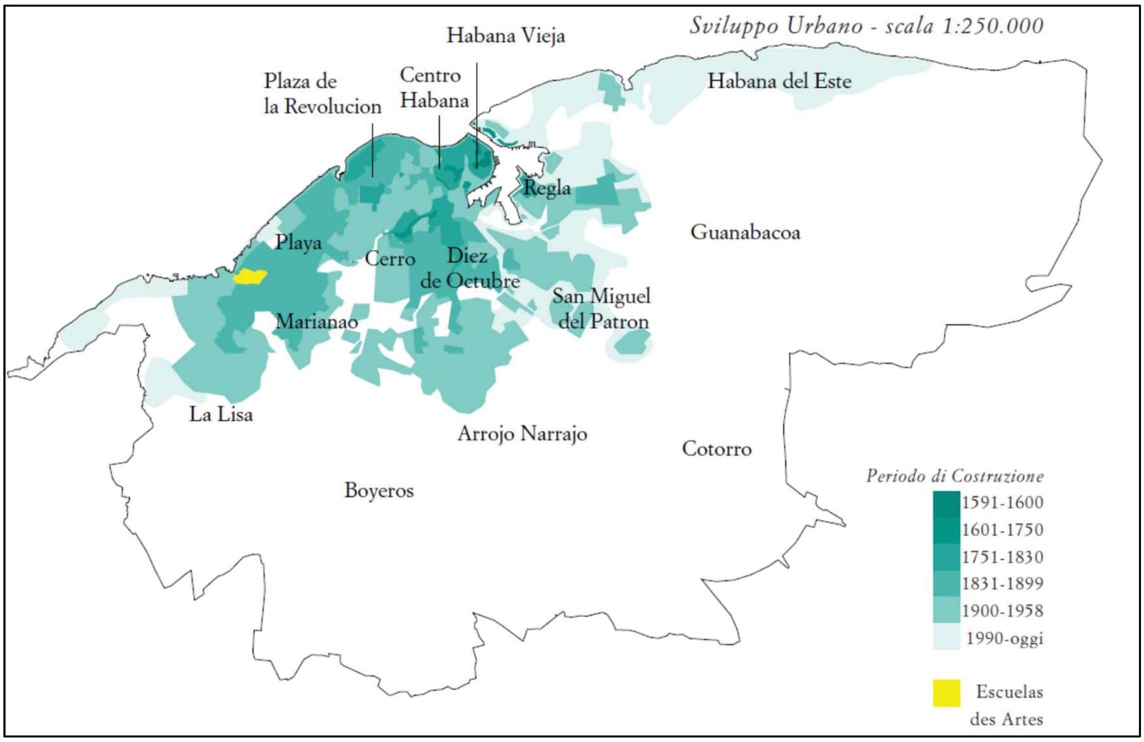


Figure 16 - Habana urban coverage history (image by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, student group 6: Marta Chiara Gobbo - Eva Maria Ronchi - Veronica Tamanza - Francesco Turrini).

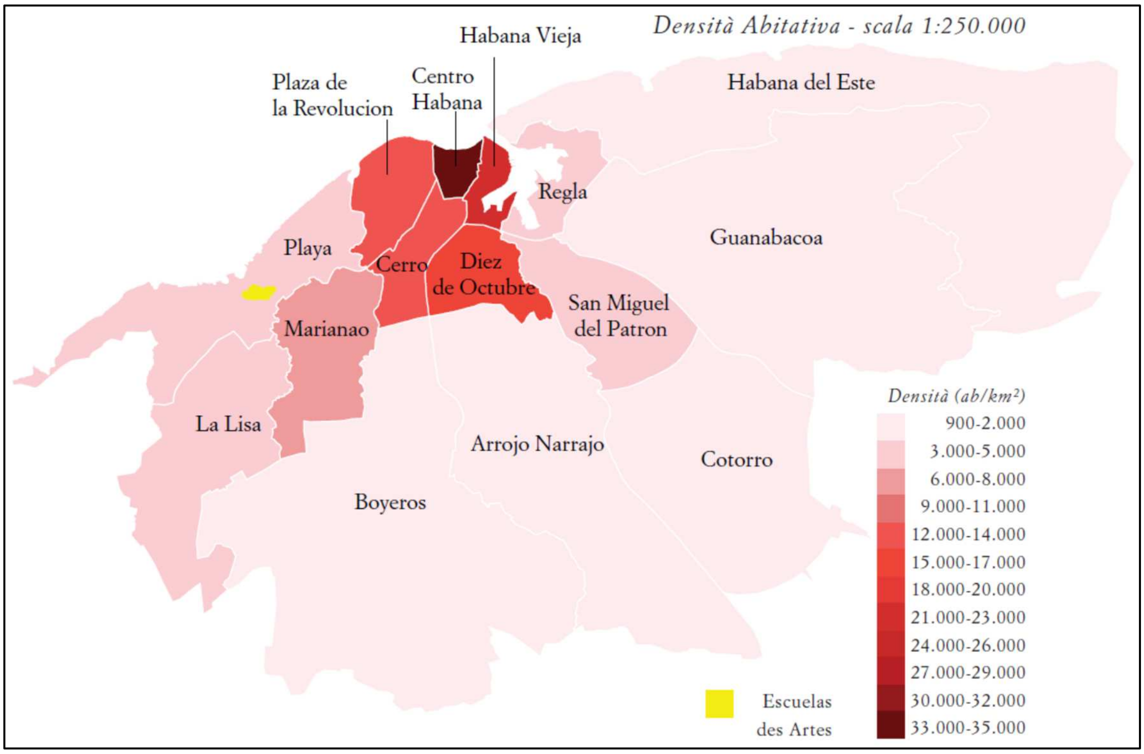


Figure 17 - Habana population density (image by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, student group 6: Marta Chiara Gobbo - Eva Maria Ronchi - Veronica Tamanza - Francesco Turrini).

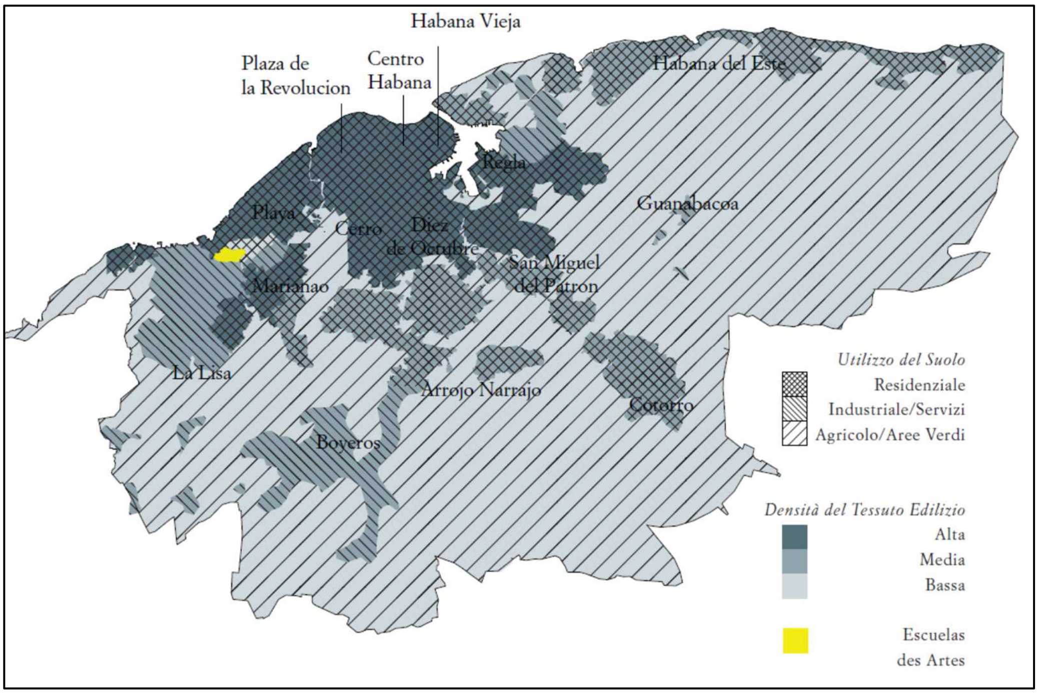


Figure 18 - Habana land use (image by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, student group 6: Marta Chiara Gobbo - Eva Maria Ronchi - Veronica Tamanza - Francesco Turrini).

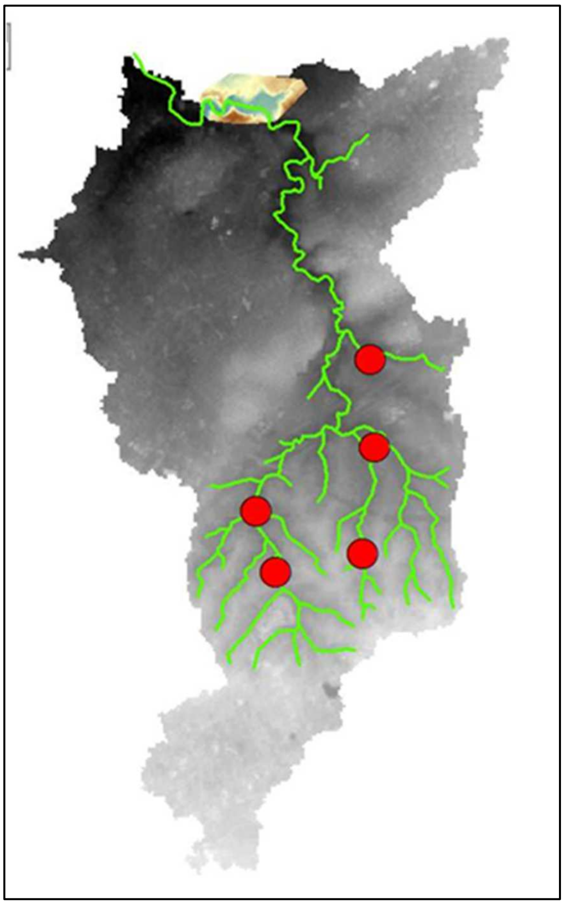


Figure 19 - Rio Quibù river catchment and synthetically derived hydrological network. Red dots are hydrometric stations potentially available. In color, the terminal area of the catchment with the School of Art, to be used as a domain for the hydraulic based flooding simulation. Resolution is 90 m, from ASTER.

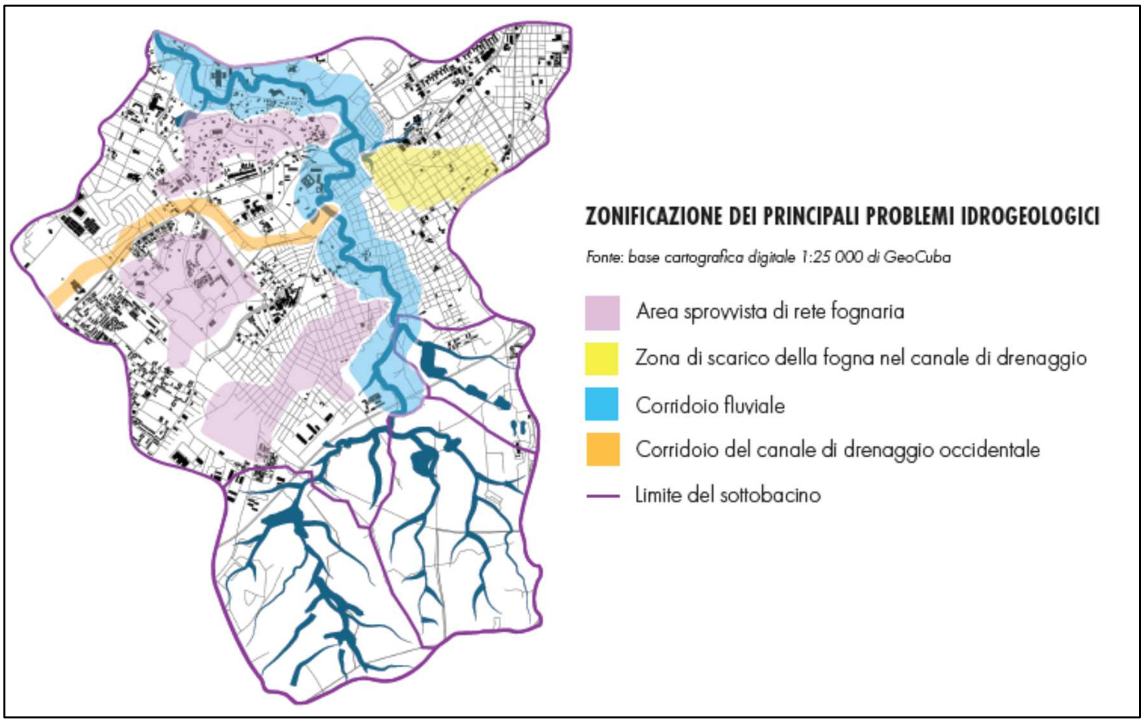


Figure 20 - Rio Quibù basin area: water-related criticalities (by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, student group 18: Sara Mazzola, Guendalina Nozza, Greta Possi, Anna Puricelli, Greta Weber). Pink: areas with no sewers system. Yellow: catchment area of sewers delivering within the Rio Quibù. Blue: river corridor of Rio Quibù. Orange. Western drainage channel delivering in the Rio Quibù.

Visibly from Figure 20, a number of the drainage channel, or sewers, deliver water to the Rio Quibù before it reaches the Country Club area. Accordingly, the Rio Quibù river is, in fact, a collector of water from the land and from urbanized areas, including with and without sewers systems.

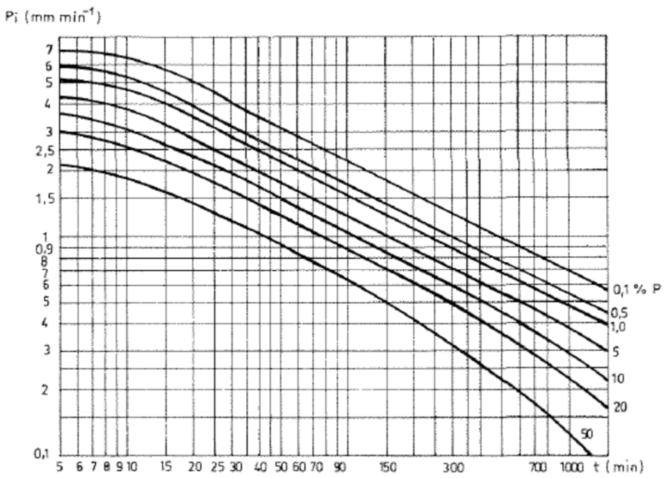


FIG. 7 Family of intensity-duration-frequency curves (1959-1982) (Havana, Cuba) (after Rodrígues et al., 1982).

Figure 21 - Diaz Arenas (1983). Extreme storms in Cuba. Frequency P, Return period T = 1/P.

3.1.3 Influence of sea-level variability

Due to the proximity of Quibù in ISA park to the outlet (about 1.4 km), it is necessary to consider the possible detrimental effect of high tide during a flood event, that could represent the downstream boundary condition for our hydraulic model of subcritical flow (in each simulation Froude number was always higher than 1).

We considered a water level of 70 cm a.s.l. at river outlet (with average high tide in Havana equal to about 50 cm), and, since river bottom at *Puente Calle* 15 is about at 0 m a.s.l., and critic water level at that section in each scenario is always higher than 70 cm, there should be no effect of high tide on Quibù water level inside ISA due to subcritical nature of river flow.

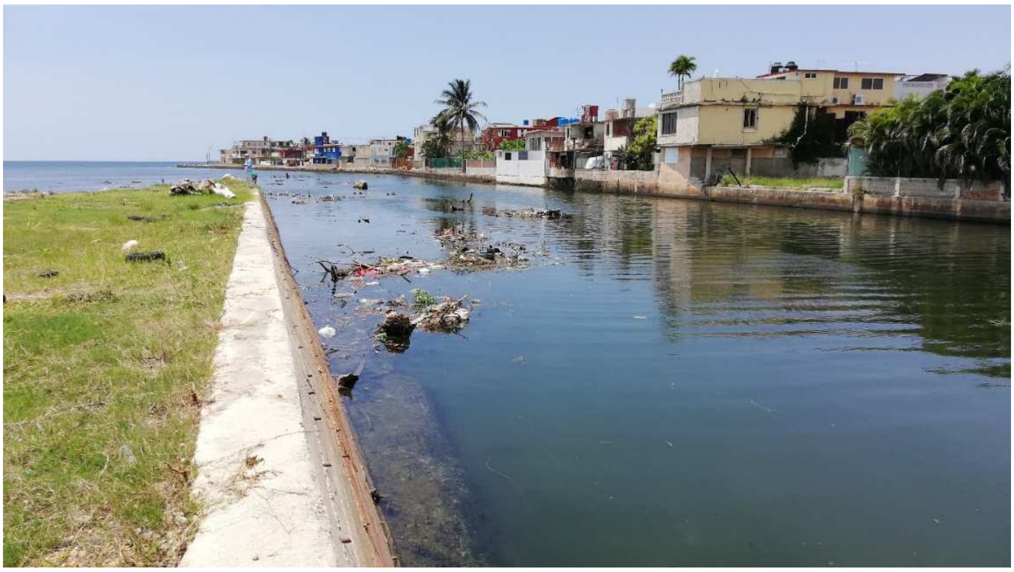


Figure 22 - The Rio Quibù flowing into the sea (Bignami D.F., 2019).

Figure 23 - The Rio Quibù at the mouth (Bignami D.F., 2019).

3.1.4 The effect of bridges

Several bridges of different size cross Rio Quibù from ISA park to the river outlet. Some of them are pedestrians and do not have large piers, which means the section area of the river is not significantly affected, and they do not reduce the discharge capability of the river unless the water level reaches bridge level. There are also bridges for car transit, whose largest is the one of 5 calle, the last bridge before the river outlet, that affect water level and may cause backwater during the flood. In this work, we focus on the bridges inside ISA, particularly on the bridge of calle 15, which is immediately downstream and it is the lowest of the park with a low chord at only 4 m a.s.l., and for this reason, it is considered a threat for School of Ballet by the experts of RH. However, for flood proofing of all Quibù area, all the bridges upstream and downstream ISA should be considered, and we have to take into account that increase the discharge capability of Quibù inside the ISA area could increase flood risk for the downstream area.

Figure 24 - The Rio Quibù that enters the park (Bignami D.F., 2019).

Figure 25 - The bridge of the 5th road, downstream the Schools' park (Bignami D.F., 2019).

Figure 26 -The bridge of the 5th road, downstream the Schools' park (Bignami D.F., 2019).

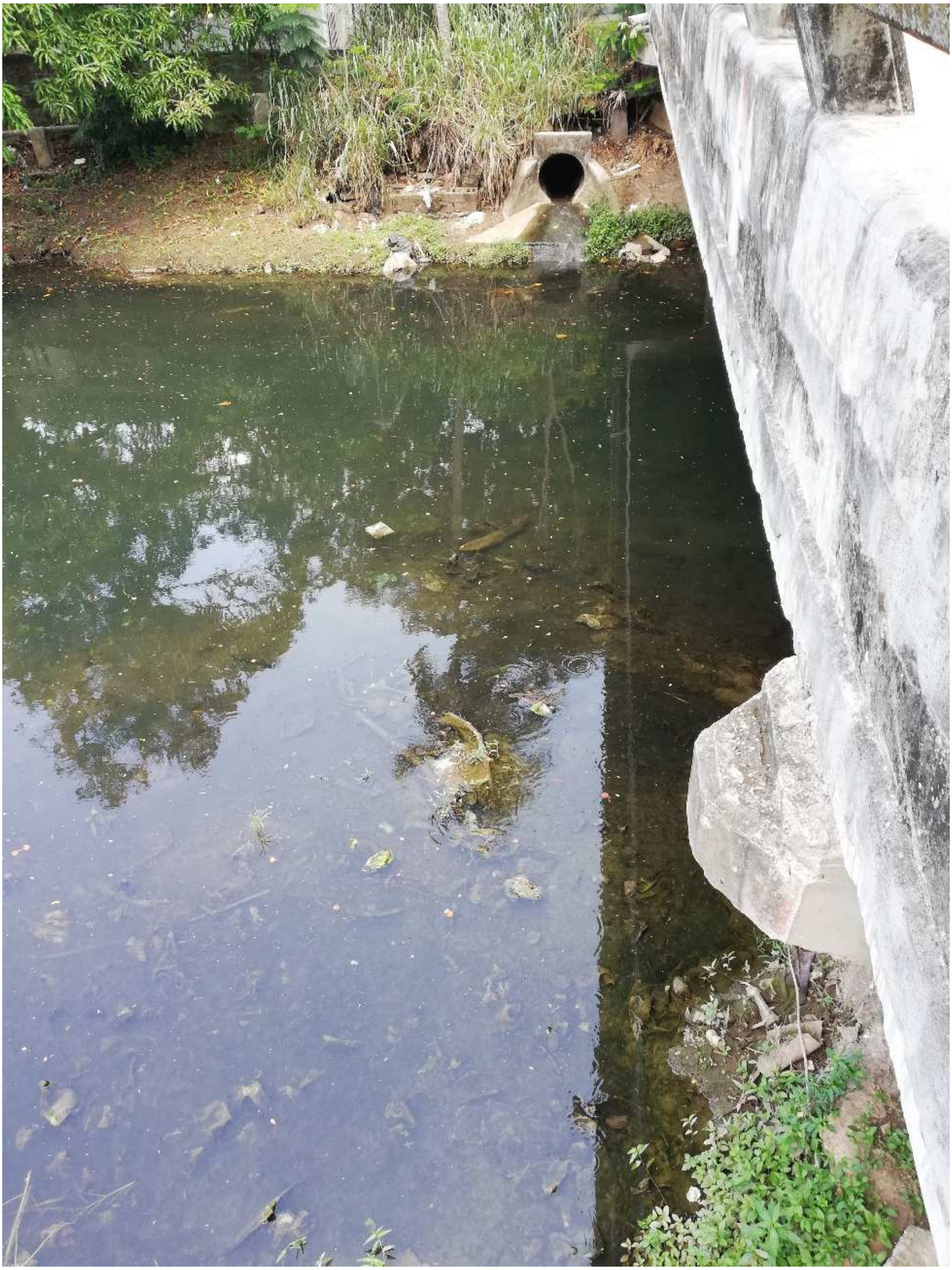


Figure 27 - The bridge downstream the Schools' park (Bignami D.F., 2019).

Figure 28 - The bridge downstream the Schools' park (Bignami D.F., 2019).

3.1.5 The efficiency and possible damages of the existing levees and flood-walls

Among the main critical points affecting flood risk in the area and ballet school, especially given its low altitude, is the large degree of damage affecting potentially protective structures therein.

As from the pictures below, gathered in June 2019, the perimetral wall of the ballet school area, clearly built with the purpose of flood protection, is largely damaged in several points.

Each of such breaches or erosion/lowering points gives rise to a potential gate for entrance of the floodwater.

When providing hydraulic modeling of the area for flood mapping, such discontinuities within the protective walls must be represented to gather a credible description of the flooding dynamics.

Figure 29 - The Rio Quibù outside the park, downstream (Bignami D.F., 2019).

Figure 30 - A view of the Rio Quibù wall alongside the Ballet area (Bignami D.F., 2019).

Figure 31 - A view of the Rio Quibù worn and unstable wall alongside the Ballet area (Bignami D.F., 2019).

Figure 32 - A view of the Rio Quibù wall alongside the Ballet area (Bignami D.F., 2019).

Figure 33 - A view of the Rio Quibù wall alongside the Ballet area (Bignami D.F., 2019).

Figure 34 - A view of the Rio Quibù wall alongside the Ballet area (Bignami D.F., 2019).

Figure 35 - A view of the Rio Quibù wall alongside the Ballet area, to be noted the wall discontinuity (Del Curto D., 2020).

Figure 36 - View from the roof of the School of Music of Rio Quibù: notice the wall discontinuity alongside the Ballet area (Del Curto D., 2020).

3.2 Hazard identification, data collection, and organization

We here exploited the available information in order to identify and assess the main sources of flood hazard. We studied the past and present setting of the area, and we pursued local surveys to reveal hotspots of risk.

We studied the available documents, reports, and information in general, covering the most recently updated flood hazard situation.

This includes especially information necessary for flood mapping, i.e., flood design against Hazard level (i.e., frequency or return period).

Particularly, in lack of sufficient information for a flood design procedure, we relied upon previous estimates as designed locally, entailing peak floods for different return periods, and we subsequently used such estimates for flood hazard mapping in the country club and ballet school area.

3.2.1 Hints from historical documents

The site of the Schools of Art has experienced over time significant transformations in response to anthropic actions. Originally conceived for agricultural production purposes, it was then adapted for recreational activities (golf club, country club), and finally moved to its present use as a University until nowadays.

Prestigious academic activities are pursued therein, such as those for the study of major arts, certainly benefiting from the natural, protected environment of the area, far from the rest of the city.

From the point of view of flood risk and of surface pluvial runoff, thanks to pictures taken in the'30 and'60 of the twentieth century, one gathers that before the school's construction, the bed of Rio Quibù river was remarkably more incised and deep than today, and with higher side banks (Figure 37, 38 below).

Likely, it was a less flood prone area than now, and likely floods would occur in areas free from buildings. This was likely due to a bigger conveyance (discharge flowing) within the riverbed and levees, and to a greater permeability of the upper part of the Rio Quibù catchment (as seen in the previous chapter), with less intense overland flow.

Nowadays, increased urbanization and re-lining of the river shores (i.e., in practice with no levees or banks) results in larger chances for flooding, with particularly visible effects in the ballet school area, given also ruining (and collapse, in some points) of the defense wall.

Also, in the rectorate area, in practice, no physical barrier (unless for the low mound, hosting the walking path, however basically descending to the rectorate level) is present to prevent floods from touching the building.

TWELFTH AND THIRTEENTH GREENS

Figure 37 - The Golf Course and the Country Club. Images from Roger Kellogg Stillson - New York 1936.

Figure 38 - The free areas of the schools' until '61 and the Rio Quibù riverbed (ISA archive).

3.2.1.1 Marking of flood levels after events

During the field survey carried out in June 2019, we analyzed historical flood marks (water levels) as visible upon the walls of the ballet school, reported in the Figures below.

As widely known, these marks indicate in practice the full entrance of the flood water within the school.

Paradoxically enough, the external flood water pressure would have damaged (and even collapsed) the building whenever kept outside, so in practice, water entering the building does not provide large damage due to pressure.

However, clearly damage to the masonry occurs due to continuous touch with water and to debris transport of wood, and sediments, as clearly visible from jamming within the buildings.

These marks can be used to qualitatively assess the results of flood modeling using HECRAS 2D in the area reported below.

In Figure 45, we report a map sketching the expected inundation area during the 2007 flood (courtesy of Christian Zecchin).

This was used as a reference for qualitative benchmarking the design flood maps, as assessed using reference design flows from literature (i.e., from INRH).

Figure 39 - The marks and debris left by the water inside the ballet school (Bignami D.F., 2019).

Figure 40 - The marks and debris left by the water inside the ballet school, approx. 1 m above the floor level (Bignami D.F., 2019).


Figure 41 - The marks and debris left by the water inside the ballet school (Bignami D.F., 2019).

Figure 42 - The water level during a recent flood according to a witness in the Ballet school area (Bignami D.F., 2019).

Figure 43 - A view of the Ballet school area taken from water entering path during local floods (Bignami D.F., 2019).

Figure 44 - The School of Ballet flooded after a cyclone. Year 2007. Photos by Christian Zecchin.

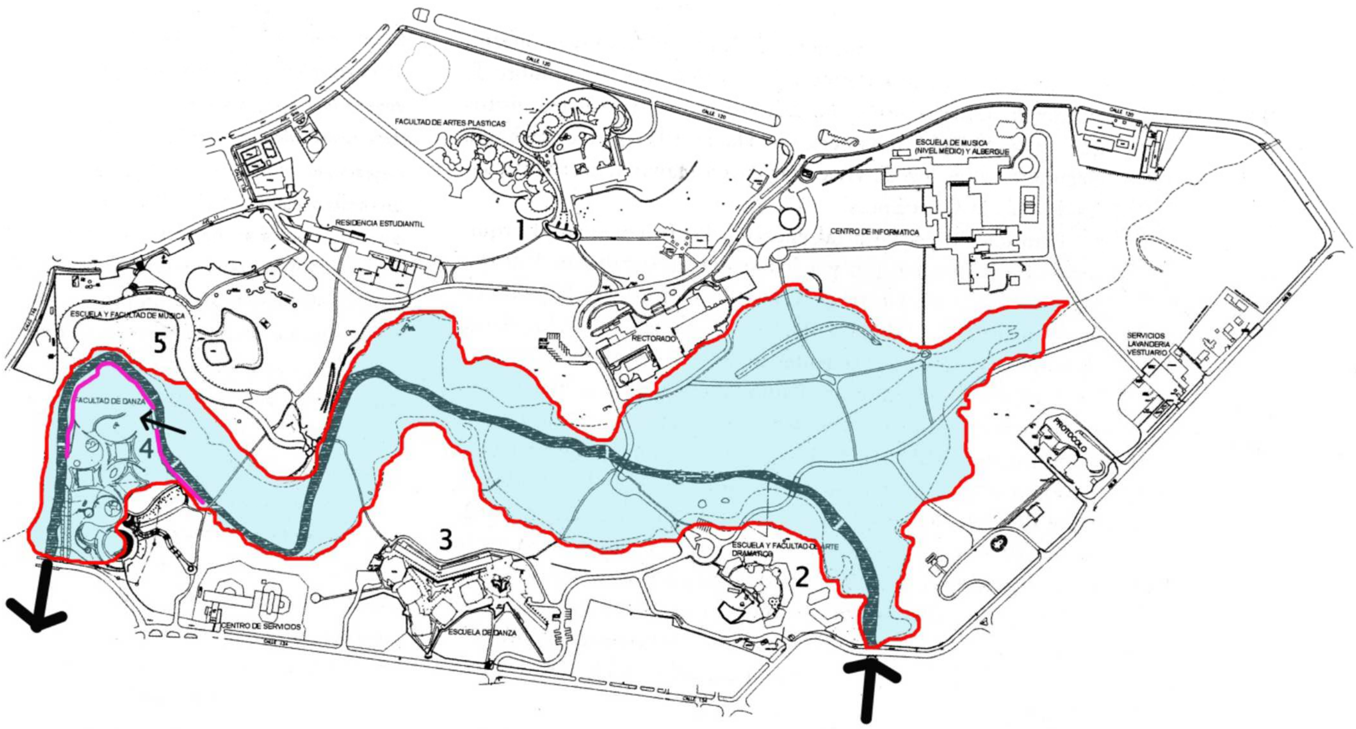


Figure 45 - A sketch map of the 2007 flood (courtesy of Christian Zecchin).

Figure 46 - The Rio Quibù during an intense meteorological event. C. Zecchin, June 2019.

3.2.1.2 Hazard analysis documentation

The flood proofing project of the Instituto Nacional de Recursos Hidraulicos (INRH) was based on critical event discharge scenarios, elaborated by E.I.H.H. in 1999. In the table below, there are reported several values of discharge in several sections responding to 4 return periods. Also, critical daily rain values were provided. It is interesting to notice that discharge for *calle cinco* (5th avenue) and *calle* 164, which are near to river mouth, are in practice taken as rain intensity (rain depth spread over 24 hours) times the basin area. Therefore no buffer effect is given by infiltration (runoff rate) or reservoir (flood dampening) was considered. For evaluating flood risk in ISA, we used INRH values at *puente calle* 15, which is immediately downstream ISA (while *puente calle* 23, and *Rectorado* are inside the park).

Table 1 - Design flow discharge, and rain according to INRH.

R [y]	**5**	**10**	**20**	**100**
Daily rain [mm]	131	171	215	341
Q *Puente Calle* 23 [m^3s^{-1}]	34,0	43,2	55,8	82,4
Q *Puente Rectorado* [m^3s^{-1}]	35,4	45,1	58,2	85,9
Q *Puente calle* 15 [m^3s^{-1}]	35,9	45,8	59,0	87,1
Q *Puente calle* 146 [m^3s^{-1}]	38,0	48,5	62,5	92,3
Q *Puente calle* 164 [m^3s^{-1}]	41,1	57,2	73,9	125
Q *Puente calle* 5 [m^3s^{-1}]	41,1	57,2	73,9	125

For reference, and possibly for planning in favor of safety, we considered a further design event with $R = 1000$ return period, using a duration-frequency curve from the only scientific work available on extreme rainfall in Havana (Arenas, 1983). Using the data available in this paper, we evaluated scaled storm intensity from $R = 100$ to from $R = 1000$ years, and then applied this ratio to 100 years peak discharge to get Q = 121,8 m^3/s for $R = 1000$ years.

3.3 State-of-the-art flood scenarios

Ballet school is subject to regular floods due to its peculiar position. Indeed, it is located in a narrow meander of the Rio Quibù, where a bridge located downstream partially obstructs the river section during floods, and furthermore, it is below a hilly area, which conveys surface runoff towards the ballet school itself.

Surface runoff coming from the hill above the school and from the school area itself is a first phenomenon leading to flooding, which during rainy periods occurs several times a year.

The drainage system here is largely clogged, and it is not able to convey water flows as designed. According to E.I.P.H.H., it is necessary to build a channel of about 130 m in length (half of it underground) that gathers overland flow from the hill and discards it into Rio Quibù about 10 m upstream of the 15th street bridge.

However, the largest flood volumes are given by channel overflooding from the Rio Quibù during storm events with a certain return period R (approx. $R > 5$ years).

Here, we pursue mapping of the hydraulic hazard of the country club area, with a special focus upon the School of Ballet.

We first gathered hydraulic information of the area. Most notably, we pursued a geometric assessment of Quibù river flow sections in a number of points, and we assessed flow velocity and discharge (using the flow-area method) in some of these points.

We further assessed streamflow using the salt tracer method for reference.

Then, using a fine resolution digital elevation model coupled with our stream section measurements, we were able to set up a 2D inundation model, which we apply in the area.

By taking reference streamflow discharge each return period as provided by the INRH, reported above, we then simulated flood areas, including flow depth and velocity.

3.3.1 On-site stream hydraulic data collection and flow measurements

In June 2019, Faculty Staff of Politecnico di Milano, with specific expertise in hydrological modeling and flood risk assessment, namely Daniele Bocchiola and Daniele Fabrizio Bignami, visited ISA to i) gather information regarding any studies conducted by local agencies on flood risk for Quibù river, and ii) carry out measurements of the geometry and hydraulic characteristics of the river within the ISA.

3.3.1.1 Hazard and hydrometeorological data of the Rio Quibù

During the above reported five days (10-14 June) campaign, some information about the river and schools' buildings were collected. The wall surrounding the School of Ballet, which is now partially collapsed and offers no protection to the School, has been inspected, so verifying its state, and the chance to integrate the missing parts with mobile structures to reduce flood risks. Ten cross-sections of the river were measured inside the ISA area (from the bridge of 15° Av. to the bridge of 23rd Av.), including four bridges, and one pedestrian bridge, that were used to

build a 1D model of the Quibù river. Also, hydraulic structures like the channel on the right bank downstream to the bridge of 23rd Av., and the culvert near the rectorate have been surveyed.
Using a flow-tracker, able to measure flow-velocity field along cross-sections, and an EC meter (i.e., one using conductivity to assess discharge through salt tracers), we measured flow discharge in several sections of the river, that were then used to calibrate roughness parameter (i.e., Manning's coefficient). Part of the area upstream ISA was inspected to further verify the suitability of building a diversion channel, to reduce discharges coming to ISA. However, the large degree of urbanization and mild slope of the area made such a task difficult. The downstream area was also inspected until the sea outlet. Therein, the river section was assessed to evaluate the potential effects of tides on river flow during floods.

3.3.1.2 Laser scanner

Using laser scanner traces measured by Dr. Andrea Garzulino during July 2019, we were able to build a high resolution (0.5 meters) Digital Elevation Model (DEM), covering a large part of the park. Also, we were able to assess the absolute elevation of the bridge in front of the rectorate, subsequently used to complement the assessment river slope in the park.

Figure 47 - Prof. Daniele Bocchiola of the Department of Civil and Environmental Engineering of Politecnico di Milano using a 2D flow tracker to estimate flow velocity, depth, and discharge in the Rio Quibù stream.

Figure 48 - Flow measurement in the Rio Quibù stream - salt tracer method.

3.3.2 Methods and models

3.3.2.1 Preliminary 1D modeling of the Rio Quibù river

First, we set up a 1D stationary model of the river, using data provided by "Investigaciones y projectos" in a 2005 document, namely cross-sections geometry, slope, and roughness (Manning coefficient n = 0.04 $sm^{-1/3}$, or Ks = 25 $m^{1/3}s^{-1}$), integrated with data from our field campaign in June 2019, also useful to validate the 2005 data.

We first built a mono-dimensional model for all the Escuela de Arte park until 15th street bridge (*puente quince*). Since by our measurements, river *thalweg* (i.e., river bottom) in that section is ca. at 0 (zero) m a.s.l., and since Quibù outlet in the ocean is about 1.4 km downstream of the bridge, based upon field measures gathered in June 2019, we assumed a 0.1% slope for the river bed downstream the bridge at 15th (while the measured slope is 0.2% in the park), which means that the thalweg at the end of the river is about 1.4 below the sea level.

This slope was then used as a downstream boundary condition (i.e., subcritical flow) for uniform flow, taking cross-sections as from the *puente quince* river section data. This approximation is in favor of safety since even considering a 60 cm sea level condition, at the outlet, one has seawater depth laid between critical and uniform depth. This means that, in the hypothesis of a constant section, the water level at bridge 15th would be at the most equal to the uniform depth.

In these hypotheses, we evaluated the maximum discharge that can be conveyed by Rio Quibù with no inundation in the present state. We used a measured value of 2.85 m a.s.l. for the riverbank, at 20 m upstream bridge 15th (that is, where most of the water enters from in the school during floods), ca. Q_{max} = 33 m^3s^{-1}. We here approximately evaluated flood volumes V_{flood} for each return period R. Since V_{flood} was always much larger than the storage volume at the school, i.e., corresponding to the relative water depth, it means that the school of ballet is flooded approximately at the same water height evaluated with the 1D model.

By using points georeferenced in a previous campaign, we were able to set up a Digital Terrain Model of the park, namely a lattice, where each cell represents the average altitude of the area therein. This model allows to approximately a flooded area and water depth for each cell for a specific event.

3.3.2.2 2D modeling of the Rio Quibù river

However, due to the high sinuosity of Quibù river inside ISA park and the need to properly assess local flood depth and velocity, we decided to pursue a 2D hydraulic model.

Indeed, water during flood tends to shorten the natural path and channel sections are no more orthogonal to river flow and. Furthermore, the presence of buildings makes the river path very complex, with streamlines highly bidimensional. Consequently, we thought necessary to use a 2D hydraulic model to correctly represent a flood event. Here we used HEC-RAS 2D software where we implemented Conservation Wave Equations, which are a simplification of Shallow Water Equations (SWE) used for subcritical flow.

Since we had no data regarding flood evolution but instead peak discharges, we implemented HEC-RAS until it reached a steady state (about 2 hours in our scenarios), i.e., no significant variation of velocity was detected. In this way, we were able to neglect the *CFL condition* for stability, which restricts the range of time step (here, we used 0.4 seconds) acceptable for the stability of the solution.

Because of the bathymetry approach used by HEC-RAS 2D, where for each cell of the domain, they are computed several parameters (i.e., hydraulic radius, volume curve), we were able to lower the resolution to 1 meter without losing information.

To build a 2D flood model, it was necessary a fine resolution Digital Terrain Model of flood area, and therefore detailed information of the buildings and of topography. We collected and joined all data available to create a 0,5 m resolution DTM of ISA. From all the sections, due to the regularity of Quibù, we could design with Autocad® software a representative section that well approximated the river. Then this section was exported to raster and georeferenced with ARC-GIS.

We used:

a) Discharge data collected in the 2019 campaign that were used to validate river slope and roughness values also provided in RI.
b) Georeferenced points and cloud of points which also was obtained in 2019 campaign using laser scanner. These were used to extract the DTM for all ISA area.
c) Design discharge for the five return periods and corresponding rain storms.

d) Bridge sections measured in the 2019 campaign. Here we considered only the bridge of the 15th road mentioned above since the other ones by a preliminary analysis based on water level and pier width should not impact significantly flood dynamic.
e) New river geometry and wall around ISA according to INRH to assess flood proofing (table 2 and image). INRH gave specific information only for the section below 15th road bridge, that needed to be enlarged to 20 m and for the section of the river from +295 m to +529 m upstream bridge 15th, while it gives just vague indications for a segment from +15 m to +295 m, that needs to be enlarged as much as possible. Since in this segment there is not much room, we chose to fix the river bottom width to 12 m (with respect to the present 8 m).

HEC-RAS 2D software which is able to solve full Shallow Water Equations SWEs:

$$\frac{\partial \mathrm{H}}{\partial \mathrm{t}}+\frac{\partial (\mathrm{hu})}{\partial \mathrm{x}}+\frac{\partial (\mathrm{hv})}{\partial \mathrm{y}}+q=0 \tag{1}$$

$$\frac{\partial \mathrm{u}}{\partial \mathrm{t}}+\frac{\mathrm{u}\,\partial \mathrm{u}}{\partial \mathrm{x}}+\frac{\mathrm{v}\,\partial \mathrm{u}}{\partial \mathrm{y}}=-\frac{\mathrm{g}\,\partial \mathrm{H}}{\partial \mathrm{x}}+\nu_{\mathrm{t}}\left(\frac{\partial^2 \mathrm{u}}{\partial \mathrm{x}^2}+\frac{\partial^2 \mathrm{u}}{\partial \mathrm{y}^2}\right)-\mathrm{c_f u} \tag{2}$$

$$\frac{\partial \mathrm{v}}{\partial \mathrm{t}}+\frac{\mathrm{v}\,\partial \mathrm{v}}{\partial \mathrm{y}}+\frac{\mathrm{u}\,\partial \mathrm{v}}{\partial \mathrm{x}}=-\frac{\mathrm{g}\,\partial \mathrm{H}}{\partial \mathrm{y}}+\nu_{\mathrm{t}}\left(\frac{\partial^2 \mathrm{v}}{\partial \mathrm{x}^2}+\frac{\partial^2 \mathrm{v}}{\partial \mathrm{y}^2}\right)-\mathrm{c_f v}\,, \tag{3}$$

Where u, v are velocity components, in x and y direction (planar), H is water elevation, $h = H\text{-}z$ is water depth, g is gravitational acceleration, c_f is bottom friction coefficient, v_t is the horizontal eddy viscosity coefficient.
Since we had no data regarding flood evolution but only a peak flood value, we implemented HEC-RAS until it reached a steady-state, i.e., no significant variation of velocity was detected.
Furthermore, due to the nature of the landscape, with low slope and the presence of structures like bridges, the flow is highly subcritical with Froude number (evaluated a posteriori) always smaller than 0,5, a condition when SWEs can be approximated to Diffusion Wave equations (DSW), where inertial terms are neglected, leading to the form:

$$\frac{\partial \mathrm{H}}{\partial \mathrm{t}}+\frac{\partial (\mathrm{hu})}{\partial \mathrm{x}}+\frac{\partial (\mathrm{hv})}{\partial \mathrm{y}}+q=0 \tag{4}$$

$$\frac{g\,\partial \mathrm{H}}{\partial \mathrm{x}}-\nu_{\mathrm{t}}\left(\frac{\partial^2 u}{\partial \mathrm{x}^2}+\frac{\partial^2 u}{\partial \mathrm{y}^2}\right)+c_f u=0 \tag{5}$$

$$\frac{g\,\partial \mathrm{H}}{\partial \mathrm{y}}-\nu_{\mathrm{t}}\left(\frac{\partial^2 v}{\partial \mathrm{x}^2}+\frac{\partial^2 v}{\partial \mathrm{y}^2}\right)+c_f v=0\,. \tag{6}$$

As boundary conditions, we used:

a) Upstream - constant discharge equal to 4 critical discharge supplied by RI.
b) Downstream constant water level. As we previously told, the ISA area is closed downstream by the bridge of road 15th, which we expect to have a negative impact on the flood, causing backwater. Since HEC-RAS 2D does not easily take into account bridges, we decided to build a 1D steady model where structures like bridges can be easily incorporated and calibrated. So, we performed a steady 1D simulation to evaluate the water table upstream bridge of road 15, which was used as a boundary condition for the 2D model. Nevertheless, since flow is always subcritical, it was necessary to assess also downstream boundary conditions for the 1D model. Since the sea is about 1.4 km from ISA, we verified the possible impact of high tide on water level down BR15, but even considering a tide high 0.60 m, this is lower than critical depth down BR15 (considering a slope equal to 0.1%, which is consistent with elevation profile extrapolated by satellite). Given these assumptions, we used as a conservative boundary condition for the 1D model uniform flow with a slope of 0.1%. This value is lower than the one used for ISA (0.2%) due to the fact that the river bed is about o (zero) m a.s.l. as reported, and by our campaign of 2019, water depth at the outlet was not over 2 m.

3.2.2.3 The 2D flood maps of the Rio Quibù and School of Ballet.

Henceforth, in Figure 49-53, we provide the so simulated flood maps, with depth and velocity for five scenarios (R = 5, 10, 20, 100, using flow estimates from INRH, and R = 1000, by scaling up 100 years flood as reported). Only for the lowest return periods, there is no modeled flooding of School of Ballet, while for R >=10 years, the whole area around ISA is submerged by water with depth and velocity increasing with return period.
No other building of ISA in these simulations is affected by the flood. For reference, in Figure 54, we report overlapping of the simulated maps with R = 100 years to the inundation sketch from the 2007 flood.
Visibly, besides some differences at the edges, the general agreement is seen.

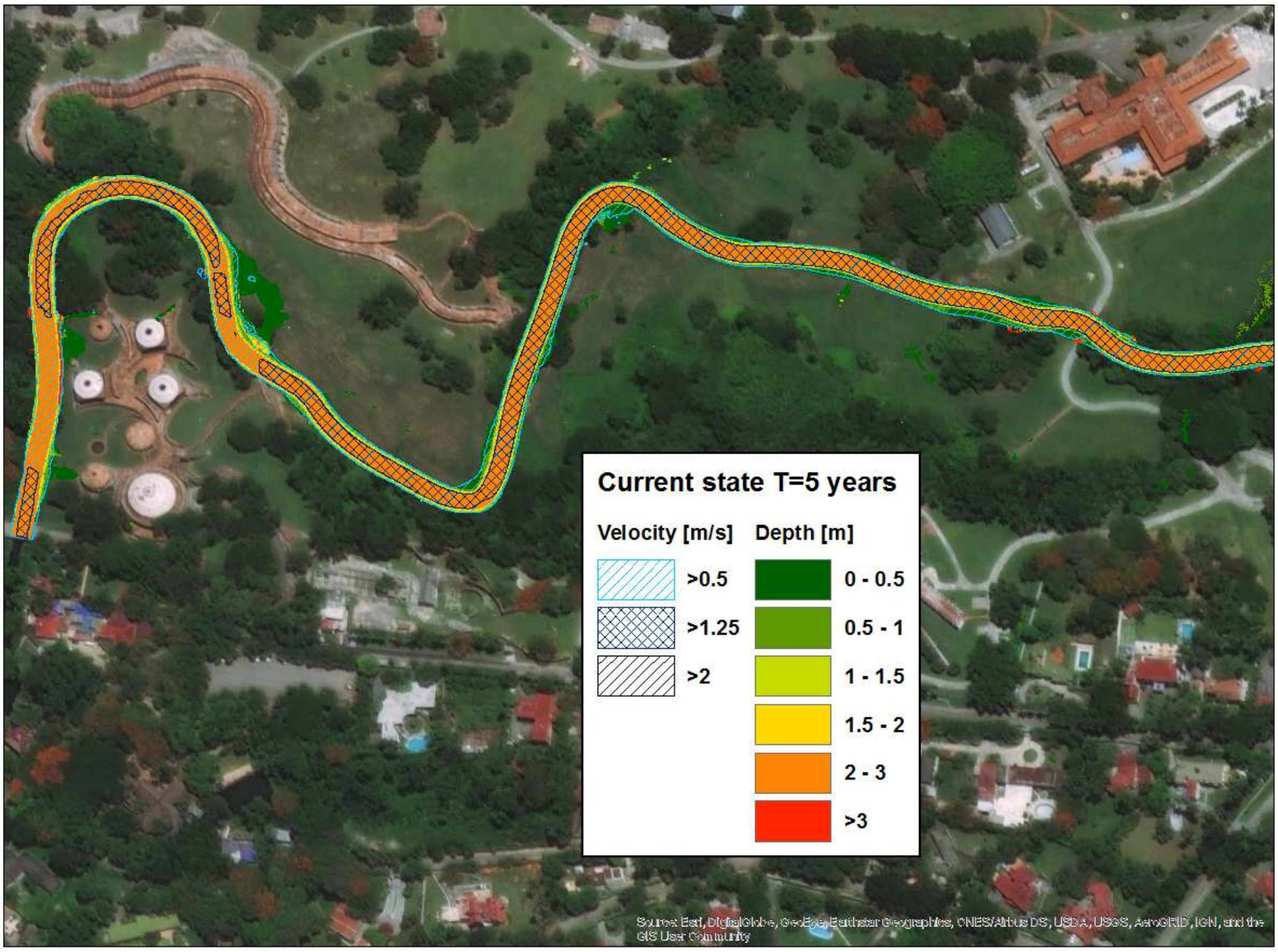


Figure 49 - Present situation. 5 years return period design flood map. We report flow depth (colors) and velocity (grids) range.

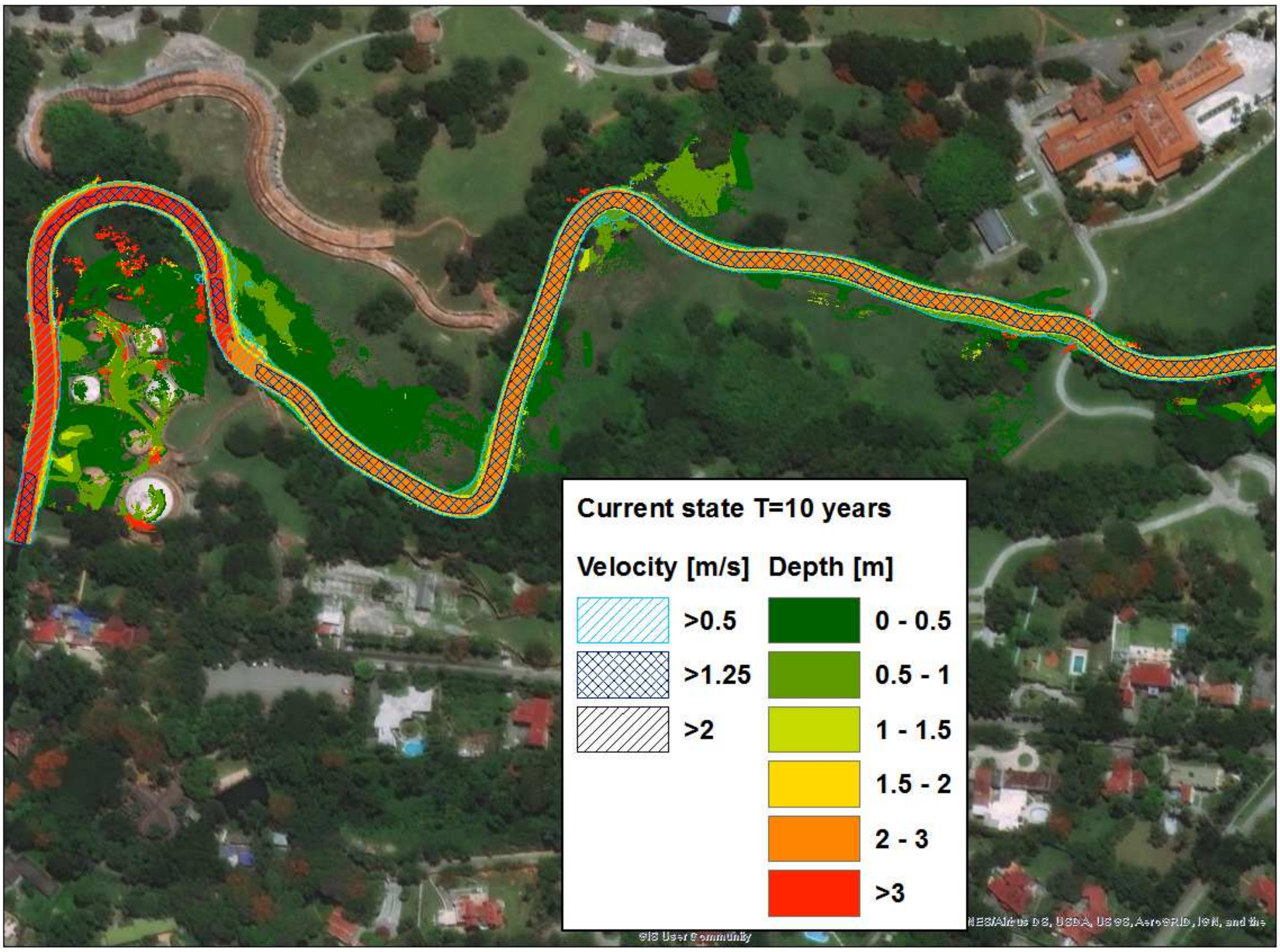


Figure 50 - Present situation. 10 years return period design flood map. We report flow depth (colors) and velocity (grids) range.

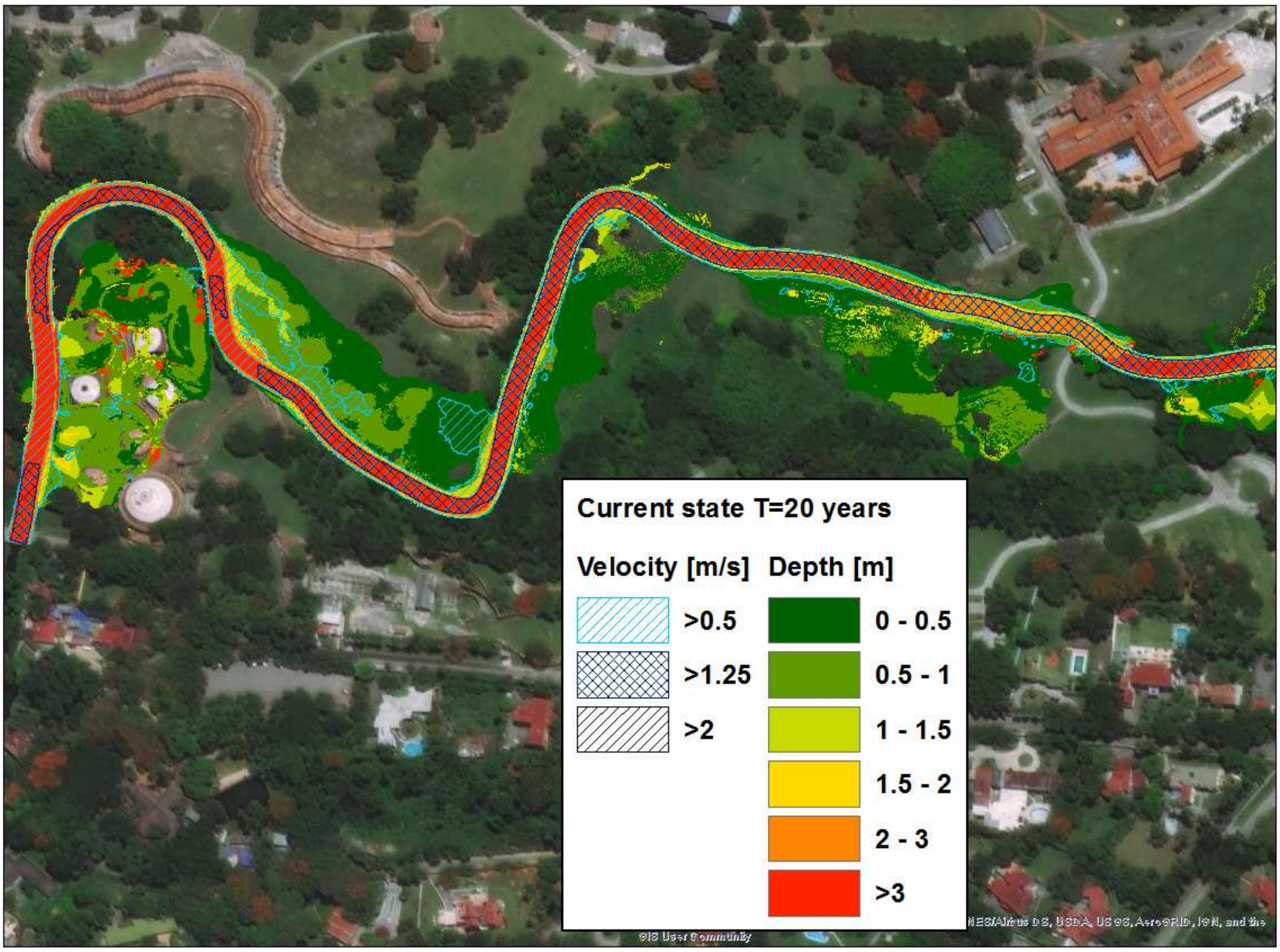


Figure 51 - Present situation. 20 years return period design flood map. We report flow depth (colors) and velocity (grids) range.

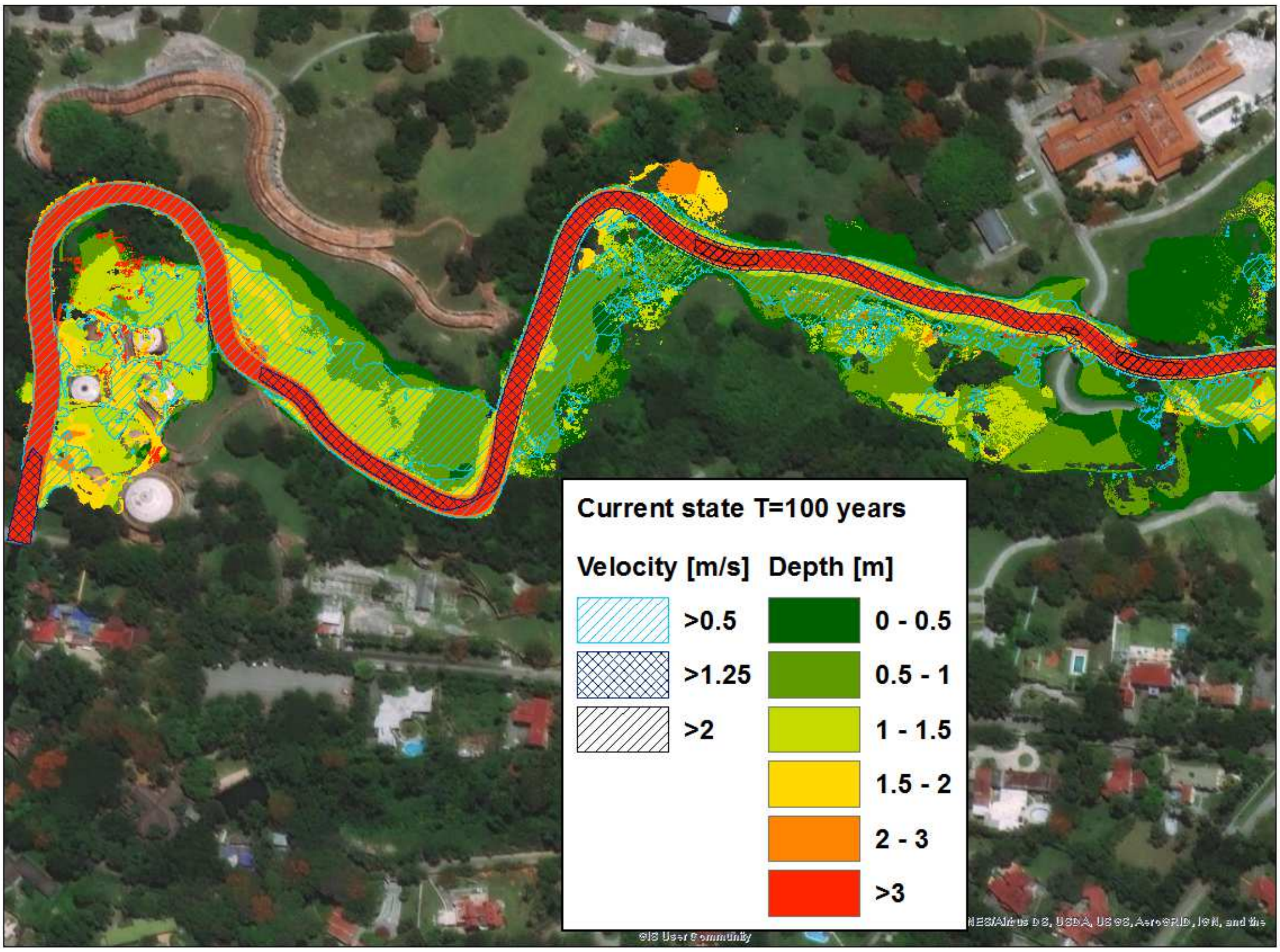


Figure 52 - Present situation. 100 years return period design flood map. We report flow depth (colors) and velocity (grids) range.

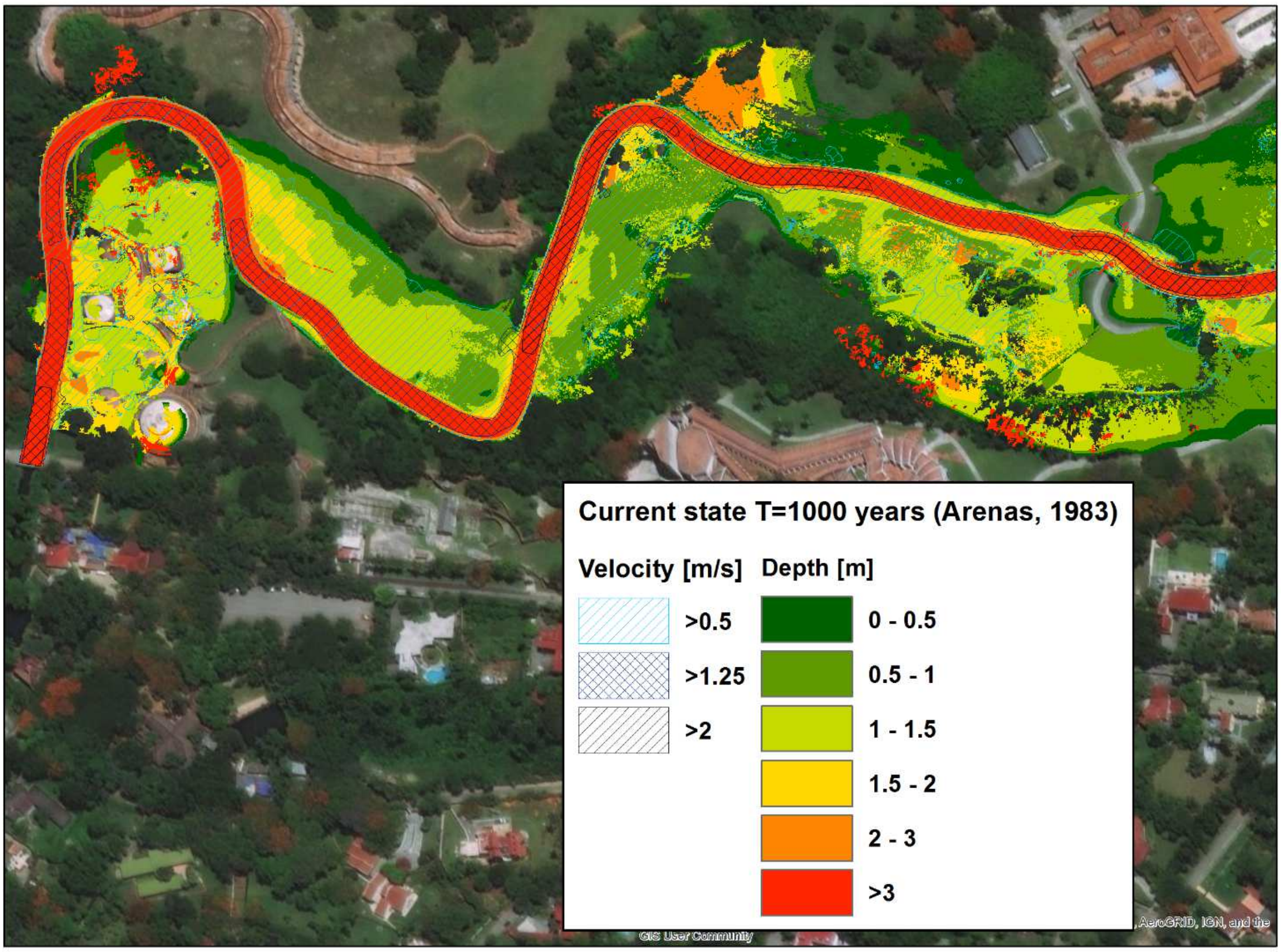


Figure 53 - Present situation. 1000 years return period design flood map. We report flow depth (colors) and velocity (grids) range.

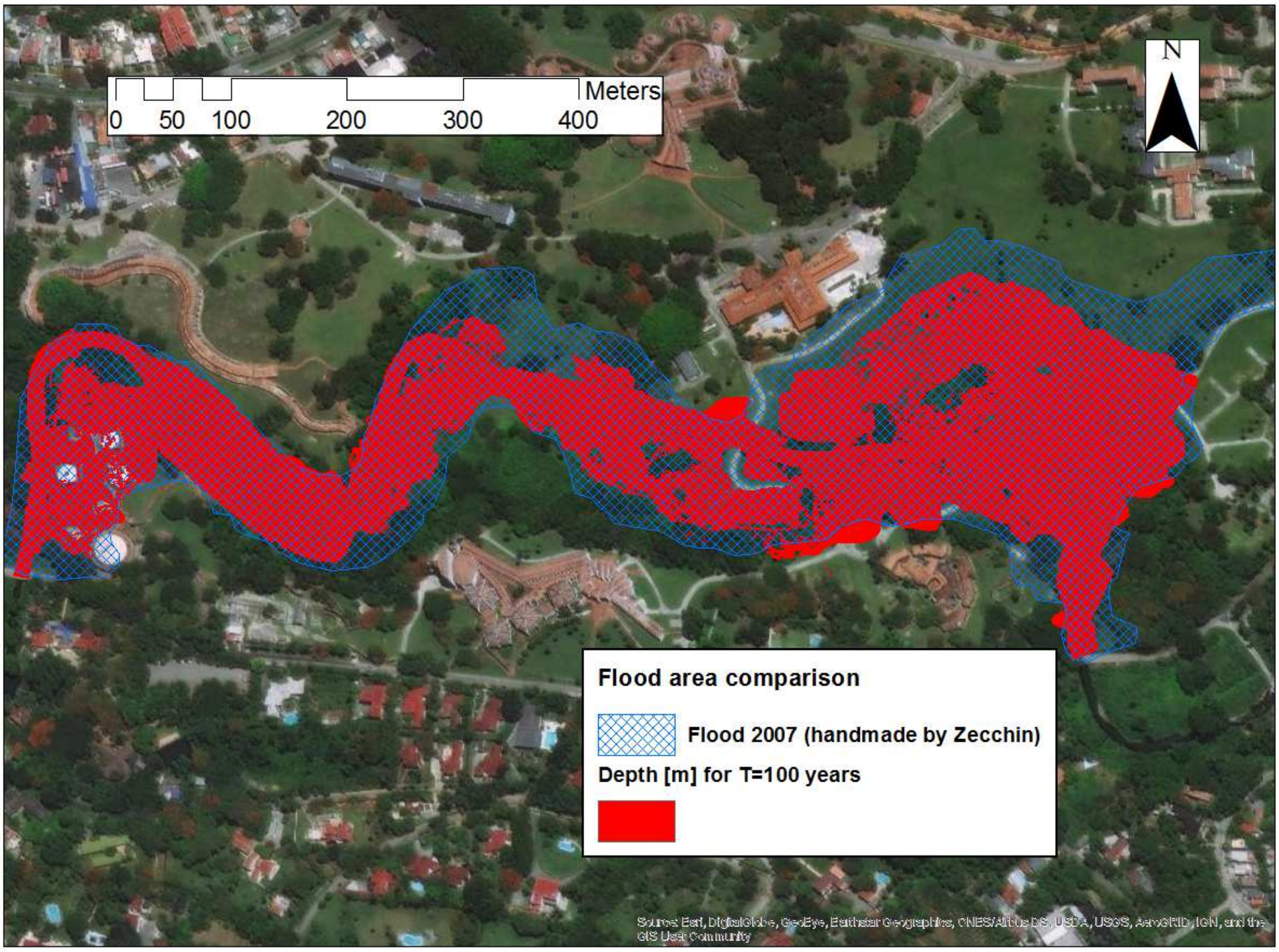


Figure 54 - Overlapping of the simulated maps with R = 100 years to the inundation sketch from the 2007 flood. In the red, flooded area in our simulation for R=100 years. In the gridded area, sketch of inundated area in 2007 flood.

Figure 55 - The discontinuity of the existing wall protecting the Ballet Scholl from the floods of the Quibù river.

3.4 Flood risk analysis and vulnerability

Two are the scenarios to consider for risk analyses and assessment, namely:

- flood events caused by Rio Quibù inside the schools' park;
- surface runoff and stagnation of water in the School of ballet site.

Also, one must take into account that the second scenario can be a simultaneous problem to be managed during floods. Here, we firstly illustrate flood risk issues, then localized surface runoff concerns, and specific targets of risk analysis, which will be subsequently analyzed for flood risk mitigation.

3.4.1 Flood risk analysis and assessment

As widely known, flood risk analysis focus on three main components: flood hazard — the probability and magnitude (e.g., depth and velocity) of flooding; vulnerability — the conditions which increase the impact of an event on assets subjected to flood hazard — the economic (or non-economic) value of assets subjected to flood hazard. Based on these components, the total risk, R, related to a particular element at risk E and to a given intensity I, is the result of a function like $R(E, I) = H(I)*V(I, E)*W(E)$. In general, R is the expected value of the losses in terms of human lives, wounded persons, damages to properties or cultural heritage, and interferences with economic activities due to the occurrence of a certain phenomenon with given intensity.

The flood risk assessment that is consequent to flood risk analysis is the work of interpretation of the quantitative analysis of risk in order to create the conditions to take decisions, considering political, social, environmental, economic, and technical factors. Here, we describe in detail the elaborations necessary to give a complete support frame to allow the possibility of adopting better strategies of defense.

3.4.1.1 Hazard assessment

As seen in chapter 3.3, hazard analysis has been investigated and illustrated through accurate models, showing water depth and water velocity caused by the Rio Quibù river, having selected different return periods on the basis of both available data and of data collected during field surveys. The next figure shows an integrated scenario-based on selected models for a return period of 100 years.

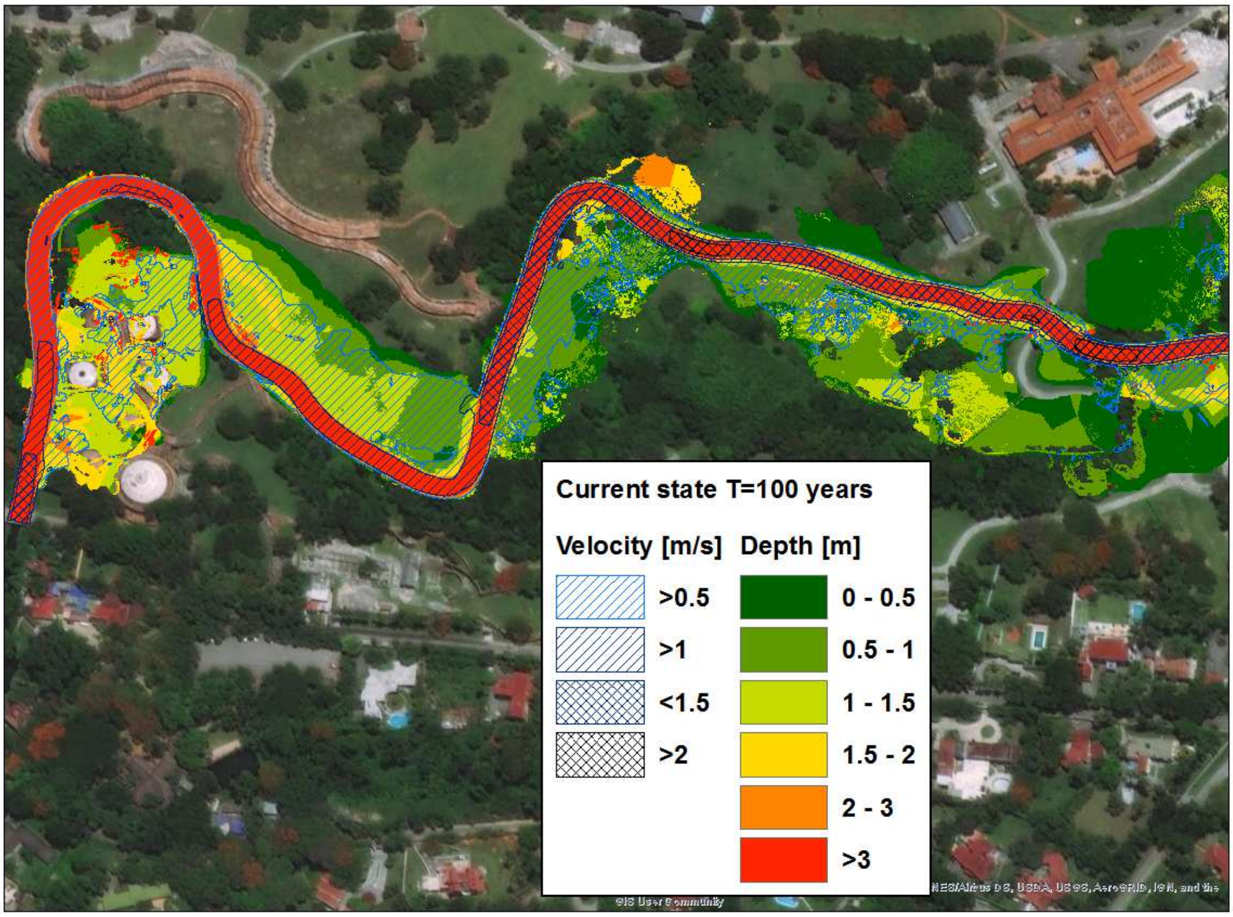


Figure 56 - Integrated scenario based on velocity and water depth (Return period 100 years) from HEC-RAS 2D.

Here, for the scope of our preliminary analysis, we used as a reference such mapping/scenario.

Our "design" hazard scenarios, obtained in a workmanlike manner, and representing the essential starting point for our work, are always and inevitably affected by uncertainty and could be, unsurprisingly, over/underestimated, above all considering field observations and trends highlighted in chapter 3.1 and 3.2. Uncertainty factors on water depth, flow velocity and the extensions of the flooding areas, synthetically, could derive from: floating materials, big-size waste or debris creating barriers and so diminishing water discharge (for instance at bridges or culverts); raising of sea level obstructing water-flow; unexpected rainfall intensity, etc.

A cautious approach in favor of safety (or "principle of precaution") may therefore suggest to include, in an advanced design step, to add further "uncertainty/safety" factors, able to give a more realistic description of events potentially affecting the park of the schools. As an example, one may adopt as a scenario for flooded areas some representation of an actual flood (i.e., here the 2007 flood), as reported in the sketch above. Notice, however, that such maps are i) subjective (handmade based on a visual assessment), ii) undefined in terms of the return period of the event (no info of flows or rainfall available), iii) unknown in terms of flow velocities (albeit assumptions could be made).

Water depth and flow velocity are the main parameters used to describe how much damage can be produced after a flood, but in many cases, other factors (often derived from them) have to be considered. This is especially when investigating the stability of humans, structures, and movable goods (for instance, cars) in a site. Among these factors, we can anticipate:

1. flow force ($h*v^2$) (e.g., Kreibich et al., 2009);
2. energy head ($h + v^2/(2g)$) (e.g. Kreibich et al., 2009)
3. intensity ($v*h$) (Kreibich et al., 2009);
4. the duration of flooding (USACE, 1996);
5. wind effects during flooding (Herath-Wang, 2010);
6. accumulated water volume (Prettenthaler et al., 2010);
7. the quality of external response and of private precautionary measures in a flood situation (Smith 1994; USACE, 1996; Merz et al., 2004; Thieken et al., 2008).

Furthermore, it could be useful to evaluate water depth effects in two more cases:

8. of presence or absence of waves changing hydrostatic pressure, both natural and caused by human errors (Messner et al., 2007);
9. of erosion, debris, or chemical/biological actions (Messner et al., 2007).

The right consideration and selection of these factors can give us the chance to investigate more in-depth potential flood defense strategies, i.e., to consider whether to act on hazard, on vulnerability, or on the exposed value (Fournier d'Albe, 1986). In Figure 57, we report the calculation of hydrodynamic pressure in the area, for R = 100 years, based upon hydrodynamic modeling with HEC-RAS 2D. This would represent the force acting (for each one meter in width) upon walls in the area.

The choice of using hydrodynamic forces (i.e., to neglect hydrostatic pressures) derives from the fact that the building of ballet school is open, so static water pressure would be balanced, and the actual pressure difference on walls (outside-inside) would be due to flow velocity outside the building.

Of course, this is representative of this specific case and assumption.

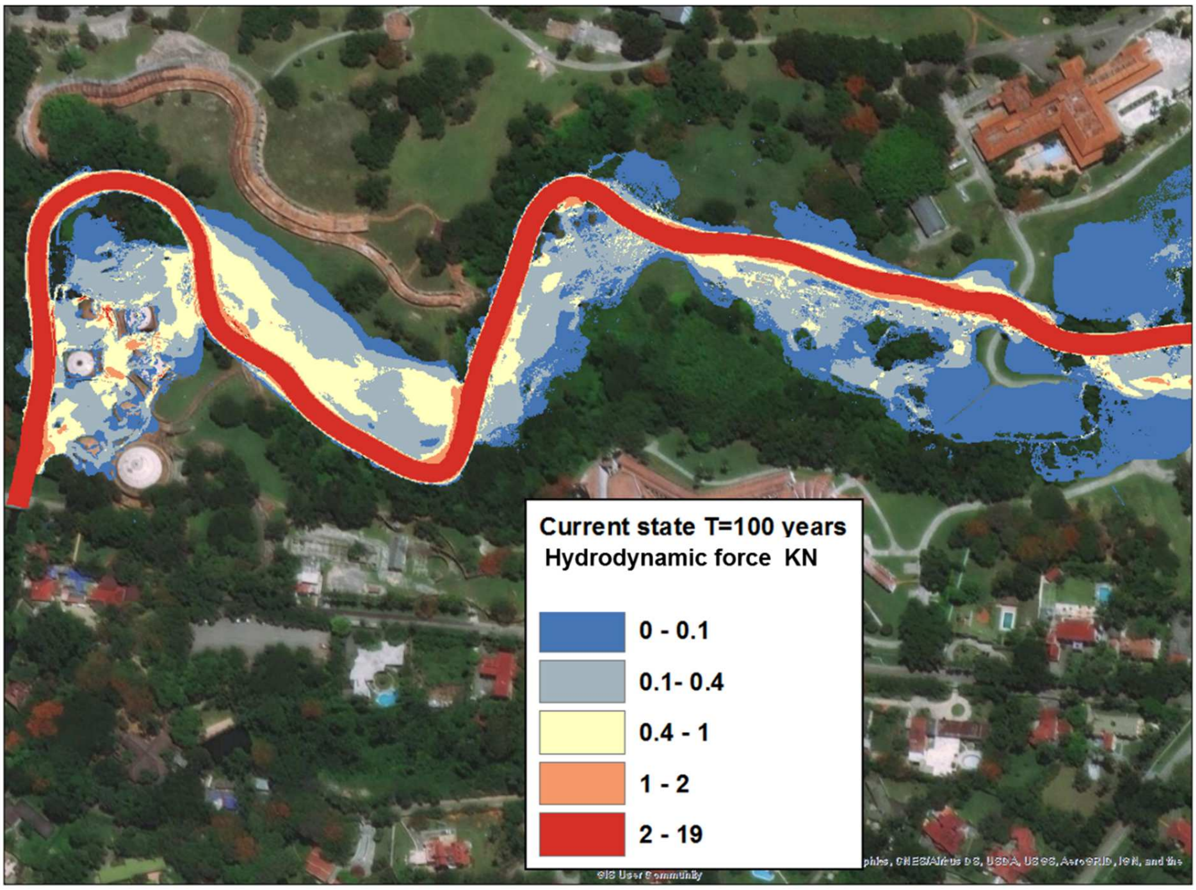


Figure 57 - Hydrodynamic force map. F = hv2.

3.4.1.2 Vulnerability and exposed value analysis and assessment

The ways a flood can impact the buildings in the area are different and important to be correctly managed. As it is well known on the basis of literature, they can be: direct/indirect and tangible/intangible (Messner et al., 2007; Thieken et al., 2008; Merz et al., 2010). Namely:

- *Directs* impacts occur as a result of physical contact; in our context, those are surely among the most important to be considered.
- *Indirect* impacts are due to the interruption of anthropic activities and are related to the extra costs induced by the emergency (from a suspension of activities to long-term effects).
- *Tangible* impacts are all the economic losses evaluated applying monetary units; they can be direct (i.e., costs of repairs and cleaning) and indirect (i.e., costs of substitute spaces to give continuity to the schools' activities).
- *Intangible* impacts, including loss of life, damages on the monumental buildings, loss of historical archives (direct), and loss of trust in academic or public authorities (indirect), are very difficult to assess in monetary terms.

Keeping in mind this scheme, the next step is to fix the target or the site to be studied. In our case, it is clear that the main targets to be considered performing the vulnerability and exposed value analyses, shown in the Figure below, are i) the School of ballet, ii) the School of music, iii) the School of dramatic arts, iv) the School of modern and folkloric dance, v) the School of plastic art, vi) the New school of music, vii) the Student house, viii) the Rectorate building and ix) some warehouses and archives inside the park of the Schools of Arts and technical networks, as roads, electricity (public lights), etc.

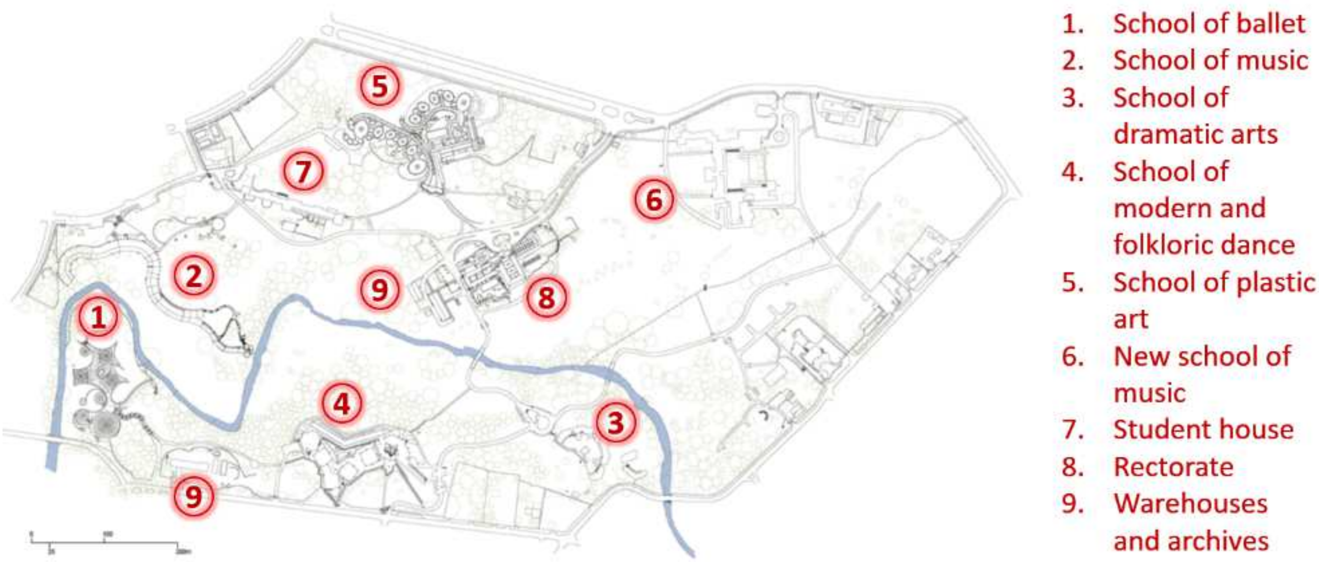


Figure 58 - The buildings inside the schools' park are considered in our analyses.

Analysis of the Exposed value

We choose to consider two factors to be, linked to the buildings, namely

- the values of buildings from the historical and architectural points of view (intangible damage);
- the presence in the buildings of humans (students, professors, technicians, etc.) (intangible damage).

In this way, we considered technical networks as a secondary problem from the point of view of value, i.e., to them, we implicitly assign a "low" level without the need for a specific analysis.

As shown in the next Figure, one may classify first in terms of historical and architectural importance, the (five) buildings that are National Monuments of Cuba, expected given their exceptionality.

Figure 59 - The buildings inside schools park: classification as National monuments (image modified from the original taken by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, with student group 6: Marta Chiara Gobbo - Eva Maria Ronchi - Veronica Tamanza - Francesco Turrini - modified).

Nevertheless, the present situation of the National Monument Schools is not the same for each building. A similarly so for other buildings. Some of them are not used presently. Others are only rarely used; others are frequently occupied. In the next figure, we represent the second factor selected, i.e., classification of the occupation frequency by humans.

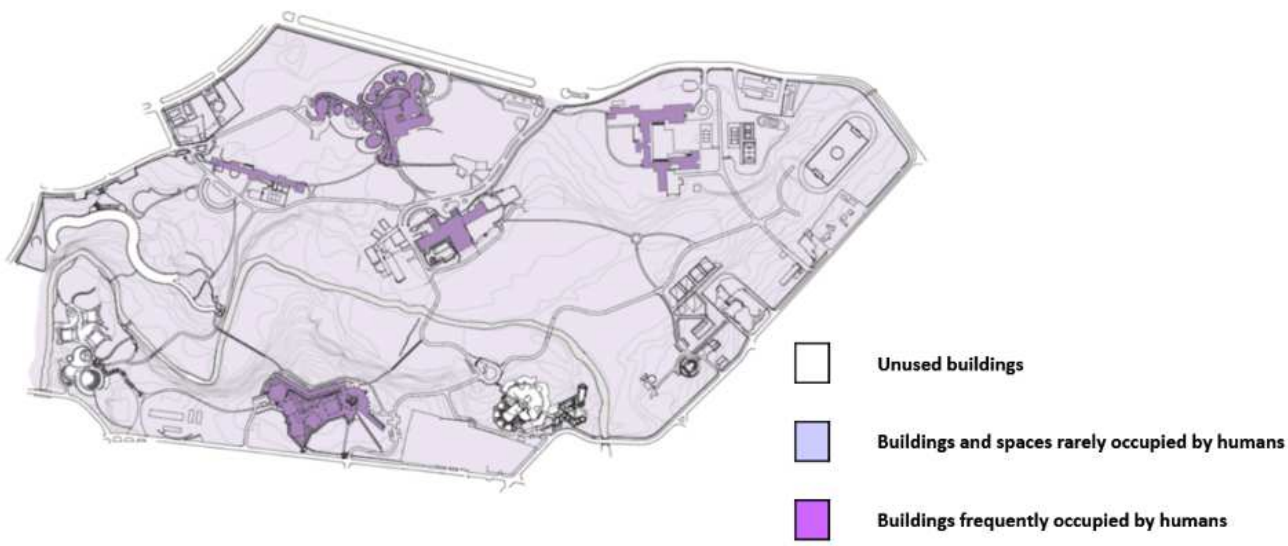


Figure 60 - The buildings inside schools park: use frequency classification (image modified from the original taken by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, with student group 6: Marta Chiara Gobbo - Eva Maria Ronchi - Veronica Tamanza - Francesco Turrini - modified).

Taking into consideration the two illustrated factors of exposed value, in the next Figure, we provide a raking of exposed value classification of the buildings inside the park, considering the situation “business as usual”.

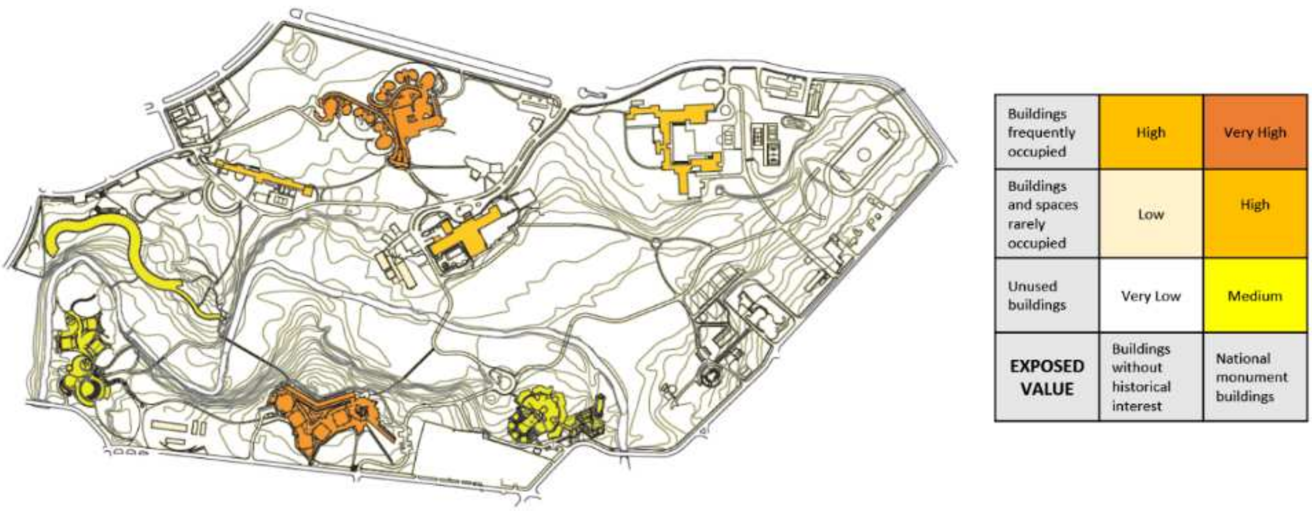


Figure 61 - Exposed value classification of buildings inside the park (image modified from the original taken by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, with student group 6: Marta Chiara Gobbo - Eva Maria Ronchi - Veronica Tamanza - Francesco Turrini).

In case of a future architectural and functional recovery of the currently unused schools (music, ballet, and dramatic arts), without actions capable of reducing the risk, the previous figures should be updated (obviously, the goal of our study is to avoid such a hypothesis).

This second scenario is important and has been produced (Figure below), taking into consideration that the main aim of our Conservation Plan is precisely to create the conditions to give new opportunities for the use of these buildings.

Figure 62 - Exposed value classification of buildings inside the park in case of architectural and functional recovery of unused historical buildings (image modified from the original taken by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, with student group 6: Marta Chiara Gobbo - Eva Maria Ronchi - Veronica Tamanza - Francesco Turrini).

Vulnerability analysis.

Unlike the evaluation of the exposed value, analysis of vulnerability also depends upon the phenomenon impacting on structures and their contained people and goods. From the point of view of human presence, we can consider the building situation as neutral, since people who attend the schools should display a homogeneous level of readiness to react to floods, and then evacuate the area rapidly, reaching a safe place easily above the expected water level, also in response to evacuation procedure as set up by the School's authorities. Coherently, frequently, or rarely occupied buildings will be evaluated from the point of view of vulnerability, without considering the presence of people (moreover, the presence of humans has been considered in the analysis of the exposed value). For the same reasons, here we add also evaluate technical networks.

This assumption of considering rapid clearance of humans in the flooded sites is essential because human (especially young's) stability thresholds are almost certainly overpassed, at list in the area of ballet school (see Figure 56, with h > 1 m, and v > 0.5 ms-1 in large areas), but possibly in many other areas of the park (USBR, 1988; Abt et al., 1989; Maijala, 2001; Milanesi et al., 2015).

Instead, the state of conservation of structures is significant to counteract the action of water during a flood. This is because of the chance to be more or less quickly replaceable, and the situation of containing documents, devices, students' works, musical instruments, etc. (clearly susceptible to be relevantly damaged). So, in this case too, we mainly investigated a direct component of the damage.

As a matter of fact, buildings' stability thresholds (Figure below) show that again, in the case of the Ballet school, we are not far from the partial damage thresholds (see Figure 56, with h > 2 m, and v = 0.5-1 ms-1 in some areas, and Clausen and Clark, 1990; Maijala, 2001).

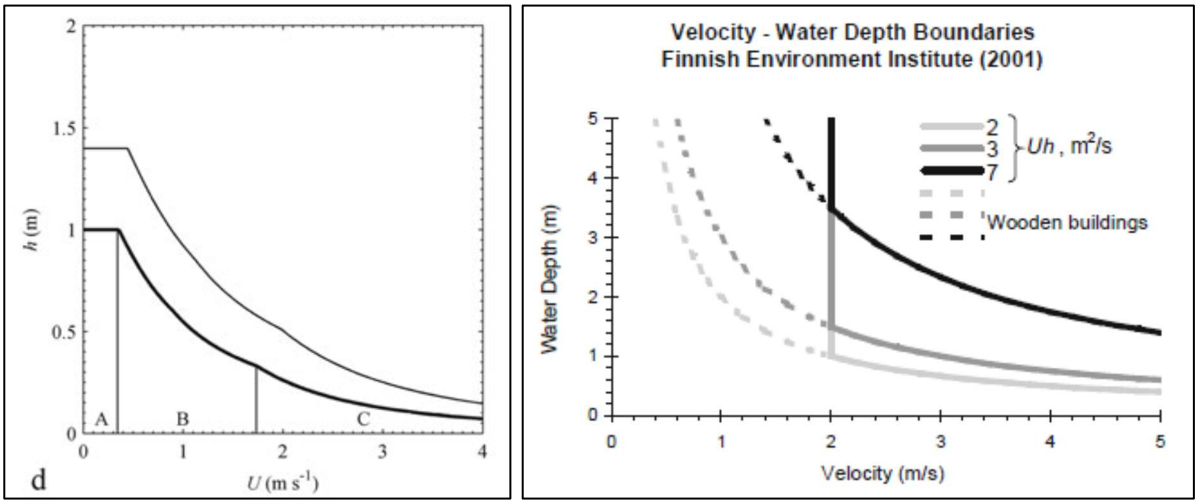


Figure 63 - Left: Stability thresholds for adults (thin line) and children (thick line), found out by Milanesi et al. (2015); right: Empirical criterion for damages to buildings of the Finnish Environment Institute—FEI (Maijala 2001): masonry buildings are the continuous lines.

About the school of music, it's easy to anticipate that there is a clear problem of resistance to the erosion of the foundations, for the portion of the edifice almost in contact with Rio Quibù.

Therefore, the next figure shows three levels of vulnerability (high, medium, and low) in the area. It is therein labeled the vulnerability of ballet and music buildings, of buildings that are not national monuments, like the rectorate, the presence of other goods that are less vulnerable, or quickly replaceable, but functional, as electricity lines (public lights), roads, etc.

1. high: bad structural conditions, no goods inside;
2. medium: good structural conditions, vulnerable goods inside;
3. low: quickly replaceable service and structures not very vulnerable.

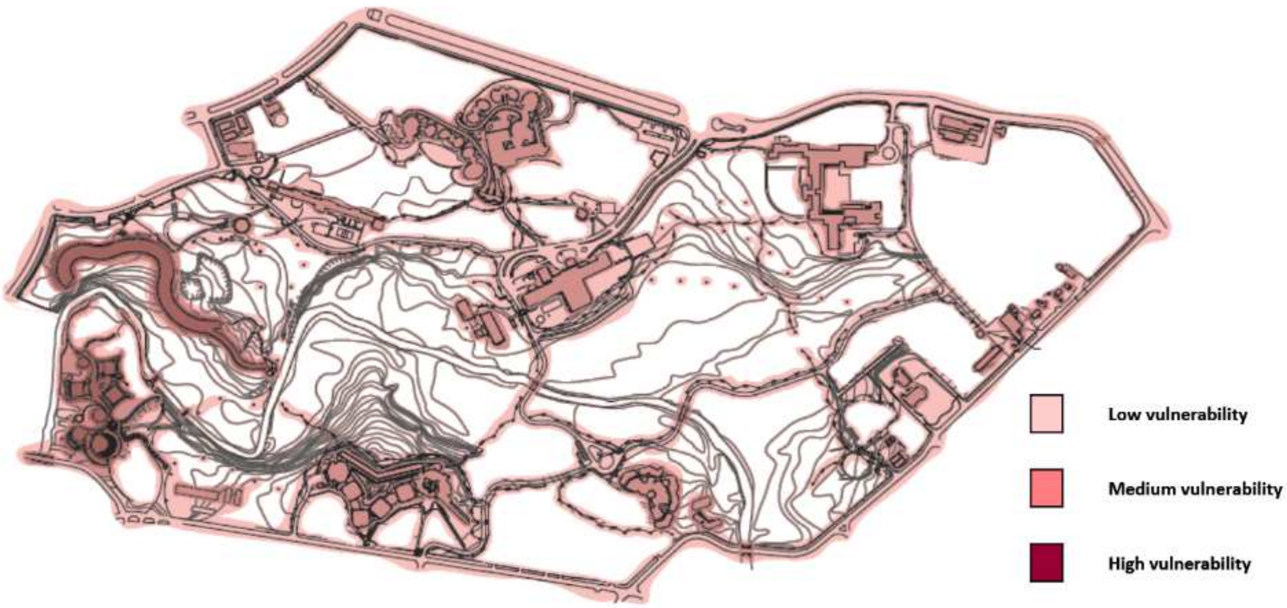


Figure 64 - Flood vulnerability classification of buildings and infrastructures inside the park (image modified from the original taken by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, with student group 18: Sara Mazzola, Guendalina Nozza, Greta Possi, Anna Puricelli, Greta Weber).

Damage (consequences) assessment.

As widely known in the literature (Fournier d'Albe, 1986; Kron, 2009), the vulnerability and exposed value, when combined, allow evaluation of the potential consequences, or damages, since the vulnerability values allow to estimate the portion of exposed value potentially lost (resulting from a specific type of disaster). A damage ranking matrix of targets inside the Schools' Park could be thus obtained, as shown in the next Figure. This considers both the situation business as usual and also the potential re-vamping and use of the three schools of ballet, music, and drama.

Targets (*today*)	Exposed Value	Vulnerability	*Damage* (*today*)
School of modern and folkloric dance	Very High	Medium	Substantial
School of plastic art	Very High	Medium	Substantial
Student house	High	Medium	Considerable
New school of music	High	Medium	Considerable
Rectorate	High	Medium	Considerable
School of ballet	Medium	High	Considerable
School of music	Medium	High	Considerable
School of dramatic arts	Medium	Medium	Considerable
Warehouses and archives	Low	Medium	Minor
Technical networks, road and infrastructures	Low	Low	Minor

Targets (*future* - without risk reduction actions)	Exposed value	Vulnerability	*Damage*
School of modern and folkloric dance	Very High	Medium	Substantial
School of plastic art	Very High	Medium	Substantial
Student house	High	Medium	Considerable
New school of music	High	Medium	Considerable
Rectorate	High	Medium	Considerable
School of ballet	*Very High**	High	Major
School of music	*Very High**	High	Major
School of dramatic arts	*Very High**	Medium	Substantial
Warehouses and archives	Low	Medium	Minor
Technical networks, road and infrastructures	Low	Low	Minor

Very High 4	*Considerable 4*	*Substantial 8*	*Major 12*
High 3	*Minor 3*	*Considerable 6*	*Substantial 9*
Medium 2	*Minor 2*	*Considerable 4*	*Considerable 6*
Low 1	*Minor 1*	*Minor 2*	*Minor 3*
EV / V	Low 1	Medium 2	High 3

Figure 65 - Obtained Damage ranking matrix, today (business as usual) and in future, under the hypothesis of reuse of the unused school (*) without risk reduction works.

Thanks to the obtained assessment of potential damage (or consequences), a first suggestion arises: there is the possibility to act on the basis of a two-stage strategy. First, in a transition period, one can act using a provisional solution. Then, from a long-term perspective, one can use interventions aimed at the reuse of the schools.

3.4.1.3 Risk analysis and assessment: priority targets to be defended

Overlapping the so obtained hazard maps with the results of the analysis of vulnerability and exposed value, one can identify targets potentially involved in the risk scenarios. The next figure derives a risk matrix for the area, combining the damage vectors obtained in this chapter and the hazard classification done in previous chapters. Upon the basis of hazard assessment, we may state that according to the European and American habit (U.S. National Flood Insurance Program and E.U. Flood Risk Management Plans):

- the areas of recurrent flood hazard are areas below the limits of the 100-year floods.
- the areas of moderate flood hazard are areas between the limits of the 100-year and 500-year floods.
- the areas of minimal flood hazard are areas above the 500-year flood level.

Targets (*today*)	Damage	Hazard	Risk
School of modern and folkloric dance	Substantial	Minimal	Low
School of plastic art	Substantial	Minimal	Low
Student house	Considerable	Minimal	Low
New school of music	Considerable	Minimal	Low
Rectorate	Considerable	Moderate	Medium
School of ballet	Considerable	Recurrent	Medium-high
School of music	Considerable	Recurrent	Medium-high
School of dramatic arts	Considerable	Moderate	Medium
Warehouses and archives	Minor	Moderate	Low
Technical networks, road and infrastructures	Minor	Recurrent	Low

Targets (*future* - without risk reduction actions)	Damage	Hazard	Risk
School of modern and folkloric dance	Substantial	Minimal	Low
School of plastic art	Substantial	Minimal	Low
Student house	Considerable	Minimal	Low
New school of music	Considerable	Minimal	Low
Rectorate	Considerable	Moderate	Medium
School of ballet	Major*	Recurrent	Very High
School of music	Major*	Recurrent	Very High
School of dramatic arts	Substantial*	Moderate	Medium-high
Warehouses and archives	Minor	Moderate	Low
Technical networks, road and infrastructures	Minor	Recurrent	Low

D \ H	Minimal 1	Moderate 2	Recurrent 3
Major 4	Medium 4	High 8	Very High 12
Substantial 3	Low 3	Medium-high 6	High 9
Considerable 2	Low 2	Medium 4	Medium-high 6
Minor 1	Low 1	Low 2	Low 3

Figure 66 - Obtained risk ranking matrix, today (business as usual) and in future, under the hypothesis of reuse of the unused school (*) without risk reduction works.

On the basis of the so obtained flood risk matrix, the selection of priority targets to be included in a conservation management plan can be provided (shown in the next Figure), on the basis of a three-level classification (A - urgent, B - important, and C - according to the possibility), in which targets with hazard classified as minimal have been excluded:

A.1 - School of Ballet: the school as a whole. Urgent.

A.2 - School of Music: south and east portions. Urgent.

B.1 - Rectorate: south front. Important.

B.2 - School of Dramatic Art: north and east fronts. Important.

C.1 - Warehouses (at the center of the park): south front. According to possibility.

C.2 - Technical networks, roads, and infrastructures: near the Quibù river. According to possibility.

The next paragraph illustrates our priority choices.

Figure 67 - Flood risk: priority targets to be included in the Conservation Management Plan.

3.4.1.4 Specific mechanism affecting selected targets

To complete the illustration of our risk analysis and assessment works, it is necessary to deepen into every single target by better specifying what was anticipated within the analyses of hazard, vulnerability, and exposure, especially about the evaluation of factors of hazard scenarios that could act on the targets giving damages.

A.1 - School of Ballet

As it is clear based on our hazard analysis, the school of ballet could be involved as a whole by flood scenarios. Both in Europe and in the United States, constraints would be placed on construction and renovation activities in these areas (i.e., according to E.U. Flood Risk Management Plans and U.S. National Flood Insurance Program). It is because of this total involvement that the School of ballet requires the most urgent actions for risk reduction.

The mechanisms acting on the buildings here strike structures directly, which evidently is in not desirable conditions. Such mechanisms can be described by fixing three initial classes (Kelman et al., 2004):

- lateral pressure from water depth, the differential between the inside and outside of a building;
- lateral pressure from water velocity;
- water contact due to slow-rise depth.

Lateral pressure from water depth is a hydrostatic action, to be calculated as the difference between the water levels outside and inside the building.

Water velocity's impact is linked to the additional lateral pressure (hydrodynamic pressure) transferred by water flowing around or against an object (cited flow force, energy head, and intensity), including effects as turbulence, suction forces, erosion, and waves.

As anticipated, the sum of the hydrostatic and hydrodynamic pressure gives the possibility, based on the physical characteristics of a building, to derive damage stages and collapse probability (Jalayer et al., 2016). Evidently, this action, often combined with buoyancy effects, can also impact movable goods and people inside or around the buildings.

Hydrostatic and hydrodynamic pressures are the most worrying mechanisms affecting ballet schools (see Figure 63 above).

Instead, the slow-rise effect, when flood advancement is without significant velocity and large hydrostatic pressures differential between the inside and outside of a building, is mainly caused by the water contact with construction materials and building plants (electricity, etc.). Some materials, exposed to the action of such a water volume up to now, are in not good conditions, even if the absence of plasters has limited a situation that could have been worse.

The presence of wind effects during floods is certainly a cause for further concern.

Chemical/biological/salt actions, capillarity, and flood duration are factors probably affecting in a poor manner the Ballet School, also taking into account Rio Quibù catchment parameters.

Figure 68 - School of Ballet, eastern side (A. Garzulino, 2019).

Figure 69 - School of Ballet, practice classroom (A. Garzulino, 2019).

A.2 - School of Music

Also, the school of Music could be partially, but significantly, involved in its south and east portions. As in the previous case, our flood scenarios would impose constraints on construction and renovation activities. Accordingly, risk reduction activities are urgent, as in the previous case, even if the magnitude of the consequences would be smaller. The mechanisms acting on the edifice are different in the south and in the east portion of the edifice.

In the side at the south of the edifice, slow-rising water, in case of bad scenarios, can reach the classrooms of the lowest floor. The next Figure shows the unprotected in front of the school.

Figure 70 - School of Music, south side: lowest classroom.

East of the building, terraces walls, in a bad state of conservation, are unprotected and exposed to the erosive action of water in case of flood, as shown below. Moreover, the stability of the foundation appears not completely guaranteed. As a matter of fact, the scenarios obtained give water depth rapidly reaching two or three meters, when the flood return period grows over five years or so.

Figure 71 - School of Music, east side: the walls unprotected, exposed to the erosive action of water in case of a flood (upstream view).

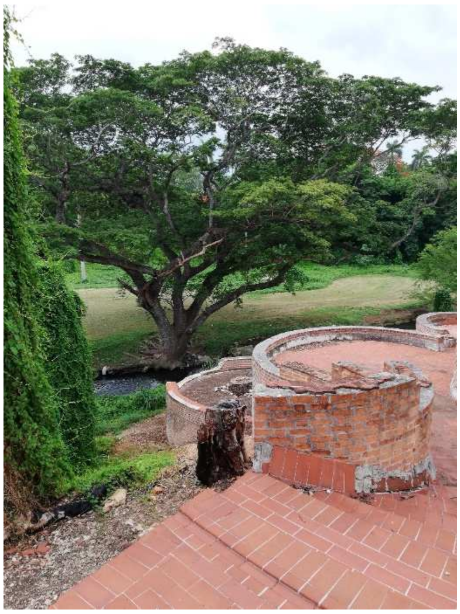


Figure 72 - (a - left; b - right) - East side of School of Music, views from downstream and from the top of the terraces.

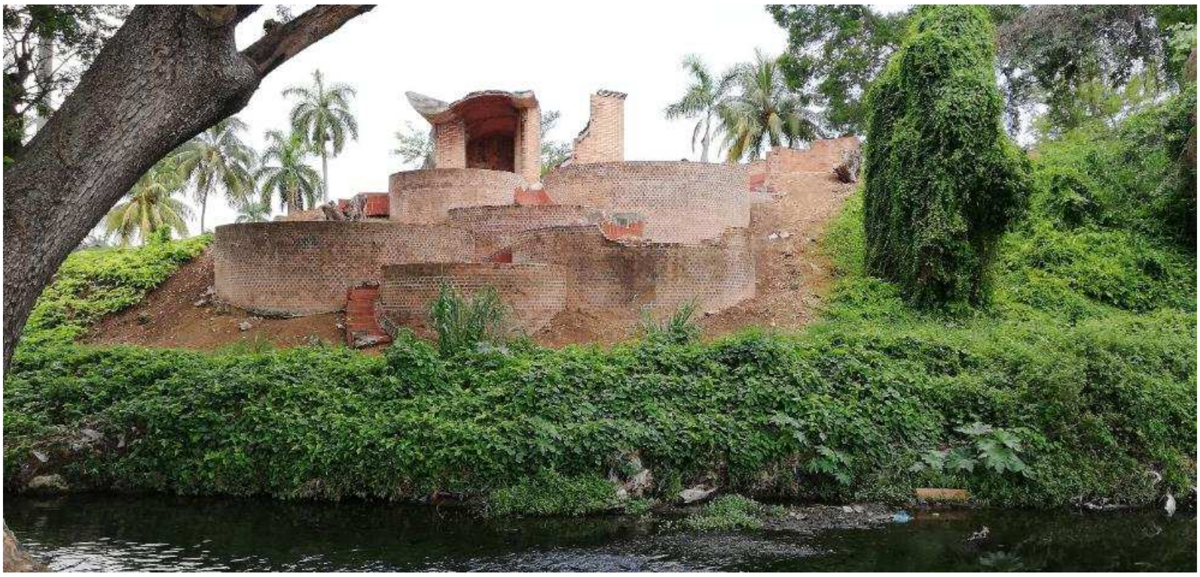


Figure 73 - East side of the School of Music: front view.

Figure 74 - East side of the School of Music: detail.

No other factors seem to have a significant impact on the School of Music.

B.1 - Rectorate, and B.2 - School of Dramatic Arts

The Rectorate, south front, and the School of Dramatic Arts, north and east fronts would be rarely touched by Rio Quibù floods. Damages may be caused by water contact due to slow-rise depth because flood advancement should be without significant velocity. In addition, the flood height predicted is not alarming. The position of Rectorate is probably more affected than that of the Dramatic Art Schools. That condition, together with the directional function of the rectorate for all the schools, made us put these buildings in a similar priority level, even if the Rectorate is not a national monument (but, as a matter of fact, its exposed value is high).

The specific mechanism affecting these two edifices would be slow-rising water; that is, in case of rare scenarios, water can reach the lowest floors.

Figure 75 - Rectorate south front. The picture is taken from the right side of the Rio Quibù bed.

Figure 76 - The road in front of the Rectorate. Rio Quibù river under the trees on the horizon (A. Garzulino, 2019)

Figure 77 - Dramatic Arts School: north front (A. Garzulino, 2019).

C.1 - Warehouses (at the center of the park)

The situation of the south front of warehouses at the center of the park is similar to that of the Rectorate. The function and the magnitude are probably less critical (from which a less important exposed value), although it would be better to carefully check the material, documents, and goods stored inside these buildings, and in case, relocate them in safer areas. In addition to that consideration, from a vulnerability point of view, the doors/gates position here seems to have been conceived in a prudential manner, and potentially above the levels of first slow-water rising up until the buildings.

Regarding roads, public lighting poles, etc., the situation seems not largely worrying, being such material either easily replaceable/repairable, or apparently able to resist to the actions of water, that, in this case, would not only be by slow-water rising up, but also by hydrodynamic pressures.

Figure 78 - Warehouse views and public lighting poles and roads (bottom-right) at the center of the park.

C.2 - Technical networks, roads, and infrastructures:

The situation of technical networks, roads, and infrastructures (bridges, etc.) in the Quibù river flooding areas is much differentiated. Although crucial for the day-by-day activities of schools, probably their consideration in the Conservation Management Plan is not a priority, being a “common” problem for the city of La Habana.

3.4.2 Surface runoff and water stagnation analysis (schools of ballet and music sites)

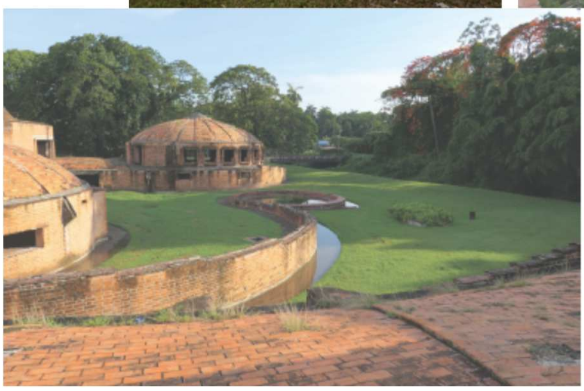
Due to the aging conditions and state of conservation, and probably because it is partially uncompleted (architectural finishes), the sites of the school of ballet, primarily, and the site of the school of music (north side), secondarily, are affected by the actions of water frequently coming in touch with their structure. This is as a result of a surface runoff not well controlled and causing water stagnation and erosion, and as a result of the absence of windows, frame, doors, etc.

In the School of Ballet, the water drainage systems, i.e., small ditches, and canals, are likely clogged and disrupted, and water collection tanks seem not to work correctly. As a result, many incorrect water diversions are present, and overland rainfall reaches the internal spaces, causing large puddles outside the building, but in not foreseen positions, and localized phenomena of erosion.

Figure 79 - Clogged and disrupter drainage system of Ballet School.

The problem is exacerbated by the local terrain morphology, seeing the school positioned downstream of a hill, whose water, being not channeled, is conveyed towards the school.

Figure 80 - The original drainage system at the entrance of the Ballet School (picture by Paolo Gasparini); a particular water collection system conceived by Garatti - right.



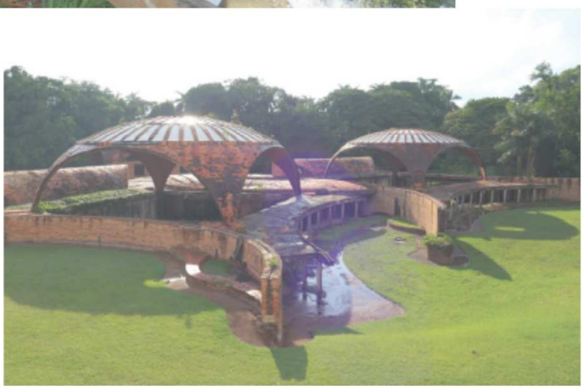


Figure 81 - Puddles inside and outside the Ballet School.

Figure 82 - School of Ballet (A. Garzulino, 2019).

Figure 83 - School of Ballet (A. Garzulino, 2019).

Figure 84 - School of Ballet (A. Garzulino, 2019).

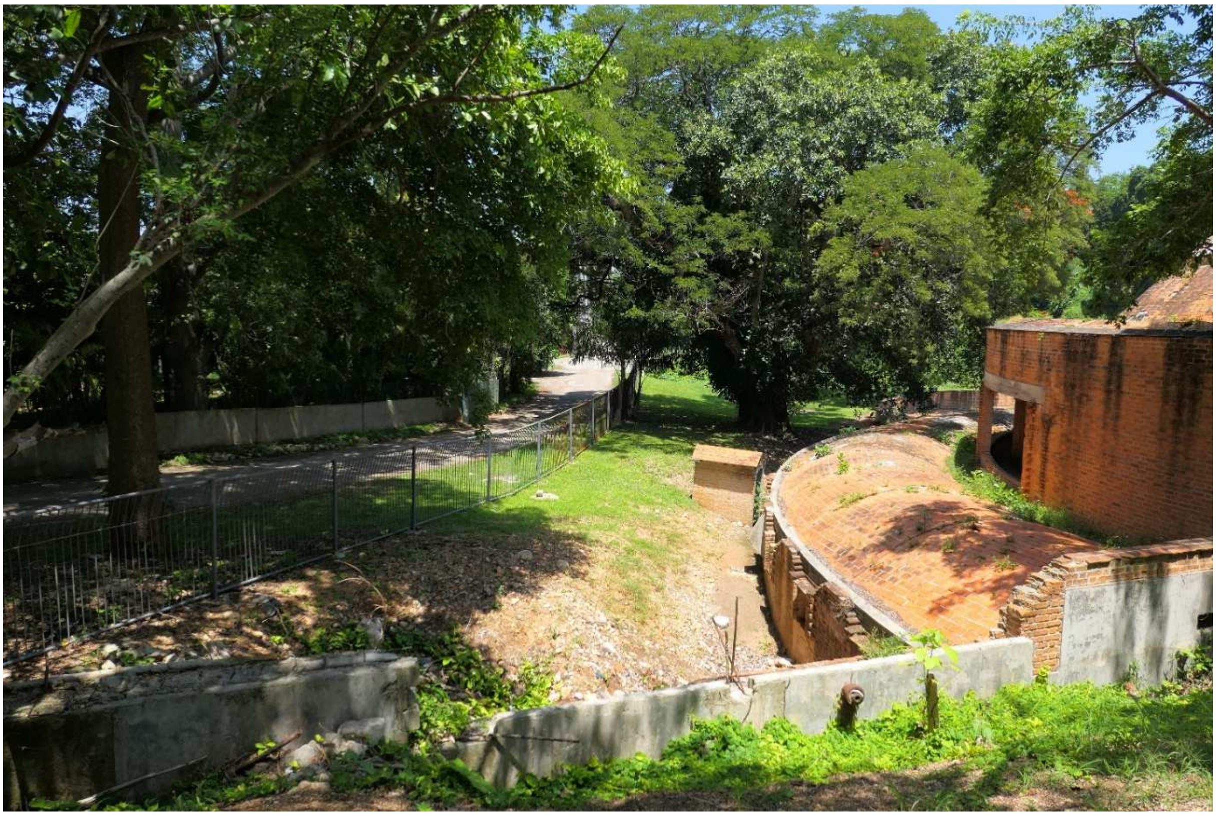


Figure 85 - School of Ballet (A. Garzulino, 2019).


Figure 86 - A concrete tank, possibly a structure originally used for water storage (A. Garzulino, 2019).

Figure 87 - Erosion and stagnation at the school of music - north side (A. Garzulino, 2019).


Figure 88 - Erosion and stagnation at the School of Music - North side (Bignami, 2019).

3.5 Flood risk reduction strategies developed by local institutions and professionals

We report and analyze here some proposed solutions for flood risk mitigation in the school of ballet area.
Such proposed solutions were found based upon analysis of the available literature and discussion with personnel of the INRH, the latter having developed a structural solution, to be expectedly implemented in the area henceforth
We provide simulations of the hydraulic conditions in the presence of such solutions, to benchmark our results concerning flood risk at the school of ballet.

3.5.1 Instituto Nacional de Recursos Hidraulicos

Based upon discussion with the personnel of the INRH, their proposed (structural) solution included:

1. Construction/restoration of a concrete wall along the ballet school island, with level 5 m asl, starting from the 15th street bridge, and until 364 m upstream;
2. Widening of the river stretch, as much as possible from puente quince to 539 m upstream, and to 20 m width for 244 m more upstream;
3. Modification/restoration of a perimetral collector to remove pluvial water, partly underground and partly as an open channel.

Here, we provide hydraulic simulation in the area, under the conditions obtained implementing points 1 and 2 above. Design flow is for R = 100, as from the INRH study.
Notice that the collector at point 3 does not affect flood risk as from river flows.

The results are reported in Figure 89. Visibly, while the perimetral wall actually seems to be able to defend the School of Ballet area, flooding of the upstream part of the area, including towards the School of Music, and the rectorate area seems not visibly limited at all when putting in place the proposed options.

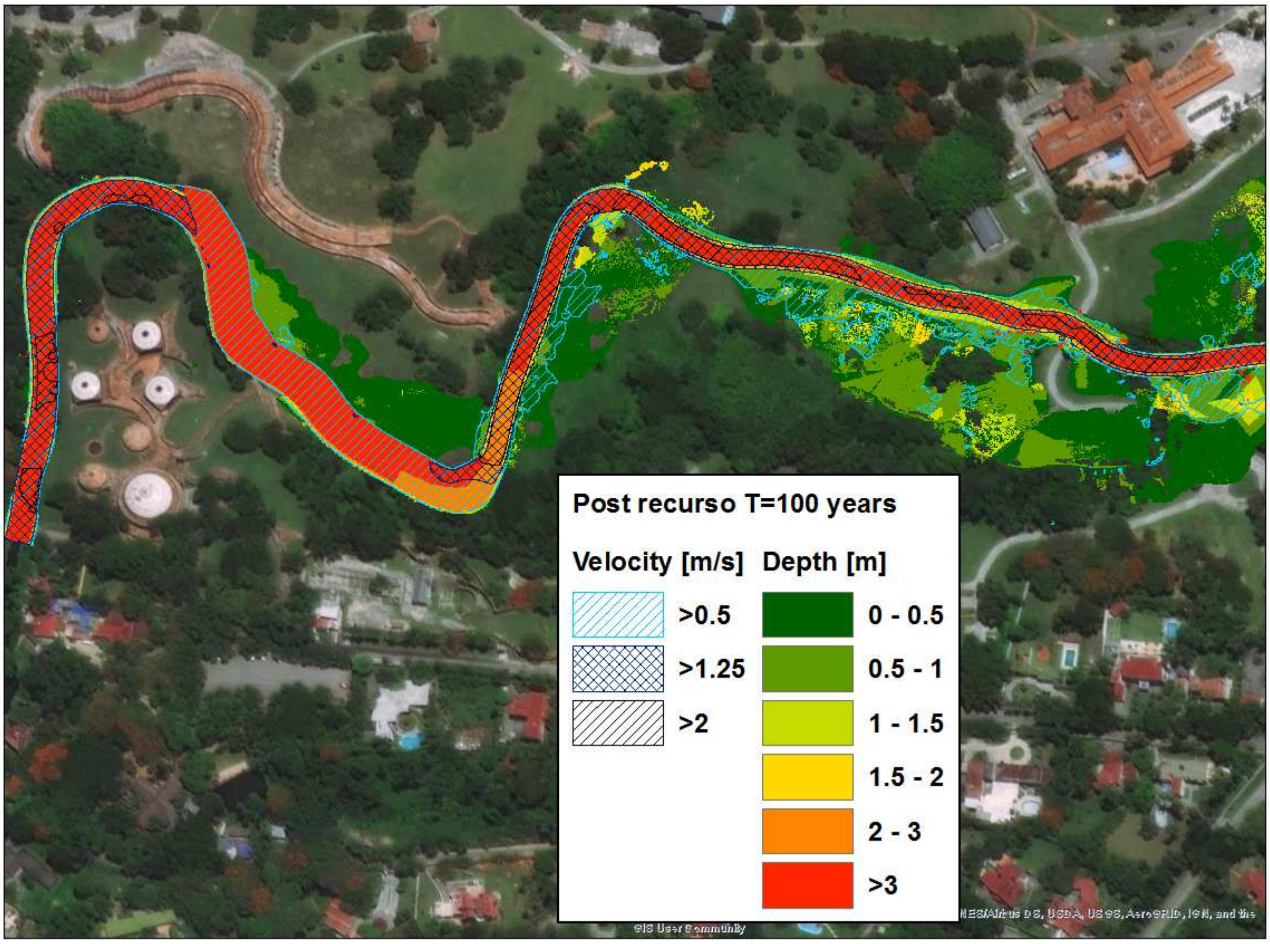


Figure 89 - Map of flooded areas with R=100, conditioned on the implementation of INRH solutions. Flow depth and velocity using HEC-RAS 2D.

3.5.2 Other planned interventions

Other, not structural options were found in informal documents and are briefly described here, namely:

1. Cleaning of the Rio Quibù river, with the removal of in-channel vegetation downstream puente quince;
2. Temporary (i.e., before/during floods) installation of inflatable hose;
3. (Permanent) installation of side banks, slopes reinforced using geosynthetic materials.

However, no information was available about the actual feasibility of such solutions, costs, and programs for the realization of such structures/options.

Below we report a thorough analysis of possible options for flood proofing of the area, with qualitative analysis of cots, feasibility, opportunity.

3.6 Flood risk reduction strategy

On the basis of the work done in chapters 3.1 - 3.4, two main fields of action for risk reduction were identified, namely:

1. River flood risk, caused by Rio Quibù inside the Country Club area and ballet school.
2. Pluvial risk, or surface runoff and stagnation of water, mainly in the ballet school site.

It is important to underline that the identified events are different, also from the point of view. of disaster risk reduction theories and practices.

River floods are one of the main events potentially affecting urbanized flat and bottom valley areas, typically caused by high streamflow overtopping natural or artificial banks, due to, e.g., a long-lasting rainfall over a broad area or a locally intense thunderstorm-generated rainfall over a comparatively smaller area.

Pluvial risk, i.e., surface runoff and stagnation of water, concern specific points of urban or natural places, when the rain falling directly over the sites exceeds the draining capacity (infiltration rate) of the soil, and further, it is not removed from a drainage system, due to the latter being broken, insufficient or absent.

Seldom enough, but not always, such events may occur simultaneously. Quickly, in particular, when floods are characterized by high enough return periods, the pluvial risk becomes a minor issue, except when river flood defense solutions are properly designed. In this last case, designers must opt for integrated answers to both problems. For this reason, the third field of action of risk reduction must be considered, namely:

3. Local drainage efficiency when flood occurs.

The next paragraphs will firstly describe the risk analyses related to floods inside the park and the water stagnation problems in the ballet school site. Then, the text will describe a survey of the alternative solutions already developed, including those designed by the Instituto Nacional de Recursos Hidraulicos (including Construcción de Muro de Protección Facultad de danza, and Puente de calle 15 que será necesario ampliar) and some ideas suggested by other local companies.

Starting from the previous analysis and the identification of the alternative solutions already developed, we will present a variety of techniques and related performances when considering their functioning in the specific contexts investigated. At the end, we suggest an abacus to resume the options, for each target considered at risk, resulting from a first assessment, and useful to give the decision-makers the best solution, also taking into account budget, and other resources available, or to be put in place.

As in many other cases of highly urbanized contexts, also in L’Habana, it is not possible to apply a defense strategy against floods only by means of massive public works like retention structures or flood detention basins, the availability of which, in terms of free land, efficiency, financial resources, and local people acceptability, is becoming increasingly difficult.

As regards the purpose of the present part of the study, which focuses on defending a heritage site, a choice of small works and flood proofing techniques offer a set of actions, which, if compared to traditional strategies, are more suitable and of which the economic feasibility is easier to achieve.
Coherently, the traditional approach to flood-control, already partially implemented in the Rio Quibù catchment, must be integrated and completed adding new options in a framework of a bottom-up approach that we can call resilience-oriented, able to shift flood-resistant actions towards a wider and complete "flood-adaptation" strategy, including flood proofing techniques and targeted choices as dynamic and combined option or component of a strategy not solely based on static or permanent solutions.
To verify this, here we present a systematic technical assessment of available options, based on the recent classification of the matter (Bignami et al., 2019), to obtain a set of possibilities of interventions to be compared and offered to decision-makers, to fight against floods and surface runoff affecting the park of Schools of Arts.

3.6.1 Permanent (or heavy) flood proofing techniques

Permanent flood proofing techniques provide solutions that can be referred to as some categories/classification. Usually, they imply a "heavy" approach, possibly changing in a relevant manner the state of the buildings or of the sites.

<u>A. Relocation of the buildings</u>

The Relocation is the safest strategy, as it eliminates the risk factor of exposed value. However, it is also the most expensive one. From a technical point of view, this technique requires the whole construction to be removed and then relocated into a safe area.
The application of such a technique is not always possible, specifically when buildings are heavy, complex, and fragile, or irreplaceable.

<u>B. Elevation of the buildings</u>

The Elevation technique keeps all habitable and usable floors of a building above the maximum flood level (for instance, positioning the building on piles or leaving abandoned the ground floor). Such a "retrofitting" technique can be used on individual buildings whose structure and facilities prove to be solid and safe at the end of work—well anchored to the ground, hence with a very low residual vulnerability if compared to earlier conditions (considering flow velocity, waves, erosion, debris flow, etc.).
Such a solution could expect the building to remain isolated during the flood and, as in the previous case, it is not always possible, not only when buildings are heavy, complex and fragile or irreplaceable, but also when the buildings extend mainly horizontally.

C. Floodwalls or levees

The installation of total or partial perimeter floodwalls, or levees, prevents water from getting to the vulnerable parts of a structure by keeping it away from the exposed goods and reducing the site's local hazard. Possible permanent works of this kind of technique are small levees or

berms or walls. Local detailed orography permitting, these floodwalls can be applied only to some of the building's sides, sometimes preventing the building from being totally isolated.

Such a solution is frequently chosen, but it needs to pay attention to verify that the obtained waterway diversion should not worsen the situation, whether upstream or downstream.

D. Dry flood proofing (external predisposition of a construction),

Dry flood proofing is obtained by sealing, structurally reinforcing, and waterproofing a building—including its foundations at least up to a range reasonably higher than the expected flood height (thus including the freeboard) to avoid floodwaters from entering the buildings. Applying this usually less costly technique, protection may be provided by using shields for openings, sealants over the walls (polyethylene films, asphalts, new masonry layers, etc.), or even buttressing external partitions. In any way, not only will such building types be isolated during the flood, but also partially submerged in water.

To apply such a solution is needed to evaluate the forecasted pressure and level of the flood with the structural resistance of the buildings' perimetrical surfaces.

E. Wet flood proofing (internal predisposition of a construction).

Wet flood proofing, which supports the natural equalization of water pressure against a construction's structures and walls (internal and external), is obtained by modifying individual buildings in order to allow water to flow in and out without causing significant damage, i.e., structure and infill restoration. This is possible, for instance, on the basis of the right material selection, but also (re)thinking about the use of a building and being sure of the availability of an adequate warning time to the evacuation.

F. Floating.

It is the most recent and experimental technique. This technique is not apt to be used to retrofit an existing building, but it has been devised to be applied to the conception of projects of new constructions.

G. Ground lowering/leveling of free land for waterway diversion and/or local storage.

Ground lowering/leveling of free land can be designed both for flow deflection purposes and for the storage of small volumes or streams of flooded water (even underground). Such a solution can be accompanied by the elevation of buildable areas and setbacks of property lots, for instance, obtaining a defensive slope. Normally it does not cause the isolation of buildings when floods occur. Compared to previous solutions, its effectiveness depends more on flooded water volumes, on local land morphology, and, in general, on the territorial and environmental contexts. This type of technique is easily inferable from the construction of levees or floodway channels, as, in a planar representation, the latter is mainly characterized by a one-dimensional or linear surface, while in this case, the geometrical structure is two-dimensional. However, it differs from flood detention basins for its small scale and the wide variety of land use.

The implementation of such a solution, especially for outdoor living areas at the neighborhood level through proper works of grading and excavation, once again demands caution while assessing that the obtained waterway diversion does not worsen the situations, whether upstream or downstream.

3.6.1.1 Preliminary examination of techniques that could be used (evaluation of alternatives for flood risk reduction)

As may have appeared evident, not all techniques can be used in every context to be defended. The following table gives a preliminary examination of permanent flood proofing techniques suitable to be used for the targets in the schools' park, as prospective alternatives to be evaluated for the decision making about flood risk reduction.

Table 2 - Permanent (or heavy) flood proofing techniques.

Permanent flood proofing technique	**Potential target that could be defended (theoretically)**	**Strengths /** ***Weaknesses of options*** **(general preview)**
A. Relocation of the buildings	Warehouses	The buildings might be repositioned outside flood prone areas and the use of the building would be guaranteed during a flood/ *Very expensive action*
B. Elevation of the buildings	Rectorate	Taking into account the type of building, such a technique could only be applied through the abandonment of lower floor, leaving it empty (no damage if flooded) / *loss of spaces used today - not easy to maintain over the years*
C. Floodwalls or levees	Ballet School Music Schools (east front) Rectorate School of Dramatic Arts Warehouses	Intuitive solution technically feasible in all five cases, and the use of the buildings would be almost guaranteed during a flood / *Expensive action, impacting on the landscape, maybe worsening flood risk level, mainly downstream; dramatic in case of failure or breach*

Permanent flood proofing technique	**Potential target that could be defended (theoretically)**	**Strengths / *Weaknesses of options* (general preview)**
D. Dry flood proofing (external predisposition of a construction)	Ballet School	Water would not be able to come in contact with the building / *facades and openings should undergo changes to resist water loads and pressures - the closure of the openings generally would not, however, be permanent and would require additional actions in real-time - access to the building would be denied or made more complicated during a flood*
	Music school (south front)	
	Rectorate	
	School of Dramatic Arts	
	Warehouses	
E. Wet flood proofing (internal predisposition of a construction)	Ballet School	Structure stability almost guaranteed - not impacting on landscape / *The use of the spaces contained goods and service facilities should be conceived to be transformed (substantially rethought or redone) to maintain the school function*
	Rectorate	
F. Floating	///	///
G. Ground lowering/leveling of free land for waterway diversion and/or local storage	Ballet School	Similar to floodwalls solution, but more flexible, including spatial design (storage and diversion areas) and underground spaces exploitations (tanks)
	Music school	
	Rectorate	
	School of Dramatic Arts	
	Warehouses	

3.6.2 Temporary and light flood proofing techniques

Temporary flood proofing techniques, also called sandbag replacement systems (SBRS), are always more used for flood fighting because less time-consuming and less intensive in terms of materials and personnel (Lankenau et al., 2019) and because less impacting and less costly than the permanent or heavy ones. Temporary flood proofing techniques are essentially based on the following selection (Bignami et al., 2019) of the categories of the previous classification presented because the others can't be implemented in a non permanent way:

A. Floodwalls or levees;
B. Dry flood proofing (external predisposition of a construction);
C. Wet flood proofing (internal predisposition of a construction);
D. Ground lowering/leveling of free land for waterway diversion and/or local storage.

On the other hand, temporary flood proofing techniques are classified into the following three classes on the basis of their mobility characteristics:

1. Demountable (liftable and fully pre-installed/fixed, also called semi-permanent);
2. Pre-arranged/Prelocated (partially transportable, partially pre-installed and fixed);
3. Removable (fully mobile, transportable, completely removed after flood event).

To these classes, we can add another class, that of:

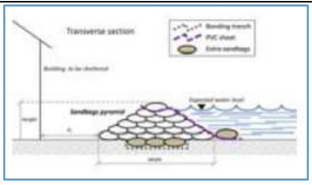
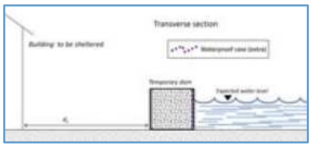
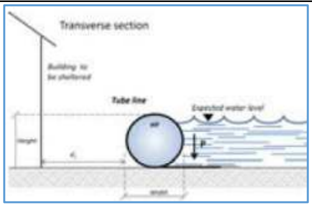
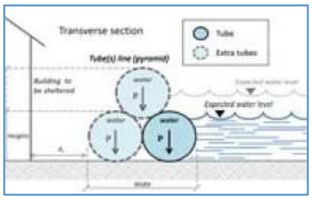
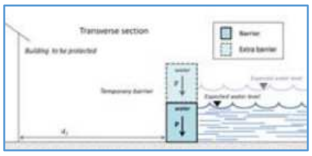
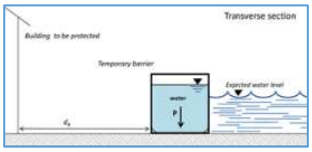
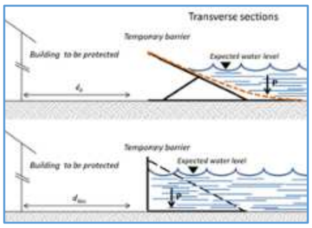
4. Small permanent techniques.

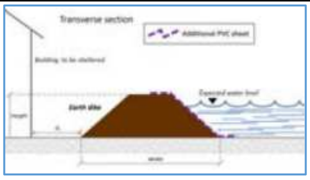
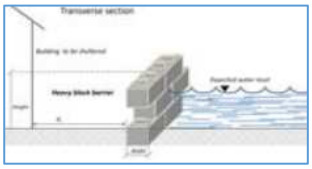
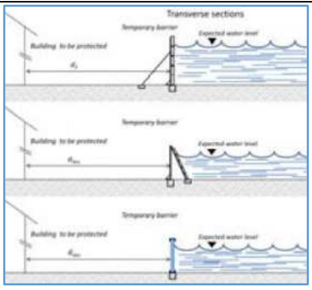
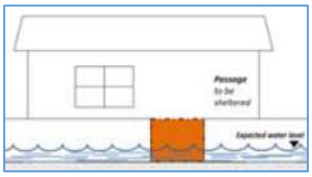
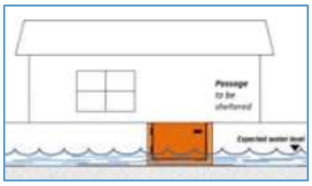
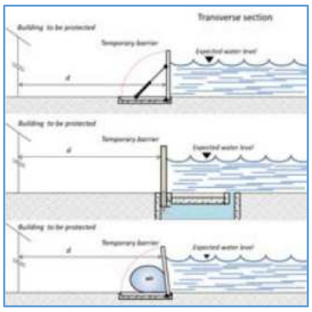
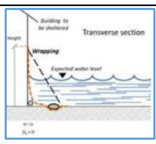
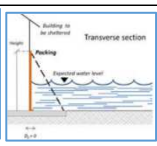
That is the use of light or small permanent changes to buildings and infrastructures (and their adjacencies), which may be considered a halfway solution between the two previous approaches: permanent and temporary solutions. Despite joined to temporary solutions, because they are all light (and often less expensive) solutions than the permanents, here we present two tables to describe potential use in the context of the park.

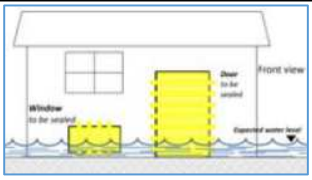
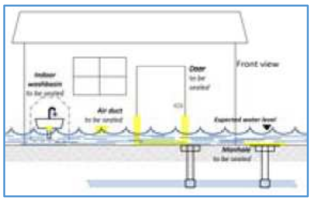
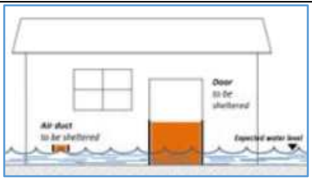
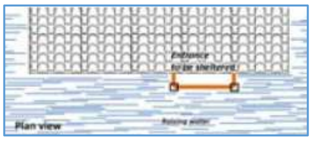
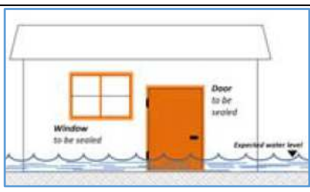
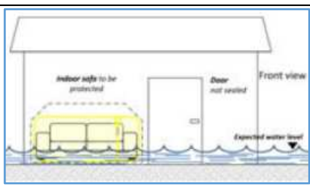
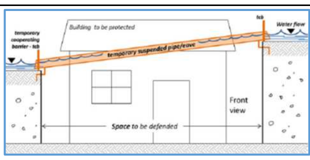
3.6.2.1 Preliminary examination of techniques that could be used (evaluation of alternatives for flood risk reduction)

As in the case of permanent heavy techniques, not all techniques can be used in every context to be defended in this case too. The following tables give preliminary examinations of temporary and small permanent flood proofing techniques suitable to be used for the targets in the schools' park, as potential alternatives to be evaluated for the decision making about flood risk reduction. Firstly, we present a temporary flood proofing technique, about which it is important to underline that almost all solutions are characterized by a very little or even absent impact on landscape or monuments.

Table 3 - Temporary and light flood proofing techniques

Temporary flood proofing technique	**Options evaluated**	**Potential target that could be defended (theoretically)**	**Strengths /*Weaknesses of options* (general preview)**
Floodwalls Removable group 1) — Stacking of individual base units filled with solid materials acting on gravity *Sandbags, temporary dikes containing reinforced earth/loose soil, as well as bags filled with innovative absorbent materials;*	  	Rectorate School of Dramatic Arts	Sandbags: Conceptually easy to be put in place / *hard work really time-consuming if high*
Floodwalls Removable group 2) — Supportive/juxtaposed use of fluid Containers *Modular tubes or containers to be filled with air or water;*	   	Ballet School Music school (south front) Rectorate School of Dramatic Arts	Quick to deploy / *Need of pumps or air-compressors - Technically not easy*
Floodwalls Removable group 3) — Self-deploying or self-supporting mobile barriers *Self-inflating barriers or barriers with a reticular structure*	 	Ballet School (flood and surface runoff) Music school (south front) Rectorate School of Dramatic Arts	Technically easy and quick to deploy (self-inflating) - easy to store / *not easy to deploy (reticular) -Relatively time consuming (reticular) - flat terrain (reticular)*

Temporary flood proofing technique	**Options evaluated**	**Potential target that could be defended (theoretically)**	**Strengths /*Weaknesses of options* (general preview)**
Floodwalls Removable group 4) — Emergency dikes and/or berms of loose solid material *Temporary earth levees/dikes and barriers of stone/ concrete blocks*		///	For heavy discharge / *heavy to manage - for flat soil*
Floodwalls Pre-arranged/Pre-located group 1) — Temporary barriers/ shields with specially crafted anchoring (temporary waterwalls) *Anchored vertical barriers (shields, gates, and panels)*		Ballet School (flood) Rectorate School of Dramatic Arts	Easy to install (detachable gate) / *Technically not easy to install and store (long span) - need maintenance*
Floodwalls Demountable group 1) — Fixed retractable barriers *Automatic vertical gates (barriers)*		Ballet School (flood) Rectorate School of Dramatic Arts	Easy to deploy in real time / *Need of particular maintenance - expensive (retractable barriers)*
Dry flood proofing Removable group 1) — Full dry flood proofing of buildings *Wrapping and packing of vertical walls with waterproof sheets (panels)*		Music school (south front) School of Dramatic Arts	Conceptually easy to be put in place / *Technically not easy*

Temporary flood proofing technique	**Options evaluated**	**Potential target that could be defended (theoretically)**	**Strengths /*Weaknesses of options*** **(general preview)**
Dry flood proofing Removable group 2)—Complementary dry flood proofing of buildings by means of removable universal apparatus *Composed by industrially produced devices thought to seal the most of common openings*	 	School of Dramatic Arts Warehouses	Conceptually easy to be put in place / *Technically not easy*
Dry flood proofing Pre-arranged/Pre-located group 1) —Selective dry flood proofing with customized watertight protections *Temporary shields or panels, watertight seals to prevent potential water seepage into the buildings (one-piece or sectional, thus more innovative than wooden boards)*	 	Rectorate Music school (south front) School of Dramatic Arts Warehouses	Easy to deploy in real-time / *Need for maintenance*
Dry flood proofing Demountable group 1) — Selective dry flood proofing with demountable watertight protections *Precisely and permanently customized, including watertight doors and windows and some automatic vertical shields*		Music school (south front) Rectorate School of Dramatic Arts Warehouses	Easy to deploy in real-time / *Need for maintenance - relatively expensive - Impacting extetically*
Wet flood proofing Removable group 1) *Hydro-repellent sacs or similar protections systems for indoor movable goods, as big sealable plastic bags*		Ballet School (flood and surface runoff) Rectorate School of Dramatic Arts Warehouses	Easy to deploy in real-time / *Need for workforce*
Ground lowering/leveling of free land Removable group 1) *Water diversion temporary activated pipes or bridges, composed of devices which do not stop but deviate water.*		Ballet School (runoff)	Easy to deploy / *Need for maintenance*

Following table shows the option for the evaluation among small permanent flood proofing techniques.

Table 4 - Small permanent flood proofing techniques

Small permanent flood proofing technique	**Potential target that could be defended (theoretically)**	**Strengths /** ***Weaknesses of options*** **(general preview)**
C. <u>Small permanent Floodwalls</u> Small elevations (berms) made of soil or other materials (concrete, bricks), just in front of building entrances (doors, basement window, etc.) or of transport infrastructures; light walls partially made in glass (both techniques are considered special kinds of light floodwalls).	Ballet School Music school (south front) School of Dramatic Arts	Solution smoothing lacks of corresponding heavy solution / *the homogeneity of the garden design could be partially affected*
D. <u>Small permanent Dry flood proofing</u> Air-bricks that under flood conditions uses the rising water to automatically shut off; concrete, brick and (external) masonry waterproofing-sealer or hydro-repellent paints or protectors; waterproof non-opening windows made with glass blocks or with reinforced glass; back-flow (non-return) valves in sewage/drainage systems, for instance with flaps floating up to block back-flow from sewers (as a special kind of light dry flood proofing).	Ballet School Music school (south front) Rectorate School of Dramatic Arts Warehouses	Water would not be able to come in contact with the building - facades and openings not changed/ *facades and openings should be subjected to load and pressure verification - the closure of the openings cannot be permanent in all part of the building and could require additional actions in real-time - access to the building would be denied or made more complicated during a flood*
E. <u>Small permanent Wet flood proofing</u> Dual function flood vents that counterbalance the pressure on internal and external walls of buildings; hydro-repellent paints or materials on internal walls; elevation of critical appliances and electrical outlets (these techniques are among the principles on which permanent wet flood proofing is based).	Ballet School (if not re-functionalized as school)	Structure stability improved - not impacting on landscape / *The uses of the spaces should be different from that of a school*

Small permanent flood proofing technique	**Potential target that could be defended (theoretically)**	**Strengths /** ***Weaknesses of options*** **(general preview)**
F. Small permanent Ground lowering/levelling of free land Artificial drainage channels and small slopes diverting water from buildings; moving flaps (sometimes to be opened when necessary) or preferential drainage ways favoring the water flows, avoiding stagnation (as a special kind of light ground lowering/leveling of free-land)	Ballet School	Similar to the heavy solution and to floodwalls light solution but excluding spatial design (storage and diversion areas) and important ground movements. Based on canalization, drainage, water distancing

3.6.3 Abacus illustrating selected options and related preliminary design-ideas for decision-makers

On the basis of the examinations illustrated in previous paragraphs, about flood proofing techniques, here we present a first selection among the alternatives illustrated, with the aim of eliminating inefficient ones, taking into account also the point of view given by the fact we are operating in an academic park with the valuable landscape, cultural heritage site, national monument, where no much resources can be quickly found to put in action every possibility. On the contrary, it is to underline that the activities of maintenance of buildings and of the park are accomplished by a competent team.

Thus, here it is important to underline that flood risk reduction through flood proofing techniques, our only realistic strategic option, could obviously result in partial, limited, or relative values, especially because working unaided or in a too demanding context, especially in the transitory period. But, indeed, if the options of flood disaster risk reduction available to a decision-maker include what is still (or residually) ‘physically manageable’ and the option of retaining by informed decision, choosing to opt for strategies based on exposed value, and not only on local hazard and goods vulnerability, in any case, a set of strategic options has been selected and elaborated (including temporary and permanent flood proofing techniques) in order to offer promising and hopeful different ways to pursue the risk reduction strategy related to the heritage site under exam, i.e., the “Escuelas Nacionales de Arte” site. This provides a diversified and partially dynamic approach, on the basis of which decision-makers in charge of the management of the site can choose and adopt implementing measures.

Obviously, the effectiveness and behavior of a selected technique modify the flood hazard or the vulnerability; furthermore, a choice about the use of a building modifies the exposed value. Taking in to account this frame and previous analyses, first of all, we present the risk reduction options related to the so-called “transitory” period (TP.n options); consecutively, we present the options related to the long term vision (LT.n options); in addition, some more complex and academic “design inspirations”, to deepen, has given (DID.n options), to complete the set of possibility to work on the site of schools.

3.6.3.1 Transitory period options

Speaking about transitory period options, we mean solutions able to cope with the problem, as it is the situation of the building and of the park, with the aim both of avoiding a worsening of the situation for "national monuments" buildings, and of increasing people and goods safety (teachers, students, furniture, goods, etc.). These options, clearly, have been selected on the basis of four main criteria:

- to be quick to be put in place;
- to be easy to be managed;
- to be not expensive;
- do not compromise the state of the places from the landscape and architectural points of view.

The following text shows the options that put together our abacus

School of Ballet - flood

Ballet School, flood, option TP.1
OPTION: Floodwalls Removable group 1) —Stacking of individual base units filled with solid materials acting on gravity TECHNIQUE: *Temporary dike containing reinforced earth/loose soil. Technical details in appendix A.* BARRIER HEIGHT: 0.9 m (when full). NOTES: The barrier may remain in line for long periods (under regular checks), waiting for conservation works. Consequently, it can be seen as provisional but not movable.

The position of the selected barrier and a picture illustrating a similar use case.

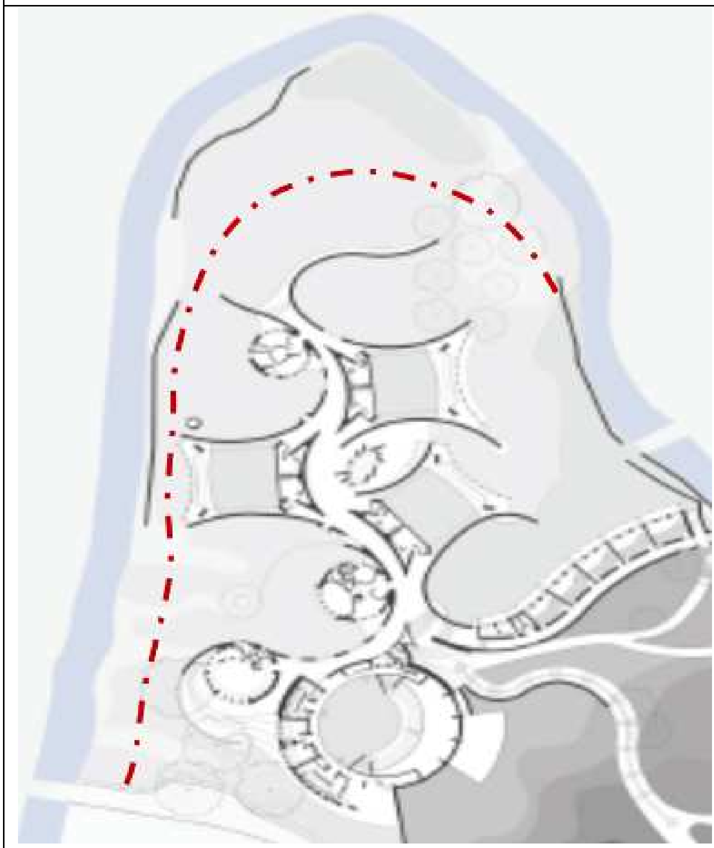
Ballet School, flood, option TP.2

OPTION:
Floodwalls Removable group 1) —Stacking of individual base units filled with solid materials acting on gravity;
or
Floodwalls Removable group 2) —Supportive/juxtaposed use of fluid Containers

TECHNIQUE:
Temporary dike containing water.

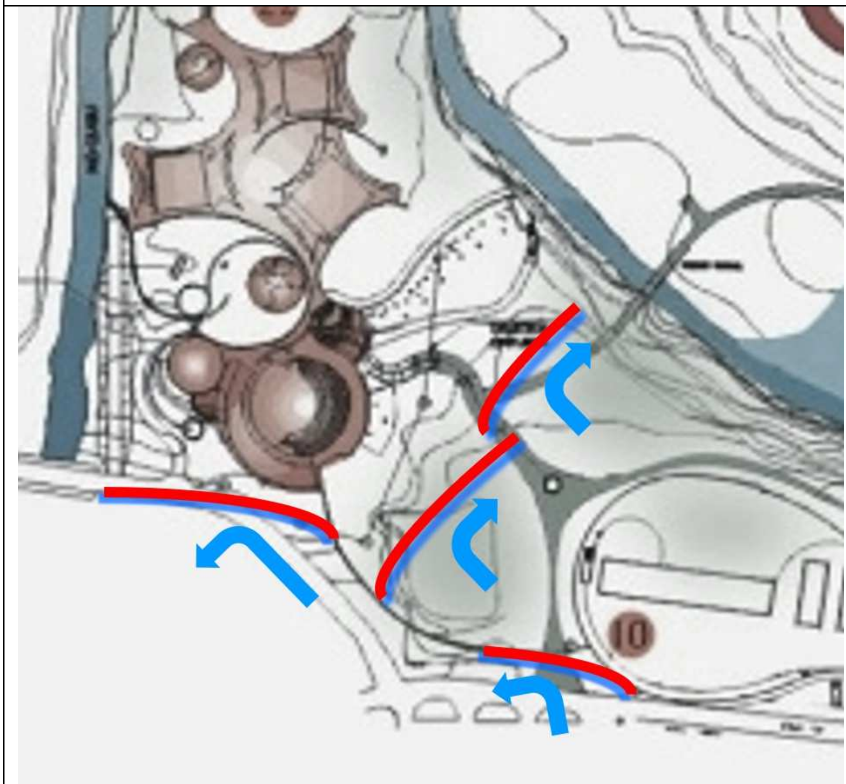
BARRIER HEIGHT:
Depending on producer

NOTES:
The barriers may remain in line for long periods (under regular checks), waiting for conservation works. Consequently, it can be seen as provisional but not movable.

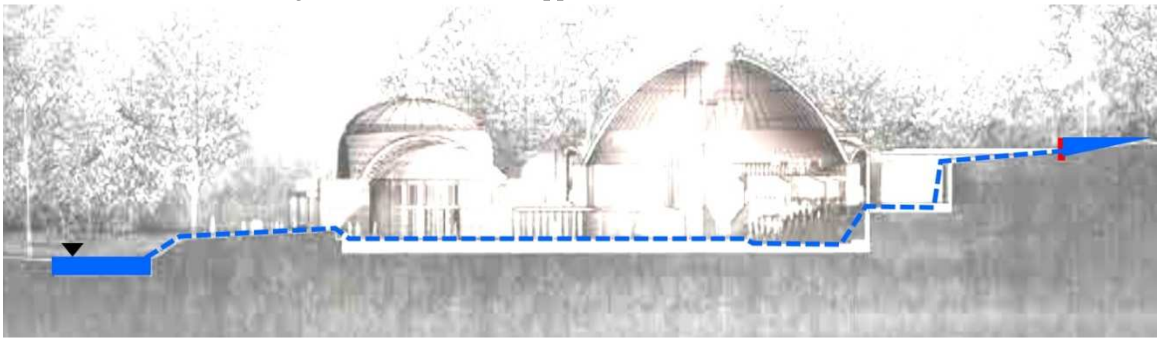


Position of the barriers and pictures illustrating similar use cases.

School of Ballet - surface runoff

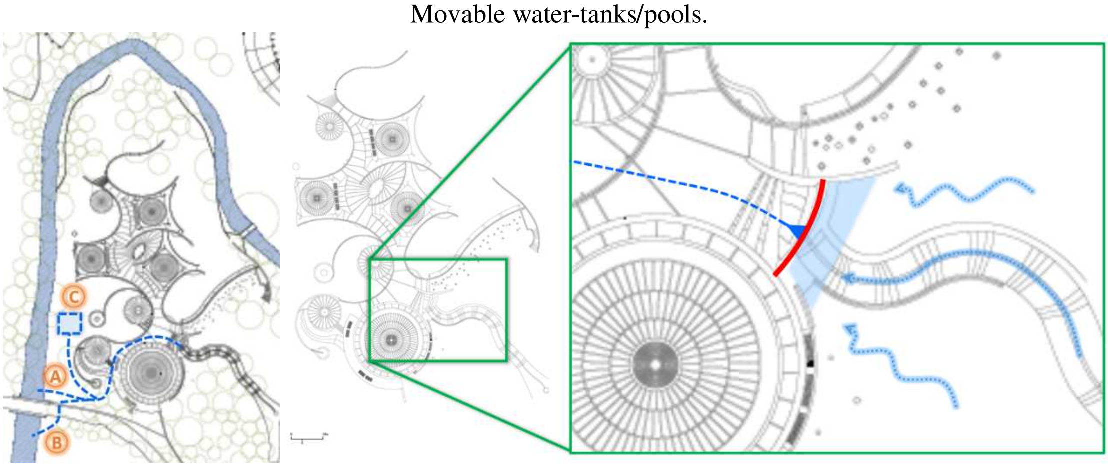
Ballet School, surface runoff, option TP.3	
OPTION: Floodwalls Removable group 3) —Self-deploying barriers TECHNIQUE: *Self-inflating barriers. Technical details in appendix B.* BARRIER HEIGHT: 0,35 (model: WL 1450) NOTES: Barriers need to be placed immediately before it rains. Switching in the long term, barriers can be re-used to act defending other targets (mainly Dramatic Arts school). This solution may work contemporary to solution T.P.4 and T.P.1-2.	
 The position of the selected barrier and a picture illustrating similar use cases.	 

Ballet School, surface runoff, option TP.4
OPTION: Ground lowering/leveling of free land Removable group 1) TECHNIQUE: *Water diversion temporary activated pipes or bridges.* NOTES: The solution may remain in line for long periods (under regular checks), waiting for conservation works. Consequently, it can be seen as provisional but not movable. Exploiting the difference in hydrostatic pressure, the solution avoids part of the flooding of school, discharging in the river thanks to a tube collecting the water before they enter the school, as shown in the sketches below; in the sub-option B tube goes beyond the 5th road, if it will be possible to pass under the road. A third sub-option (C), useful during flood events, could be water discharging in one or more pre-positioned pools or tanks inside or outside the edifice. This solution may work contemporary to solution T.P.3 and T.P.1-2. A movable water-tank or pool, sometimes changing the position to protect the grass, could be assembled using box-wall barriers of appendix E.



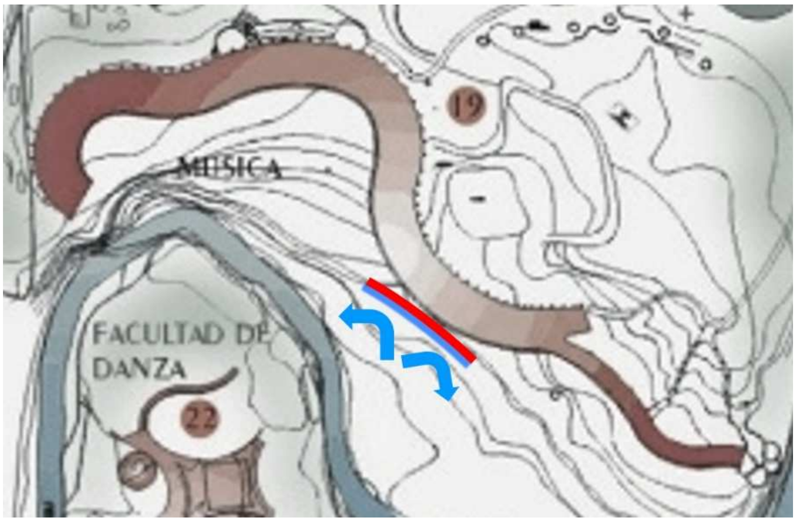
The scheme of use of the selected option.

Movable water-tanks/pools.

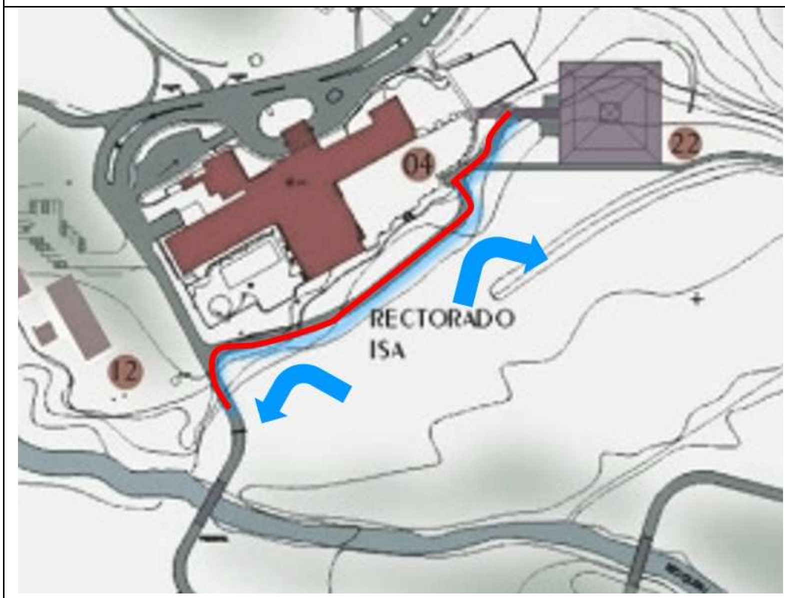


The positions of selected devices.

School of Music

Music School, flood - south front, option TP.5	
OPTION: Floodwalls Removable group 3) —Self-deploying barriers TECHNIQUE: *Self-inflating barriers. Technical details in appendix B.* BARRIER HEIGHT: 0,66 (model: WL2650) or 0,81 (model: 3250) NOTES: Barriers need to be placed immediately before the raise of water. Switching in the long term, barriers can be re-used to act defending other targets (mainly Dramatic Arts school).	
 The position of the selected barrier and pictures illustrating similar use cases.	 

Rectorate building

Rectorado, flood - south front, option TP.6	
OPTION: Floodwalls Removable group 3) —Self-deploying barriers TECHNIQUE: *Self-inflating barriers. Technical details in appendix B.* BARRIER HEIGHT: 0,66 (model: WL2650) NOTES: Barriers need to be placed immediately before the raise of water. Switching in the long term, barriers can be re-used to act defending other targets (mainly Dramatic Arts school).	
 The position of the selected barrier and pictures illustrating similar use cases.	 

Scholl of Dramatic Arts

<table>
<tr><td colspan="2">Drama School, flood, option T.P.7</td></tr>
<tr><td colspan="2">OPTION:
Floodwalls Removable group 3) —Self-deploying barriers

TECHNIQUE:
Self-inflating barriers. Technical details in appendix C.

BARRIER HEIGHT:
0,66 (model: WL2650)

NOTES:
Barriers need to be placed immediately before the raise of water. Switching in the long term, barriers can be re-used, just adding the new ones (see long term options).</td></tr>
<tr><td>
The position of the selected barrier and pictures illustrating similar use cases</td><td>
</td></tr>
</table>

Warehouses

Warehouse, flood - south front, option TP.7
OPTION: Floodwalls Removable group 1) —Stacking of individual base units filled with solid materials acting on gravity TECHNIQUE: *Sandbags and plastic sheets (as well as bags filled with innovative absorbent materials). Technical details in the appendix.* BARRIER HEIGHT: 0,60 (3 raws) NOTES: Barriers need to be placed immediately before the raise of water.

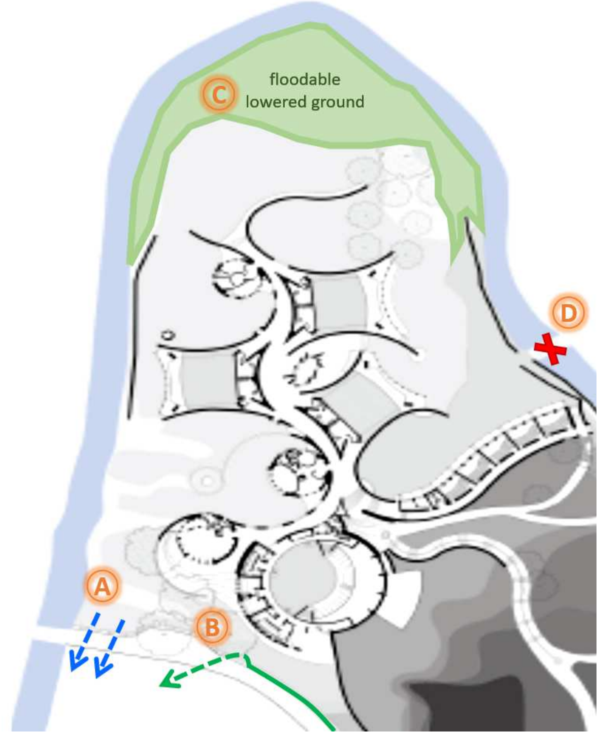
A picture illustrating a similar use case.

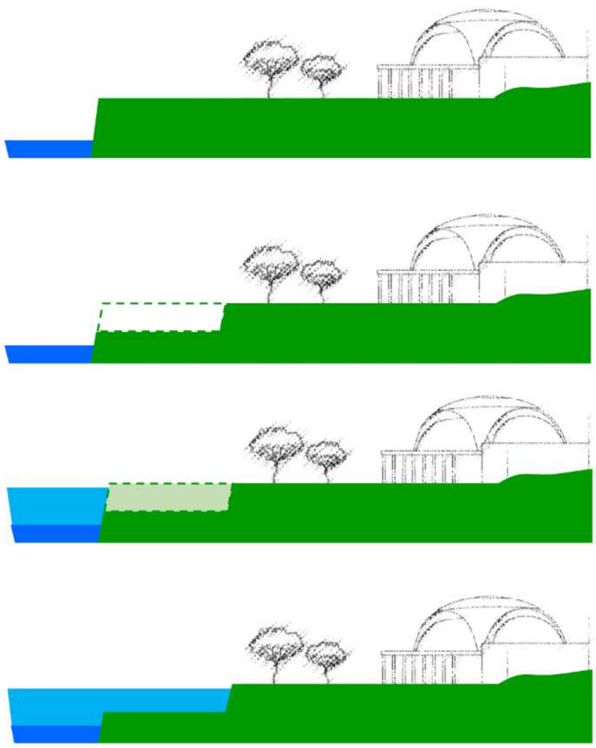
3.6.3.2 Long term options

Moving to the discussion about long-term options, speaking of which we mean solutions able to cope with the problem, having minimized the risk in a rational manner, when all the buildings inside the park will reach an operating level at full capacity, here we present some hypotheses to be put in place having obtained sufficient funds. Such hypotheses can be permanent or temporary (always in force, but put in place only in need), but not provisional. Attention has also been paid to considering the workforce for maintenance and activation needs.

School of Ballet - Flood

<table>
<tr><td colspan="2">Ballet School, flood, option LT.1</td></tr>
<tr><td colspan="2">OPTION:
Ground lowering/leveling of free land for waterway diversion and/or local storage.
TECHNIQUE:
Earth excavation, bridge demolition and positioning of pipe culverts.

NOTES:
This solution works in both cases of rebuilding or not of the bridge of 5th road and may work contemporary to solution L.T.2 and (partially) L.T.3.
It is a combination of four sub-solutions (shown by the following images):
A - a pair of culverts to allows the water of Rio Quibù to flow under 5th road in case of need.
B - a 5th road surface drainage system to divert water downstream, also passing under the road.
C - the soil removal inside the bend of the Rio Quibù in order to create a floodable lowered ground and coming partially back to the former riverbed of Rio Quibù.
D - the demolition of the existing bridge.</td></tr>
<tr><td>

The position of the selected sub-solutions and an image showing sub-solution C (drawing not in scale).</td><td></td></tr>
</table>

A couple of images illustrating similar use cases of sub-solution A.

A couple of images illustrating similar use cases of sub-solution B.

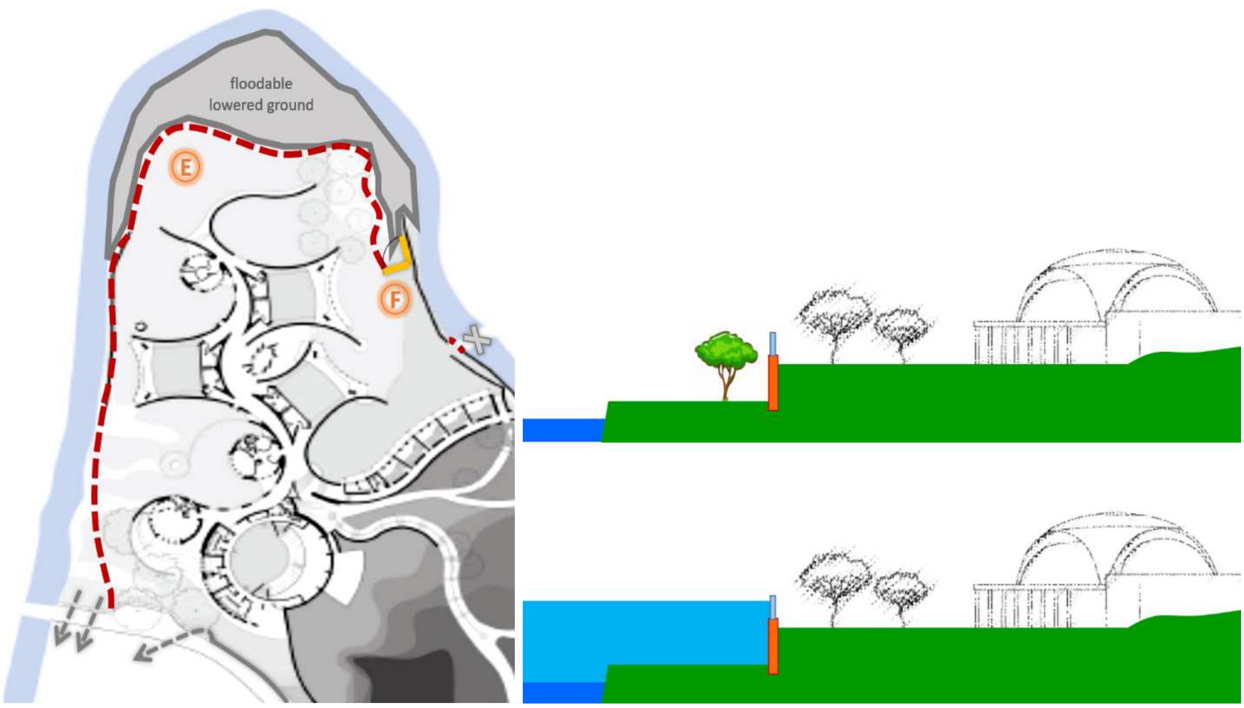
Ballet School, flood, option LT.2

OPTION:
Floodwalls

TECHNIQUE:
Flood Proof Glass Walls and flood wood gate. Technical details in appendices D and G.

NOTES:
This solution works in both cases of rebuilding or not of bridge of 5^{th} road and may work contemporary to solution L.T.1 and (partially) L.T.3.
It is a combination of two sub-solutions (shown by the following images):
E - One f*lood proof glass walls on top of a wall*
F - One (or more) *flood wood gate*

The result is a partial glass barrier with no loss of visual amenity that can be used as a direct first line flood defense. The wall, on top of which the glass will be fixed, being built far from the erosive action of the river and being less high, will be more stable and will be less impacting from a landscape protection point of view, also because it will be easy to hide or mask it with different types of bushes and trees.



The position of the selected sub-solutions and an image sketching sub-solution E (drawing not in scale).

A couple of images illustrating similar use cases of sub-solution E.

A couple of images illustrating similar use cases of sub-solution F.

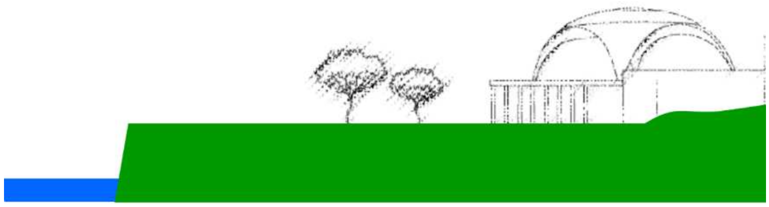
Ballet School, flood, option LT.3

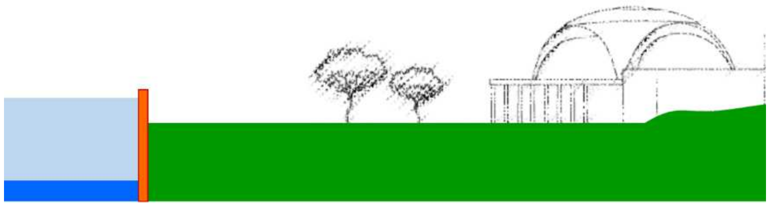
OPTION:
Floodwalls

TECHNIQUE:
Concrete wall

BARRIER HEIGHT:
5 m asl

NOTES:
This option is a modification of the project of INRH, i.e., construction of perimetral wall, <u>without widening of the river section upstream.</u>

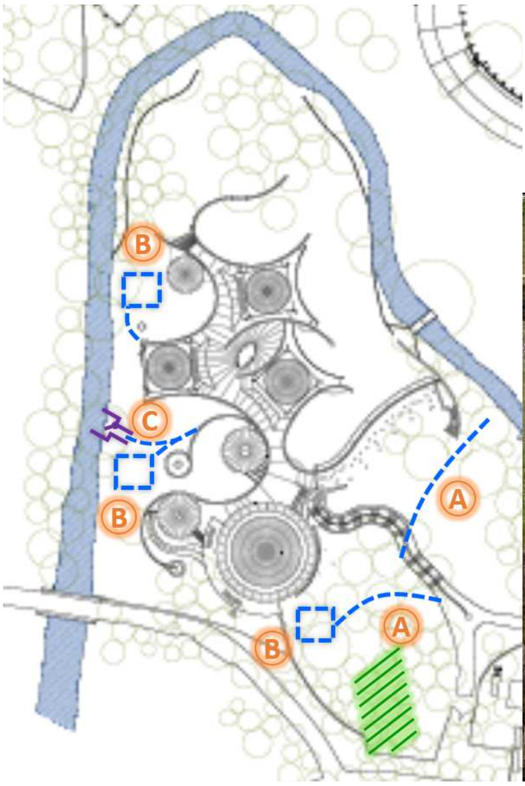




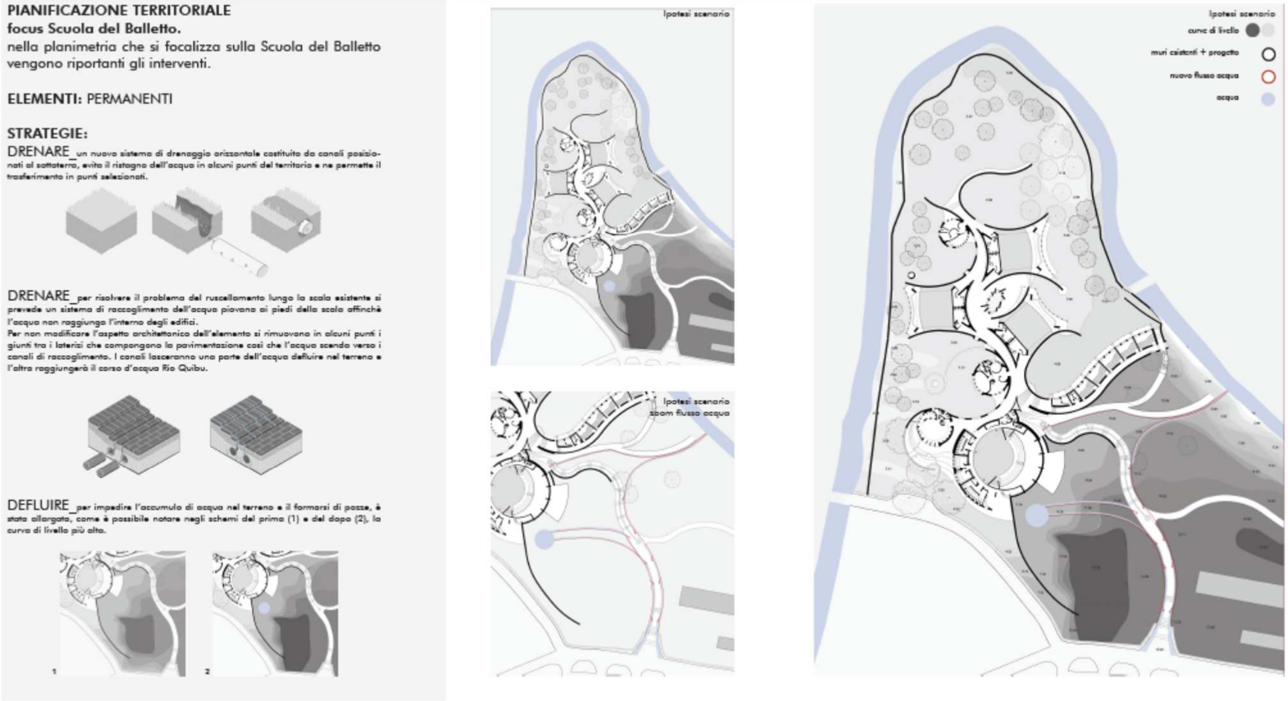
HEC-RAS 2D maps of flow depth and velocity, option LT.3.
Possibly, channel widening as proposed by INRH is not necessary.

School of Ballet - Surface runoff

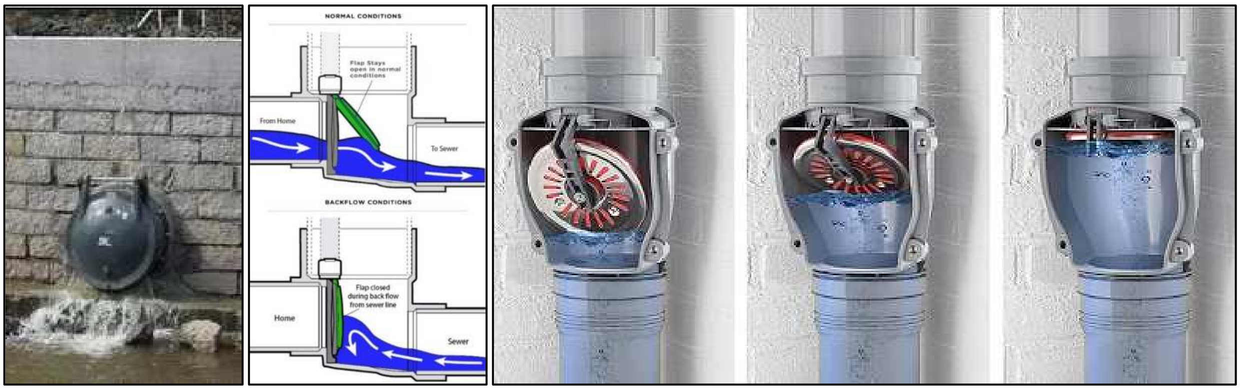
Ballet School, surface runoff, option LT.4
OPTION: Ground lowering/leveling of free land for waterway diversion and/or local storage. TECHNIQUE: *Positioning of drainage systems and of underground water tanks.* NOTES: This solution, conceived to operate jointly with the original drainage system that we can imagine working correctly again after conservation works, is a combination of three sub-solutions (shown by following images): A - A new drainage system on the hill and in the garden near the river, including soil movement to divert water. B - Some underground water tanks to store the water, especially during floods, when discharging in the Rio Quibù could be impossible (and no return flap valves stop the water flow. C - No return flap valves, or flap gates, as self-operating control devices, to be used to stop or to maintain water level differences in the system naturally flowing between the 2 sides of the portions of the water bodies by allowing unidirectional flow. The high water level on the upstream behind the gate, from the hill or the school, will allow flow through the gate. Conversely, the high water level on the downstream end (in front of the opening side of the flap), the Rio Quibù, will shut the flap to avoid flow upstream.



Indicative positions of the selected sub-solutions and an image representing sub-solution E (drawing not in scale).



A first concept of this solution by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, student group 7: Simona Dicostanzo, Sofia Scalisi, Chiara Simonelli.



Few images illustrating similar use cases of sub-solution C.

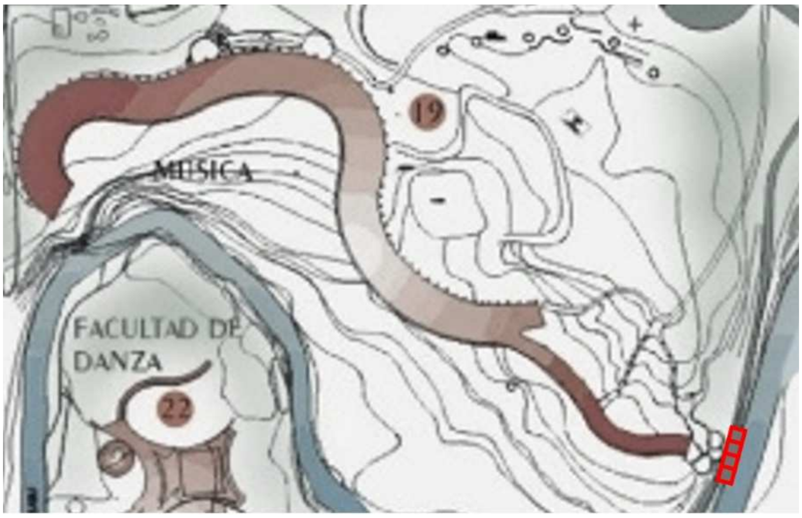
School of Music - East front (erosion)

Music School - East front, erosion, option LT. 5

OPTION:
Ground lowering/levelling of free land for waterway diversion.

TECHNIQUE:
Positioning of anti-erosive heavy mesh steel wire gabion baskets for water and soil protection.

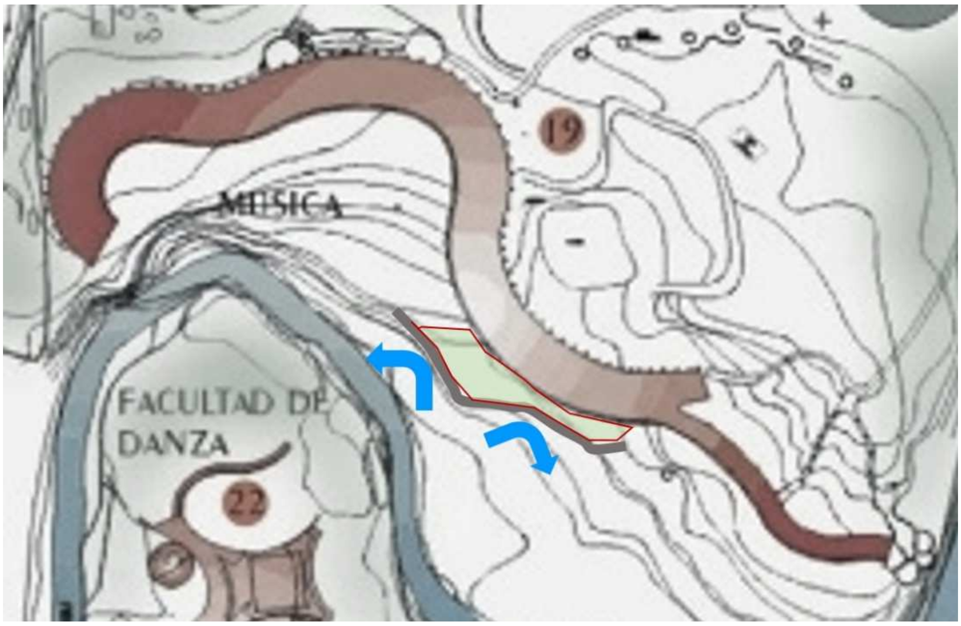
NOTES:
This solution, rock-filled, will stop water action allowing erosion control.



Indicative position of the selected solution and an image representing the suggested technique.

School of Music - South front (flood)

Music School - South front, flood, option LT. 6
OPTION: Ground lowering/leveling of free land for water diversion. TECHNIQUE: *Earthmoving.* NOTES: This solution stops the water from avoiding contact with the building.



Indicative position of the selected solution (above) and an elaboration representing suggested solution (below).

School of Dramatic Arts

Drama School, flood, option LT.7

OPTION:
Floodwalls Removable group 3) —Self-deploying barriers

TECHNIQUE:
Self-inflating barriers. Technical details in appendix B.

BARRIER HEIGHT:
0,35 (model: WL 1450) and 0,66 (model: WL2650)

NOTES:
The defense line is an enlarged version of that of the transitory period. Barriers need to be placed immediately before the raise of water. Additional barriers can also be partially procured, re-using those of other targets, purchased for a transitory period, if and when other targets defense has switched to long term options.

The position of the selected barrier and pictures illustrating similar use cases

Rectorate building

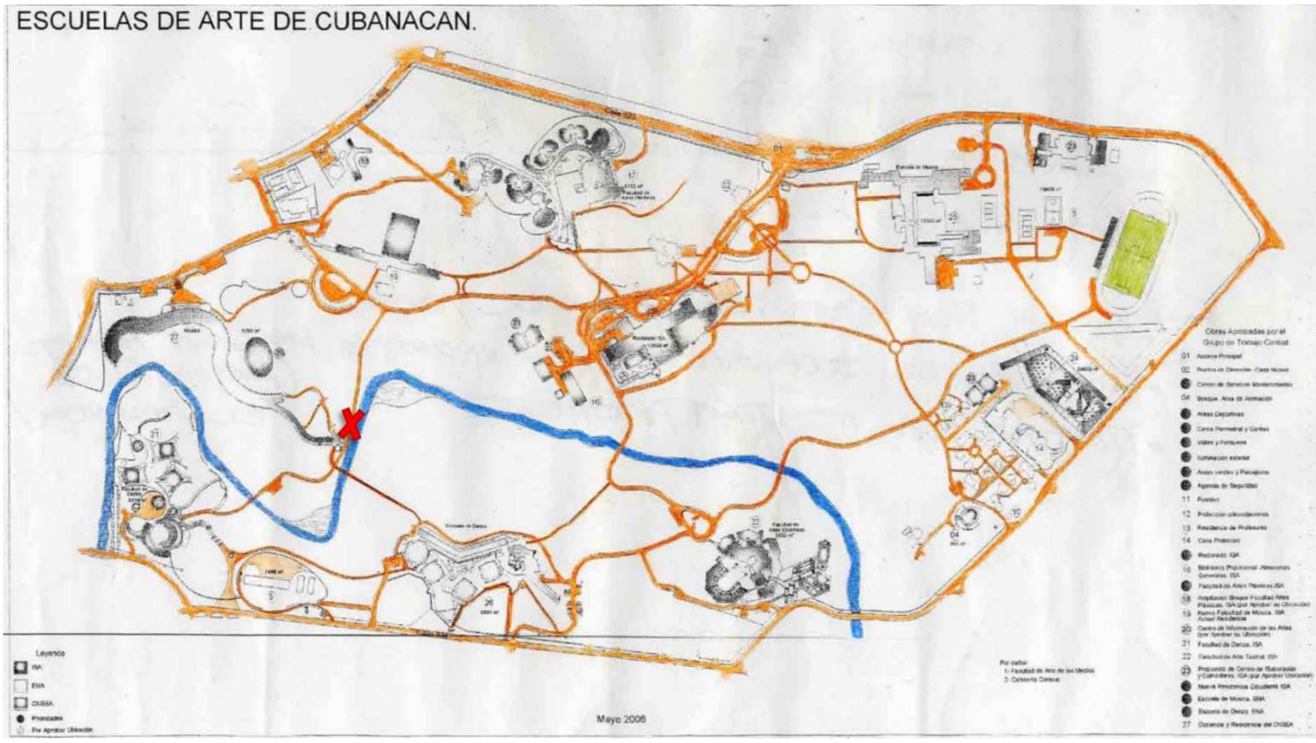
Rectorate, flood, option LT.8	
OPTION: Floodwalls Removable group 3) —Self-self-supporting mobile barriers TECHNIQUE: *Barriers with a reticular structure; Technical details in appendix E.* BARRIER HEIGHT: 0.5 m NOTES: Barriers need to be placed immediately before the raise of water.	
 The position of the selected barrier and a picture illustrating a similar use case.	

Warehouses

Warehouses, flood - south front, option LT.9
OPTION: Dry flood proofing Pre-arranged/Pre-located group 1) —Selective dry flood proofing with customized watertight protections TECHNIQUE: *Temporary shields or panels, watertight seals to prevent potential water seepage into the buildings. Technical details in appendix F.* BARRIER HEIGHT: 0.6 m NOTES: Barriers need to be placed immediately before the raise of water.
 A picture illustrating a similar use case.

Internal paths and services

Drama School, flood, option LT. 10
In this case, our suggestion is to change the internal path below the music school, alongside the Rio Quibù, foreseen in the Plan Rector. The path would be too close to the river in a flood prone area and consequently, both, out of order during a flood event and exposed to be damaged by the erosive water action. It would be better to move up the path, at least above the balconies of the school in front of the river.



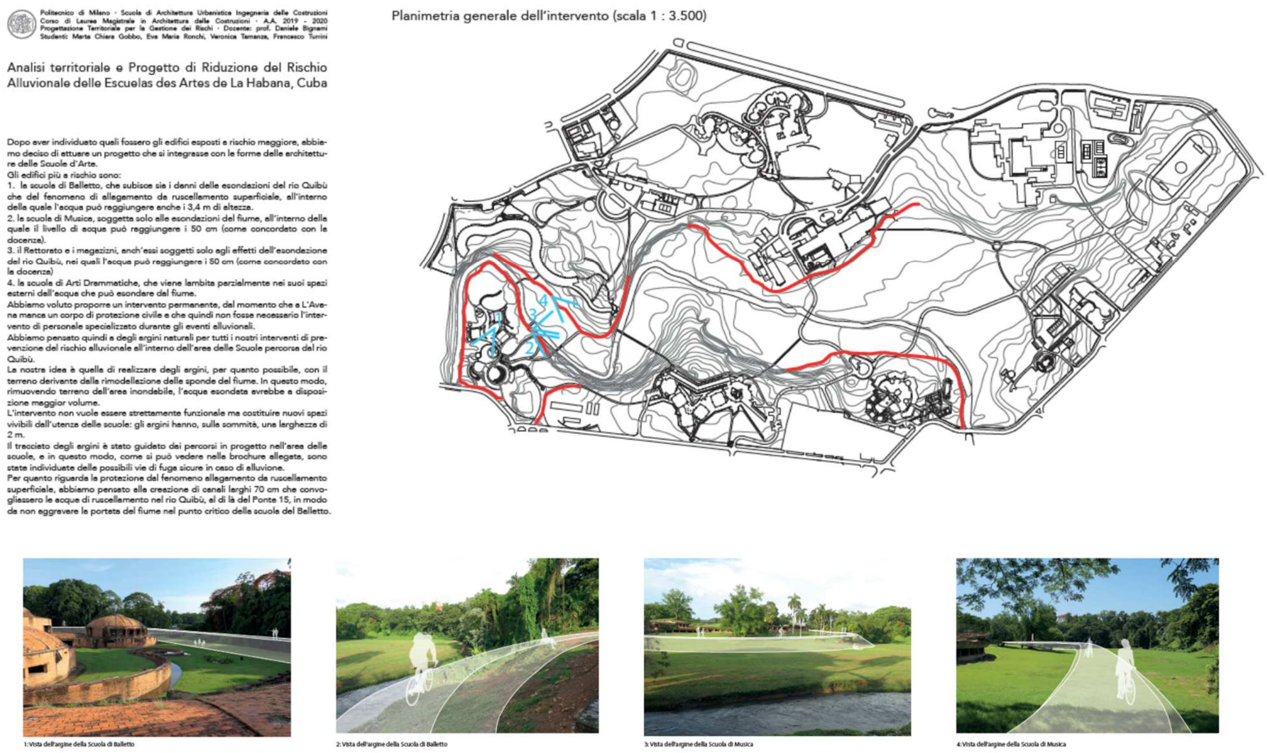
A map showing the path to be modified.

3.6.3.3 Design inspirations" (to deepen)

Below some further reflections are presented, still to be developed, especially in consideration of their possible impact on the objects of intervention, belonging to the category of cultural heritage, and on the landscape context.

Internal paths for flood control (integrated solution)

Rectorate, Music, Ballet and Drama School, warehouses / flood and surface runoff (Ballet), option DID.1
This option provides for the revision of the internal pedestrian paths, for practicability also by bicycle. These raised paths should also have a function of containing flooded areas and surface runoff. However, the intervention would have a significant impact on the current layout of the park. The next figure shows the first concept of this idea.

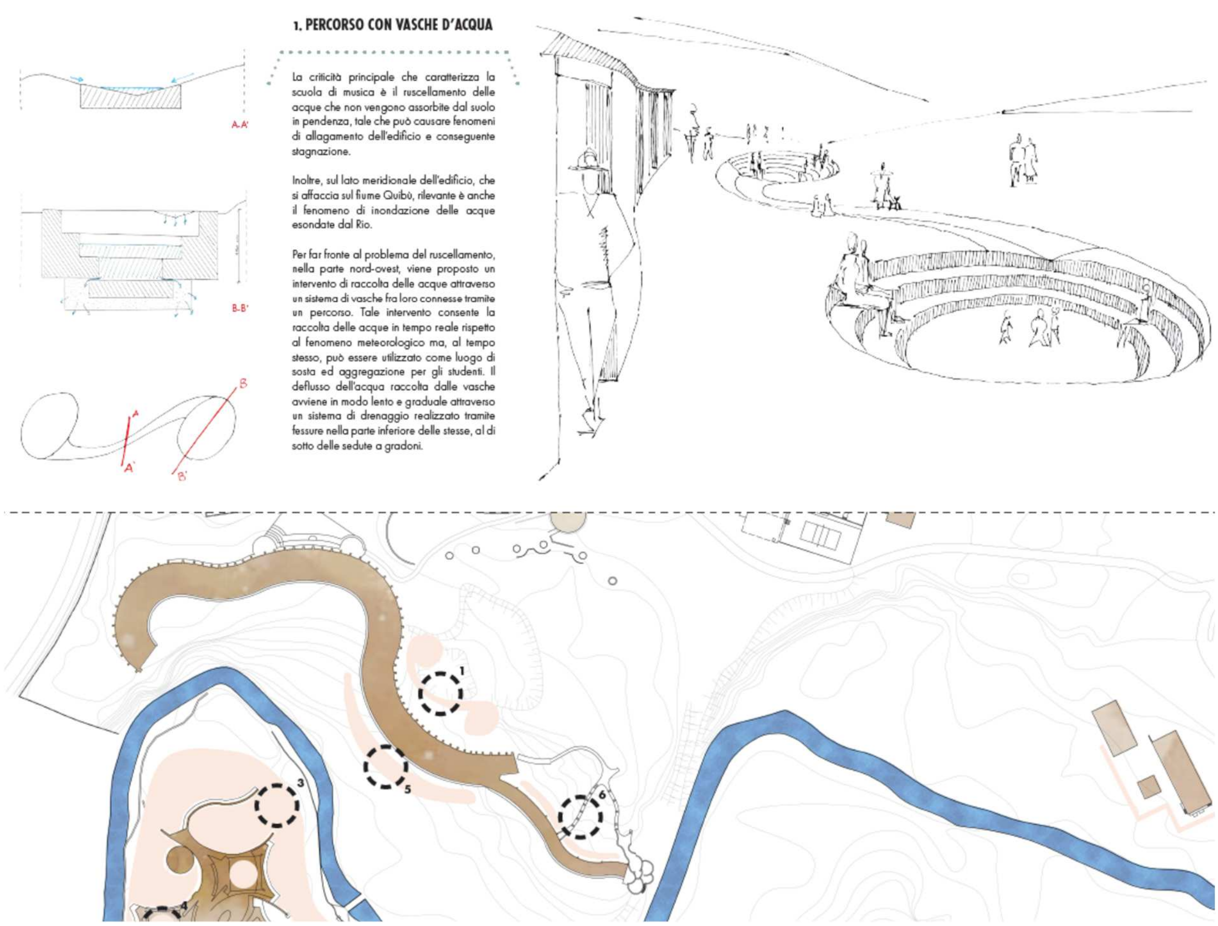


A first concept of this solution by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, student group 6: Marta Chiara Gobbo, Eva Maria Ronchi, Veronica Tamanza, Francesco Turrini.

School of Music - Surface runoff

Music School - North front, Surface runoff, option DID.2

This option, a solution belonging to the class of Ground lowering/leveling of free land for waterway diversion and/or local storage free land, works to manage the surface runoff partially affecting the school, giving the possibility of reasoning about the outdoor spaces of the school.
The approach is to pursue two goals, integrating the needs in a single action, suggesting the creation of public spaces, a sort of little squares, able to attract and to store the water, avoiding erosion actions.

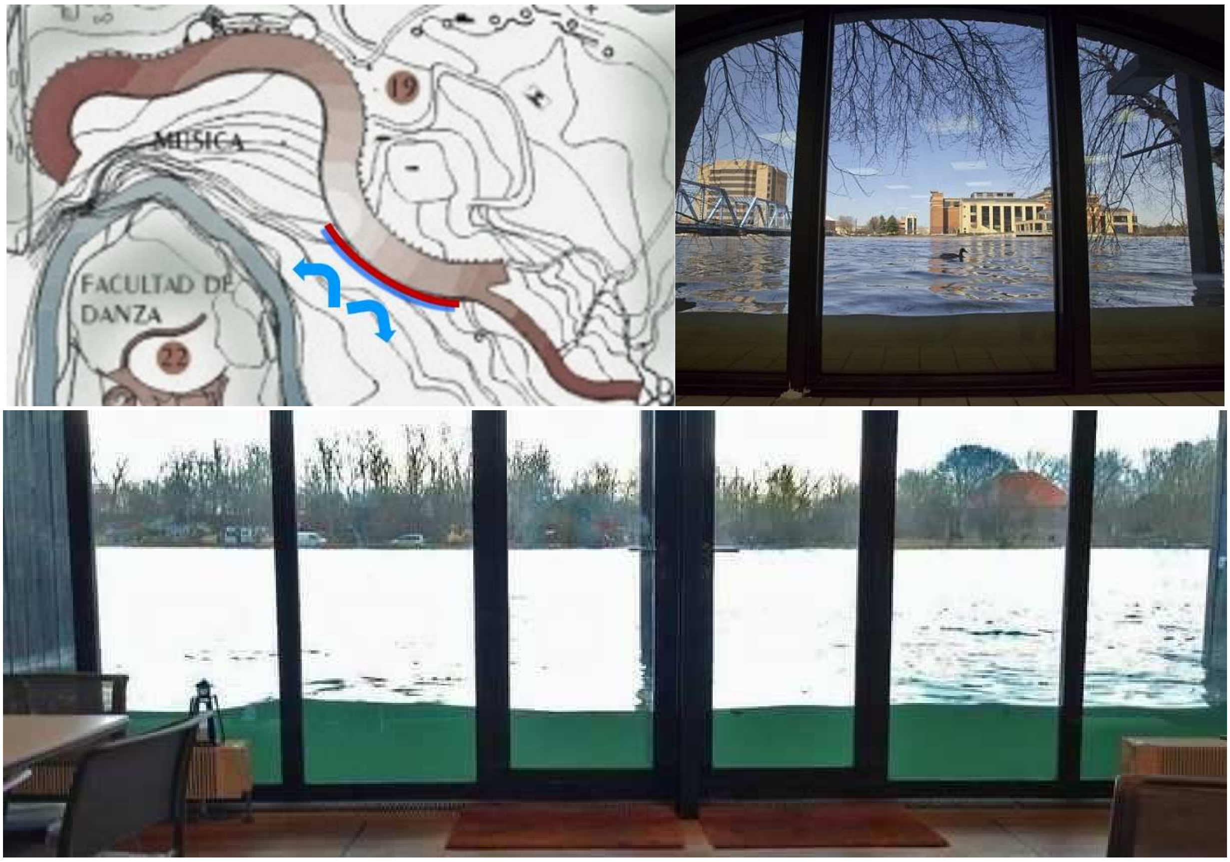


The first concept of this solution (circle number 1) by Land Planning for Disaster Risks Management course of Politecnico di Milano - Prof. D.F. Bignami, student group 18: Sara Mazzola, Guendalina Nozza, Greta Possi, Anna Puricelli, Greta Weber.

School of Music - Flood

Music School - South front, flood, option DID.3

This option is based on the Dry flood proofing Demountable group 1), namely the selective dry flood proofing with demountable watertight protection techniques. These kinds of techniques are precisely and permanently customized, including watertight doors and windows, techniques that we want to signal as theoretically apt to protect the south front of the school, in case of raising water over the wall of the façade of the school.
Furthermore, this solution could be mixed to small permanent dry flood proofing techniques, namely masonry waterproofing-sealer or hydro-repellent paints or protectors and waterproof non-opening windows made with glass blocks, or small walls to protect windows if soil movement will partially cover the building above windowsill (coherently this set of solutions may work contemporary to solution L.T.6).
Clearly, such a kind of solution is characterized by an important impact, to be carefully evaluated. From the safety point of view, in any case, this option is not ranked as mandatory at the moment of the analysis.



The position of the selected barrier and pictures illustrating similar use cases of watertight windows.


A couple of pictures illustrating similar use cases of small walls if soil movement will partially cover the building above the windowsill.

A sketch trying to illustrate suggested hypotheses.

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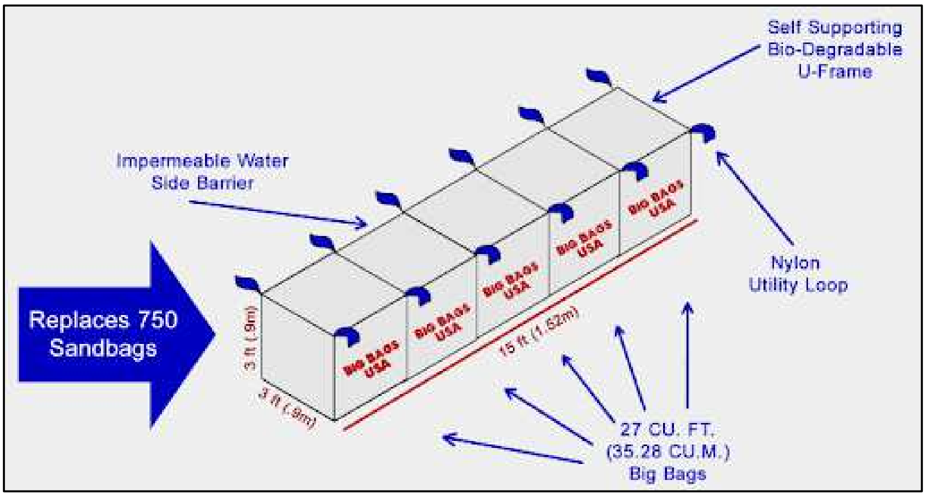
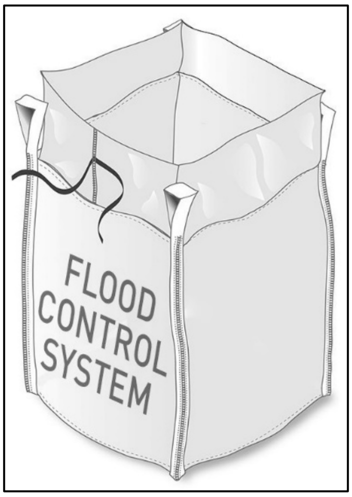
Appendices

A. Temporary dike containing reinforced earth/loose soil - technical details

The chosen technique is commonly called “Big bag”. Each sand- or earth- (or concrete-) filled flood barrier of one of the versions on the market consists of five connected heavy-duty cubic yard bags, but the barriers can be connected to form one contiguous and continuous line of any length. The barrier systems can also be stacked to achieve vertical height (but often enlarging the basis). The flexibility and the heaviness of the barrier allow the product to be used on all surfaces without the need for trenching or leveling to get a water-tight seal. The barrier, fillable using many different types of equipment (front end loader, conveyor belt trucks, etc.) are reusable, fast to deploy, and without clean-up costs after use (Cfr. http://bigbagsusa.com/).



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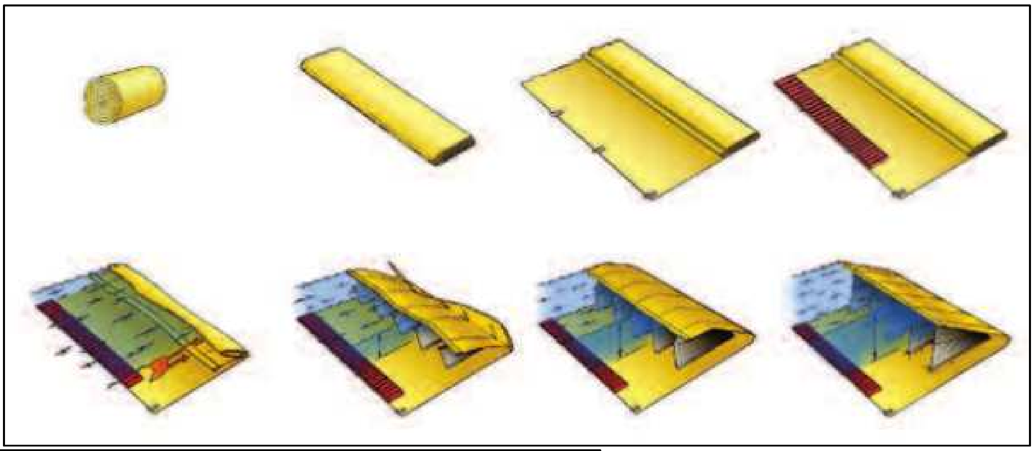
B. Self-inflating barriers - technical details

The most famous version of this barrier is called Water-gate. Water-Gate is a flexible emergency flood barrier that can be installed on any kind of terrain because it harnesses the power of floodwater to automatically fill, unfold and stabilize itself, without anchoring, thanks to friction forces.

This kind of barrier can be installed at the last minute, just before the water arrives, and it is also possible to deploy the dam when flooding has already begun. Single barriers can be quickly connected to one another with no need for tools and can be folded like an inflatable boat. The barriers do not require any special maintenance if stored properly. No electrical equipment (e.g. pumps) or metal components (e.g. fasteners/connectors) that could deteriorate (Cfr. https://en.megasecureurope.com/).









2 EXPRESS PROTECTION/DIVERSION KITS (<50 KG)

These dams are easy to handle and can be unrolled by a single person

WL 0617 (15 cm x 5,2 m) :

- Maximum water retention height: 15 cm
- Protection length: 5,2 m
- Width (depth of ground surface): 60 cm
- Packaging: W 42cm x L 30cm x H 28cm
- Weight: 14,0 kg

WL 0630 (15 cm x 9,1 m) :

- Maximum water retention height: 15 cm
- Protection length: 9.1 m
- Width (depth of ground surface): 60 cm
- Packaging: W 40 cm x L 38 cm x H 28 cm
- Weight: 19.4 kg

WL 0650 (15 cm x 15,2 m) :

- Maximum water retention height: 15 cm
- Protection length: 15.2 m
- Width (depth of ground surface): 60 cm
- Packaging: W 45 cm x L 75 cm x H 29 cm
- Weight: 29.8 kg

All Water-Gate dams can be connected to each other regardless of their height, with the exception of the WL0630 and WL0650 dams, which can only be connected to dams of the same height (15 cm).

WL 1430 (35 cm x 9,1 m) :

- Maximum water retention height: 35 cm
- Protection length: 9.1 m
- Width (depth of ground surface): 140 cm
- Packaging: W 37 cm x L 106 cm x H 29 cm
- Weight: 24kg

WL 1450 (35 cm x 15,2 m) :

- Maximum water retention height: 35 cm
- Protection length: 15.2 m
- Width (depth of ground surface): 140 cm
- Packaging: W 49 cm x L 108 cm x H 33 cm
- Weight: 39.7 kg

WL 2030 (50 cm x 9,1 m) :

- Maximum water retention height: 50 cm
- Protection length: 9.1 m
- Width (depth of ground surface): 200 cm
- Packaging: W 44 cm x L 74 cm x H 29 cm
- Weight: 30.4 kg

WL 2050 (50 cm x 15,2 m) :

- Maximum water retention height: 50 cm
- Protection length: 15.2 m
- Width (depth of ground surface): 200 cm
- Packaging: W 58 cm x L 76 cm x H 38 cm
- Weight: 50.2 kg

3 HIGH FLOOD PROTECTION

WL 2630 (66 cm x 9,1 m) :

- Maximum water retention height: 66 cm
- Protection length: 9.1 m
- Width (depth of ground surface): 264 cm
- Packaging: W 44 cm x L 102 cm x H 31 cm
- Weight: 38.6 kg

WL 2650 (66 cm x 15,2 m) :

- Maximum water retention height: 66 cm
- Protection length: 15.2 m
- Width (depth of ground surface): 264 cm
- Packaging: W 54 cm x L 106 cm x H 34 cm
- Weight: 62.9 kg

WL 3230 (81 cm x 9,1 m) :

- Maximum water retention height: 81 cm
- Protection length: 9.1 m
- Width (depth of ground surface): 324 cm
- Packaging: W 56 cm x L 84 cm x H 41 cm
- Weight: 62.5 kg

WL 3250 (81 cm x 15,2 m) :

- Maximum water retention height: 81 cm
- Protection length: 15.2 m
- Width (depth of ground surface): 324 cm
- Packaging: W 66 cm x L 84 cm x H 51 cm
- Weight: 104.0 kg

WL 3930 (100 cm x 9,1 m) :

- Maximum water retention height: 100 cm
- Protection length: 9.1 m
- Width (depth of ground surface): 396 cm
- Packaging: W 56 cm x L 116 cm x H 41 cm
- Weight: 76.8 kg

WL 3950 (100 cm x 15,2 m) :

- Maximum water retention height: 100 cm
- Protection length: 15.2 m
- Width (depth of ground surface): 396 cm
- Packaging: W 69 cm x L 116 cm x H 51 cm
- Weight: 126.8 kg

WL 5030 (100 cm x 9,1 m) :

- Maximum water retention height: 127 cm
- Protection length: 9.1 m
- Width (depth of ground surface): 508 cm
- Packaging: W 66 cm x L 103 cm x H 53 cm
- Weight: 117.5 kg

WL 5050 (100 cm x 15,2 m) :

- Maximum water retention height: 127 cm
- Protection length: 15.2 m
- Width (depth of ground surface): 508 cm
- Packaging: W 84 cm x L 103 cm x H 69 cm
- Weight: 187.7 kg

WL 6030 (152 cm x 9,1 m) :

- Maximum water retention height: 152 cm
- Protection length: 9.1 m
- Width (depth of ground surface): 608 cm
- Packaging: W 66 cm x L 129 cm x H 48 cm
- Weight: 123.8 kg

WL 6050 (152 cm x 15,2 m) :

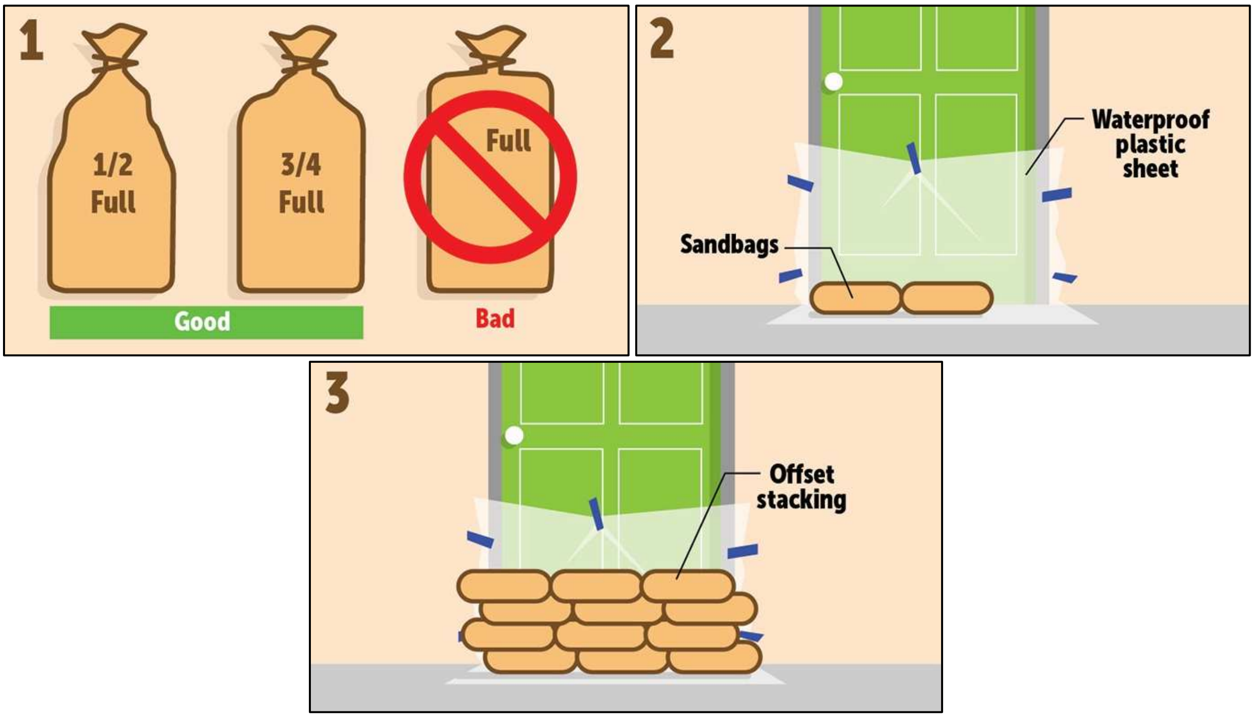
- Maximum water retention height: 152 cm
- Protection length: 15.2 m
- Width (depth of ground surface): 608 cm
- Packaging: W 86 cm x L 129 cm x H 61 cm
- Weight: 204.8 kg

WL 7850 (198 cm x 15,2 m) :

- Maximum water retention height: 198 cm
- Protection length: 15.2 m
- Width (depth of ground surface): 792 cm
- Packaging: W 109 cm x L 203 cm x H 66 cm
- Weight: 241.8 kg

C. Sandbags for doors defence - technical details

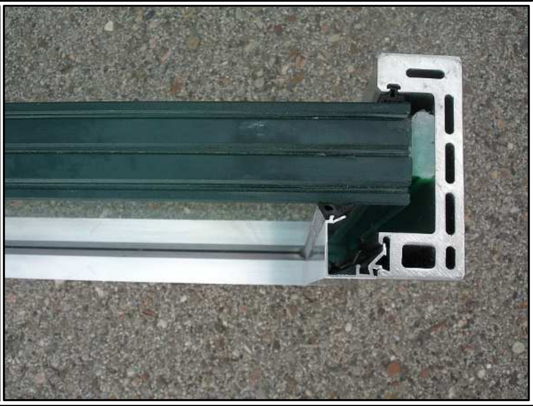
Sandbags solution no needs presentation. In any case, choosing among many others on the web, here some suggestions about how to use sandbags for a barrier protecting a door (Cfr. https://www.hillsboroughcounty.org/en/newsroom/2019/06/13/sandbag-machines-make-fast-work-of-tough-job). To use sandbags properly: don't overfill your bags - fill only 1/2 or 3/4 full; tape plastic sheeting in front of the door to cover the space between the door and the floor; offset stack sandbags on top of the plastic sheeting.

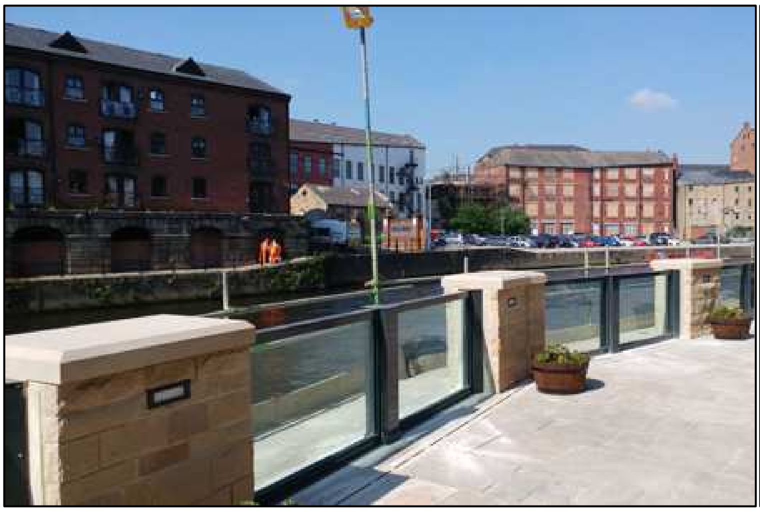


Furthermore, it is important to note that market offers sandless sandbags, very easy to handle.

D. Flood Proof Glass Walls- technical details

This kind of permanent glass barrier, requiring no operation during a flood, utilizes a combination of specially designed high strength structural self-cleaning glass, engineered frames designed to withstand the static and impact loads of the specific location, a structural anchoring system, and specially designed watertight and impact-resisting sealing technology. Flood protection heights are important, up to 1.8m as standard (Cfr. https://www.floodcontrolinternational.com/PRODUCTS/FLOOD-BARRIERS/glass-barriers.html or https://www.lakesidefloodsolutions.co.uk/products/glass-flood-walls/).

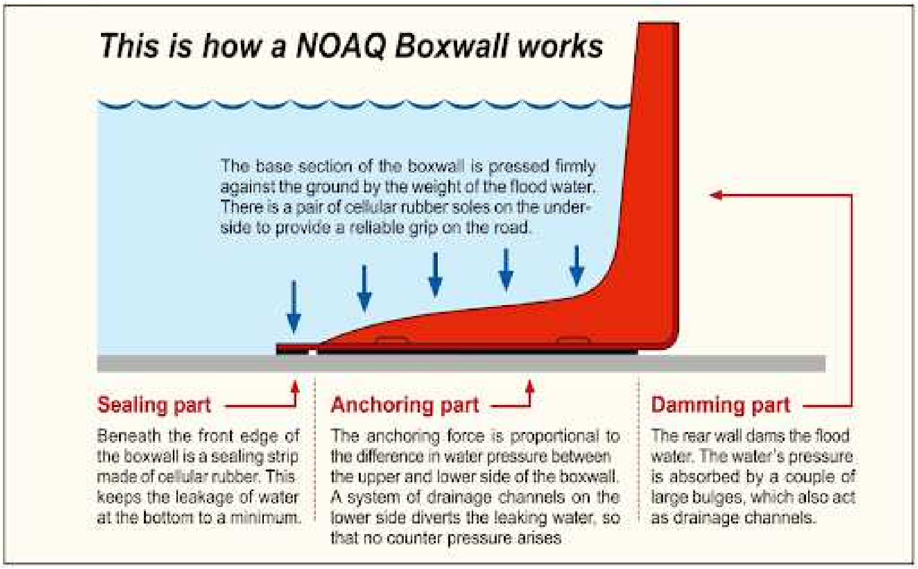


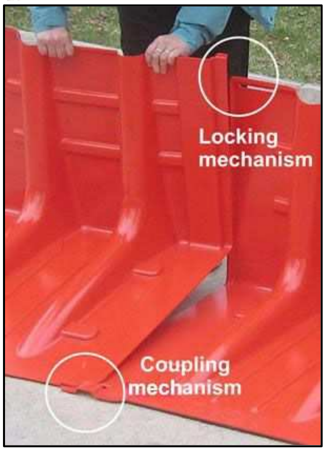


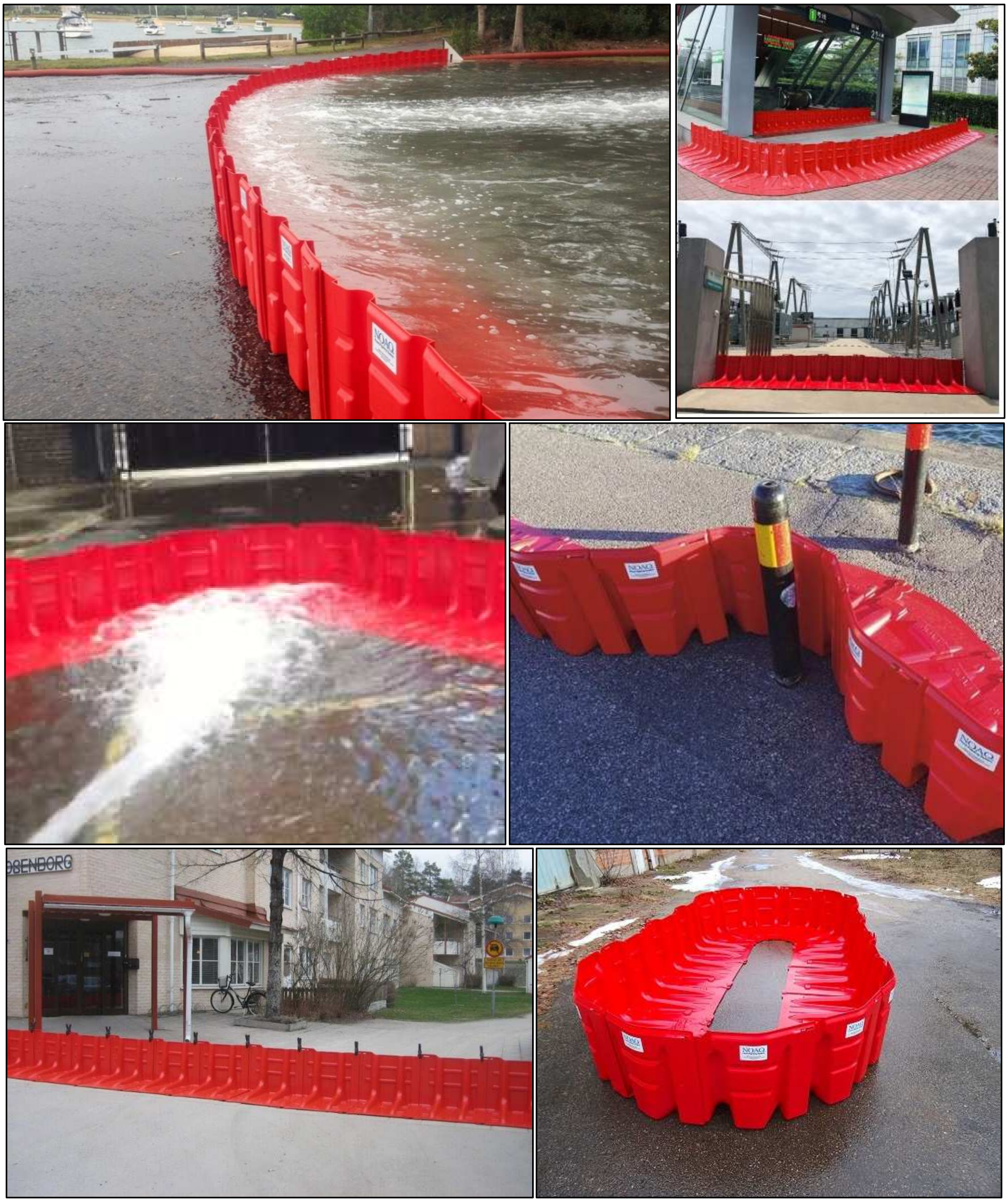
E. Self-supporting mobile barriers - technical details

This kind of barrier is a freestanding temporary flood barrier designed for fast response to flood threats in an urban environment, on hard and even surfaces like tarmac, paving, and concrete.

After the flood, the Boxwall is easily dismantled and can be cleaned using a garden hose. The box sections are stackable, which means they require very little space to store and are easy to transport.



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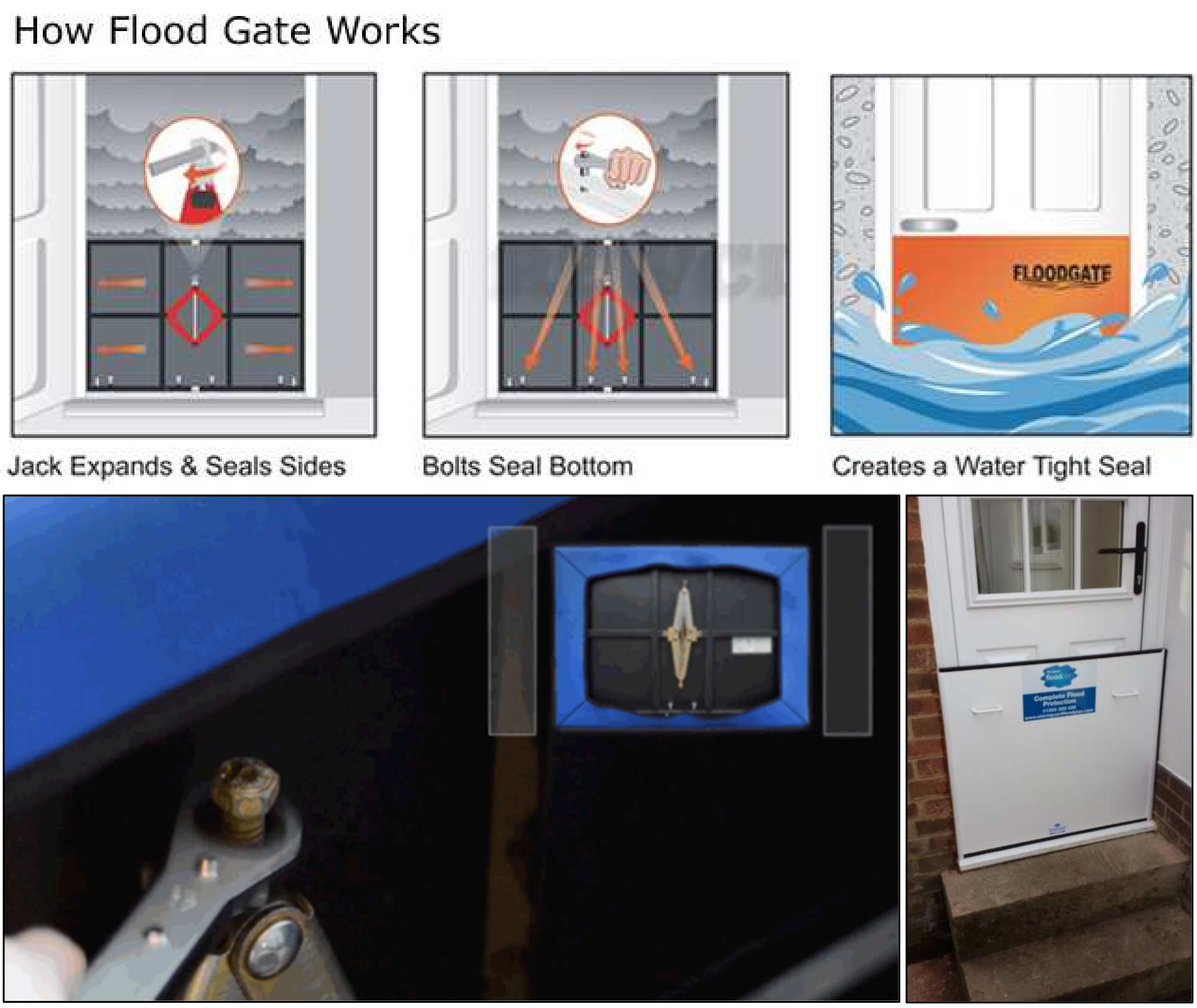
F. Temporary shields or panels, watertight seals to prevent potential water seepage into the buildings - technical details

Such a kind of doors barriers comprises a thick, boxed steel frame covered by a thick neoprene cover (or similar materials). Jacking mechanisms attached to the rear of the frame allows the barrier to expand (telescopically) widthways into the walled area (the reveal) immediately in front of the door. Bolts situated along the bottom edge of the frame can be present to adjust to provide a seal along the ground.

Such barriers sometimes do not need permanent fittings to the property and do not require pre-drilling of the door frame, making it ideal for use on old and listed buildings. In any case, remedial works which may be required to square the surfaces to help achieve a tight seal can usually be easily done (Cfr. https://www.floodgate.ltd.uk/floodgates/).




FLOODGATE
FLOODGATE
Standard
Width: 77cm - 89cm
Height: 68cm
Weight: 15Kg


FLOODGATE

G. Customized watertight gates - technical details

Swing flood gates are generally designed for settings where a quick response to flood is much needed. They are installed on an entry point with an elevated ground surface.

Ideal for delicate landscape and heritage context the wood-covered version of this kind of barriers (http://www.flooddivert.co.uk/flood-divert-timber---wood-flood-gates.php).

Aknowlegdments

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The present project profits from help from the personnel of Climate-Lab, an interdepartmental laboratory of Politecnico di Milano on Climate Change (https://www.climatelab.polimi.it/), kindly acknowledged.

Action 4

Energy and environmental sustainability

Action 4: Energy and environmental sustainability

Action 4 is specifically focused on environmental sustainability that is how to reduce the energy demand of buildings.

Therefore, the topic specified herein analyzes these buildings' thermo-hygrometric satisfaction conditions, considering the tropical climate of the area, the state of conservation of the buildings, and the economic possibilities required to manage the intended complex educational purpose, which entails different needs.

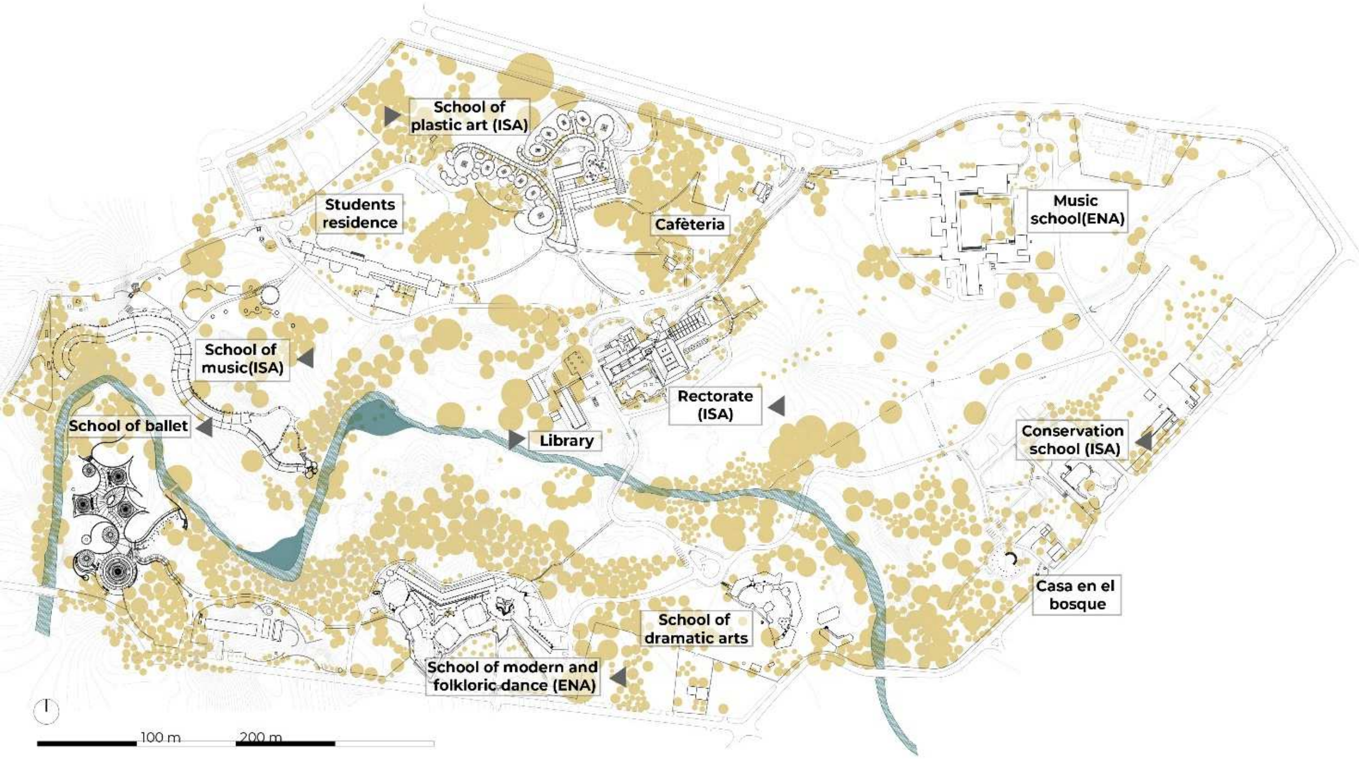


Figure 1 - Site plan of National Art Schools pointing out the buildings in which the thermo-hygrometric measurements have been carried out.

The outcome of the functional analysis of the on-campus buildings was collected through the management system designed and articulated within the CMP by means of a G.I.S platform. Data gathered from studies and on-site activities are recorded to provide the user with descriptive information on the buildings. For instance, the platform allows to easily identify the spaces where an air-conditioning unit is installed, access data concerning the building materials or the state of repair, but also to create thematic maps, such as plans illustrating the intended use of each building (which is especially useful when studying energy consumption features). The functional analysis also proved essential to outline the following steps of the energy study, both suggesting which parameters to measure and delimiting further investigations. Indeed, due to the buildings' considerable size, an in-depth study of all environments was not viable. Such a tool helped understanding the building's intended use and, therefore, the comfort requirements of each analyzed function.

The energy aspect, barely debated so far, has been explored through due considerations on the comfort conditions for users of the buildings and, more specifically, of the twentieth century's architectural heritage.
First of all, it is important to emphasize the above-mentioned economic factor. As a matter of fact, due to the strengthening of the economic, commercial, and financial blockade[1], Cuba's situation is currently worsening. This condition led to a widespread energy supply problem: power outages and fuel shortages became more and more frequent, turning into a significant issue for Cuban population. When referring to this context, the reason why within the Schools air-conditioning is unused (even when present) becomes very clear. Reducing energy consumption as much as possible is thus a primary goal, as not only energy is costly, but it also insufficient to cover the demand.
Given the situation, within action 4 measurements of thermo-hygrometric data were taken in some selected buildings on-campus. In particular, the choice was to survey the buildings that are currently being used for school purposes to obtain a descriptive frame of the microclimate conditions of the most used spaces. The study hence focused on the Rectorate building and on the School of Plastic Arts. The former is the original Club House (built for the former golf course), while the latter is one of the five iconic architectures comprising the National Art Schools and represents one of the clearest examples of modern architecture in the Latin American countries. Since its construction, the School of Plastic Arts has always been used. However, some analyses were also carried out on the architectures that are not currently used, such as the Schools of Ballet and Music. Here, the aim was not merely to collect data to provide an accurate description of their conditions but also, and most importantly, to develop a further work of comparison between some of the elements detected during site inspections.

Research Assumptions and Objectives

As part of this study, instrumental measurements were carried out to simulate the internal microclimate of some of the Schools' areas. The microclimate, defined as the combination of temperature, relative humidity, and air velocity detected in an environment, affects its users' well-being and productivity. The investigations aimed to increase knowledge of indoor microclimatic conditions, as well as to evaluate the thermo-hygrometric comfort of people actually using such spaces. Also, it helped outlining appropriate strategies to better preserve the buildings themselves and their architectural features, and detecting any thermo-hygrometric imbalances. Achieving thermal well-being means being satisfied with the environment itself, which is an essential condition in order to reach the overall well-being of the users. The feeling of well-being differs from individual to individual and depends on the mentioned environmental parameters, which should be adjusted according to the desired degree of comfort:

- air temperature is affected by passive and mechanical heating and cooling;
- air velocity quantifies the speed and direction of air movements in a room. Sudden fluctuations in the airspeed can cause situations of local thermal discomfort. The air movement produces thermal effects even without variation of the air temperature and can favor heat dissipation.

[1] Cosentino I., *Cuba: riformare l'economia per superare la crisi*, Sicurezza Internazionale, LUISS, 10 January 2020.

- too high or too low levels of humidity in the air can cause uncomfortable situations. At low temperatures, very dry air increases the perception of cold, while for temperatures above 32 ºC with relative humidity values above 70%, the sensation of heat is emphasized.

It is here essential to recall the concept of thermal comfort. As described above, there are several parameters involved in this assessment; among these, the individual user's sensitivity and its usual comfort conditions. It should be noted that the present study proposes a comfort analysis based on assessment methods and features of temperate climate conditions and thus of a context that is clearly different from that of the Havana's National Schools of Art. In fact, analyses and evaluations refer to European parameters of comfort. Local users might have different comfort levels and perceive as acceptable values that are not acceptable to the authors. This is an essential premise to fully understand the assessments that were made, which took into account the measured numerical values as well as real conditions.

Controlling the thermo-hygrometric parameters is crucial to ensure the preservation of the buildings – and thus the building materials they are made of – but also of the objects they contain. An example can be found in the School of Plastic Arts, where students store their works, or in the Heritage Faculty, where a collection of precious items (of different nature) is kept to be restored and preserved. It is possible to simplify the range of parameters to be considered optimal for each material to be maintained.
The reference standard is UNI EN 15757: 2010 Conservation of Cultural Property - Specifications for temperature and relative humidity to limit climate-induced mechanical damage in organic hygroscopic materials.
The environmental conditions reported here only take into account the chemical-physical nature of the material. In some cases, keeping an item in the reported environmental conditions or introducing it in a different environment can be dangerous. In order to assume an RH% value, it is essential to take into account at least the following factors: any possible treatment underwent by materials before processing, the environmental conditions to which an item has been subjected over time, any possible presence of mechanical stress.
In addition to these considerations, the inspections carried out were essential to gain the real perception of the conditions mentioned earlier related to the site's climatic conditions. February was a significant month for our inspections, as the average daily temperature was about 27°C and the rainy days average was 9, unlike the period between June and October when the average temperature rose to 30/33°C daily and the days of precipitation consistently increased (reaching up to 26 days), thus causing very high humidity levels (80-90%)[2].

[2] https://www.climieviaggi.it/clima/cuba and https://it.climate-data.org/america-del-nord/cuba/l-avana/l-avana-229/

Table 1 - Examples of suitable parameters for the conservation of materials.

MATERIAL[3]	T°C	RH%
Art paperworks, printings, etc	18 - 22	18 - 22
Fabrics, *velaria*, curtains, carpets, fabric upholstery, tapestry, silk, natural fiber materials, etc	19 - 24	30 - 50
Paintings on canvas, oil paintings on canvas and towel, temperas, gouache works	19 - 24	40 - 55
Archival documents on paper or parchment, papers, manuscripts	13 - 18	50 - 60
Polychrome wood sculptures, painted wood, paintings on wood, icons	19 - 24	50 - 60
Mosaics of stones, stones, rocks, minerals, fossils and stone collections	15 - 25	20 - 60
Plaster works	21 - 23	45 - 55
Wall painting, frescoes, sinopias (removed)	10 - 24	55 - 65
Drywall paints	10 - 24	45 - 50

Table 2 - Climate data in Havana

HAVANA - AVERAGE TEMPERATURES												
MONTH	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
MIN (°C)	19	19	20	21	22	23	24	24	24	23	21	20
MAX (°C)	26	26	28	29	30	31	31	32	31	29	28	27

HAVANA - AVERAGE PRECIPITATIONS													
MONTH	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**		**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
PREC. (MM)	70	45	45	60	120	165	125	135	150	170	80	60	1225

HAVANA - SUNSHINE DURATION												
MONTH	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
SUNSHINE (HOURS)	7	7	9	9	8	8	9	8	8	6	7	6

[3] Sileo M., Gizzi F. T., Masini Gizzi N., *Monitoraggio microclimatico: passato, presente e prospettive future*, in *Salvaguardia, Conservazione e Sicurezza del Patrimonio Culturale. Nuove metodologie e tecnologie operative,* Zaccara Editore, Lagonegro (PZ) - Istituto per i Beni Archeologici e Monumentali del Consiglio Nazionale delle Ricerche for the Project "PRO CULT", 2007-2013.

Considering all the aspects described so far (architectural, functional, climatic, economic, etc.), the focus was set on the system's energy component and the different conditions present in two different types of architectures. The comparison between buildings that coexist in the same place but have very different characteristics gave us an idea of the architectural solutions. In addition, by observing the users' attitude, we were able to understand how to implement the comfort locally, by means of simple solutions.

Figure 2 - Shaded area cooled by the Rio Quibù.

Figure 3 - Roofed study space.

4.1 School of Plastic Arts

The School of Plastic Arts was designed and has always been used for educational purposes, to serve as the current Faculty of Visual Arts (*Artes Visuales*), which encompasses painting, sculpture, scenography, etc.

According to the functional analysis carried out[4], within this building we can find a significant percentage of use of the spaces (Figure 4), with a continuous use of practical and theoretical classrooms, and less constant use of the ateliers located in the regularly shaped rooms. These spaces are often closed and can go a long time without being used, as they are managed by individuals who are not regular users of the school.

In consideration of the significant size of the architecture and the impossibility to carry out analyses in all rooms - or even to access all of them – thanks to this knowledge it was possible to identify which areas to analyze in order to understand the general behavior of the building. Moreover, some considerations on the building's energy performance emerged from the on-site inspections, as will be illustrated in the following paragraphs.

Figure 4 - School of Plastic Arts, ground floor use.

[4] See *1.3 Description and general assessment of the state of conservation.*

4.1.1 Description of energy performance

4.1.1.1 Passive thermic performance of the building

In addition to the use conditions and state of repair of the architecture – both essential to describe the current state of the building, the purpose was to increase our understanding of the conditions of thermal comfort and rooms' energy situation in relation to their environment.

From a design and architectural point of view, the present study brought to light some features of the architecture that were typically intended to contribute to the improvement of the thermal well-being of the users, mainly focusing on refrigeration and cooling of the spaces (given that the building located in a tropical climate area).

Such aspects need to be taken into account when trying to work on the relationship between the building and the natural, technological, and cultural environment.

However, it should be noted that the schools were originally designed to be completely air-conditioned. This looks evident when considering the School of Music, for which technical drawings with the indications of the positioning and functioning of the never built conditioning units were drafted. Given that the five schools were conceived in the same years, and that air-conditioning demand was consistently increasing at the time, it is reasonable to assume that the five buildings were intended to be provided with air conditioning.

Nevertheless, the technical system was never installed due to maintenance difficulties and to the inconsistency between the high energy demand of such a large building and the managing institution's available resources.

However, while analyzing the School of Plastic Arts, some architectural elements contributing to an improvement in the spaces' comfort were found. Considering both an in depth study of the plan arrangement and the time spent in the indoor and outdoor spaces, some design criteria could be suggested to overcome the hot humid climate, reducing solar gain by creating shaded spaces and enhancing natural ventilation.

Walking through the building, it is possible to observe how the outdoor vaulted porticos are shaded for most of the day, and being the fulcrum of distribution of paths inside the building, they represent a pleasant route to move within the building. The sinuosity and the tracks' design that unfold throughout the building allow to reach every room while remaining on a shaded path to prevent solar radiation exposure (Figure 5). The size and position of some paths also provide slight natural ventilation that improves these spaces' use.

An element that can help achieving a feeling of comfort, especially in a hot humid climate, is flowing water which is made available by fountains placed in the outdoor open spaces and produces a refreshing sound. The main square has a fountain that fills a pool on the pavement, from which small channels spread, making water flow from the central plaza to the main entrance (Figure 8). To date, this detail is no longer visible as the fountains are not active, leaving only the brick flooring. Other elements, unused or even broken, are the drinking fountains placed along the covered paths, which are equipped with an adjacent seat, to rest and enjoy a cooling break during the visit.

Figure 5 - School of Plastic Arts, covered paths.


Figure 6 - School of Plastic Arts, covered paths.


Figure 7 - School of Plastic Arts, roofed paths.

Figure 8 - School of Plastic Arts, the presence of water.

Figure 9 - School of Plastic Arts, an old picture of the square.

Figure 10 - School of Plastic Arts, the court today.

The sinuosity of the architecture allowed to create open spaces characterized by a strong presence of vegetation. This element enables users to walk through the building without losing contact with the surrounding nature and, at the same time, it provides shaded areas to ensure the possibility to use outdoor spaces without suffering from sun radiation (Figure 11). As in urban areas, vegetation with the effect of evapotranspiration and shading of plants can significantly reduce the heat re-radiated from the buildings' façades and all other "solid" volumetric constructions[5]. Regardless of calculations and data analysis, vegetation's presence provides a pleasant feeling in using open spaces and the spaces overlooking them.

Figure 11 - School of Plastic Arts, vegetation.

[5] Magliocco A., Perini K., *La vegetazione in ambiente urbano: comfort e riduzione del fenomeno isola di calore*, Dipartimento di Scienze per l'Architettura (DSA), Università degli Studi di Genova, in Tecniche 08, 2014.

Figure 12 - School of Plastic Arts, vegetation.

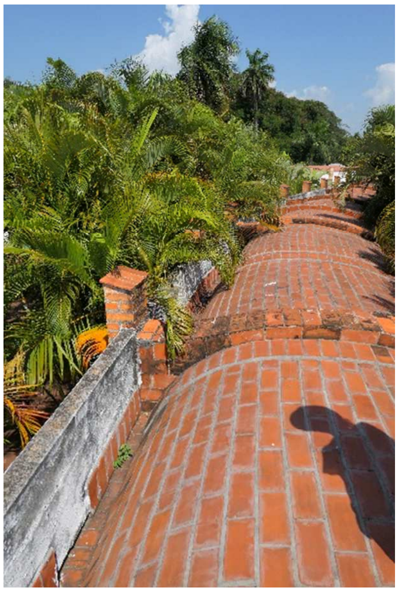


Figure 13 - School of Plastic Arts, vegetation.

A final element to consider is the patio adjunct to each theoretical classroom. This element is important to improve the comfort of the classrooms as it protects the fully glazed wall of the room from direct radiation. The patios are rather bare spaces, having only clay tile cladding and fence walls shaded only for some hours of the day. The risk however is that they are entirely exposed to the sun in the hottest hours of the day.

Figure 14 - School of Plastic Arts, spaces outside the theoretical classrooms.

Figure 15 - School of Plastic Arts, spaces outside the theoretical classrooms.

These measures were probably intended to guarantee a more comfortable environment as well as to reduce the energy demand for cooling indoor spaces or, as we would say today, create a group of energy-efficient buildings. But these solutions and the renewable energy approach to the design of the built environment were not fully implemented and developed in the early 1960s because, probably, the schools were also designed to be wholly or partially air-conditioned.

4.1.1.2 Thermo-hygrometric data

As emerged from previous studies, the energy aspect of these buildings had never been concretely discussed. Therefore, analyses of the thermal and energy behavior of the School of Plastic Arts or the other buildings had never been carried out.

Firstly, it was important to collect the data to correctly approach the building and, above all, to obtain a reliable database on which to develop further considerations. In fact, at this early stage, it was important to carry out some primary assessments to describe the comfort conditions:

- evaluation of the thermal characteristics of the materials and the ability of the building to transmit or prevent radiation;
- evaluation of thermal conditions (temperature, humidity, temperature distribution) in some significant spaces;
- assessment of the presence of favorable conditions of thermo-hygrometric comfort for users, also suitable for the conservation of the buildings and the architectural items and detecting any situations of specific thermo-hygrometric imbalance.

The measurements, data processing, and renderings that are shown below were carried out by Architect Luca Valisi, Laboratory Building Analysis and Diagnostic (LADC, Department of Architecture and Urban Studies, Politecnico di Milano)[6].

The investigations carried out are of two types:

- continuous automatic monitoring: timely measurement of temperature and relative humidity inside some buildings, in addition to an external point of view (3-D representation). The measurements were carried out using an automatic system of thermo-hygrometers with local storage installed on January 26th, 2019;
- direct measurement (psychrometries and thermographs): direct on-site surveys carried out in order to map the environmental distribution of temperature, relative humidity, and air mixing ratio through a digital psychrometer[7].

Continuous automatic microclimatic monitoring

As for the School of Plastic Arts, measurements were taken in a significant environment: a dome of medium size which can represent a generic condition in the practical classrooms (Table 3). The outcomes of the survey are reported in the following pages.

The data collected by sensor 04 are represented in a linear graph and show the temperature [°C] trend (red line), relative humidity [%] (blue line), superimposed on the corresponding parameter detected outside (T °C and RH% gray line).

To get a complete frame of the microclimate behavior, it will be necessary to wait for the next data download which will complete an annual cycle, as sensor 04 was installed on 19 June 2019, i.e., during a subsequent task.

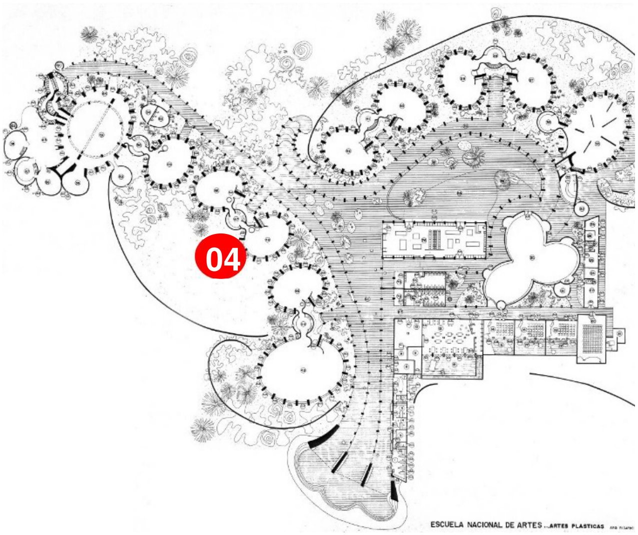
This space was chosen mainly because it is representative of the areas that are used continuously for didactic activities. Therefore, it is intended for people to stay and carry out artistic activities. The doors and windows were partly opened in certain conditions of high imbalance (for example, too high RH).

[6] See *Annex 4 A Microclimate survey*.
[7] https://www2.polimi.it/index.php%3Fid=6247&sel_brevetto=5079.html

S04 | SCHOOL OF PLASTIC ARTS

<table>
<tr><th>ACQUISITION PARAMETERS</th><th>LOCATION</th></tr>
<tr><td>ESCORT I-LOG DATALOGGER
Temperature (°C) and relative humidity (%)

with screen for displaying the current value.

Resolution / Accuracy °C 0,1°C; ±0,3°C
Resolution / Accuracy %UR 0,1%UR; ±3%UR
Interval Measurement from 1 sec to 10 days
Degree of Protection IP51
Polycarbonate Case
Green Led (Active)
Red (Alarm)
Response Time in Air 90% in 4 min (°C)
90% in 50 sec (RH)
Dimensions Ø=75mm H=36mm
Weight 70 gram</td><td>

SENSOR 04, T-RH% (INTERNAL)</td></tr>
<tr><th>(GENERAL) PHOTOGRAPHIC REPRESENTATION</th><th>(SPECIFIC) PHOTOGRAPHIC REPRESENTATION</th></tr>
<tr><td></td><td></td></tr>
<tr><td colspan="2">Notes</td></tr>
<tr><td colspan="2">Installed on 19/06/2019.</td></tr>
</table>

Table 3 - Sensor 04 (LADC - Lab. Analysis and Building Diagnostic, Arch. Luca Valisi).

Table 4 - Temperature data T °C - Probe 04 (LADC - Lab. Analysis and Building Diagnostic, Arch. Luca Valisi).

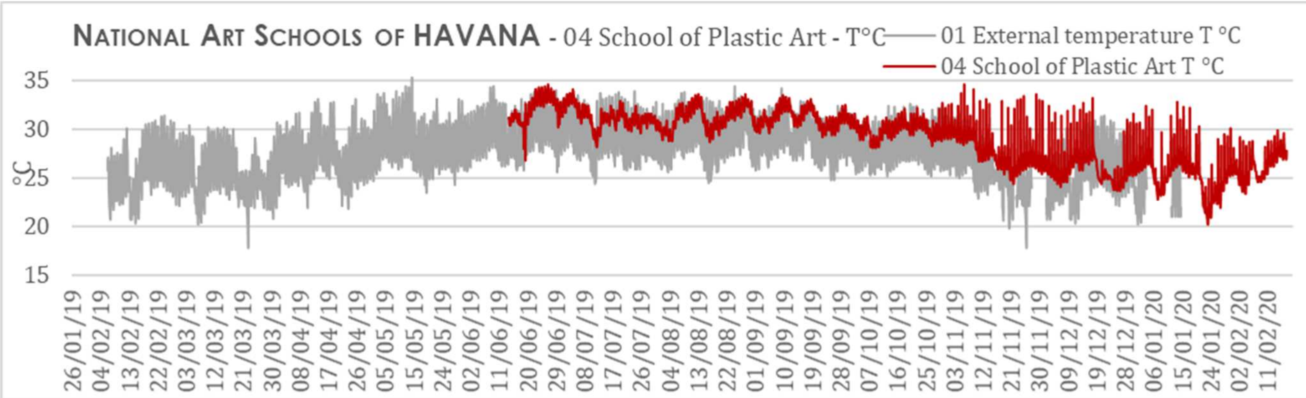
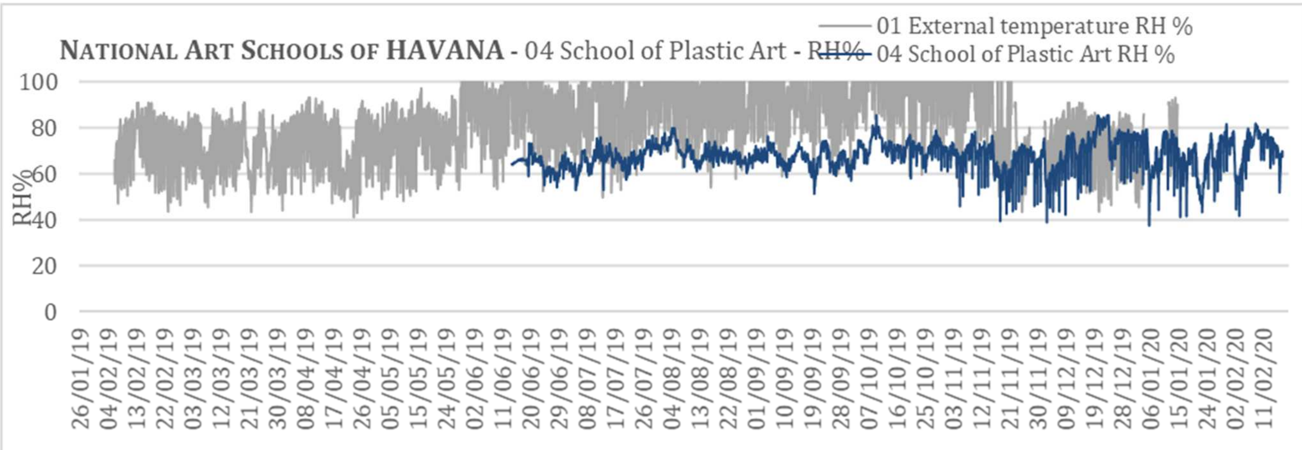


Table 5 - RH % Data - Probe 04 (LADC - Lab. Analysis and Building Diagnostic, Arch. Luca Valisi).



Direct monitoring - psychometric surveys

This type of survey[8] was carried out in some spaces chosen basing on the building's use conditions and comparing spaces in different situations. This was set on various uses such as windows always open or closed, the presence of doors and windows, all surveyed during the first inspections in which the spaces' perception allowed to determine in which places it was interesting to carry out this type of tests.

The psychrometer used, made by LADC[9], is a device for spatial mapping of environmental parameters on-site (temperature, relative humidity, specific humidity), as part of the preventive conservation of cultural heritage (EN 15758:2010 *Conservation of Cultural Property - Procedures and instruments for measuring temperatures of the air and the surfaces of objects* and EN 16242:2012 *Conservation of cultural heritage - Procedures and instruments for measuring humidity in the air and moisture exchanges between air and cultural property*). It consists of a thermally insulated psychrometer/transmitter, with a handle grip on which sensors such as dry bulb thermometer,

[8] Executed during the inspections on February 2020.
[9] https://www2.polimi.it/index.php%3Fid=6247&sel_brevetto=5079.html

wet bulb thermometer (connected to a water tank), barometer are installed. There is a software that controls the device for data acquisition and storage and allows their processing. Environmental data are acquired by positioning it at the points identified by a virtual Cartesian XY (Z) grid[10] placed on a horizontal (plan) or vertical (section) level. The linear interpolation of the detected values generates a map with isolines (contour lines) representing the distribution of environmental values in space, in two or three dimensions. This device is held in hand by the operator to map environmental values at eye level, installed onto a graduated rod, a vehicle, etc., to map both indoors and outdoors values at an elevated height from the ground.

Figure 16 - School of Plastic Arts, analyzed spaces

The results of the mapping operations of the rooms that will be discussed later are reported below. The T °C Temperature map is shown in red, the RH% relative humidity map is in blue, and the g / Kg mixing ratio map in green.

[10] https://www.polimi.it/index.php?id=6247&sel_brevetto=5078

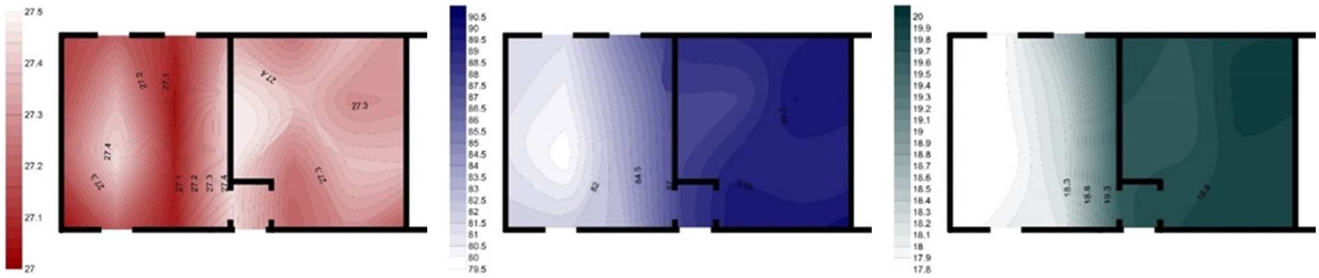


Figure 17 - 14.2.2020 - PHOTO LAB - PSYCHROMETRIC MAPS
T °C (RED), RH % (BLU), MR g/kg (GREEN), Environment A.

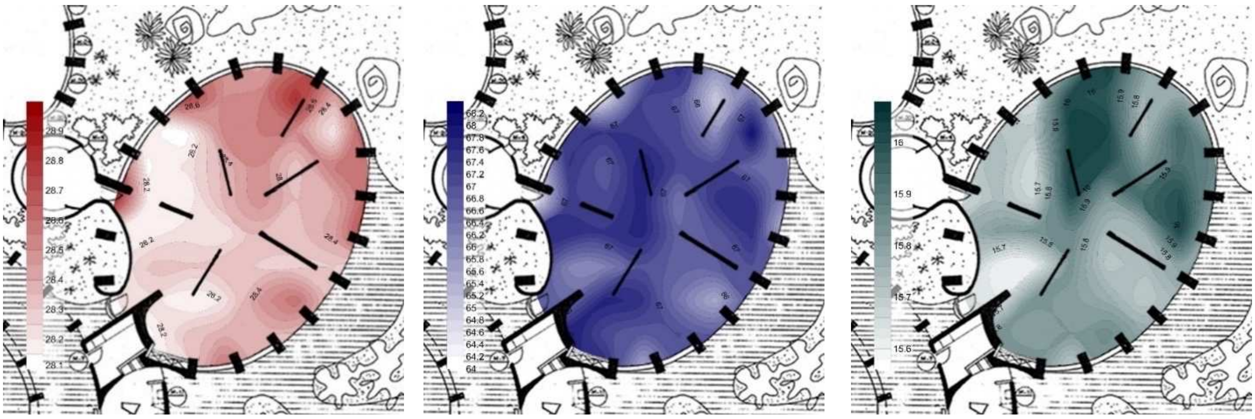


Figure 18 - 14.2.2020 - PHOTO LAB - PSYCHROMETRIC MAPS
T °C (RED), RH % (BLU), MR g/kg (GREEN), Environment B.

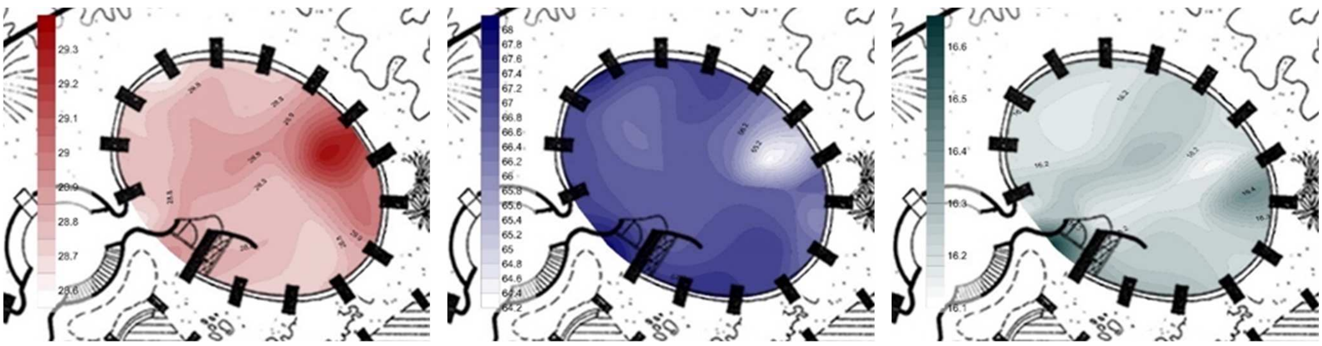


Figure 19 - 14.2.2020 - PHOTO LAB - PSYCHROMETRIC MAPS
T °C (RED), RH % (BLU), MR g/kg (GREEN), Environment C.

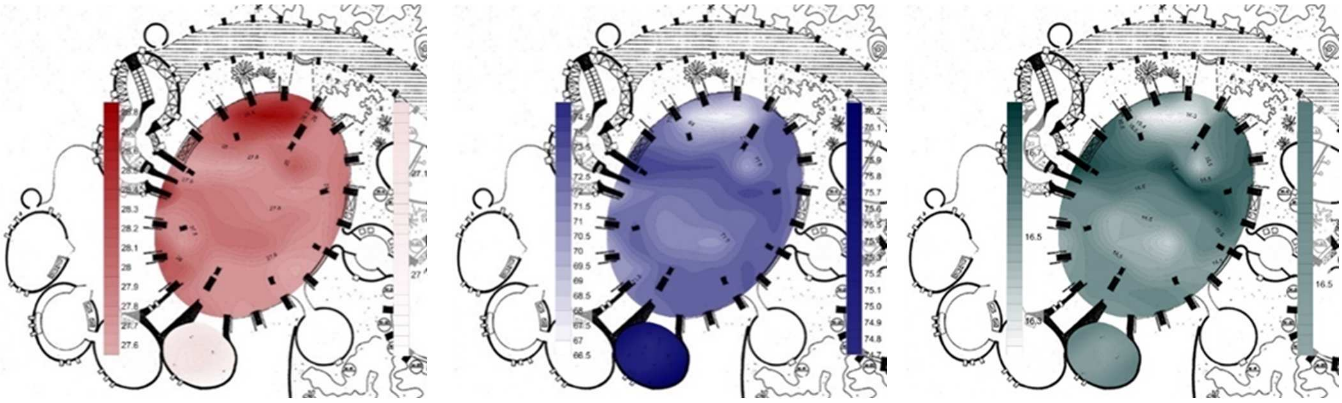


Figure 20 - 14.2.2020 - PHOTO LAB - PSYCHROMETRIC MAPS
T °C (RED), RH % (BLU), MR g/kg (GREEN), Environment D.

4.1.1.3 Results and analysis of room comfort status

Continuous automatic microclimatic monitoring

For continuous automatic microclimatic tracking, it was decided to analyze a space that is representative of all practical classrooms with a medium-sized dome (Table 3). A first evaluation of these data highlights that the relative humidity is almost constantly higher than 60%, with a variation of temperature lower than an interval of 10 °C, confirming tropical climates' typical problems. Comparing the external and internal data, although there is a lower daily variation, the internal temperature is similar to the external one, and this can lead to think that the architecture of the school does not have good thermal inertia and shows a low performance as a screen between the outside and the internal space. On the other hand, the building envelope allows having the same temperature condition, as shown in the graph (see Fig. 18). The architectural structure's effect is different when considering relative humidity, which is lower inside and higher outside (Table 5). This results in a slightly more comfortable condition inside the practical room compared to what is perceived outside, especially in the period from June to October - corresponding to the rainy season – in which the outside environment has a constant relative humidity of around 80/90%. The dome's environment still has an RH% value that fluctuates between 65 and 70%, which is high and causes a thermo-hygrometric discomfort.

The RH is crucial to use the environments: for each RH% value, there is an optimal maximum well-being temperature. Generally, with a value of 60%, most individuals experience a sensation of sultry heat as soon as the air temperature exceeds 24.8 °C, a condition that occurs in the environments analyzed herein, as shown in the graphs.

In this case, the dome encompasses a wide range of materials, ranging from building materials to the supports used by the students for their artwork. In both cases materials can be sensitive to microclimatic conditions. The conditions of discomfort in this school are thus significant not only for the users but also for the artistic works.

Direct monitoring - psychometric surveys

As mentioned, the photography laboratory (A) is one of the less used spaces of the School. It is located in the regular-shaped eastern block, adjacent to a series of spaces that, while meant to host warehouses and storage units, were never used and are constantly locked. Therefore, this space is devoid of air ventilation, despite photographic material in the laboratory. This situation probably represents the lowest condition of discomfort inside the school, and therefore the direct test was carried out therein.

For reasons of use, the room does not have openings towards the outside and has very high RH values, between 80% and 90%, 20-30 percentage points higher than the outside, even the MR rate is higher (+2; +4); the total lack of ventilation creates unfavorable conditions both for conservation and use of the spaces.

The large dome of the Practical Room (B), dedicated to the exhibition and laboratory of paintings, has an RH percentage higher than the outside value, of about 6-10 percentage points. The spaces are ventilated by keeping the doors and windows open; temperatures are slightly lower than outside (data were collected between 12.45 and 1.00 PM). It should be noted that, even with a lower temperature outside, the RH is still higher than 67% and considering that works are exhibited therein, this aspect should not be underestimated. In this case, air ventilation was not sufficient to guarantee favorable conditions.

The medium-sized dome (C) was chosen at a different point from that where the sensor 04 is located (the choice was caused by limited accessibility to the spaces during the site inspection). The T °C values are slightly lower than the outside, while RH corresponds and is partly higher. It has values and characteristics of use similar to the previous dome and MR rates of +0.8 g / kg, probably due to a lower air exchange compared to the outside. Plus, on rainy days, there is an infiltration of rainwater from the vaults in this dome.

In this case, the openings are only windows mostly closed with a windowsill in which, as can be seen, T °C is lower, and RH is high. Storage of micro-climate sensitive artistic works in this environment should be considered thoroughly.

The last room analyzed is the foundry (D)'s large dome, which has been compared with the smaller secondary dome. The large room is continuously ventilated, as windows are frequently open during the day. The small dome connected to the foundry, on the other hand, has no openings except for the connection with the main dome. When comparing the values, it can be notice that they are similar to the other domes. Indeed, the instruments detected a very high RH rate in the small dome, but not a high MR. The value is explained by observing the lower temperature of about 1°C, and RH, with the same water vapor, appears higher. RH in the foundry does not at any point reach the peaks reached in the domes seen previously, remaining around 60%.

4.1.2 Evaluations

4.1.2.1 Comparison between preliminary issues and analysis of the collected data

The investigations carried out helped developing a complete frame of the situation outlined by simple points expressed following the inspections.

The pleasant perception of open and ventilated spaces, opposite to those that are always closed, is confirmed by the psychrometer data obtained in various significant areas of the building. Rooms that are still closed have a high humidity value, which can be dangerous for the materials contained therein, the permanence of people, and the entire space's healthiness, unlike airy environments where RH% is in line with external conditions or even lower. Spaces such as the photography laboratory (room A) are comparable to a not used room as reported by the functional analysis. This type of space risks causing more damaging situations, and the internal conditions do not encourage users for their reopening. They do not even act as a safe deposit or warehouse as the storage of particular material could be put in danger by the thermo-hygrometric conditions. Given that some similar spaces have been found, it is even more necessary to emphasize the topic of function in relation to comfort.

The same consideration can be applied to the practical classrooms, the domes. As noted during the inspections, in these rooms without an air-conditioning system, the presence of windows and doors and the ventilation is also relevant in the measurements' results.

Ventilation contributes to a lower humidity level, which, with the same T °C, brings better well-being conditions for the user. Although the RH% value is slightly lower than the external one, the windows' repeated opening prevents the increase of such value, bringing better conditions for users to stay.

Indeed, the measurements and the subsequent processing of the data led to a knowledge that it was impossible to perceive during the inspections. The building envelope, although conceived with some finishing adjustments, does not have good thermal inertia. In other words, it does not help shield the internal space from external conditions. The passive solutions adopted in the design are perhaps a purely perceptive aid and not a contribution that can be counted with data and graphics.

4.1.2.2 Comparison with the original design

Despite these considerations on the well-being of users of the School of Plastic Arts and the conservation of the works, in about 60 years, this building has never changed its intended use. This data could reflect on the spaces' architectural adequacy concerning the activities and the number of users, but most notably on the adaptation to different conditions, due to the scarce economic possibility of improving them.

The passive architectural solutions mentioned in the previous paragraph for the improvement of energy conditions could simply have arisen from the awareness of designing in a tropical climate area, but not with the actual intention of carrying out functions from an energy point of view. The installed systems would have solved this problem.

Therefore, art schools can be seen as an early and unconsciously "sustainable" complex of buildings due to their ability to perform their original function even without fully efficient technical systems. The Art Schools can also be considered an example of “resilience” because they have been fulfilling their original role for over sixty years, even if the original project was never completed. On the contrary, it has been subjected to constant adaptations.

4.1.2.3 Existing problems

In conclusion, although the building has been continuously used since the 1960s according to its original function, the School of Plastic Arts does not provide users sufficient thermal hygrometric well-being. Could the school be waiting for completion? Do users have different capacities and standards than users of a different climate? These are debating questions to be asked, but do not really address the issue of improving the thermo-hygrometric conditions. The difficulties encountered can be summarized as follows: a relevant ratio between T °C and RH% in the practical domed classrooms which also contain the students’ works of art; poor conditions found in closed spaces; air-conditioning systems not in use; use of low-quality mechanical fans; unexploited potential of the patios of the theoretical classrooms; little consideration of passive aspects; a widespread problem with the new type of doors and windows which are hermetically closed with little air ventilation between inside and outside. The installation of a centralized system for air-conditioning could be an immediate solution. However, this leads to further considerations in terms of economic and sustainability impact, as well as of conservation and suitability aspects.

Considering the economic situation, installing a system in a building of this type is unimaginable and unsustainable if considering the extensive consumption and the lack of resources. However, it can be a solution that significantly improves the aspects described in this work. The economic difficulty of the operation of the system and the installation could be expensive. The conservation of the material and architectural elements could involve adopting particular solutions other than the simple installation of air-conditioning systems. The previous problems highlight an unconvincing premise to proceed in such a way. If the few installed devices are not in use already for economic reasons for reducing consumption, can this strategy still be pursued?

However, given the didactic function of the spaces, students’ continuous presence in most of the rooms may suggest making some improvements without resorting to the installation of impacting systems.

4.2 Rectorate building

The historical building of the Club House, designed by Luis Echevarrìa, is another case considered to assess the thermo-hygrometric comfort conditions. It was chosen because it is currently used as the location of the Rectorate of the *Instituto Superior de Arte*. Although it doesn't show any marked architectural relevance, the building is of great interest from the managing point of view. Indeed, it is a central building that can more easily find practical feedback for projects and interventions.

There is a central block dedicated to vertical distribution and services and four wings in the cardinal points' direction from a functional point of view. The north wing hosts the classrooms of the current music school. The east wing is currently inaccessible due to a construction site in progress. The south wing, now the most used, houses the teachers' offices on the second floor and a large room for performances and the canteen on the ground floor. Finally, the west wing includes other classrooms for teaching the music school on the second floor and is inaccessible on the ground floor and basement.

During the inspections, some criticalities were found regarding this building's thermo-hygrometric comfort and the most used rooms: the internal temperature is very high, and the passive systems adopted, ventilation and natural shading, are not sufficient to guarantee a comfortable use of the spaces.

Figure 21 - Rectorate building - Basement floor use.

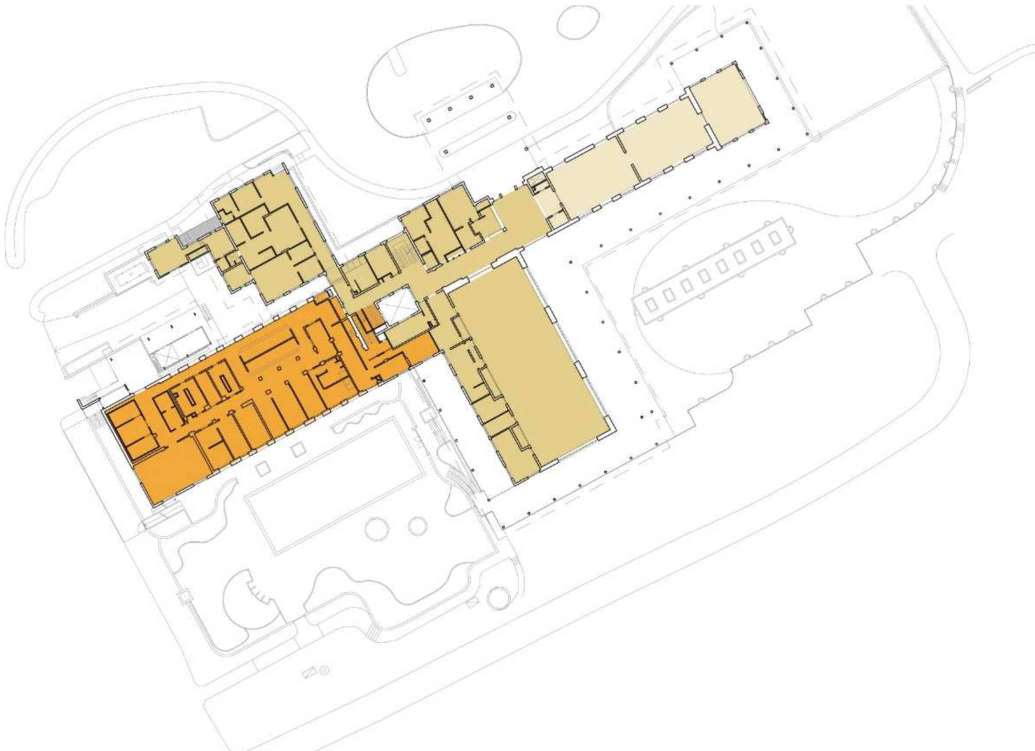


Figure 22 - Rectorate building - Ground floor use.

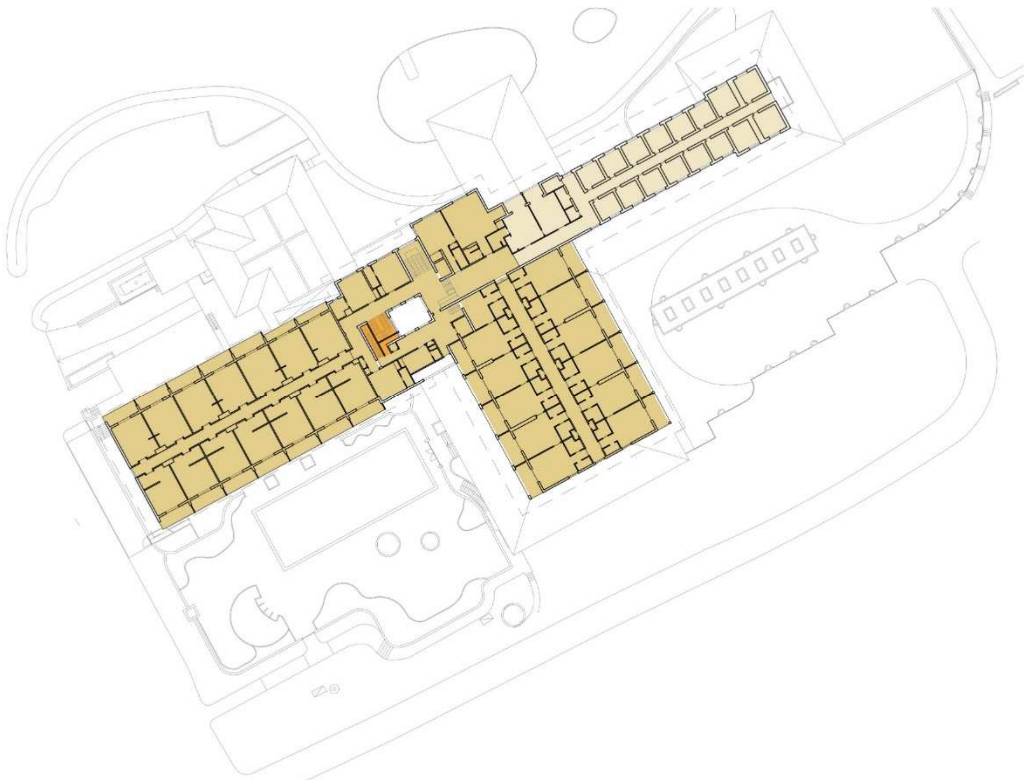


Figure 23 - Rectorate building - First-floor use.

4.2.1 Description of energy performance

4.2.1.1 Passive thermic performance of the building

The Rectorate architecture has some expedients that contribute to improving the passive thermal performance of the building. The large overhangs of the floors that cover the balconies on the second floor, the large porticoed areas on the ground floor, and the partial basement contribute to create shaded open spaces for walking and resting and, above all, to protect the external walls of the building from direct sunlight (Figure 24). The south façade of the west wing (outdoor swimming pool) is devoid of porticoed areas on the ground floor and does not have these benefits, unlike in the past, when there was a shading canopy on this façade too. This absence contributes to the discomfort detected in this wing's spaces and to users abandonment, resulting in the current state of deterioration.
Shutters almost always protect the large openings on the second floor. The aim is to protect the indoor area by reducing direct sunlight and heat while allowing the wind to blow through and promote ventilation.
On the ground floor, almost all the openings are equipped exclusively with aluminum and glass windows. Although partially covered by the large overhanging ceilings, they negatively affect the indoor climate and its temperature when directly affected by solar radiation.
Finally, an important task is that of the large tropical plants that surround the building, which represent an essential element to promote the hygrometric balance, create shaded areas on the walls, and carry out outdoor activities.

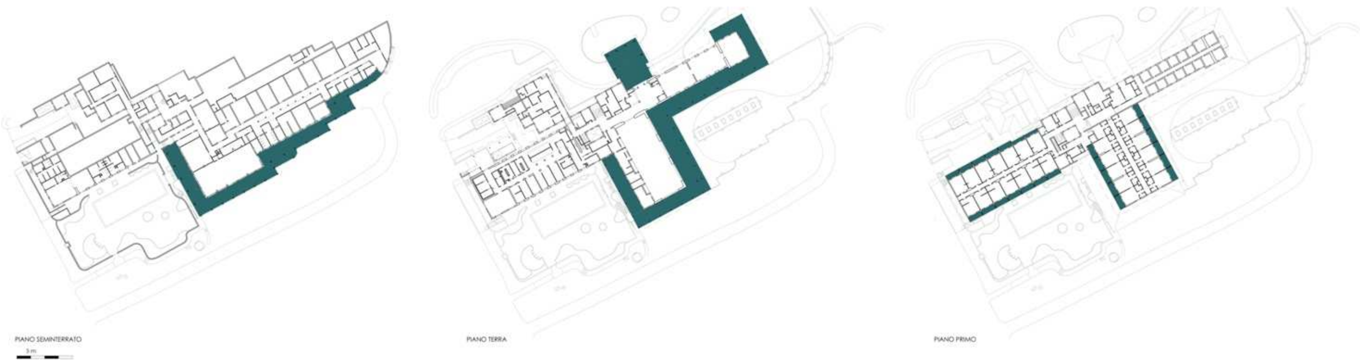


Figure 24 - Rectorate building - Porched areas and loggia.

4.2.1.2 Thermo-hygrometric data

For the Rectorate building, the LADC carried out continuous microclimatic monitoring since June 2019, when a sensor was installed in the Rector's office on the second floor of the south wing[11]. The following is a summary sheet with the parameters relative to the sensor and its location in plan and photographic documentation.
The space in which the sensor has been placed is the teachers' office wing, and it is a used space (Rector's office), equipped with windows and air-conditioning systems.

[11] Analysis and measurements performed by *LADC - Lab. Analysis and Building Diagnostic, Department of Architecture and Urban Studies, Politecnico di Milano,* Arch. Luca Valisi.

S05 | RECTORATE BUILDING

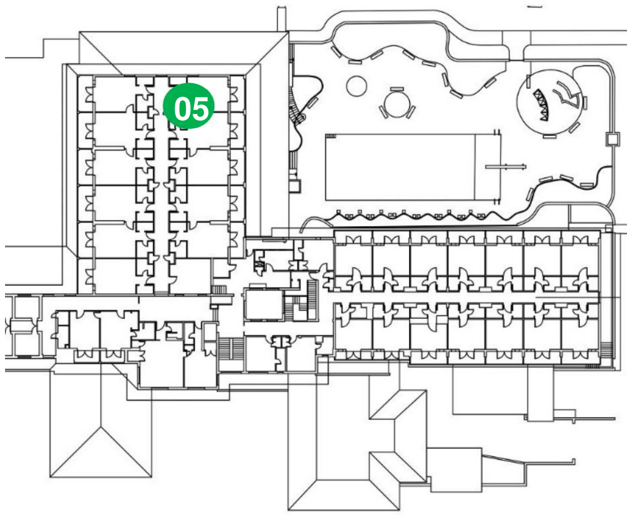
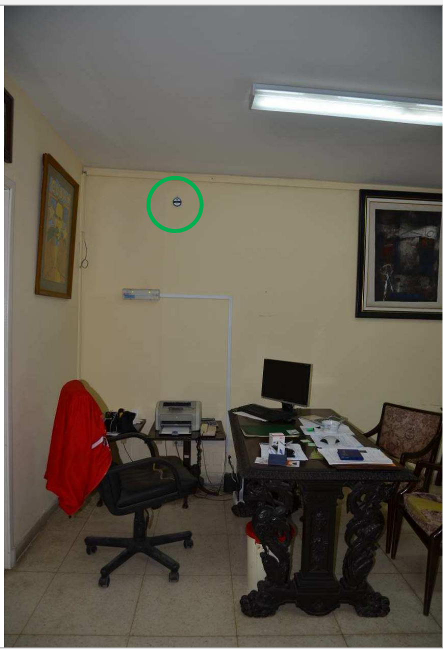
ACQUISITION PARAMETERS	LOCATION
ESCORT I-LOG DATALOGGER **Temperature (°C) and relative humidity (%)** with screen for displaying the current value. *Resolution / Accuracy °C* 0,1°C; ±0,3°C *Resolution / Accuracy %UR* 0,1%UR; ±3%UR *Interval Measurement from* 1 sec to 10 days *Degree of Protection* IP51 *Polycarbonate Case* *Green Led* (Active) Red (Alarm) *Response Time in Air* 90% in 4 min (°C) 90% in 50 sec (RH) *Dimensions* Ø=75mm H=36mm *Weight* 70 gram	 SENSOR **05**, INSIDE **T-UR%**
(GENERAL) PHOTOGRAPHIC REPRESENTATION	**(SPECIFIC) PHOTOGRAPHIC REPRESENTATION**
	
Note	
Installed on 21/06/ 2019.	

Table 6 - Sensor 05 (LADC - Lab. Analysis and Building Diagnostic).

The sensor allowed to obtain the linear trend of temperature °C (in red) and relative humidity % (in blue) compared with the corresponding data of temperature and relative humidity outside the building (in grey).

Table 7 - Sensor 05: linear trend of the temperature in the Rector's office compared to the outside temperature.

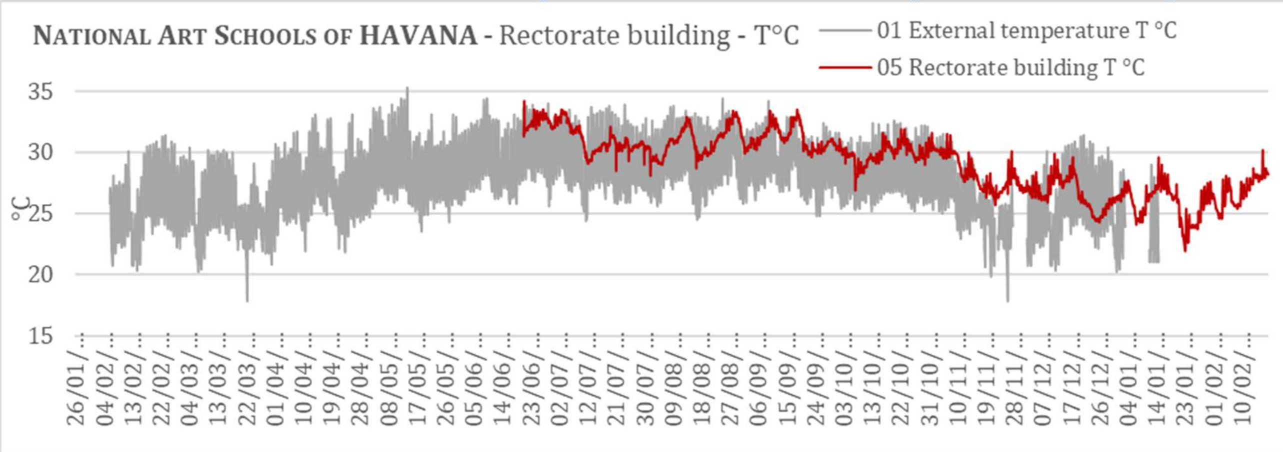
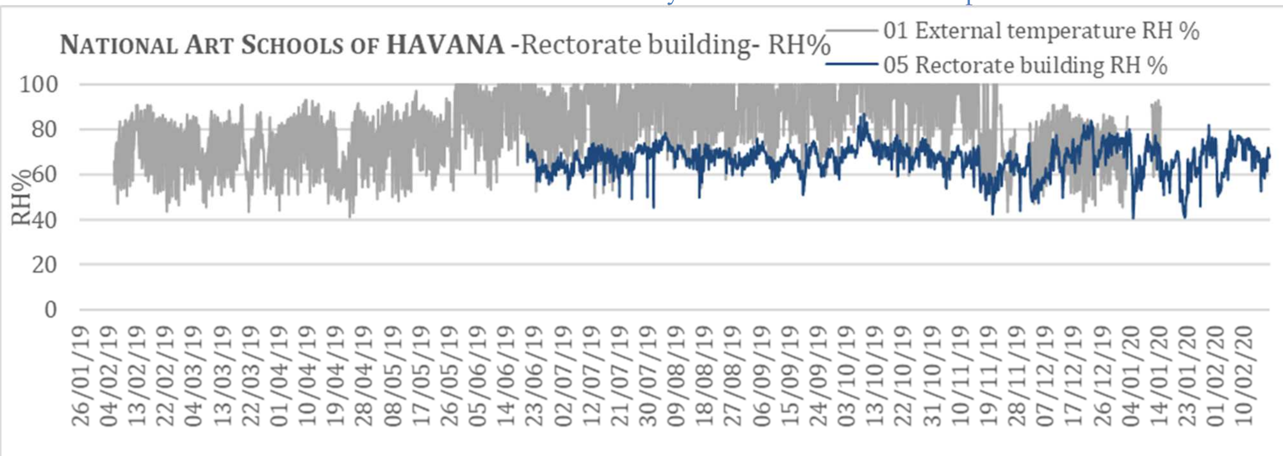


Table 8 - Sensor 05: linear trend of relative humidity in the Rector's office compared to the external on.



4.2.1.3 Results and analysis of room comfort status

The previous graphs refer to the data of the inspection in February 2020 and were acquired by sensor 05 installed on June 21, 2019 (Table 7 and

Table 8). It will be possible to obtain a more complete and comparable analysis at the end of the whole monitoring cycle (which is one year after installation). For now, the eight months of data available are considered.

The red curve (Table 7) shows a space with very high temperatures ranging from a minimum of 22°C to a maximum of 34°C. Data do not show significant differences from the other buildings and the external temperature and relative humidity values, confirming that the air-conditioning system is scarcely used (even though present). The blue curve (

Table 8) shows a space with high relative humidity levels (65-70%) with steady movement and high daytime excursion (e.g., on 1st August, there are values of 46% and 68% with a variation of 42 points) and is even higher during the winter months.

4.2.2 Evaluations

4.2.2.1 Comparison between preliminary issues and analysis of the collected data

During the inspections occurred in February 2020, it was possible to assess the spaces' discomfort in the Rectorate building directly and, particularly in the south wing, the most used one. It was chosen to place the sensor in one of these offices because it is used daily, intensively, and with more unfavorable exposition. The placement of the sensor has the objective to analyze its current conditions, in order to look for a solution that will respect the historical material of the building, and, at the same time, improve the comfort of the users, promoting its use and conservation. All offices in the south wing are particularly hot and humid, and users have found timely but insufficient solutions to solve the problem, such as the use of fans. In the few rooms equipped with air-conditioning, you could get a nice cooling. Still, the significant difference in temperature recorded in these environments compared to the outside is so high that it contributes to users' general discomfort passing from one room to another.

4.2.2.2 Existing problems

The air-conditioning system designed for a part of the Rectorate building has an inadequate response from a practical perspective and has involved installing external equipment (Figure 25). These impact the building's façades, in contrast to the conservation of a historic structure and an intelligent design that cleverly considers shaded and naturally ventilated areas to improve users' comfort.

Figure 25 - External units that compromise the aesthetics of the building.

Historical buildings require a system that must be able to maintain specific thermo-hygrometric conditions and, at the same time, fit and integrate the situation, preserving the original structure. For the Rectorate building the split air-conditioning system wasn't probably the best solution.

As experienced during the inspections, the temperature excursions between the air-conditioned rooms, the outside, and those not equipped with air-conditioning, are too high. The relative humidity levels detected are not significantly improved.

Even if used for different functions, the building was initially able to guarantee comfortable space use thanks to an intelligent design and attention to the building's passive thermal behavior, with economic advantages. Over time, the users' needs, who now stay for several hours in the building and need to store paper documents and musical instruments, have changed.

In addition to the different functional requirements, the various building interventions have decreased the building's passive performance over the years. For example, replacing the original windows with new resistant ones led to lower ventilation. The demolition of the large canopy in the south, near the swimming pool, increased the façade's direct radiation.

4.3 School of Music

The School of Music was never completed or used. Today some spaces are under the management of different subjects such as storage, carpentry laboratory, and art laboratories (Figure 26 and Figure 27).

It can be described as a two-level building, although the elevations change along its entire development, following the ground's contour lines. Small individual cubicles characterize the lower floor, partly underground. The upper floor has larger classrooms and a covered, open path connecting them.

The carrying out of the analysis on comfort situation allows for comparison with other architectures for design choices. Given the considerable size of the building, it is inadvisable to analyze all rooms. Therefore, measurements were only carried out in some significant rooms, one for each level.

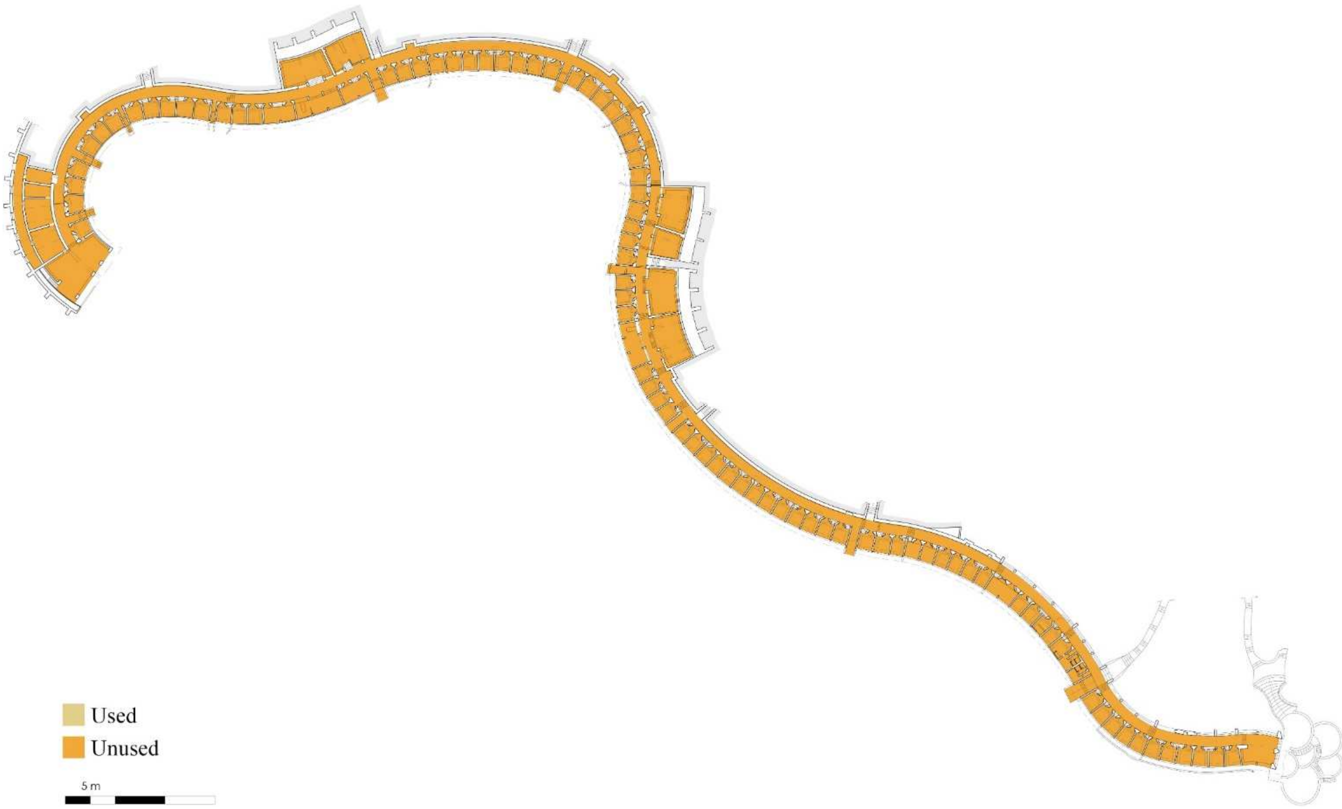


Figure 26 - School of Music - Lower floor use.

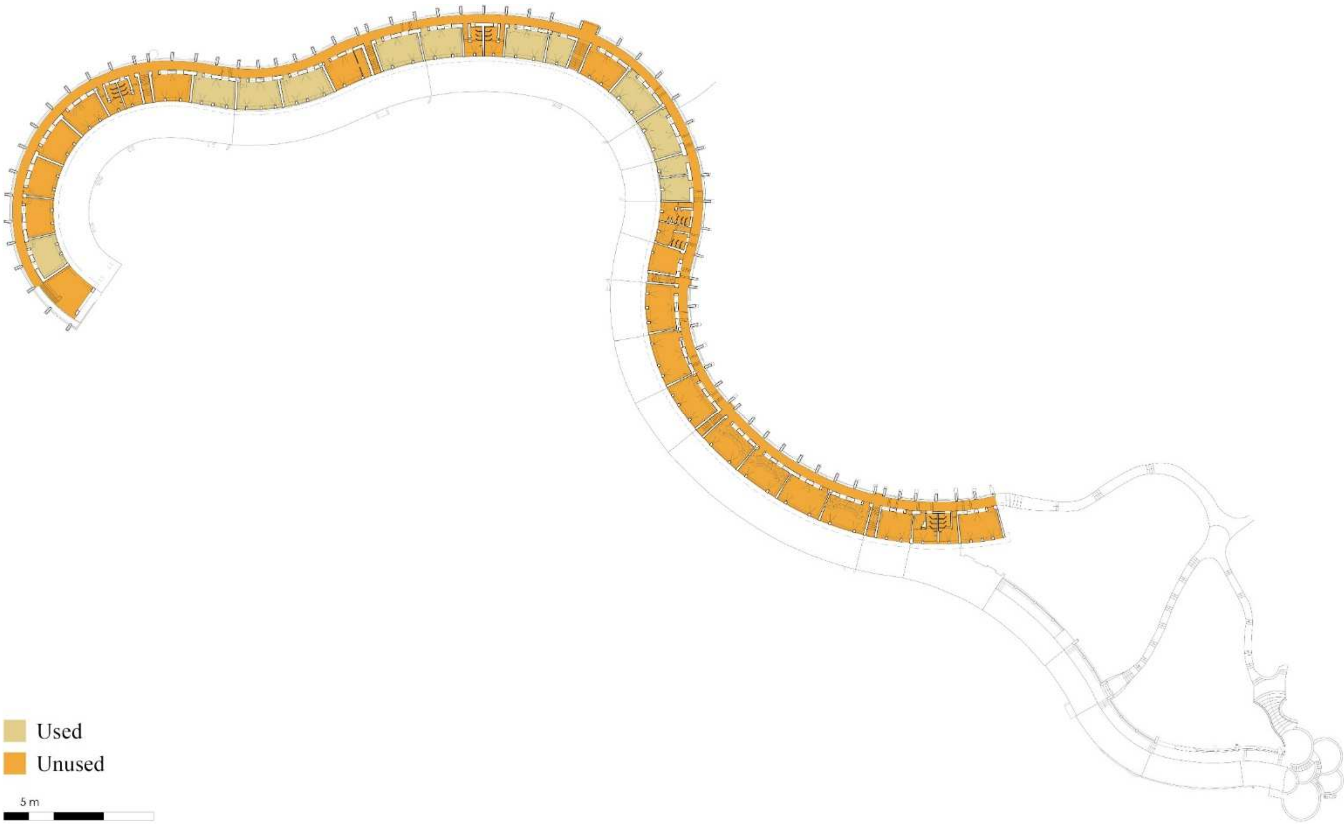


Figure 27 - School of Music - Upper floor use.

4.3.1 Description of energy performance

4.3.1.1 Passive thermic performance of the building

As for the School of Plastic Arts, the School of Music's in-depth study has highlighted the architectural elements designed to improve the thermo-hygrometric comfort of these spaces' users located in a tropical climate. These architectural aspects work on the relationship between the building and the natural, technological, and cultural environment. The School of Music was designed to be completely air-conditioned, as can be observed from the original blueprints, complete with detailed performance drawings of the systems, the surveys, and inspections carried out on site. Nowadays conducts that should have housed the cooling system are still visible. Due to the large size of the school in relation to the resources available, the state of disuse of the building and the high energy costs have contributed definitively to the missing system.

Despite the original design included a mechanical system for cooling and probably for dehumidifying the rooms (Figure 28, Figure 29), the architecture has elements to optimize natural shading and ventilation, to guarantee greater comfort than the hot and humid outdoor climate. All the upper floor classrooms are connected by an external covered path (Figure 30) that offers shade to the classrooms' exterior façade for many hours a day, avoiding overheating. This covered walkway is made with a perforated brick wall that characterizes the architecture from a formal perspective and creates charming plays of light and shadow, providing comfortable ventilation. Even if external, this path is the only one to connect the school's upper floor's classrooms and spaces. It must be shaded and comfortable for the users.

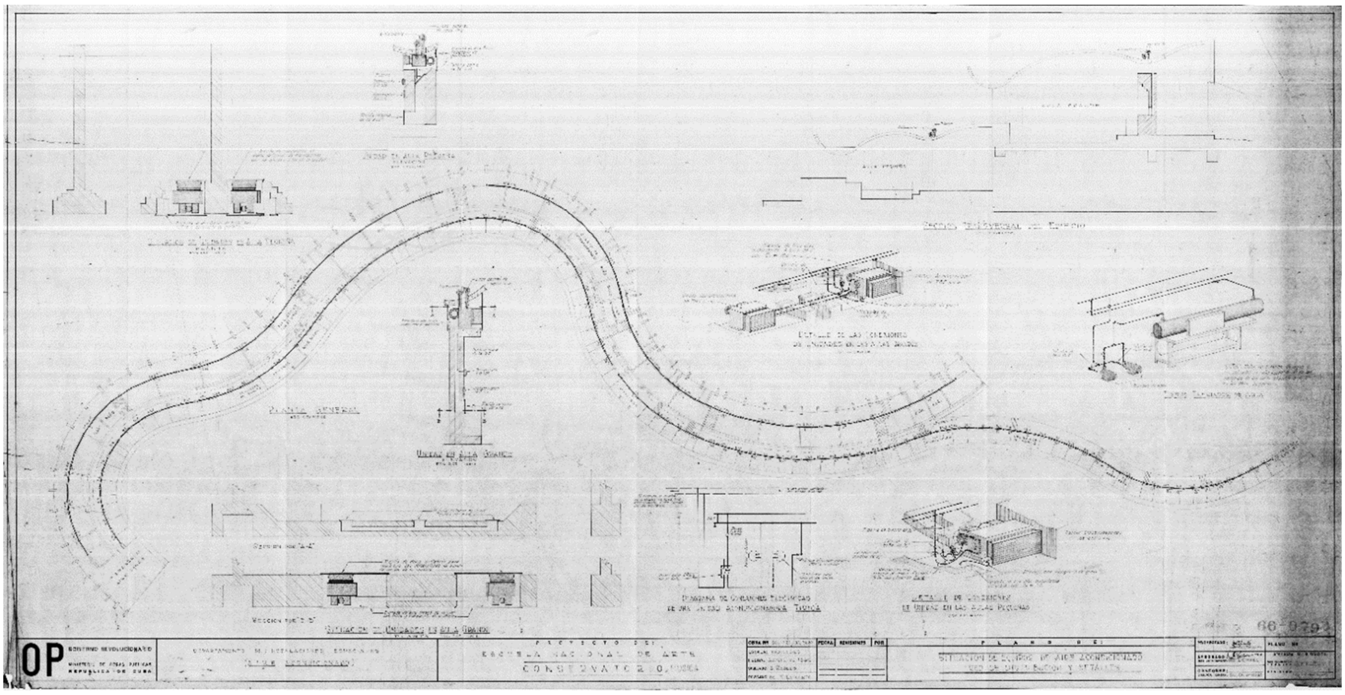


Figure 28 - School of Music – ISA archive, executive drawings of the air-conditioning system.

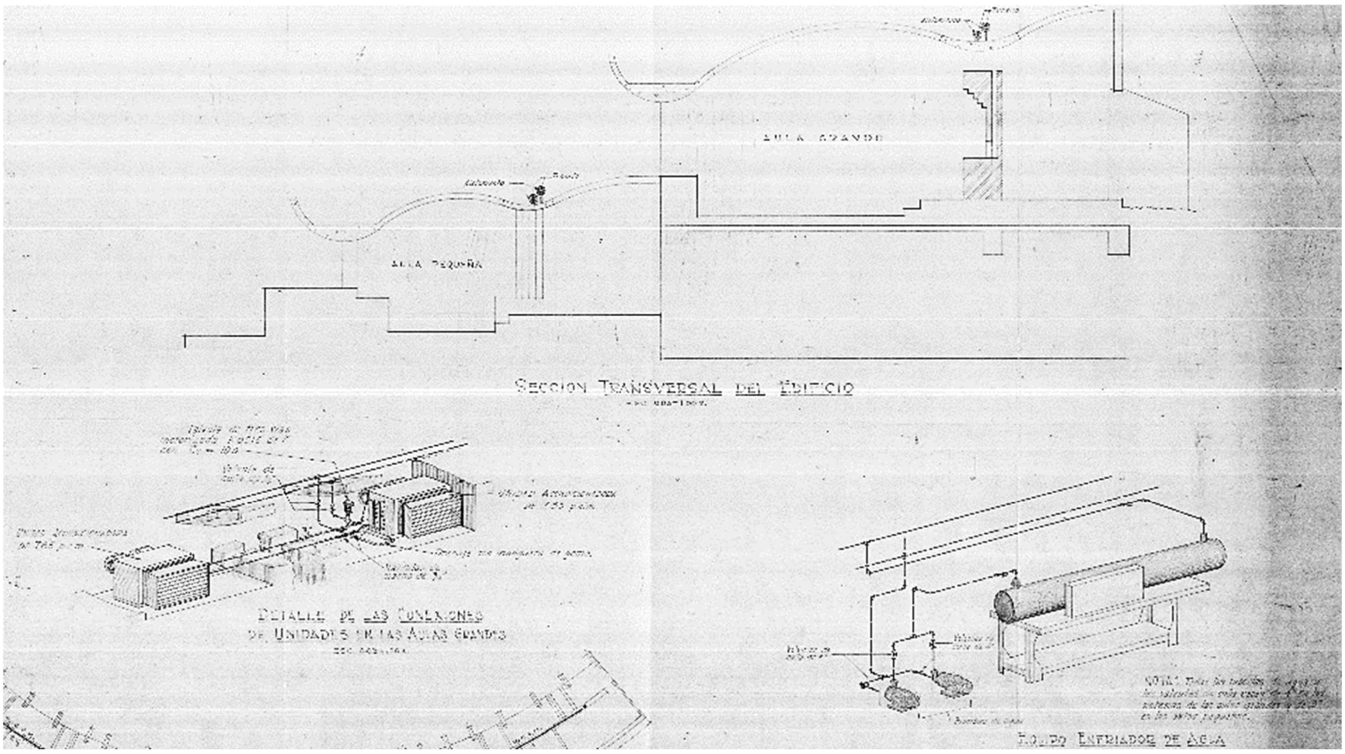


Figure 29 - School of Music, ISA archive, executive drawings of the air-conditioning system.

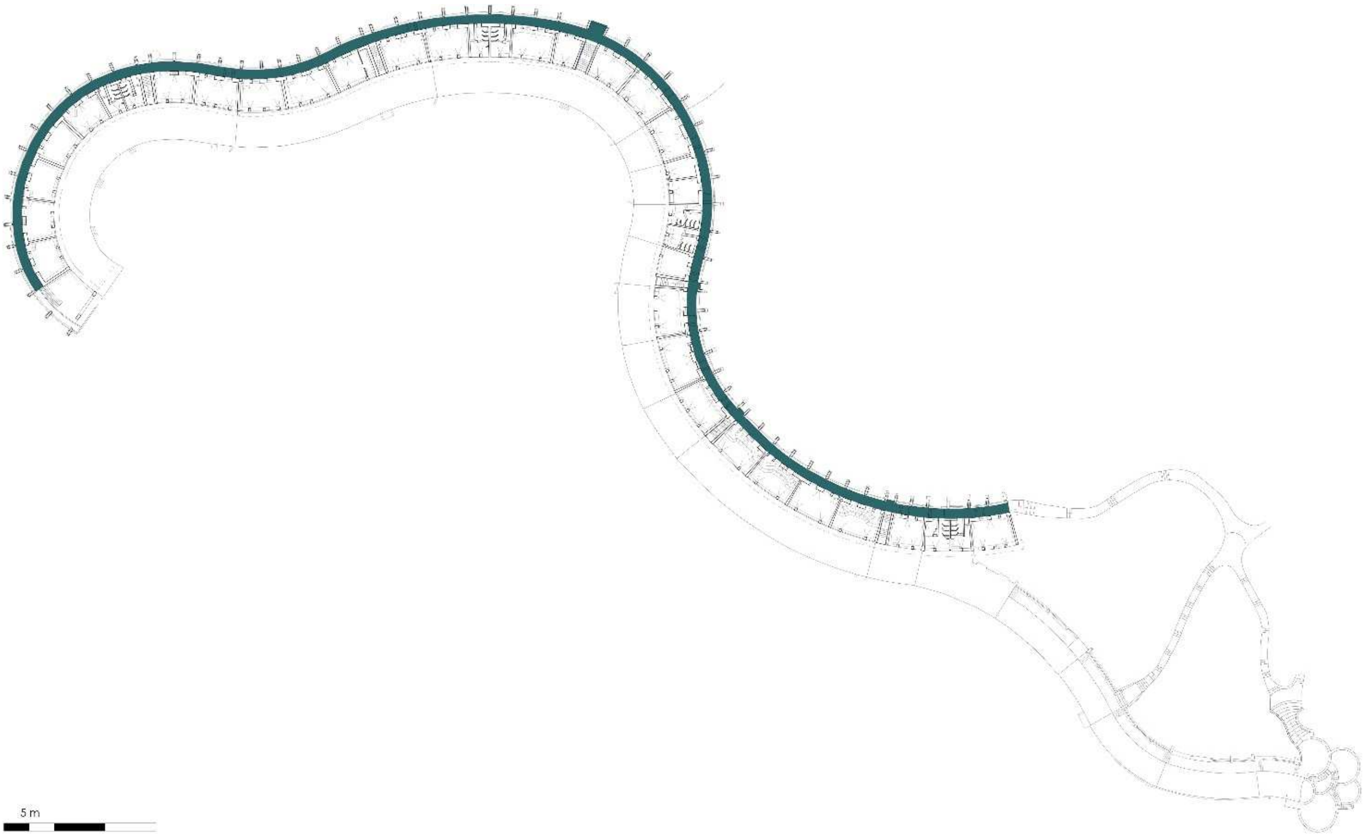


Figure 30 - School of Music, open covered path.

Figure 31 - School of Music, open covered path.

Both music school levels have vaulted concrete roofs that end, on the south side of the building, with deep planters jutting out from the edge of the classrooms' external wall.

In this case, this is a detail designed to improve the classrooms' thermal conditions: the shadow of the planters, projected on the classrooms' façades, protects them from direct radiation and overheating of the internal environment (Figure 32, Figure 33). Moreover, the vegetation, to carry out its vital processes, captures part of the humidity.

Figure 32 - School of Music, overhanging planters on roofs, south façades.

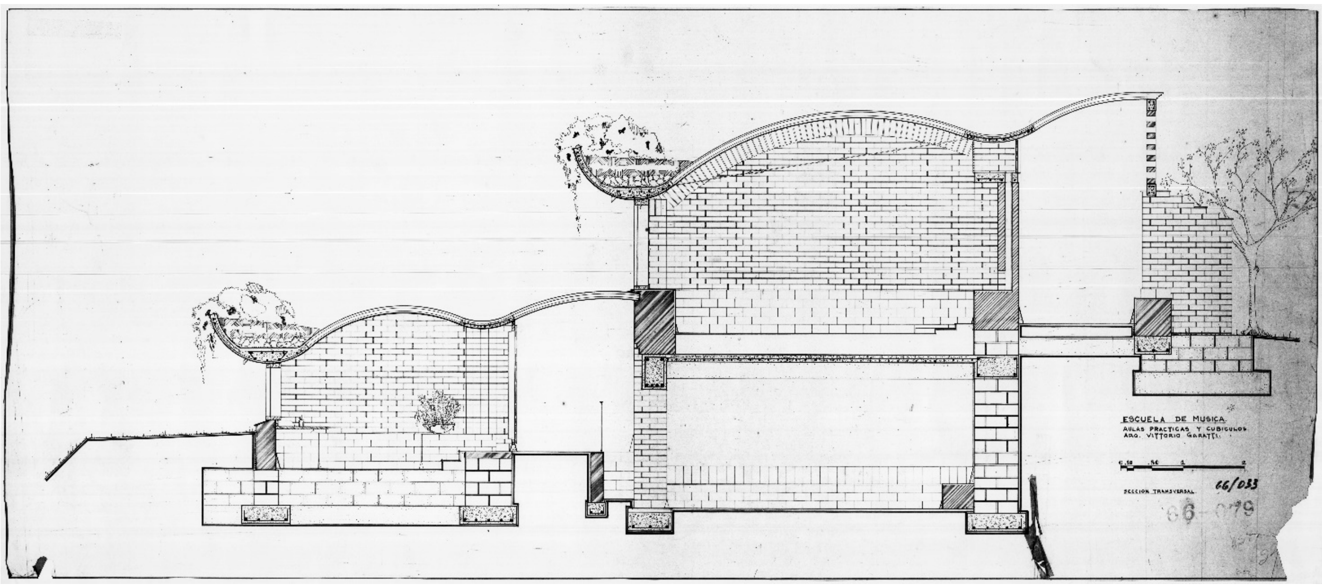


Figure 33 - School of Music, ISA archive, section project drawing.

The roofs projecting on the most exposed side of the building allow for large openings, on which they provide shade. For the project, on the upper level, the openings can guarantee an air match with those on the opposite side towards the external covered and shaded path. The feedback is towards the internal distribution corridor and partly against the ground, therefore cooler for the lower level.

4.3.1.2 Thermo-hygrometric data

As previously said, the air-conditioning system was never realized in the School of Music. Given the state of abandonment and disuse of the entire building, no one ever made studies on its thermal and energy performance. As for other buildings, the materials' thermal characteristics, the environmental parameters (temperature, humidity, temperature distribution) inside and outside, and the requirements of thermo- hygrometric comfort for the users are the points considered for these evaluations.

LADC carried out measurements, data processing, and graph outputs. For the School of Music, the LADC carried out continuous microclimatic monitoring in two rooms: a classroom on the upper floor (sensor 06) and a classroom on the lower floor (sensor 07). They are both small and significant for describing the overall school's microclimatic situation as they conform to the architectural, material, and dimensional characteristics of all the other rooms.

Even though the building is nearly abandoned, an occasionally used room on the upper floor (sensor 06) and a disused room on the lower floor (sensor 07) were selected to be analyzed. Both the selected environments do not have windows and doors and are in direct contact with the outdoor climatic conditions.

The two sensors were installed in June 2019, and the data collected concerns the 8-month monitoring. After completing an annual cycle, we will have a complete picture of the building's microclimatic behavior. The data are shown in linear graphs and lead the trend of temperature °C (red line) and relative humidity % (blue line) in relation, respectively, to the trend of temperature and relative humidity (gray lines) outside the building.

S06 | SCHOOL OF MUSIC (Lower floor)

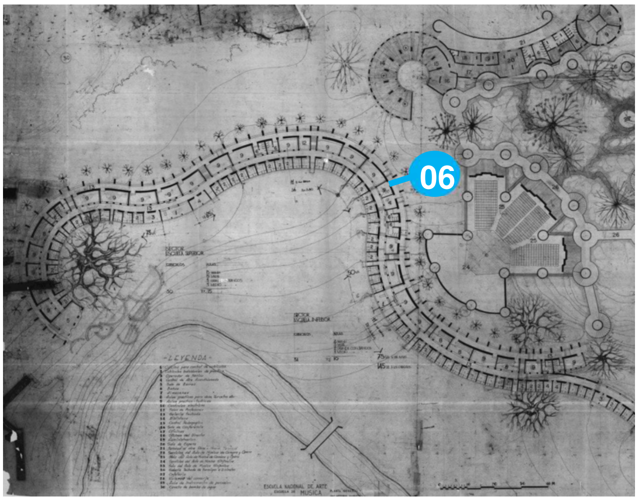
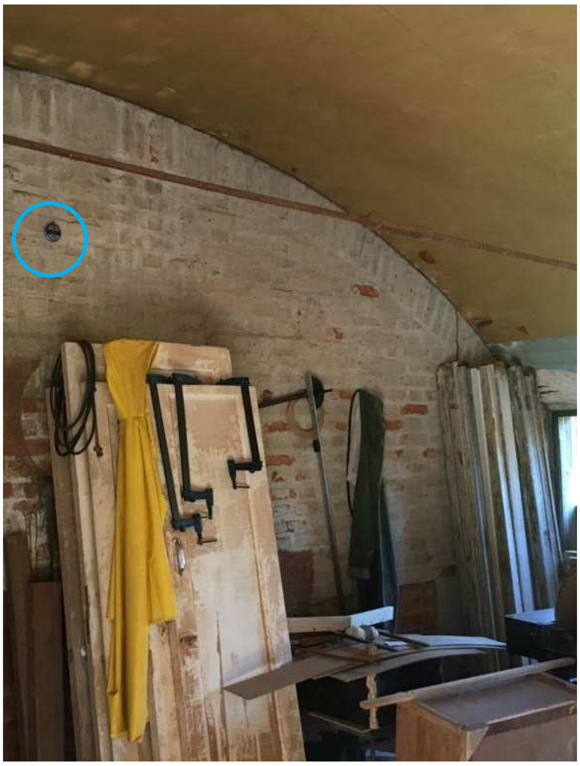
ACQUISITION PARAMETERS	LOCATION
ESCORT I-LOG DATALOGGER **Temperature (°C) and relative humidity (%)** with screen for displaying the current value. *Resolution / Accuracy °C* 0,1°C; ±0,3°C *Resolution / Accuracy %UR* 0,1%UR; ±3%UR *Interval Measurement from* 1 sec to 10 days *Degree of Protection* IP51 *Polycarbonate Case* *Green Led* (Active) Red (Alarm) *Response Time in Air* 90% in 4 min (°C) 90% in 50 sec (RH) *Dimensions* Ø=75mm H=36mm *Weight* 70 gram	 SENSOR **06, T-UR%** INSIDE
(GENERAL) PHOTOGRAPHIC REPRESENTATION	**(SPECIFIC) PHOTOGRAPHIC REPRESENTATION**
	
Note	
Installed on 25/06/2019	

Table 9 - Sensor 06 (LADC - Lab. Analysis and Building Diagnostic).

S07 | SCHOOL OF MUSIC (Upper floor)

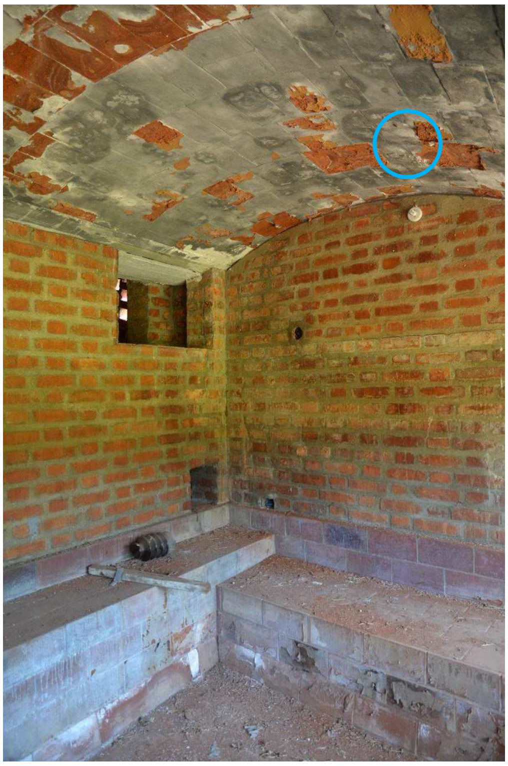
ACQUISITION PARAMETERS	LOCATION
ESCORT I-LOG DATALOGGER **Temperature (°C) and relative humidity (%)** with screen for displaying the current value. *Resolution / Accuracy °C* 0,1°C; ±0,3°C *Resolution / Accuracy %UR* 0,1%UR; ±3%UR *Interval Measurement from* 1 sec to 10 days *Degree of Protection* IP51 *Polycarbonate Case* *Green Led* (Active) Red (Alarm) *Response Time in Air* 90% in 4 min (°C) 90% in 50 sec (RH) *Dimensions* Ø=75mm H=36mm *Weight* 70 gram	 **SENSOR 07, T-UR% INSIDE**
(GENERAL) PHOTOGRAPHIC REPRESENTATION	**(SPECIFIC) PHOTOGRAPHIC REPRESENTATION**
	
Note	
Installed on 24/06/2019. The sensor is located in a covered space but also opened because there aren't windows	

Table 10 - Sensor 07 (LADC - Lab. Analysis and Building Diagnostic).

Table 11 - Graph 1/sensor 06: linear trend of the temperature compared to the outside temperature .

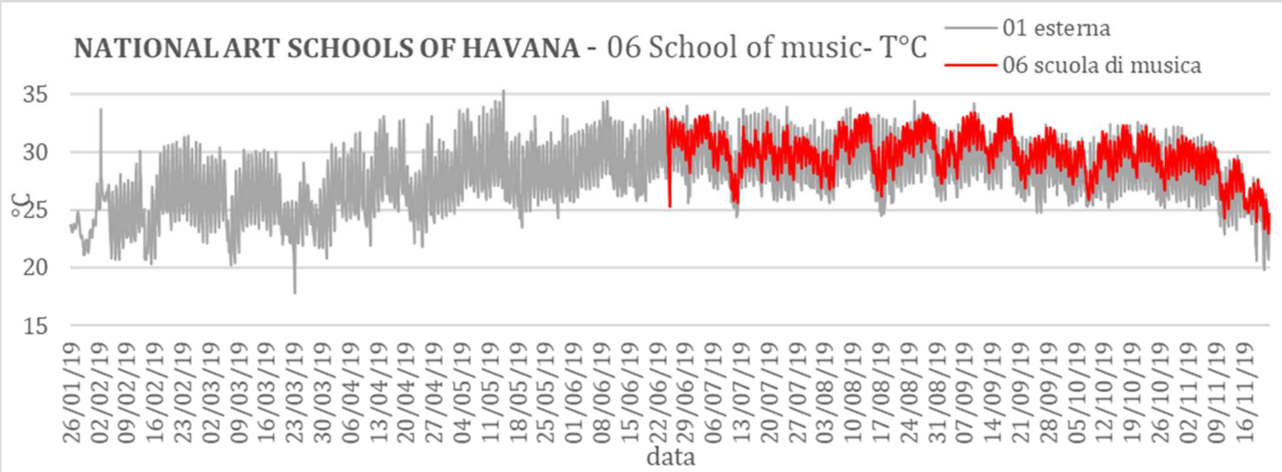


Table 12 - Graph 2/sensor 06: linear trend of relative humidity compared to the external one.

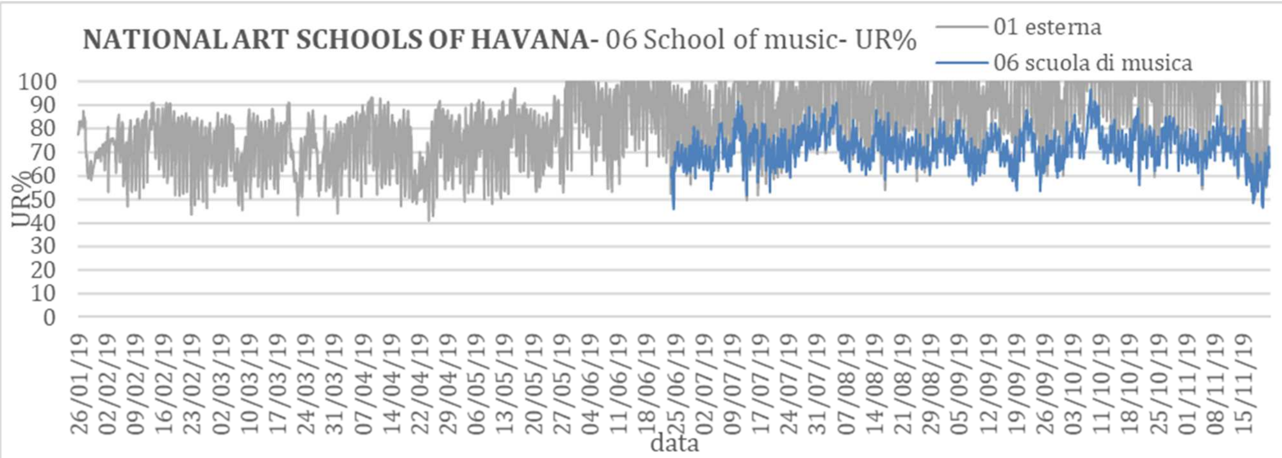


Table 13 - Graph 1/sensor 07: linear trend of the temperature compared to the outside temperature.

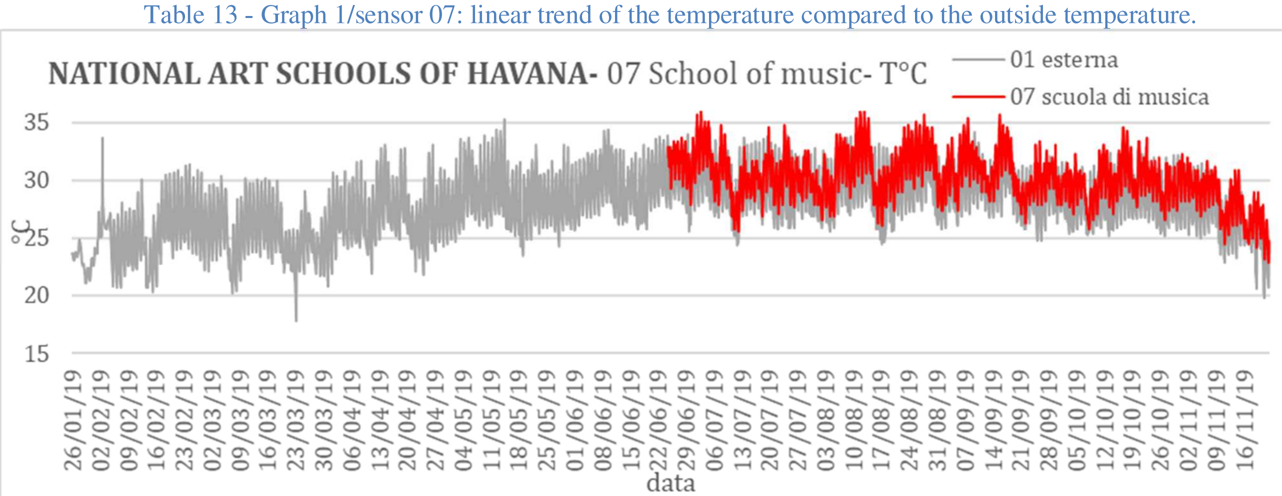
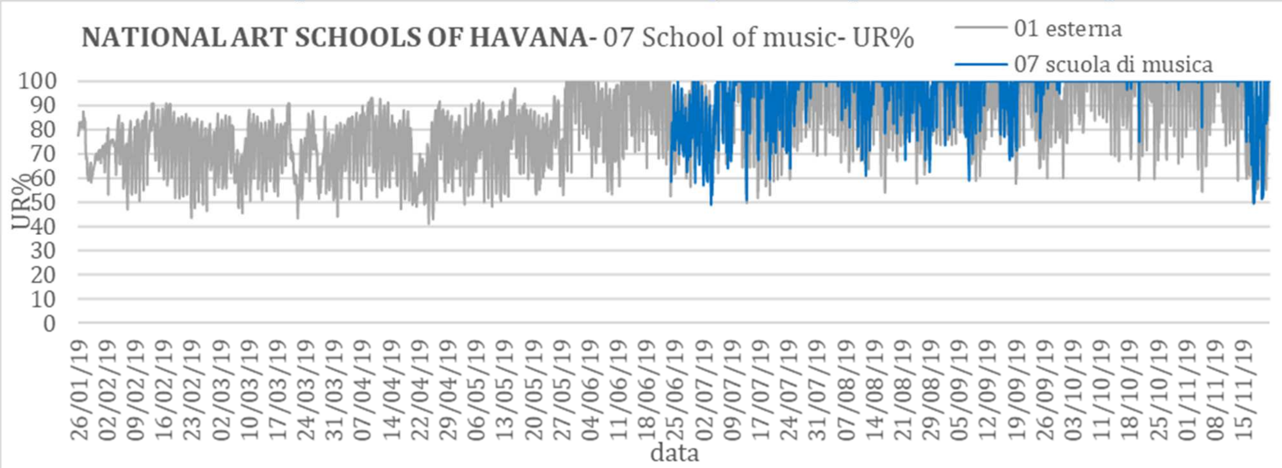


Table 14 - Graph 2/ sensor 07: linear trend of the temperature compared to the outside temperature.



4.3.1.3 Results and analysis of room comfort status

The graphs in the previous paragraph refer to the data of the sensor downloaded in February 2020. They were acquired by sensors 06 and 07, installed respectively on 25th June 2019 (Table 11 and Table 12) and 24th June 2019 (Table 13 and Table 14). We have to wait to conclude one complete monitoring cycle (greater or equal to one year after installation) to obtain a comprehensive analysis compared to the other sensors installed in January 2019. Therefore, the following considerations take place based on data collected in 8 months.

The classroom analysis in the upper level (probe n. 6) and the relative T °C graph show space with high temperatures, from a minimum of 23°C to a maximum of 33°C.

As can be expected for an environment without air-conditioning and windows, the indoor air temperatures are comparable to those recorded outside (gray line). The UR% graph shows a value inside the room, for the greater one lower than the outside. There is a minimum value of 46% in June and a maximum of 91.5% in October, the only high recorded within a lower value trend. Although a space without separation element from the outside, there is a different value from the external environment due to adequate natural ventilation, given by both sides' openings. Natural ventilation is confirmed as an essential factor to decrease the level of relative humidity and consequently improve indoor comfort conditions.

Sensor 07 marks the data of a room on the lower floor. The characteristics of this level are architecturally different. The rooms are smaller than those of the upper level. The corridor that connects them has reduced ventilation points because there are only some skylights on the roof, and one side is against the ground. Temperatures range from a minimum of 23°C to a maximum of 35°C. They follow the outdoor temperature values. The relative humidity values, instead, are higher than the upper floor and often reached 100%, therefore similar or worse than the RH% detected outside.

For the lower level, the temperatures are the same as outside. In contrast, the humidity, which is lower inside the classroom on the upper floor than outside, is higher inside the classroom than outside and defines an even more unpleasant space than the tropical climate outside.

These considerations depend, at the moment, from the complete lack of frames and systems of protection from the external environment, which, inevitably, coincide with the internal one. The situation on the upper floor is improved by natural ventilation that reduces the level of RH%. In contrast, it is worse on the ground floor due to the lack of ventilation, since one side is against the ground, and due to the level of the environment below ground and in shadow for most days.

4.3.2 Evaluations

4.3.2.1 Comparison between preliminary issues and analysis of the collected data

As expected, the data confirmed worrying humidity values for the rooms downstairs. Here natural ventilation is limited as a closed corridor serves it, unlike the upper floor rooms. Although they can be compared to the values acquired outside, the humidity levels found in these rooms on the lower floor do not make them comfortable and suitable for the use they were designed, i.e., for people's alone permanence and the housing of musical instruments. Although these conditions are probably due to the state of abandonment of the building, these results emphasize the reuse of these spaces and their assigned function. During the inspections, it was possible to verify that the rooms on the upper floor, which can be reached through a comfortable outdoor path, covered and shaded, are less humid. There is no difference between the external distribution corridor and the internal environment. The spaces on the upper level are more comfortable than those on the first floor, even though they are not optimal conditions for the analysis team. Given the unfinished architectural elements of finishing and closing, there are still no right conditions for the spaces' continuous use and enjoyment.

The surveys and data analysis have allowed translating objectively and numerically what was noticed during the inspections. The comparison between the study of the graphs and the passive architectural solutions shows that these are not sufficient to ensure, by themselves, the thermo-hygrometric comfort of the interior spaces but represent added values to the perception of comfort by the user.

These considerations to date are incomplete because the spaces analyzed of this architecture are not considered as "interiors" because they do not have the essential characteristics as described above.

4.3.2.2 Comparison with the original design

For the School of Plastic Arts, it was possible to state that, despite the considerations made on the internal microclimate, the function for which it was designed has been maintained over time, showing how much the building responds in a discreet way to the needs of users and related activities. We cannot make the same observation for the School of Music because it has never been used. We can assess the perceptions we had during the inspections and the stories of the experiences of those who, spontaneously, have occupied these places and adapted to their needs.

The building's passive performance would have been secondary, given the installation of a cooling and probably dehumidification system in every room.

However, there is no way to affirm or deny the effectiveness of such a system design that has never been realized. Certainly, knowing the place's economic situation is not the most advantageous among the possible solutions from this point of view.

4.3.2.3 Existing problems

In conclusion, the School of Music's lower level is the one that is in a worse condition than the upper level that presents favorable situations to be explored in later steps.

Although according to our team's parameters, the data analysis shows no thermo-hygrometric conditions suitable for use. During the inspections, we found spontaneous uses and attempts to adapt the spaces to the user's needs. Probably the users, driven by practical needs of lack of space for their activities, were able to find a good compromise to make the best use of these places, focusing on the upper floor that has better comfort conditions. Some rooms have been adapted to different managers' needs temporarily, closing the openings with simple gratings or sheets.

With a view to reuse, an immediate solution could be to complete the project with the insertion of windows and install an air-conditioning system using the existing ducts. Resuming the comparison paragraph with the original project, perhaps we can say it would be not very likely and not very concrete to think of realizing it.

The Rectorate building and the School of Plastic Arts already have such a system installed in some rooms that are not used most of the time. Why? Most likely because of a problem related to economic issues compared to the need for such a system, since other less expensive methods are used. This choice emphasizes how much the way to complete the system for the School of Music is equally useless to follow in view of possible reuse of the building.

4.4 School of Ballet

The School of Ballet was designed by Arch. Garatti and is located near the Rio Quibù. Since its construction, the building has never been unused, and this led to the removal of most of the window frames that were laid during construction as well as to the complete absence of technical systems (Figure 34). To date, this School is therefore comparable to a large abandoned covered space.

The choice to carry out analysis on comfort conditions, as for the School of Music, allows comparison with other architectures for design choices. Given the considerable size of the building, which means that it is impossible to carry out analysis in all rooms, some significant spaces were identified to understand the building's general performance, which is supposedly very similar to external conditions.

The inspections were carried out to study the building's thermo-hygrometric conditions with analysis at different times of the day.

Besides, the building is cyclically flooded due to the overflow of the Rio Quibù and the absence of protective barriers. This implies the need to control the rooms' humidity level and the conservation of the structures and building materials.

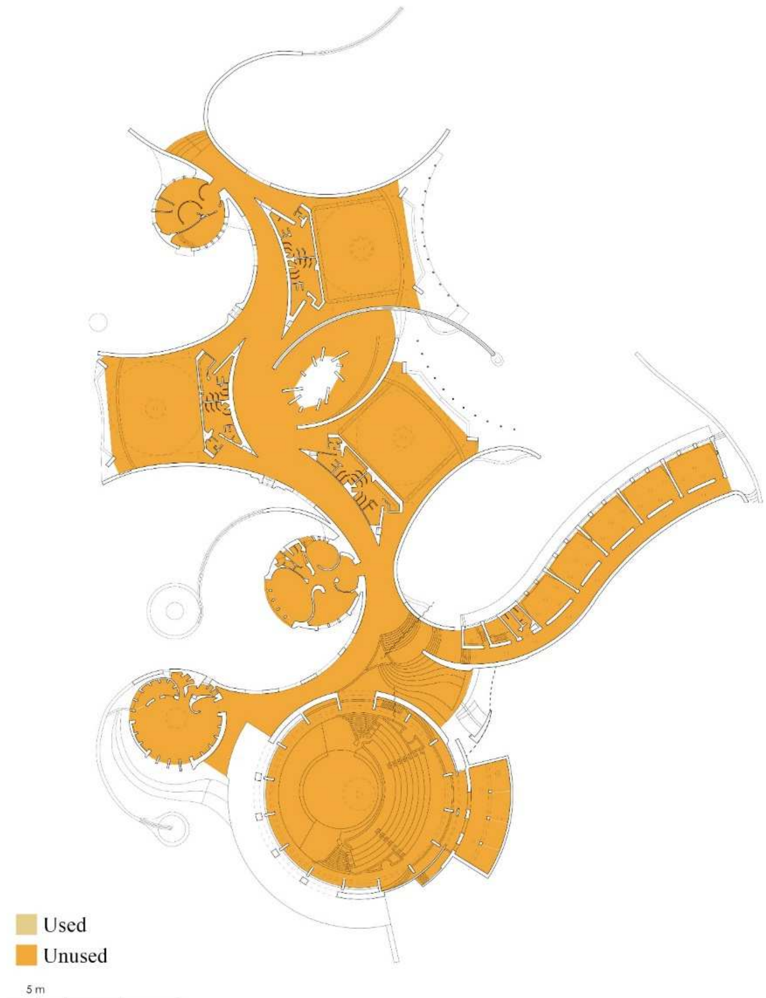


Figure 34 - School of Ballet, ground floor use.

4.4.1 Description of energy performance

4.4.1.1 Passive thermic performance of the building

The issues to be studied in depth in this school's analysis are mainly the rooms' thermal comfort conditions concerning the environmental context to evaluate the architecture's conservation.

In this case, the study of the original architectural design has brought out elements of this architecture that should have contributed to an improvement in thermo-hygrometric performance for the users in the tropical context in which we are.

From the energy point of view, it is mentioned that schools are probably designed to be fully air-conditioned or at least to have such a system in some spaces. This is affirmable for the School of Music, of which we have technical and executive drawings, as described in the previous chapter. Given the classrooms' considerable size and the executive details of the surfaces' closures, the architect thought about comfort differently, excluding the air-conditioning system. Systems were never included since the building never came into operation, but some architectural choices can be found that would have contributed to an improvement in comfort in the spaces. Moreover, recent executive drawings reported in the archive research and carried out by Arch. Mosquera show a design approach to semi-passive solutions for the thermo-hygrometric comfort of the school.

Figure 35 - School of Ballet, interior covered corridor.

Figure 36 - School of Ballet, interior covered corridor (ISA archive).

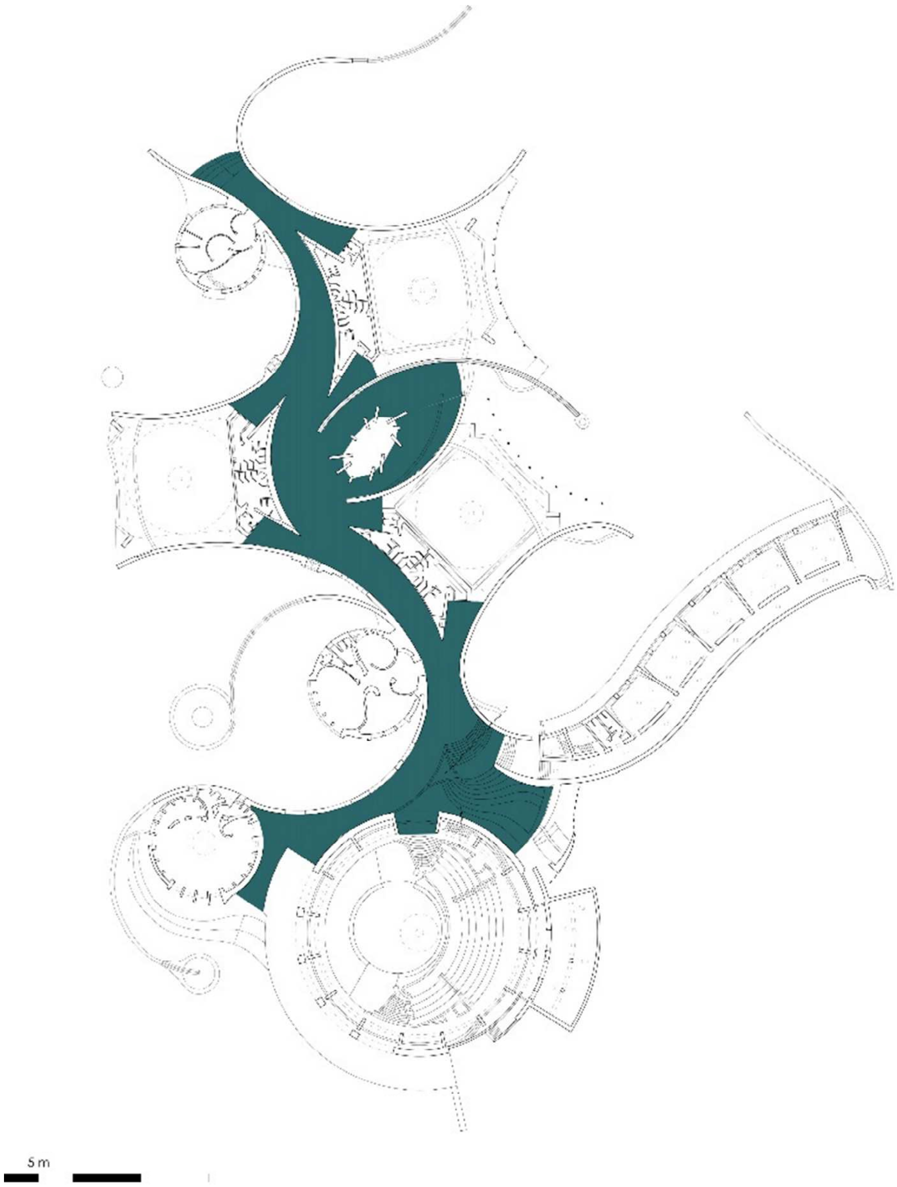


Figure 37 - School of Ballet, interior covered corridor.

When you enter the School of Ballet, you arrive directly at the main connecting corridor. This is designed as a space vaulted by several rib vaults that leave an opening between them, made at a lower level of the external ground, with large openings only on one side. This hallway is shaded for most of the day, making it a comfortable space for the users. The two entrances to this corridor are two staircases partly covered by vaulted segments, placed on two opposite sides, which creates slight internal ventilation. From the architectural devices present, it can be assumed that this was a shaded and ventilated space thanks to the different openings in the façade and between the vaults. The current openings are all on the side that observes the Rio and the vegetation that characterizes it, giving the space's user a comfortable visual perception towards the outside. Therefore, the path's sinuosity and the design that goes throughout the building allows to reach each classroom remaining in a comfortable space to avoid being exposed to solar radiation.

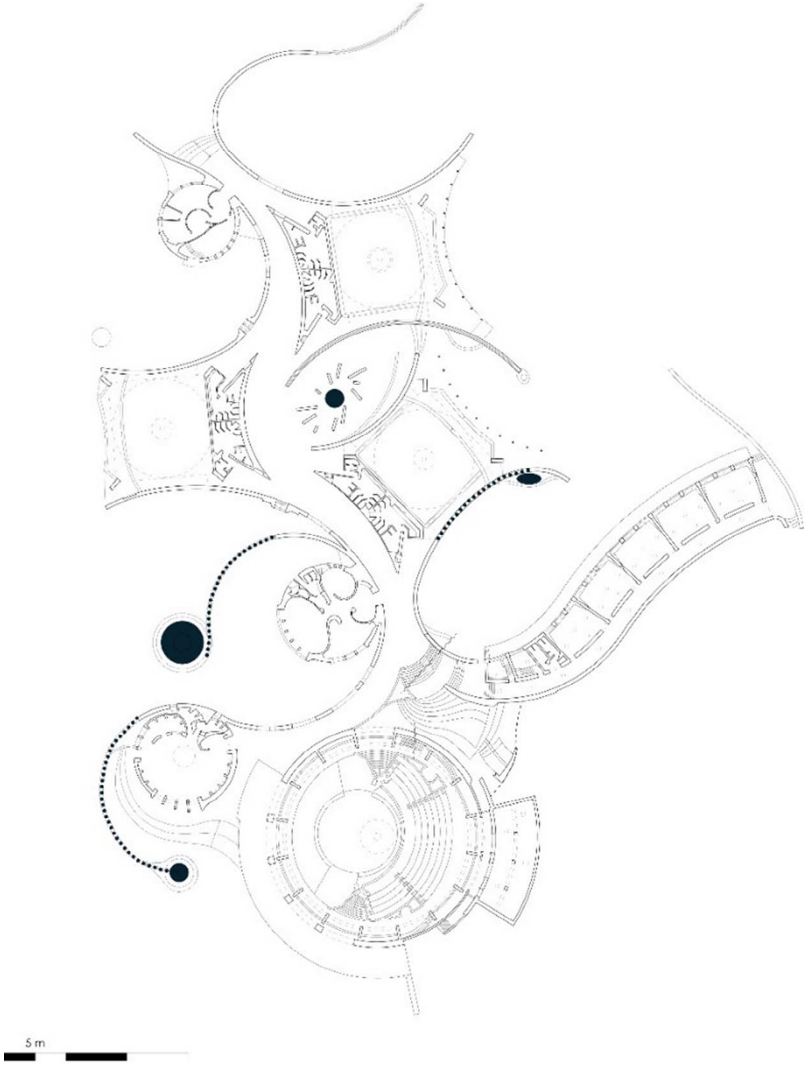


Figure 38 - School of Ballet, the presence of water.

Figure 39 - School of Ballet, ISA archive, external canals (before). Figure 40 - School of Ballet, external canals (today).

An element that helps achieving comfort, especially in a hot humid climate, is moving water that gives a refreshing sound. This is accomplished by designing fountains at different points and a series of little canals outside the building. Of these design details, you can only perceive the external elements' design and architectural presence. The fountain in the patio is not even visible due to the high presence of weeds.

Figure 41 - School of Ballet, vegetation.

Another perceptual element significant for a better thermo-hygrometric comfort is vegetation. For the School of Ballet, it is an essential data of the design since the school's shape takes inspiration from it. However, the interior spaces overlook the park surrounding the building, framing stretches of river, tall trees, etc. This element allows walking through the building with a constant view towards vegetation points that offer a pleasant sensation to the user. Regardless of calculations and data analysis, the perceptible effect due to vegetation's presence is appreciable when using open spaces as well as in the areas overlooking them.

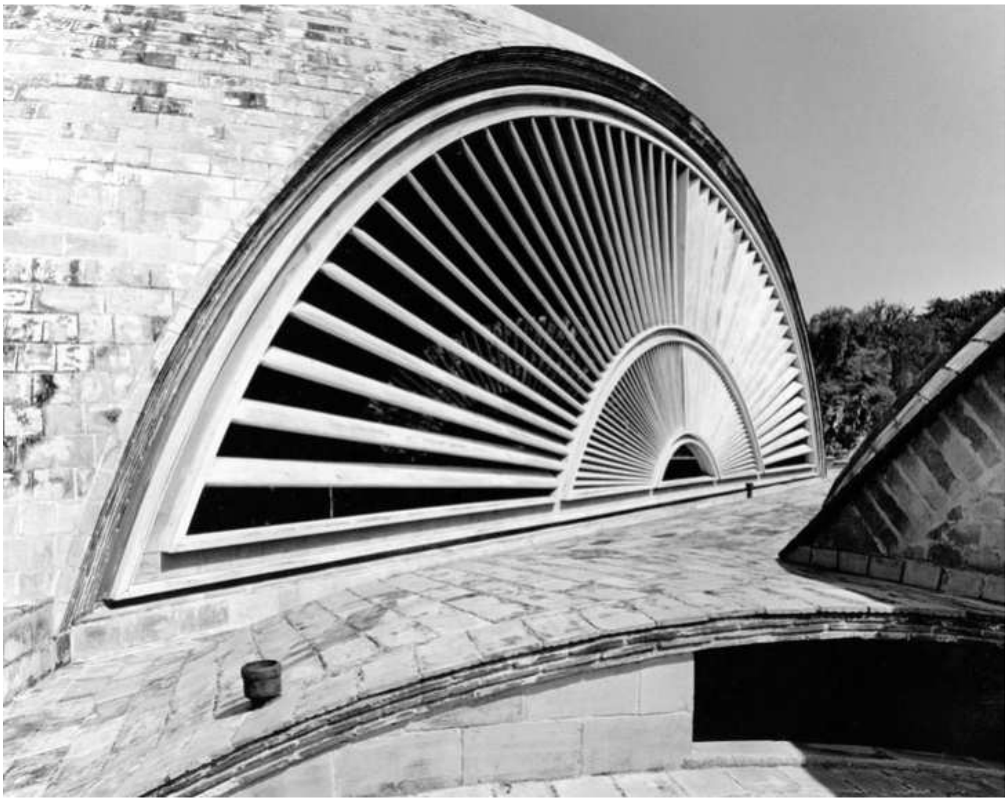


Figure 42 - School of Ballet, ISA archive, *ventanas.*

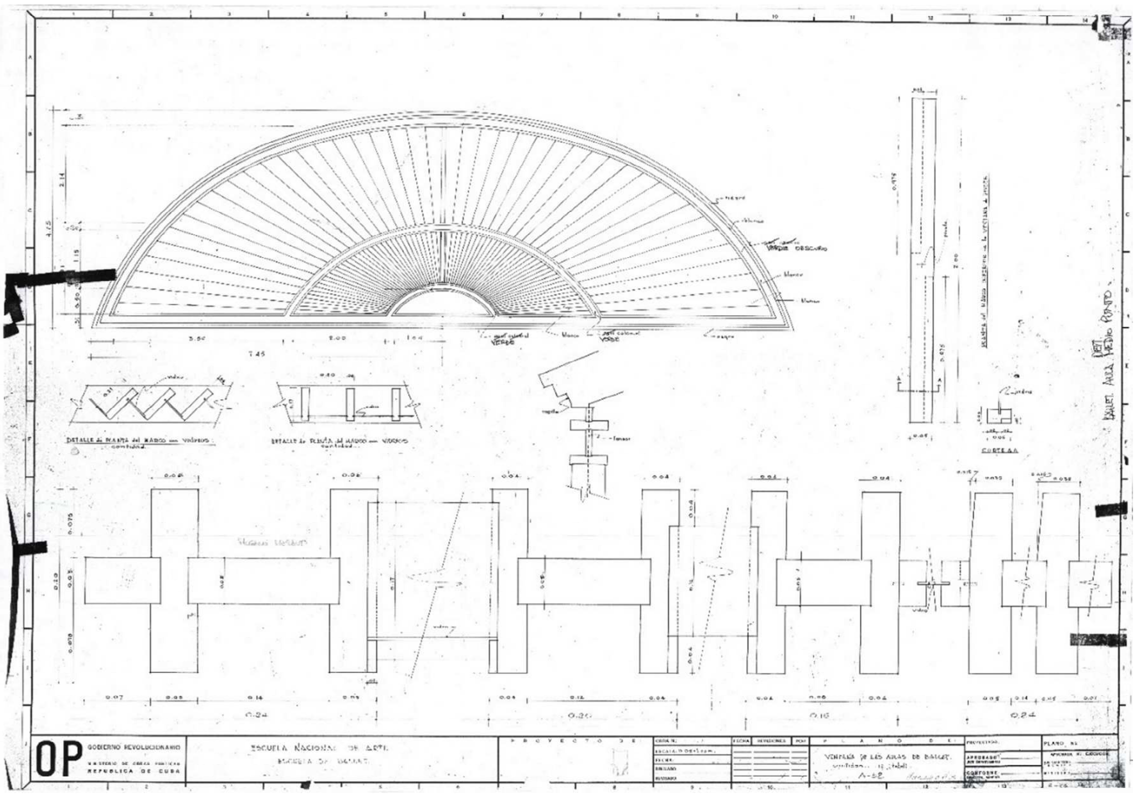


Figure 43 - School of Ballet, ISA archive, executive drawings of the windows.

Other design elements that are currently missing are windows and doors (*las ventanas)*. They were designed in the practical classrooms' large openings, choreography theatre, and other smaller volumes.

The large windows in the classrooms were designed as sunshades, for shading and natural ventilation of the space. Each window and door frame was designed and made with slats oriented according to their building position. Each one is different and designed for the correct orientation. This hints at the fact that the rooms in the practical classrooms were never meant to have an air-conditioning system.

Installed as planned, the wooden windows were subsequently removed due to the absence of any use for the building, and today there is no visible trace of them.

Each dome was designed to have a skylight at the zenith, but, in the practical classrooms they were never realized and currently configure as holes.

2009/2010 Mosquera's drawings show a design approach aimed at the passive solution of comfort problems. The drawings display a study of the chimney effect's, identified as a possible solution to improve ventilation and exploit the openings present to circulate air and reduce relative humidity. A counter-ceiling element is inserted to conduct the air circles along the dome's surface to the skylight. In some places, in the previous project's drawings, the air extraction system was foreseen to improve ventilation and internal air circulation conditions.

These design measures aimed to improve internal comfort and the user's feeling. However, since this architecture never fulfilled its original purpose, these elements were never truly put in action and tested, unlike the School of Plastic Arts. The project's study, which highlighted these features, is important for understanding the building's concept and studying the possibilities from an energy point of view.

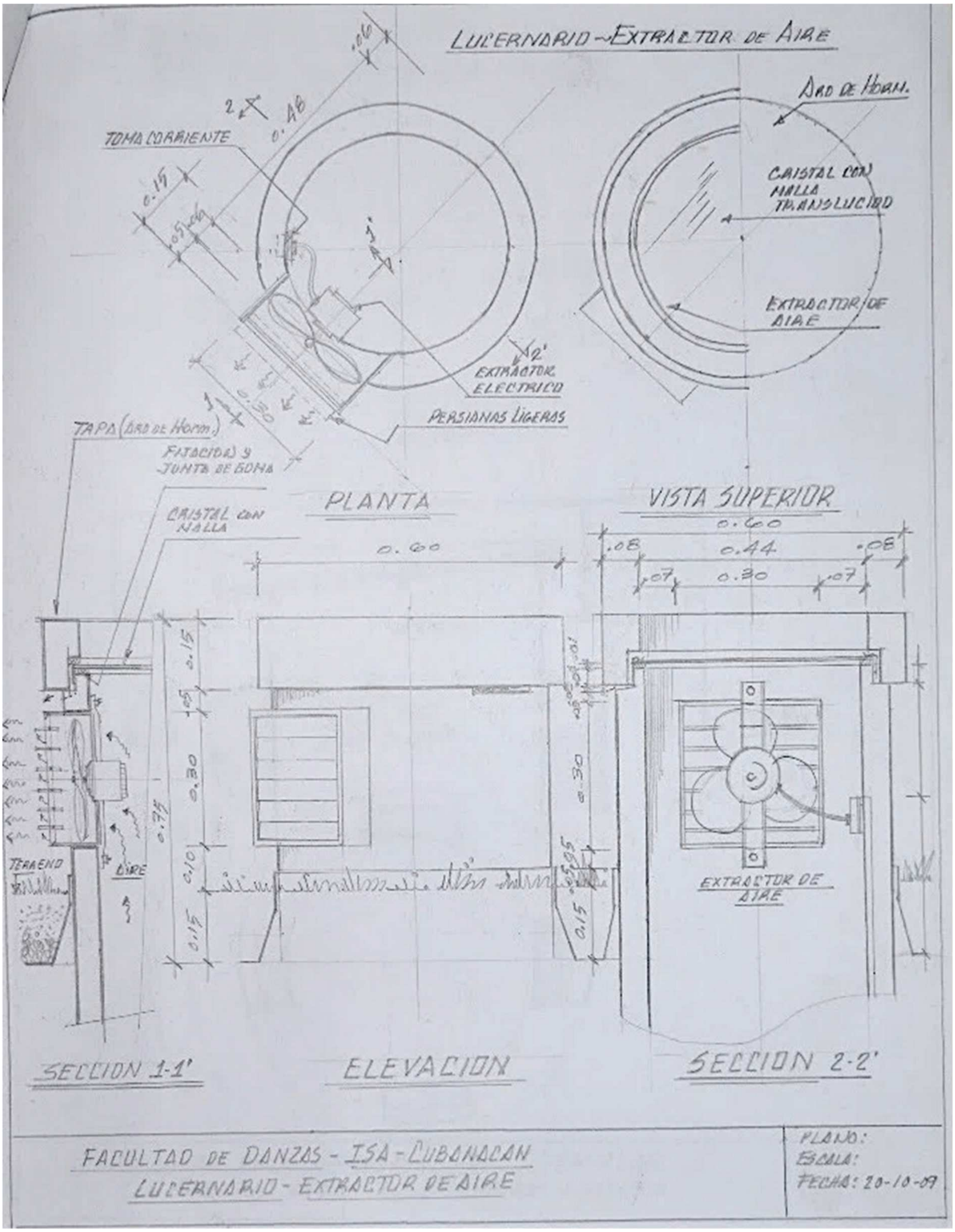


Figure 44 - School of Ballet, ISA archive, executive drawings by Arch. Mosquera.

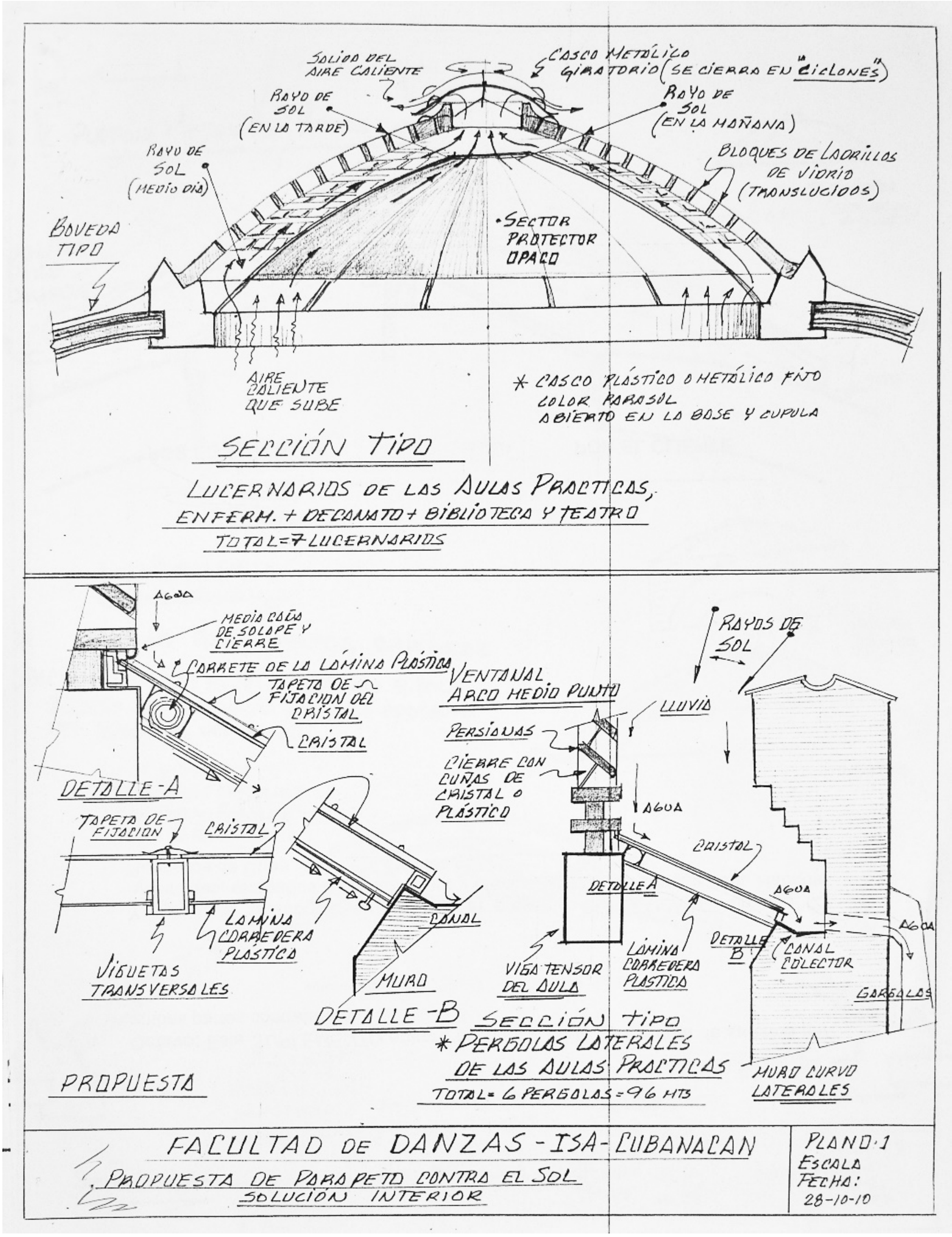


Figure 45 - School of Ballet, ISA archive, executive drawings by Arch. Mosquera.

4.4.1.2 Thermo-hygrometric data

Although this building has never been used, it is important to collect data for an initial study approach and, above all, to obtain a reliable basis of elements on which to develop subsequent considerations. In this first phase, it is necessary to carry out some principal evaluations to describe the conditions of comfort:

- evaluation of thermal conditions (temperature, humidity, temperature distribution) in some significant spaces;
- evaluation of favorable conditions concerning thermo-hygrometric comfort for people's permanence and suitable for conservation.

The measurements, data processing, and the graphs shown below were carried out by Luca Valisi of LADC (Politecnico di Milano). The investigations carried out are, as for the School of Plastic Arts, of two types:

- continuous automatic monitoring;
- direct measurement (psychrometries and thermographs)[12].

Continuous automatic microclimatic monitoring

For the School of Ballet, it was decided to carry out this type of monitoring in the most significant space from the original project's point of view: the choreography theatre. This space is an arena with a central area dedicated to performances, and around it, there are steps for the public. There are openings towards the outside and on one side a covered space at the highest walkway level.

The entire space is covered by a large dome made with a concrete skeleton and external covering in ceramic elements. The data collected by sensor 08 are indicated in a linear graph and show the trend of temperature °C (red line), relative humidity % (blue line), superimposed on the corresponding parameter detected outside (grey line).

In order to obtain a complete picture of the microclimatic performance, it will be necessary to wait for the next data download to complete an annual cycle.

This space's choice is given because it is an architecturally significant environment in this building and could be used for exhibitions and shows from a design point of view. Sensor 08 is positioned in a more covered area and not near the outside to obtain data more similar to an interior space.

[12] https://www2.polimi.it/index.php%3Fid=6247&sel_brevetto=5079.html

S08| SCHOOL OF BALLET

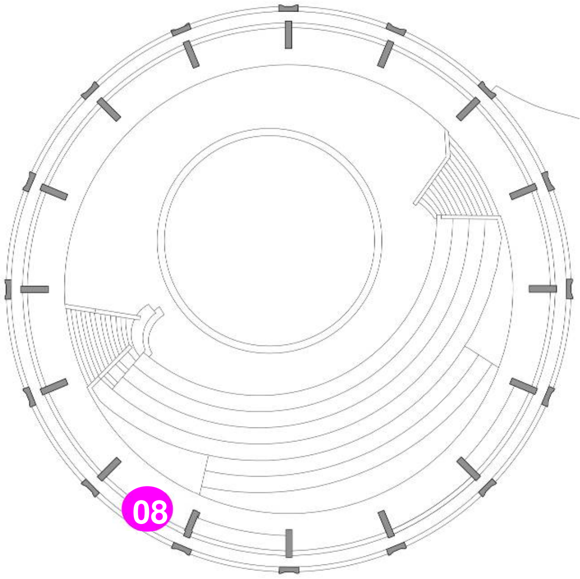
ACQUISITION PARAMETERS	LOCATION
ESCORT I-LOG DATALOGGER **Temperature (°C) and relative humidity (%)** with screen for displaying the current value. *Resolution / Accuracy °C* 0,1°C; ±0,3°C *Resolution / Accuracy %UR* 0,1%UR; ±3%UR *Interval Measurement from* 1 sec to 10 days *Degree of Protection* IP51 *Polycarbonate Case* *Green Led* (Active) Red (Alarm) *Response Time in Air* 90% in 4 min (°C) 90% in 50 sec (RH) *Dimensions* Ø=75mm H=36mm *Weight* 70 gram	 SENSOR 08, T-UR% INSIDE
(GENERAL) PHOTOGRAPHIC REPRESENTATION	**(SPECIFIC) PHOTOGRAPHIC REPRESENTATION**
	
Note	
Installed il 21/06/2019	

Table 15 - Sensor 08 (LADC - Lab. Analysis and Building Diagnostic).

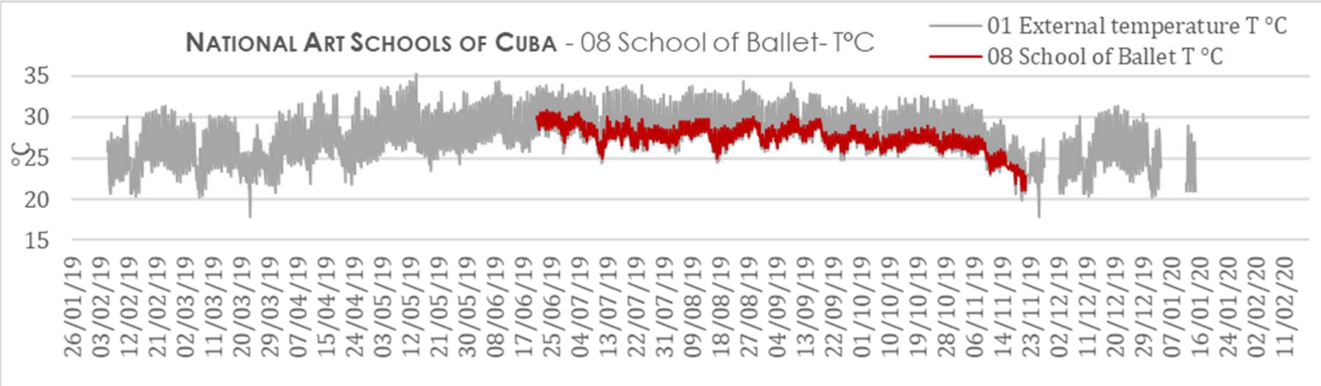


Table 16 - Temperature data T° Sensor 08 in the School of Ballet, compared to the outside temperature.

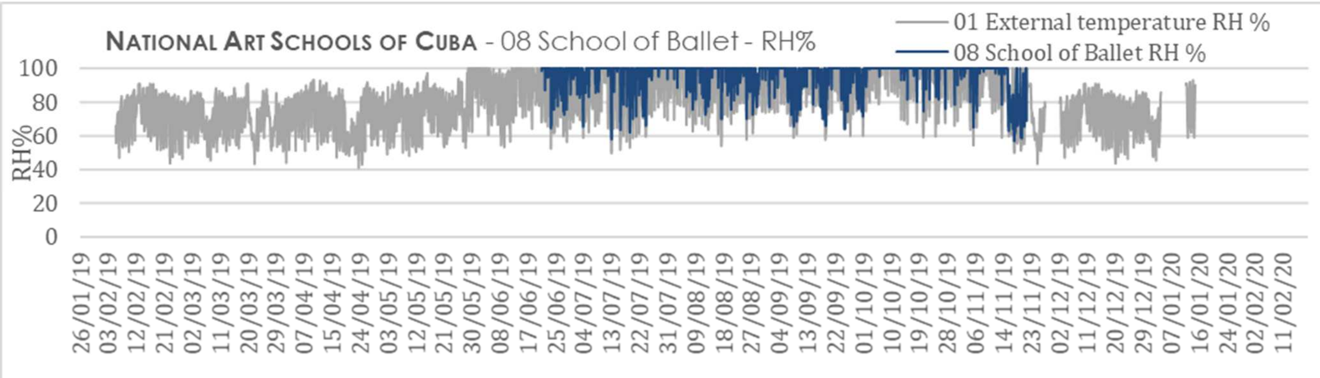


Table 17 - RH% Data Sensor 07 in the School of Ballet compared to the outside one.

Direct monitoring - psychometric surveys

This type of survey, performed in February 2020, was carried out in some significant areas of the School.

The objective is to have a more detailed knowledge of the architecturally significant environments that can describe the spaces most similar to closed environments, excluding practical classrooms, which are entirely open.

The results of the mapping of the spaces are displayed below and will be discussed later. In red, the temperature T °C map is shown. In blue, the relative humidity RH% map and the mixing ratio MR g/Kg in green.

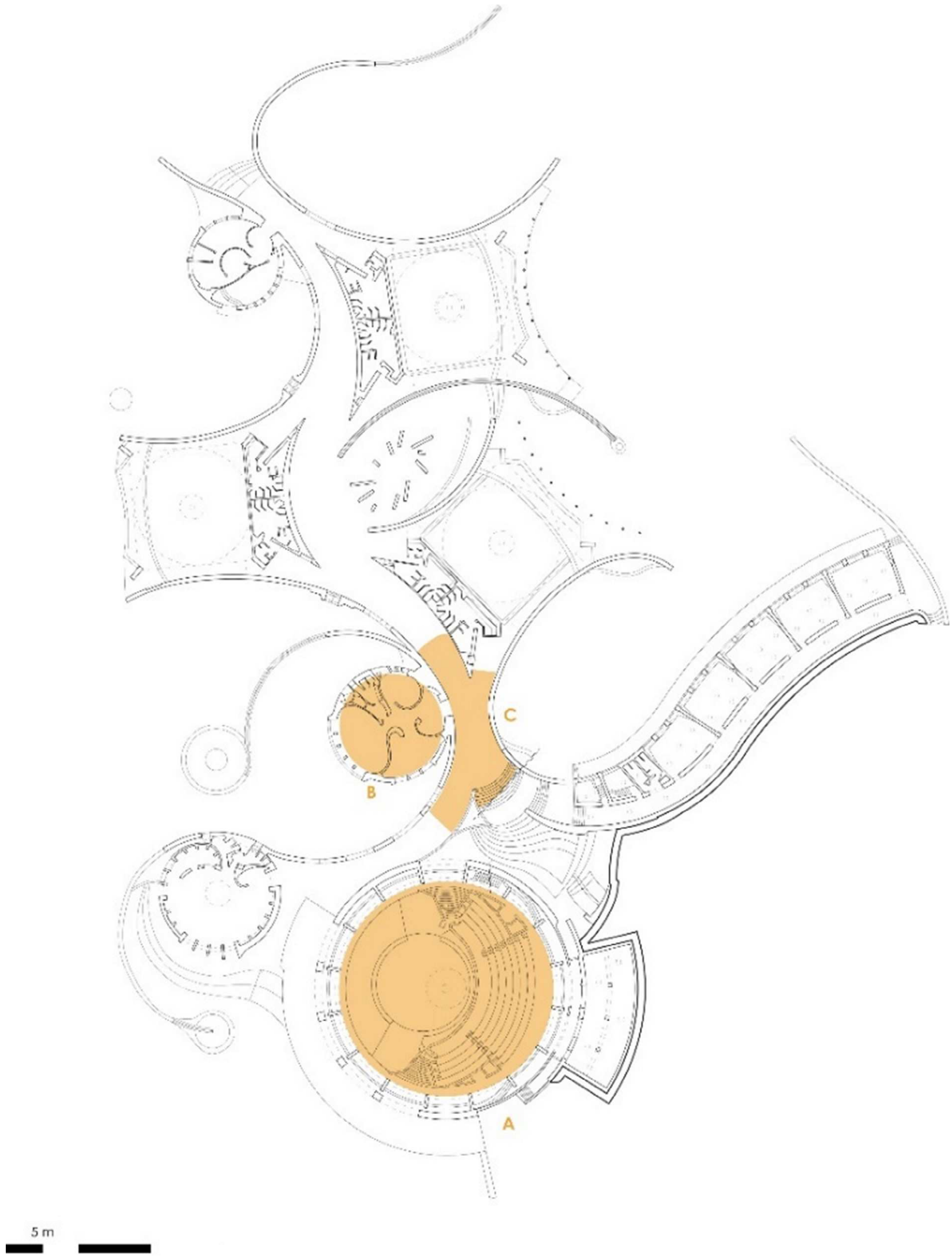


Figure 46 - School of Ballet, analyzed spaces.

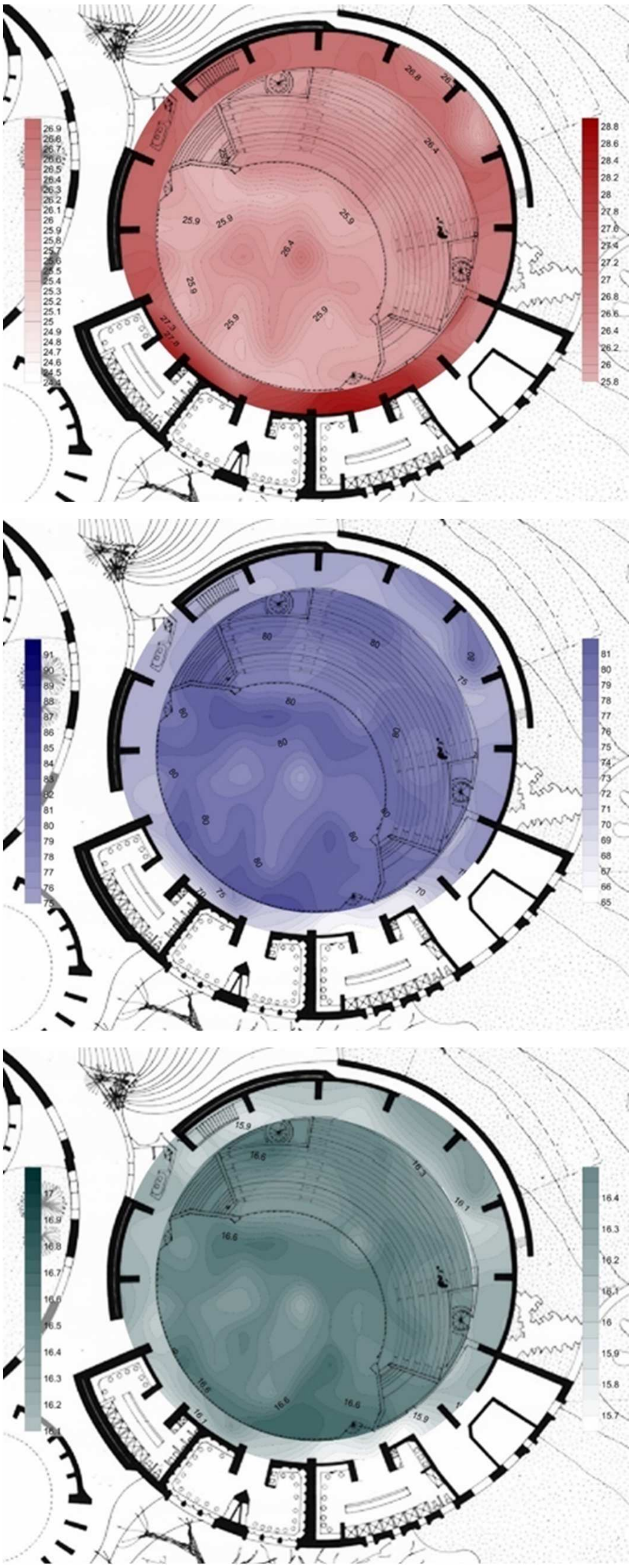


Figure 47 - 13.2.2020 - PHOTO LAB - PSYCHROMETRIC MAPS.
T °C (RED), RH % (BLU), MR g/kg (GREEN), Environment A

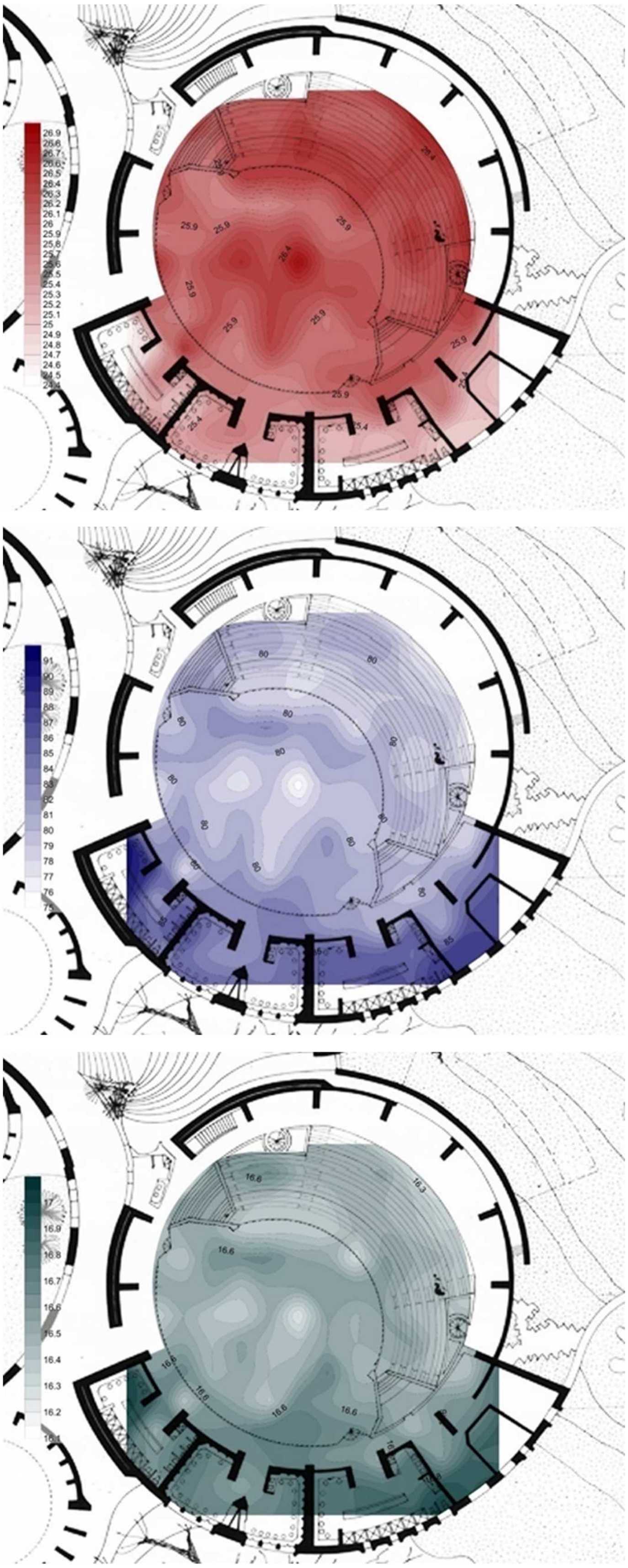


Figure 48 - 13.2.2020 - PHOTO LAB - PSYCHROMETRIC MAPS.
T °C (RED), RH % (BLU), MR g/kg (GREEN), Environment A (lower level)

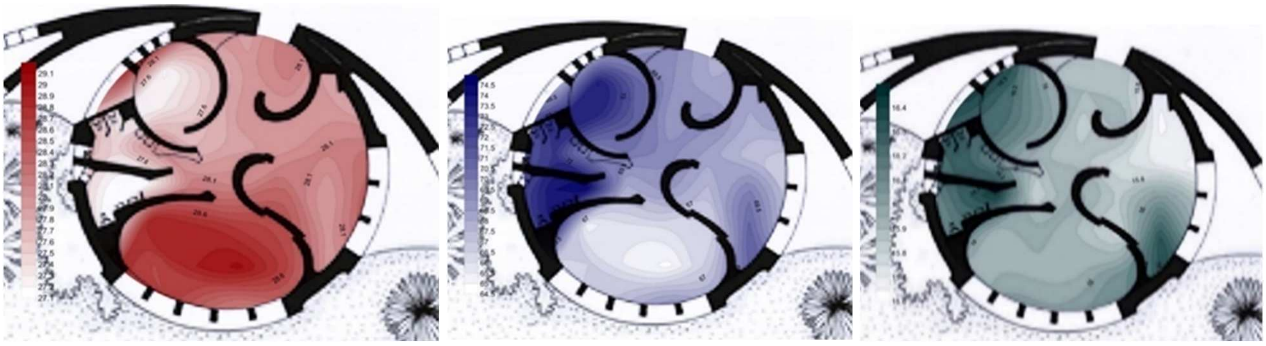


Figure 49 - 13.2.2020 - PHOTO LAB - PSYCHROMETRIC MAPS
T °C (RED), RH % (BLU), MR g/kg (GREEN), Environment B.

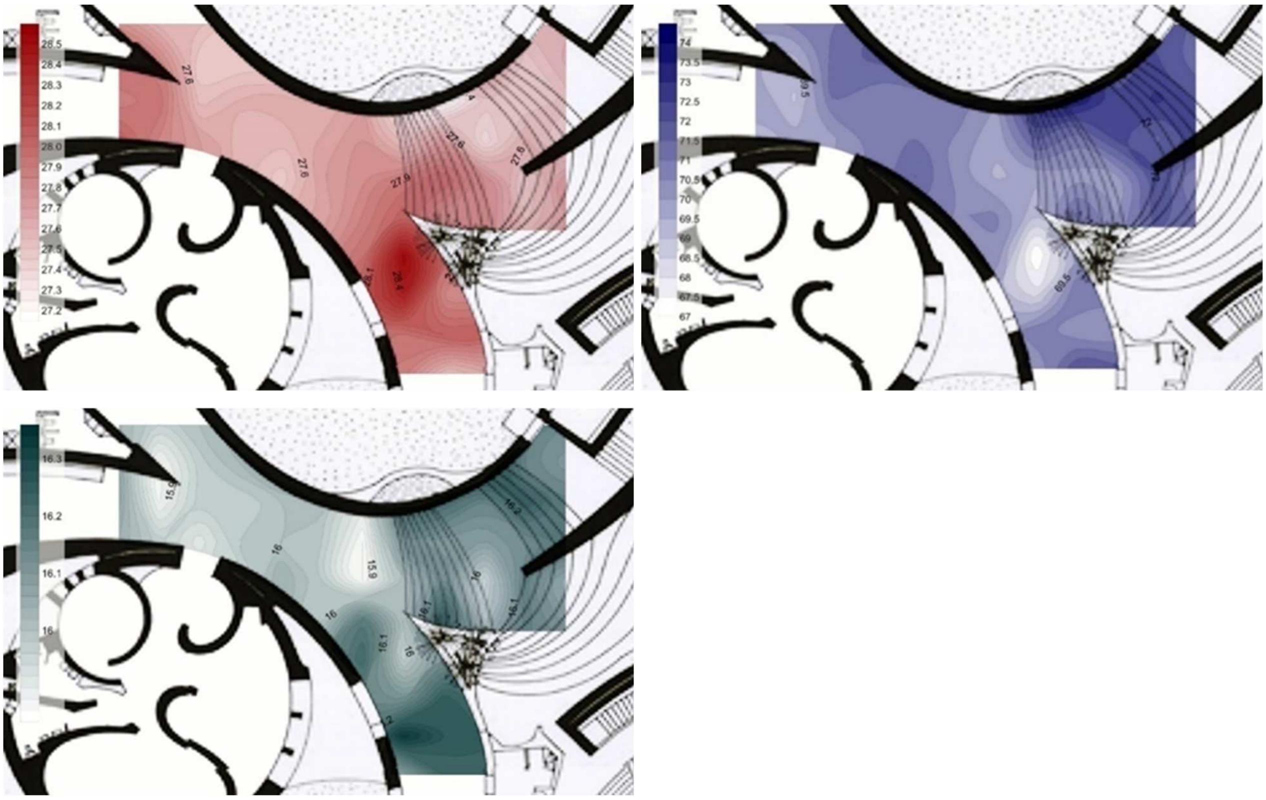


Figure 50 - 13.2.2020 - PHOTO LAB - PSYCHROMETRIC MAPS
T °C (RED), RH % (BLU), MR g/kg (GREEN), Environment C.

4.4.1.3 Results and analysis of room comfort status

Continuous automatic microclimatic monitoring

The first evaluation of these data shows that the relative humidity is very high in the School of Ballet. As deduced from the measurements, this building's condition is among the worst in the complex from a hygrometric point of view. The values are similar to those recorded outside and often even higher than them (Table 17).

The best thermal conditions are recorded, with temperatures between 20°C and 30°C that follow the external T with slightly lower levels (Table 18). Natural ventilation is an essential factor in obtaining these results. It is relevant since the building is in a state of abandonment and, therefore, without frames or closing elements to block the air passage. Unlike the School of Plastic Arts, since the closing elements of the openings are absent, it is impossible to evaluate the effect of the structures' inertia from the data obtained.

The School of Ballet is subject to repeated flooding phases from the Rio Quibù, which runs close to the building. This involves the presence of water at critical levels for specific periods of the year. The flooding certainly causes damages to the structures and materials. Still, it also causes a considerable increase in humidity in the rooms, which remain cold and humid even after the floods have ended. During the surveys in February 2020, it was observed that part of the rooms adjacent to the lowest floor of the arena still showed remains of the last flood. The indoor environment detected has a UR% value ranging between 85-100%, which is very high, and a symptom of strong thermo-hygrometric discomfort, mainly with T °C detected slightly lower than the external ones.

Figure 51 - School of Ballet, choreography theater, flooding in 2007.

Sensor 08 was installed inside the theatre, which suffers considerable flooding. Although it is located at a higher altitude, the room's interior is affected by high humidity conditions.

Furthermore, except for the fully open practice classrooms, the Ballet School interior does not have strong sunshine and is shaded for most of the day.

Adequate natural ventilation allows reducing the T °C compared to the outside. However, it does not reduce the humidity, which, on the contrary, keeps increasing due to the absence of sunshine, areas in constant shade, and water accumulation resulting from continuous flooding, increasing discomfort for the possible user. The conditions of discomfort in this School are considerable and do not allow any use of the spaces in their current state.

Direct monitoring - psychometric surveys

In the School of Ballet, the rooms chosen for this monitoring have different characteristics regarding size and exposure to external agents. In the large dome of the theatre (room A), the surveys were carried out at two levels. One at the arena's level and the second at the mezzanine level. The lower level of the theater and the annexed basement spaces were partly flooded during the survey. On the ground floor, the temperature is lower, by a few degrees compared to the upper level. This is because it is not reached by sunlight, and there are no openings directed towards the outside as happens on the upper level. The RH% values at this level are about 5 points higher than at the upper level. This is probably due to the lower ventilation of these semi-underground rooms and the absence of solar radiation, which causes the room's humidity to stay in relation to the external humidity. The points detected in the small rooms connected to the arena (bathrooms and dressing rooms in the original design) are the coolest and most humid until they reach 24.4°C (-4.5°C compared to the outside), 91% RH (+24% compared to the outside) in the room facing north-west.

The upper level of the arena has a temperature that varies according to the sun exposure (-0.7°C in the points directly exposed with openings; -1.2°C in the points that do not have direct openings are connected to rooms behind).

From the maps shown in Figure 47 and Figure 48, it can be seen that in the points with higher temperatures, the RH% is lower and the other way around.

Where it is reached by solar radiation, the very humid room undergoes a reduction of this value.

However, space's total balance is negative because the values found, even at the upper level of the arena, are comparable to those recorded outside and therefore not comfortable for use. The second space detected is one of the small annexes, which were supposed to house the School of Ballet's auxiliary services. In particular, the small dome (room B) that should have hosted the bathrooms was taken into consideration, divided inside by vertical partitions, not at full height, and covered by a dome. Also, in this case, the area facing west, subjected to direct sunlight, has equivalent T °C compared to the outside and the highest in the space (28.6°C), the temperature falls in the remaining area. The rooms with reduced openings and less irradiated by the sun at the survey time are cooler (-1.4°C) and humid (+8%). RH% values are higher at low-temperature points, creating very damp and cold rooms with a high level of discomfort.

The third space is the distribution corridor (space C), especially from an architectural point of view as it is a single large space that connects all the other rooms in the school.

Compared to the data measured outside, the average temperature here is slightly lower (-1°C), except for points near an opening through which sunlight enters, where the values are the same as outside. As far as the RH% values are concerned, they are slightly lower than the other measured environments but still a little higher than the external parameters. The corridor is a space that is often shaded, which helps to have slightly lower temperatures. On the other hand, it is not possible to have lower humidity as it is a space that is continually flooded and, due to the shading, conditions of high RH% are maintained.

4.4.2 Evaluations

4.4.2.1 Comparison between preliminary issues and analysis of the collected data

The investigations carried out helped acquiring a better knowledge of the School of Ballet situation outlined after the inspections. As recorded on a perception level during the inspections, after the analysis, it is confirmed that there are no rooms of the School of Ballet that have adequate comfort conditions for use.

As has been said many times, this building has a dominant problem concerning repeated flooding. This problem affects the analyses from a thermo-hygrometric point of view because floods cause an increase of UR% in the rooms that remain almost always "wet" and, as found during inspections at different times of the day, the spaces don't receive direct sunlight that would reduce discomfort in cool and humid environments.

The fact that the Ballet School is abandoned and without locks or filters from the outside allows natural ventilation in the rooms. Still, it does not improve conditions at the same levels described for the Music School's upper floor. Even though it is entirely open, the rooms in this architecture have a high humidity level that is worrying for the materials, the permanence of people, and the healthiness of the whole space, often being similar to outdoor conditions, which are only slightly worse.

The spaces analyzed, mainly thanks to psychrometer measurements, show how these spaces' architectural design greatly influences indoor conditions. In particular, environments designed to be shaded, for the most part, would have caused comfortable sensations in the user allowing protection from radiation and high outdoor temperatures. The high level of humidity found today, on the other hand, causes worse conditions in these shaded areas because the combination of a cool site and very high humidity is not comfortable for the user. The points with the same temperature as outdoors are the points where direct sunlight enters and are at the same time the points where RH% drops.

The passive solutions adopted in the design would have been assessable under conditions of use and completion. Repeated flooding causes a high level of humidity that is difficult to reduce with simple passive architectural measures.

4.4.2.2 Comparison with the original design

As mentioned in the previous paragraph, this building's design influences the comfort conditions of the spaces, some of which are basements, others with few openings, others with greater exposure. Unlike the School of Plastic Arts, where the function for which it was designed has been maintained over time, this architecture could not have the same practical impact since it was never used, not even spontaneously as happened to the School of Music. Thanks to Mosquera's designs, recently produced, it can be seen that the passive effects are essential in order to guarantee a reasonable degree of internal comfort, given the absence of air-conditioning systems.

After analyzing the passive elements of this architecture and the elements designed in the original and subsequent projects, we can say that this building was designed to have covered, shaded, and very ventilated spaces.

This can be compared to what was analyzed for the large corridor, for the practical classrooms closed by *ventanas*, for the spaces of the "small domes" and also for the choreography theatre, a large room covered by a dome and open to the outside, with additional spaces in the shade or semi-basement. In these architectures, with the techniques indicated in the detailed drawings (Figure 45), the internal features could be improved, completing the architecture in its closing elements.

Is it necessary to restore some elements to have a usable and comfortable building? It would be theoretically affirmable, but, after years of neglect, internal conditions are strongly influenced by the external environment, i.e., repeated flooding. The spaces that were supposed to be shaded and cold are not comfortable because there is no balance with the excessively high levels of UR%, and paradoxically there is better comfort at the points reached by solar radiation.

4.4.2.3 Existing problems

In conclusion, the School of Ballet, from a thermo-hygrometric point of view, today is not usable for the function for which it was designed.

There are no thermo-hygrometric conditions favorable to the fruition, even sporadic, of the environments from the data analysis. There are two leading causes of this, repeated several times in the previous paragraphs: floods that raise the RH% level, which is subsequently difficult to lower, the absence of filters with the outside, especially in practical classrooms which are now covered spaces.

The School of Ballet today is a fascinating scenic element in the landscape, used as a frame or scenography for artistic interventions by ISA or exteriors. Still, internally it does not offer adequate conditions for any further activity.

This architecture has an initial obstacle concerning flooding by the Rio Quibù. This is unusable for several periods because it is filled with water up to a high level and useless afterward because humidity remains. Therefore, a first step to be carried could already lead to better indoor conditions and more traceable to what originally designed.

4.5 Comparison and conclusions

4.5.1 Comparison between the buildings and their evaluations

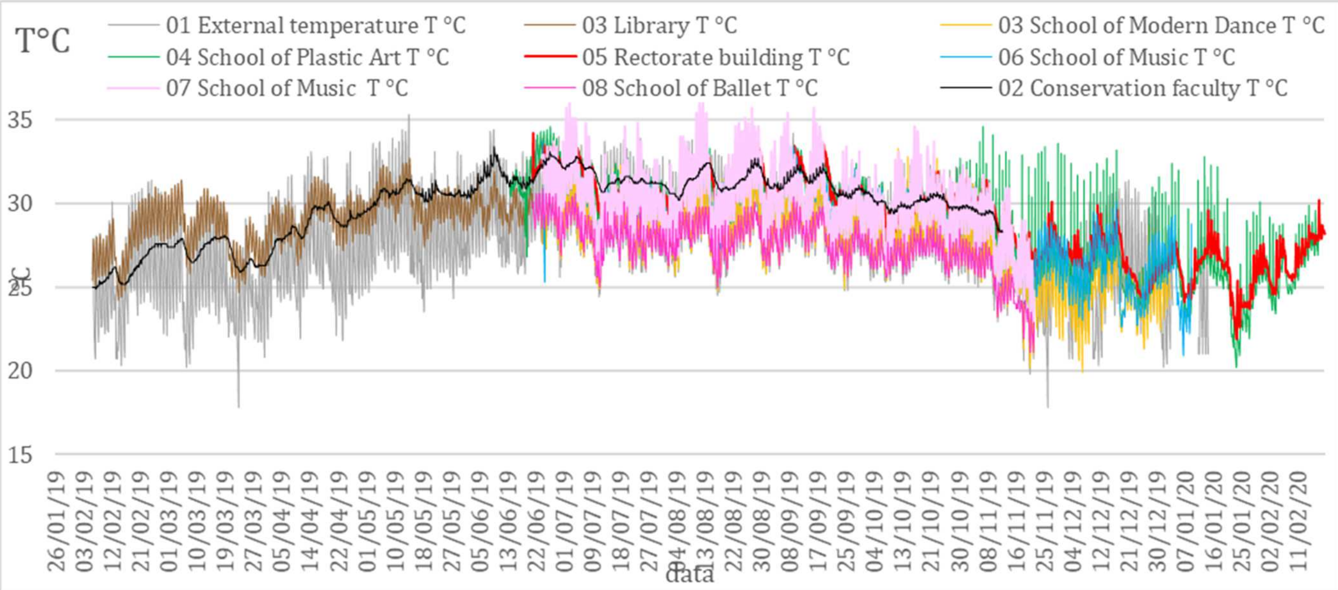


Table 18 - Temperature data T °C, comparison of the data of the buildings analyzed.

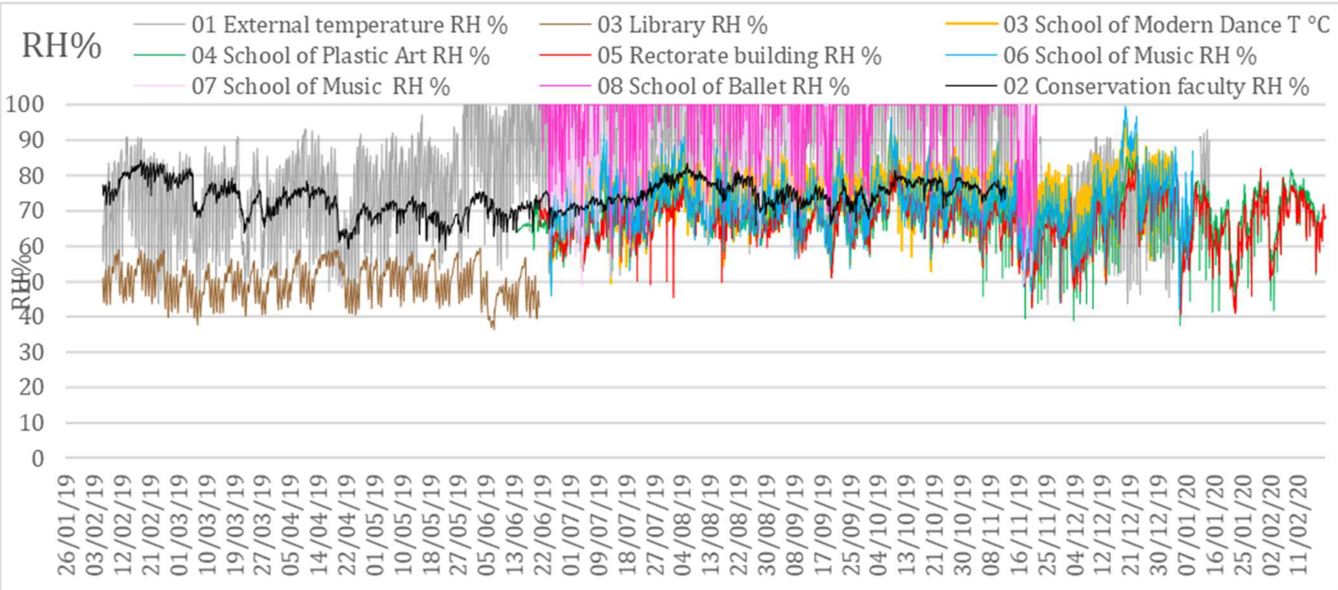


Table 19 - RH%, comparison of the data of the buildings analyzed.

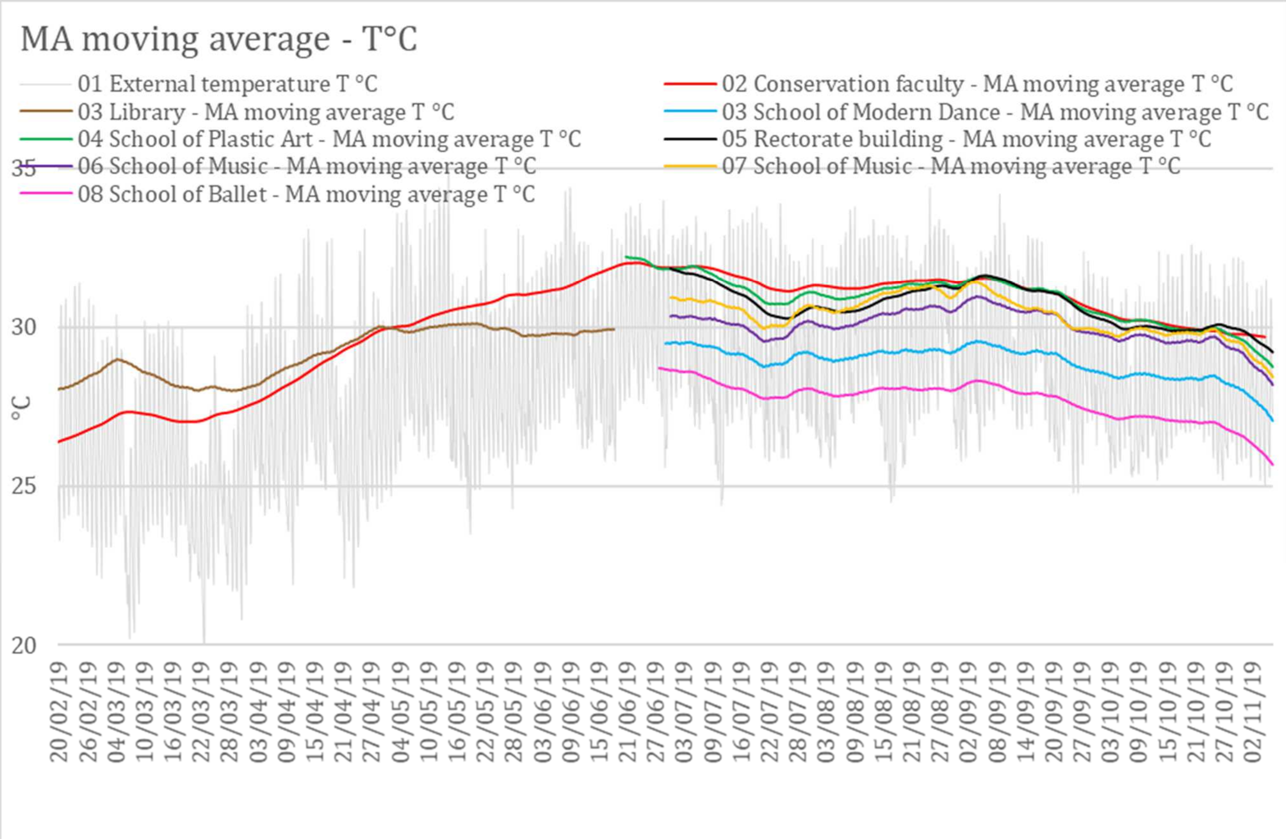


Table 20 - Temperature data T °C - moving average, comparison of the data of the buildings analyzed.

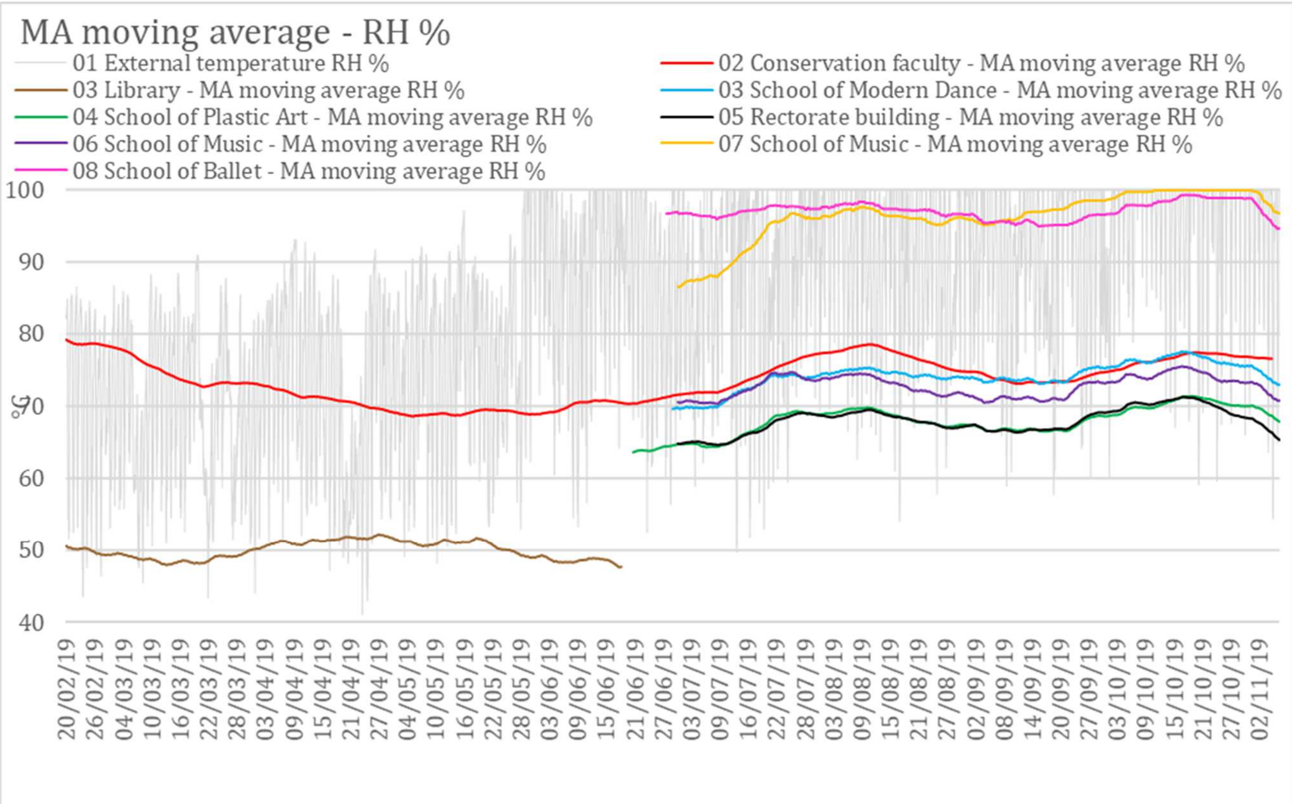


Table 21 - RH% - moving average, comparison of the data of the buildings analyzed.

After analyzing and describing the energy problems of some selected buildings, we open a final comparison with the data of other buildings in the complex. Enlarging the field helps understanding at 360° the situations described so far and evaluate if the best conditions of other buildings can eventually be taken up and reproduced in the architectures studied.

The data now reported is the continuous monitoring carried out with probes such as those already described.

In addition, for a simplified reading of the daily linear graphs (Table 18 and Table 19), which may be unclear at a first approach, we proceeded with the calculation of the moving average, evaluated over 30 days to exclude peaks and represent the "historical climate" of the monitored environments (EN15757: 2010). The correct representation of a historical climate can, in reality, only be obtained after one year of monitoring. Therefore, new assessments will need to be done when complete data will be available. However, it is still possible to compare the different monitoring and develop interesting considerations for the objective set (Table 20 and Table 21).

From the observation of the linear graphs of the temperatures of two buildings examined (in green the School of Plastic Arts and in red the Rectorate building), a similar and perfectly overlapping condition emerges in August, September, and part of July. The graph follows the representation of the external T °C with daily temperature excursions. Moreover, in the School of Plastic Arts there are slightly higher temperatures (2-3°C) compared to the Rectorate building and a greater diurnal temperature range (Table 18) probably owed to the different inertia of the materials that make up the building envelope, a fact also found in the graphs of the school and considered separately.

From the observation of the linear hygrometric graphs, in the same way, the values in the Plastic Arts building are comparable and almost totally overlapping with those in the Rectorate building.

This further result, which is not very predictable, could reveal how the building shell has little influence on the rooms surveyed. In fact, even if the external conditions are the same and even though they are made with different stratigraphies, the internal conditions are really similar, especially during the rainy season. Both buildings from July to September have UR% much lower than the outside (65-70% inside compared to 80-90% outside) in terms of hygrometric results. Fortunately, these buildings' continuous use allows a relatively stable condition that probably favors more linear maintenance of the data than external changes.

This can be stated considering the data collected in the School of Music (pink line) and Ballet (magenta line). In these two buildings that were never used and have no windows or doors, as expected, the internal conditions constantly follow those of the external environment, both in terms of T °C and UR% values, except for the rooms that are in good ventilation conditions (Music School, upper floor) where the hygrometric data are comparable to those of the schools in use.

In comparison with the whole complex, these two architectures (considering the lower level of Music) have the highest values of RH% (>80%). At the same time, they record T °C values slightly lower than the external one designed to be "cool" and shaded spaces.

From these considerations, it can be deduced that, despite the differences from a morphological and material point of view, the School of Plastic Arts and Rectorate respond in a similar way to the outdoor climate, probably aided by design and construction expedients and constant use conditions. Therefore, it is more interesting to compare the data with other buildings in use on the complex rather than with abandoned architecture.

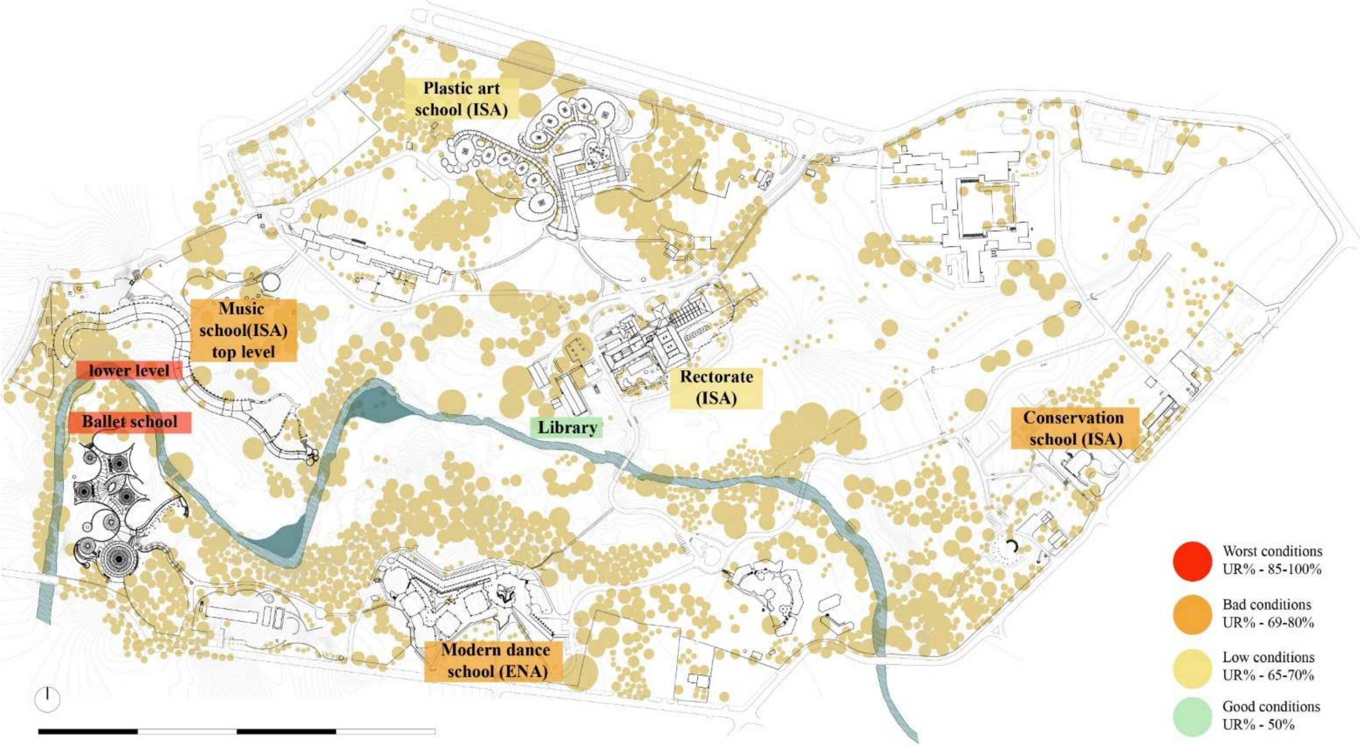


Figure 52 - Site plan of National Art Schools in the city of Havana pointing out the buildings in which the thermo-indication of thermo-hygrometric analysis results.

From the analysis of the hygrometric curves, it can be seen that, despite the very high values measured in the Rectorate building and the School of Plastic Arts, there are buildings with even higher humidity levels. Suppose we exclude the School of Music and the School of Ballet, affected by cyclical flooding of the Rio, for which the very high levels are justifiable. In that case, the building of the Faculty of Heritage (black line) and that of the School of Modern Dance (yellow line) remain more humid. The Faculty of Heritage records the most unfavorable thermal and hygrometric values (the highest of the environments used). However, it is the space with the lowest daily thermal and hygrometric excursions. Entirely out of the average and with decidedly more comfortable values, there is the library (brown line) whose values are decidedly explanatory of an environment with conditions of well-being, the best of the complex. These results are justified given the presence of dehumidification and air-conditioning system, even if this is little used. In this case, the UR% values are around 50%, a condition that is certainly good and can be considered a cue for similar situations, i.e., the permanence of people and the conservation of objects inside.

From this point of view, we can evaluate this type of system as a more sustainable and effective solution than the air-conditioning system, which would involve higher energy consumption and lower costs, as repeated several times in the previous chapters.

4.5.2 Conclusions and suggestions for buildings in use

After a long and descriptive analysis, we consider some improvement measures for these buildings, especially after a brief comparison with the other realities present inside the complex.

The two chosen buildings have been constantly used since their construction. It certainly appears to be more fruitful to continue to invest resources in them before embarking on reuse projects for schools that never worked.

Therefore, it is crucial to avoid further waste and finalize targeted interventions to solve some previously mentioned problematic situations, without the ambition of completely changing the layout of the architecture, converting an entire building, or achieving theoretically perfect results.

As a general rule, according to the adopted parameters, the two examined buildings do not have comfortable thermo-hygrometric conditions and are thus unsuitable for hosting the activities that are currently carried out (especially those concerning artistic production, in which the conservation of materials and tools is also to consider). Despite the architectural expedients already suggested in the design phase to improve interior comfort (vegetation, fountains, covered and therefore shaded outdoor paths, darkening elements, and porticoes, etc.), the two buildings have a low thermal and hygrometric response (despite the positive data when compared to the other buildings in the complex).

In conclusion, we propose some simple ideas to mitigate the discomfort conditions found following the initially analyzed points.

1. The topic of windows and doors is undoubtedly an essential aspect of improving thermo-hygrometric well-being. Ventilated rooms with natural aeration respond, both in terms of physical perception and data reading, to better indoor conditions. The replacement of the windows and doors in both buildings did not consider that the airtight and "draft-free" closures would have worsened the internal hygrometry. Not wanting to propose a further replacement that would be economically unsustainable but also useless, the maintenance interventions with a controlled opening of the windows and doors at certain pre-established times of the day could be a solution. This can help to improve the natural ventilation inside both the School of Plastic Arts and the Rectorate building. In the former, it would also be interesting to evaluate the opening of skylights that could help the movement of air inside the domes, a hypothetical "chimney effect". With this simple solution optimal conditions would not be reached, but it could make practical and theoretical classrooms more pleasant. In the Rectorate's building, the windows and doors opening, although it may be beneficial to natural ventilation, clashes with a problem of use. It can be problematic due to a mixture of functions that are not fully compatible. The doors and windows open in places where people are staying, cause the diffusion of the sound produced during music lessons, disturbing professors working in their offices. In these spaces, a closed door and window option should be chosen to install a dehumidification system, both in the offices and in the music classrooms on the first floor.

2. The restoration of the School of Plastic Arts' water element could also improve the outdoor spaces' perception, certainly of the large square, which could become a more pleasant place, thanks to the coolness that the water flows from the fountain.

3. Will installing technological air-conditioning and dehumidification systems be economically sustainable and manageable in a context like this? Or would it be better to think and improve the passive performance of buildings already sought after the original projects? Perhaps the design choices help to improve thermo-hygrometric wellness, even if they contribute to a pleasant perception of the spaces. The library's example is easily reproduced in rooms where the air-conditioning is never operated (Figure 53 and Figure 54). Still, fans are used, which consume a quantity of electricity that could be replaced with the insertion of a dehumidifier, which improves the spaces' conditions.

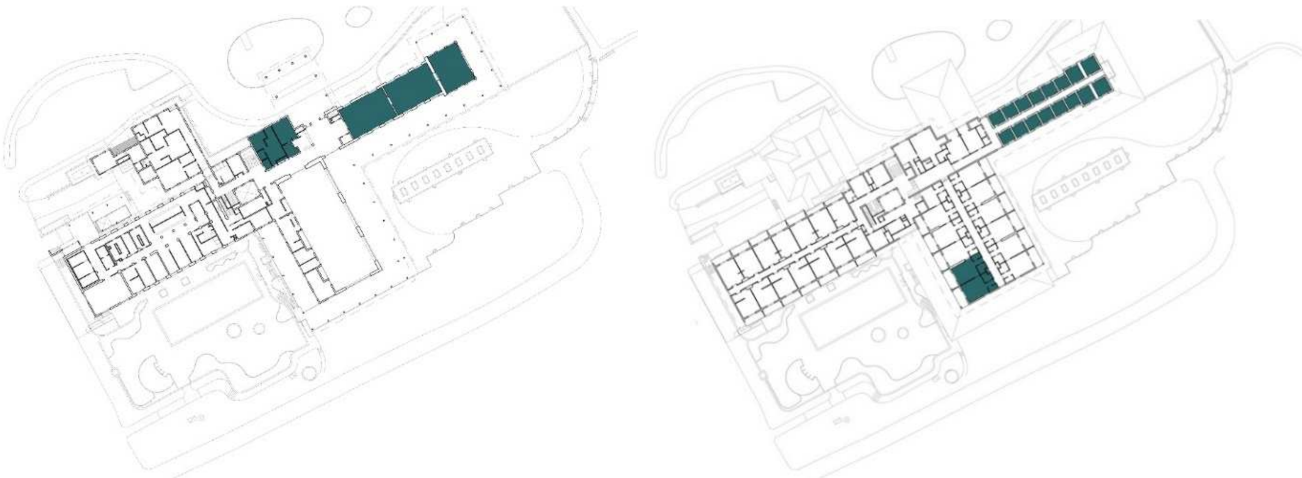


Figure 53 - Rectorate building, actual air-conditioned spaces.

Figure 54 - School of Plastic Arts, actual air-conditioned spaces.

4. An important issue for the School of Plastic Arts is the conservation of the artifacts therein, especially in closed environments. This involves greater access control in these environments to control the opening of the doors and windows and ventilate to improve internal conditions. However, the School of Plastic Arts has been operating for 60 years as designed. This suggests that the realization of the artistic products and their conservation in the domes and the special rooms is not compromised more than that.

4.5.3 Conclusions and suggestions for unused buildings

As for used buildings, for the abandoned Ballet School and Music School, it is unavoidable to think about which elements could be improved. The two buildings have not been used for 60 years and it is not easy to think about their reuse today, considering both their dimensions and state of repair. It is necessary to take into account the entire complex in order to avoid further waste and finalize targeted interventions aimed at solving some problematic situations. Without the ambition to start reusing these schools and obtain theoretically perfect results from a thermo-hygrometric perspective.

Generally, the two buildings examined here don't have comfortable thermo-hygrometric conditions. They are suitable to host any permanent and temporary activity (except the Music School's upper floor, thanks to adequate natural ventilation). This is a rhetorical statement from the point of view of the energy aspect and the other design characteristics.

Despite the architectural expedients already thought in the design phase to improve indoor comfort (vegetation, fountains, covered and therefore shaded outdoor paths, darkening elements, and porches, etc.), the two buildings have an inadequate thermal and hygrometric response, especially for spaces with high humidity and the slightly lower temperature outside.

A second emphasis should be placed on preserving the architecture and the material, which are also at risk because of poor thermo-hygrometric conditions.

Therefore, the solutions illustrated below are written because of subsequent design steps within the system; some should be developed immediately, others in the further phases of the work.

1. For both Music and Ballet schools, we can start a design thinking about the elements to be restored to complete the building. Described and detected several times, thanks to measurements, the theme of windows and doors is undoubtedly an important aspect for improving the thermo-hygrometric well-being. Here it is necessary to distinguish the two schools to develop a first design step. The school of Music has better conditions on the upper floor, where, moreover, some rooms are already used for different functions and in a spontaneous way. These spaces are ventilated with natural air circulation contributing to physical perception and data reading to offer better indoor conditions. A first intervention could restore the missing finishes and adequate windows and doors in these rooms, starting a design sector by sector, more economically compatible for the complex. It should be borne in mind that doors and windows designed in the 1960s allowed the passage of ventilation and were made with a simple wooden design. In the same sector, we can intervene in the restoration of the other missing brick elements, that is the brise soleil in the external path. The realization of these elements, regardless of the design and architectural choices to be evaluated elsewhere, leads to a conception of space close to the original project but, above all, similar to other schools' areas. Once these crucial elements will have been restored to complete the architecture for constant use, it is advisable to repeat the thermo-hygrometric data measurements in order to compare them

with the other buildings in use and to evaluate the possibility to insert a system based on the new registered value of UR%.

As far as the music school's lower floor is concerned, the rooms are unhealthy because of the high humidity, the little solar radiation and the lower natural ventilation. In this case, no space is used. Still, the classrooms' small size can help provide economically sustainable interventions, thinking to small areas, if possible, because of the complex reuse these spaces. Here, however, the restoration of the architectural elements of completion must probably be accompanied by a system of dehumidification or forced air recirculation, since the measured values are very high and difficult to decrease with the completion of the building. The very high humidity would remain confined into the rooms that would not receive the sun's rays and therefore it is necessary a system that helps to reduce the humidity.

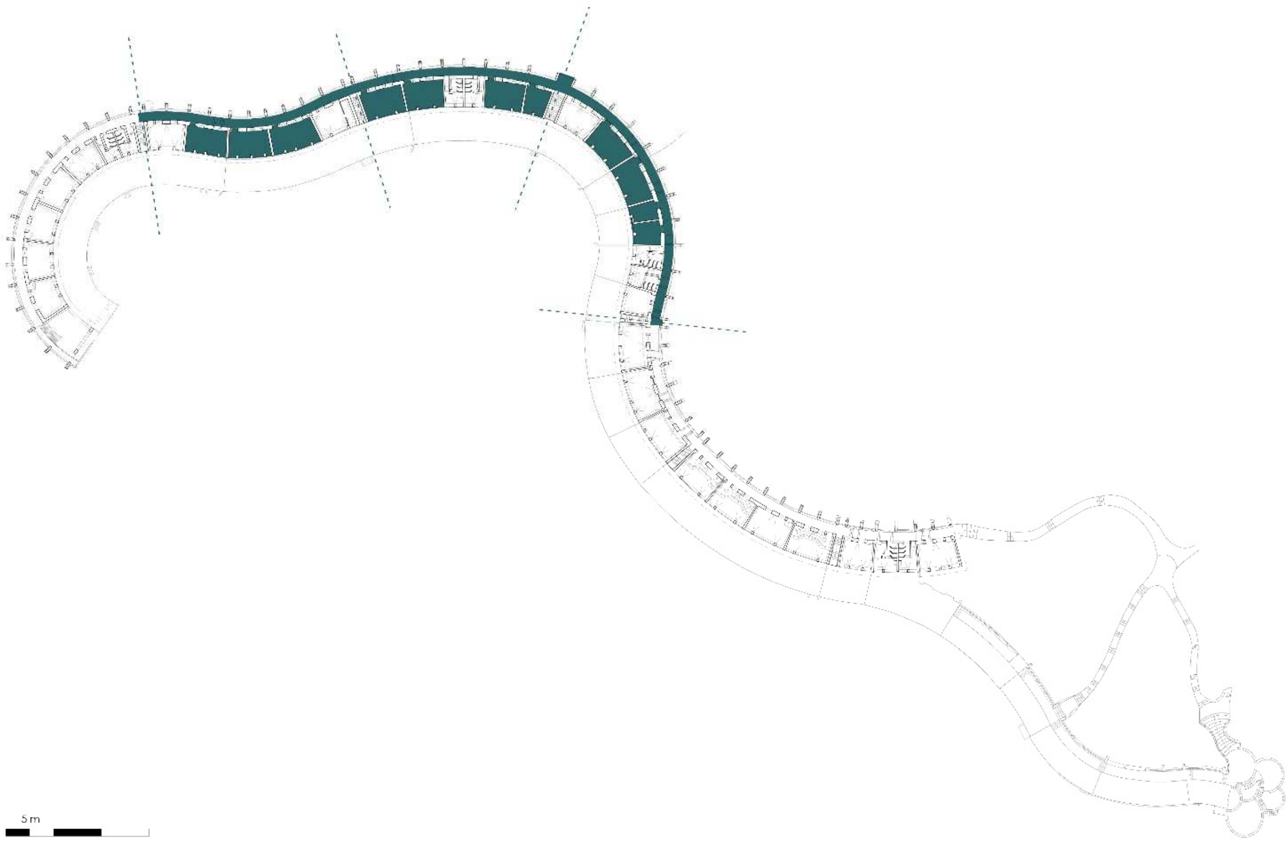


Figure 55 - School of Music, upper level, used spaces, and division into sections.

Such an approach cannot be brought back to Ballet School because the spaces' dimensions are much larger. The main problem is to find a solution to the flooding of the Rio Quibù, so it is assumed that the solutions indicated in action three have been successfully implemented. Therefore, delving the problem of high humidity, decreasing the constant moisture remains. New measurements are expected to be repeated over several months in February and April to assess whether natural ventilation helps reduce the RH% over time in the absence of the leading cause. A double way of use is opened: constant use of the building or occasional use for events. The second is the one that is decided to deepen for a more realistic design within the priorities of the complex and because the external spaces of this building are already the scene of occasional performances. To make the spaces usable sporadically, it is not necessary to reach optimal comfort levels; therefore, this is the first approach to reuse the building. Every space in the school needs different arrangements. The least effort can be made in the choreography theater and the distribution corridor. Once the humidity level has decreased (it is thought that it can decrease with the absence of flooding and drying of the structures), it is necessary to restore the finishes. Since the temperature values are good, they could already be used. As for the practical classrooms, instead, the situation is subject to an architectural choice of closing these spaces with *ventanas* that can allow the passage of air and ventilation but reduce solar radiation, as designed by Garatti. For the current conditions, these spaces cannot be used as designed.

2. The restoration of the water element could also improve the external spaces' perception, but we refer to a final phase and full use of the building.
3. The question regarding installing equipment in used buildings is more likely to be reported for abandoned buildings. If they were installed, the air-conditioning systems were not working due to economic and consumption problems. It is better to reason about what design choices could be made for unused buildings. The Music School was designed to contain an air-conditioning system that reaches every classroom, whose performance details can still be read today in the building. Perhaps these design choices are now utopian because of the considerable size of the building, and for the same reasons, it was reflected in used buildings. The lower floor of the Music School might prove necessary to reduce the high UR% present and constant in the rooms. For the Ballet School, as we think of the original design, the system should work in huge spaces and have too high consumption, and therefore it is very unrealistic to submit.

Based on the different reflections or perhaps upstream of them, asking ourselves for what possible use could these two Schools be reactivated. Original use? New and different functions such as the upper floor of the Music School? Sporadic uses and occasional events?

It is essential to think about this to direct the choices from an energetic point of view, as outlined in the previous paragraphs. It is shown that comfortable use is possible through some design tricks and that, therefore, a vision of activity after 60 years is not yet lost.

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Action 5

Development of the management system strategy and tools

Action 5: Developing a management strategy and tools

Action 5: goals and work phases

This section of the CMP outlines the overall management strategy envisioned for the National Schools of Art.

The report focuses on two main issues:

1. the design of a management tool, tailored to meet the needs of the specific case;
2. the description of the operational guidelines for an adaptive reuse and development of the whole complex, which includes the conservation guidelines for materials and architectural elements set out in Action 2.

The two issues - tool and guidelines- are closely linked since the second depends on a highly rigorous and transparent process of analysis and evaluation, supported and directed by the management tool.

5.1 Designing a management and decision supporting tool

The first part of the report outlines the process of design and implementation of the management tool. In the process of selecting the type of device, threesome basic requirements have been identified.

First, **multidisciplinarity and multiscalarity**, as the ability to support different types of materials and scales of analysis, to represent the various topics at a general or more detailed level. The overlap of these different thematic layers and levels of analysis is meant to overcome the challenge of describing a large complex that entails very different degrees of interest and requirements regarding conservation, refurbishment, reuse, and management.

Indeed, the management tool is conceived as a collector of all the data, documents, and other disciplinary contributions gathered or produced during the project. All that information should be referred to a specific level of detail.

On a large scale (environmental level), the National Schools of Art can be seen as a well-integrated territorial system that includes several constructions, bridges, footpaths, and routes in an environmental context that includes natural elements as the Rio Quibù and the lush vegetation of the park.

Although the research focuses on the buildings, and more precisely on the 5 schools built in the 1960s, that overall view cannot be disregarded since there are issues that cannot be addressed without considering broader and general dynamics, such as those related to use that request an in-depth analysis of the needs and the urban framework to have an overall picture of the masterplan. Therefore, the current and potential connections with urban surroundings should be described and analyzed at that level.

The same goes for crucial conservation problems such as the water-related damages caused by the floods of the Rio Quibù. E.g., the poor state of repair of the School of Ballet largely depends on flooding and cannot be solved without an overall intervention to increase the protection structures located along the river.

For the architectures, two sub-levels of description can be identified.

First, general data are collected to describe each building in the complex, which has variable degrees of interest and value and are partly used for lessons, workshops, and other functional needs and partially not used. The description includes a brief historical overview, dimensional and technical data, information on their state of repair, and the historical and actual function.

Second, the Schools designed by Garatti, Gottardi, and Porro request a narrower perspective to describe the challenges to be faced and develop suitable intervention protocols, calibrated on the spaces' specific features and the state of conservation of each material, e.g. the focus on the state of repair of the vaults.

These two sub-levels are interdependent but integrate vastly different information.

Second, **reliability and ease of use** to support the CMP's drafting and the subsequent management phases.

As said before, the tool collects the different data produced by the working groups, such as documents, maps, photographs, and information deriving from instrumental diagnostics. These data are recorded in specific forms and are linked as an attribute of each building and/or space.

The tool should allow easy retrieval of information that can be viewed directly on the site managers' floor plans to highlight trends and priorities.

In the process of drafting the C.M.P. of the schools, by providing that synoptic picture, the use of the management tool made more objective and retraceable the process of analysis, evaluation, and planning. In the future, the management tool could be updated with the outcomes of the activities performed over time and with the data produced in further studies. The tool's continuous update will lead to a better knowledge of opportunities and critical points and, therefore, a review of the evaluation and a fine-tuned set of directions and maintenance schedules.

The third required feature closely links to the previous point because the management tool should act as a **unique workspace and common decision supporting tool for different stakeholders**.

The project involved different professionals with different backgrounds, skills, and working methods and has benefited from the active and constant cooperation with the local stakeholders.

The sharing of goals and issues within the Cuban working group has been essential in the whole project and, particularly, when defining the management tool and strategy. That teamwork has allowed the research group to understand the cultural significance of the National Schools from a "situated" perspective and get the critical issues, the needs but also the potential that can be developed for better use of the complex from the direct testimony of those who daily manage and use the spaces of the schools.

The suggestions and indications that emerged during the numerous discussions with the Rector and with the I.S.A. teachers also consider the development lines envisaged for the I.S.A. already described in the Action 1 - Analysis and documentation of the site and the building. Besides, during the fieldwork, ISA teachers and collaborators took part in the inspections and supported the researchers in the interviews conducted with teachers, staff, and students in all schools. This invaluable collaboration has allowed us to develop a lexicon and a research methodology that best fits the needs and locals' point of view.

Figure 1 – The Rector of ISA prof. Alexis Sejio Garcia considering the layout f the complx with the workteam.

The ISA research group (dean Prof. Silvia Ramirez Paseiro, Decana Facultad de Artes de la Conservación del Patrimonio Cultural; Prof. Tamara Gispert Galindo; Prof. Leticia Fundora Rangel; Prof. Beatriz Lorenzo Gomez; Prof. Nelson Andry Uliver Cruz) supported us throughout the activity discussing the criteria for the analysis of the buildings and the methodology, and besides, the students of the heritage classes were actively involved in compiling the analysis forms[1].

Considering these requirements, it was decided to organize a unitary work plan through a G.I.S. management system, including in the CMP multiple levels of detail, systematize different topics, and compare the analyzes performed by the different operators set a common work framework for the site managers.

The chosen management tool is a G.I.S. (Geographic Information System). The Quantum platform seemed to be the most appropriate choice because it is open-source software that the site managers can easily use and implement overtime.

The Information System combines carefully selected graphic support bases such as cartography, modern and contemporary maps, and aerial images. In addition, other information layers deriving from the geomorphological and hydrographic studies have been processed and associated. It will also be useful to include the terrain's elevation by defining the contour lines and the construction of a Digital Surface Model (D.S.M.) and a Digital Terrain Model (D.T.M.) of the site. The platform also operates as a database in which the data are hierarchically organized to establish different thematic areas, using different layers of information. The G.I.S. allows a potentially infinite number of subjects to share knowledge, thoughts, and evaluations on general or specific issues.

[1] See Annex 5A Registro fotográfico preliminar del estado de conservación y uso de los espacios de las Escuelas Nacionales de Artes (Febrero 2020).

5.1.1 From a site- analysis to the operative guidelines

The last part of the text presents the directions and guidelines resulting from the analysis and interviews.

As said before, the tool supports a rigorous methodological process that, taking into account the cultural representativeness of each building and space and its specific features, highlights opportunities, priorities, and critical issues and support decisions and detailed projects.

The analysis is summarized in the main 4 thematic maps: cultural significance, state of conservation, intensity of use, consistency of use. Each evaluation depends on the analysis recorded in the form that describes each space and on specific evaluation criteria to ensure the maximum traceability and transparency of the decision-making process. That evaluation determines the possible level of change of each space, displayed in a further map and to the intervention guidelines that describe the actions to be carried out, taking into account the state of conservation, the evolution of phenomena over time, the and the opportunity for redevelopment of each building.

The guidelines consider both the presence of significant elements, which must be preserved and, where possible, enhanced, and progress problems. Depending on their nature, these may require specific intervention strategies. By drawing up an illustrative and non-exhaustive list, such interventions may include adjustments of a distributive, technological, functional nature or, otherwise, they require to renovate the furnishings and other building equipment. Therefore, the guidelines include both conservation and change in the dual meaning of admissible and desirable transformation.

Calendar of activities (2019-2020)

The June 2019 mission had the purpose of setting up the management tool's primary structure and establishing the data hierarchy. An extensive analysis of the buildings and the state of conservation has been carried out, working closely with the ISA teachers and students. Dimensional and spatial data are useful for the cartographic and geometric re-definition vectorial support bases have been acquired. After the mission, the maps have been inserted, and the database structure has been designed.

The considerable amount of data, the need to organize them assuming the structure of a G.I.S., the identification of possible queries, thematic and spatial correlations make it necessary to create a unitary project to maintain an overall vision of it and, at the same time, allowing to pursue specific aims at the different levels of investigation.

The management system setup phase involved defining different information levels to which external references, numerical and/or textual databases, and spatial information were mainly associated, establishing the relationships between the various sections. The attribute fields linked to the spatial entities have also been defined in thematic sheets divided into location and identification, Functions, Technological Elements, Technological Systems, Equipment, Use adequacy, Transformability, Evaluation, Hydraulic analysis, References, and notes. Some fields are forced type by choosing the content from the drop-down menu with a pre-set value, while others are free to enter numerical or textual information. In addition, the main queries of the database and the relative graphic returns were established. The queries can be direct, with a visual result for a single attribute field, or complex when several areas are involved in obtaining a single thematic map.

Therefore, the action in June 2019 made it possible to acquire a large amount of information suitable for the subsequent phases of setting up and implementing the Geographic Information System (G.I.S). The obtained data were also processed for the morphological definition of the terrain near the Rio Quibù, useful, above all, for the activities connected to Action 3 concerning landscape management and flood risk assessment and mitigation.

During the February 2020 inspection, the data acquisition was completed on the Music and Plastic Arts Schools and then, the reliability of graphic supports has been verified. A photography campaign of the entire area was also completed. After the mission, the database was implemented, and the guidelines were produced.

5.1.2 Organizing the data in the management tool

5.1.2.1 Reference system and cartographic basis

The adopted coordinate reference system was the WGS84 (ID of the EPSG authority: 4326), on which the first geographic information was loaded. An in-depth analysis of the collected materials revealed some critical issues regarding the metric and morphological accuracy of the aerial images and the collected modern cartographies due to low quality or huge representation scale (greater than 1:10,000) that not allowed to distinguish the elements and their main characteristics easily.

Therefore, all cartographic sources available online from different satellite/air databases were verified, including the most important: Planet, Google, Esri, Apple, Bing, WorldImage.

We proceeded with a metric, morphological and qualitative verification of about 25 aerial and satellite images acquired over about ten years (from 2010 to 2019), identifying three recent aerial photographs to be included in the main structure of the management system:

- Google Satellite_November 2018;
- WorldImage Aerial_December 2018;
- Bing VirtualEarth_January 2019.

Among these, the aerial image "Bing VirtualEarth" has proved to be the most reliable from a metric point of view for its reduced distortions as well as for the best photographic quality and definition. For this reason, it was selected as the starting primary base of the system (Figure 2).

Figure 2 - Aerial image "Bing VirtualEarth", January 2019.

In fact, the image does not have significant perspective areas, often easily identifiable in the immediate closeness of the buildings, it shows good chromatic quality, the shadows are not so marked, allowing to distinguish details of the covered areas, and the aerial photo refers to a very close moment (January 2019). To avoid problems related to georeferencing operations, the three selected aerial images were imported into the G.I.S. system through direct WMS connection (acronym for Web Map Service) to reproduce maps of data spatially referred to geographical information dynamically.

It is also worth mentioning the possibility of investigating numerous cartographic thresholds deriving from satellite images in the Planet company database. In 2018 the access to their complete database was requested. This made it possible to view, through the company's G.I.S. system, all the images taken for the interest area from 2010 to now with a weekly, monthly, or even daily acquisition rate for some specific periods. These images can help understand the evolution of green and wooded areas, but they cannot be used as general support maps for the management system as they are made on a scale that is not sufficiently detailed (1: 25,000).

Finally, it was decided to insert other WMS maps as it proved to be functional for the verification of the road infrastructures, the surrounding areas, and the urban organization of the neighborhood, maintaining the possibility of verifying, for example, the names of the streets and significant networks present:

- ESRI Satellite;
- ESRI Transportation;
- SERI Topo World

- OpenCycleMap;
- OpensStreetMap;
- OCM Landscape;
- OCM Public Transport;
- OSF TF Outdoors;
- Pioneer;
- Mobile Atlas;
- Neighborhood;
- Wikimedia Labelled and Unlabeled layer.

The selected and inserted maps were useful for connecting the position references and contextualizing the National Art Schools area. Given the possibility of not having a stable and adequate internet connection for loading the WMS thresholds, we have also chosen to insert four raster levels corresponding to a part of the WMS cartographies. These have an extension referring only to the analyzed area:

- Bing Virtual Earth Rectified;
- Google Satellite Rectified;
- World Image Map Rectified;
- ESRI Satellite Rectified.

5.1.2.2 3D data as support to the management system

As part of the on-site analyses and the capacity building activities[2], the large- and small-scale three-dimensional acquisitions were made mainly concerning the School of Music, the School of Ballet, and the School of Plastic Arts with the collaboration of *Zenith Ingegneria* and *Restaura y Proyecto Companies*. The goals were to create a whole planimetry of the area and the detailed surveying of two domes of the School of Ballet to export geometrical drawings and models meant for the structural analysis.

For the detailed survey activities, a high-density three-dimensional acquisition method was chosen to record all the data useful for the structural analysis and the intervention project's definition on three selected portions of the schools. Specifically, two practical classrooms have been previously identified as case studies, one from the Ballet School and one from the School of Plastic Arts and the Choreography Theater of the School of Ballet. For this type of survey, two terrestrial laser scanners (Z+F IMAGER 5010c and FARO Focus S350) were used to cover the needs arising from the different data types to be recorded. In fact, we concentrated in parallel on the detailed acquisition of the schools' geometric information (through the Z+F laser scanner) and the geometric information concerning the schools' connection with the entire area (using the FARO laser scanner).

[2] See 2.2 On-Site Analyses and Capacity Building.

Three different high-density point clouds with greyscale coloring were obtained regarding the schools' detailed acquisitions. These clouds have been sectioned to bring graphic drawings at varying levels of detail and were also used to create three-dimensional models useful for defining the detected portions' structural behavior and better understand their morphology. Regarding the large-scale recordings, different groups have been created and based on the acquisitions' location with the consequent creation of different point clouds (some of them with the real RGB color information applied). The obtained results helped to contextualize the detailed surveys and allowed the check of the project plans and the past drawings of the Ballet, Music, and Plastic Arts Schools.

Processing phase of the long-range three-dimensional data

Regarding long-range laser scanner acquisitions, a specific processing method was used due to the nature of the recordings, the different purposes, and the level of detail of the representation. The survey project was developed considering the buildings' morphology and location affected by the recordings and considering the spaces' architectural, dimensional, and material characteristics. The work organization was defined paying attention to the morphological trend of the terrain and using two different approaches whose synergy allowed to obtain a result of high precision without excessively weighing down the implementation times that were concentrated in four days of work. Therefore, it was decided to carry out three-dimensional scans associated with high resolution panoramic photographic acquisitions and acquire three-dimensional scans in grayscale, therefore without recording the chromatic data. The network layout was rather complex, considering the particularly articulated geometries and the desire to create closed networks. These guaranteed greater control over any angular and linear error. The instrument used for three-dimensional recordings was a high-speed non-contact terrestrial laser scanner (FARO S350) equipped with a 5-megapixel sensor digital camera. This tool is of limited size and weight, especially useful in complex situations. All scans were performed with a 360° rotation of the instrument around the vertical axis and 300° around the horizontal axis, between 0.50 and 2.00 meters from the ground level. It was preferred to use similar quality parameters ("2/4" and "3/4") to obtain homogeneous results, paying attention to the position and dimensional differences of the spaces. In general, for the smaller and geometrically simpler areas (for example, the inner rooms of the Schools or confined external portions), complete scans were performed at a limited resolution level ("1/10" - "1/8"). In contrast, we opted for a more significant number of scans at a higher resolution and point density ("1/5" - "1/4" - "1/2") for larger environments or architecturally more complex external areas to create a continuous network with large areas of overlap[3]. A total of 161 laser scanner acquisitions were taken, 63 with spherical color images recorded by the same instrument (Figure 3).

[3] For further information about the scans and their parameters see Annex 5B Three-dimensional scans parameters.

Figure 3 - General plan of the ISA with the scan points' location (in green the scans registered in grayscale, color scans are purple).

Once the acquisition of geometric and photographic information was completed, the data was processed first on the individual scans or portions by applying automatic pre-processing filters. In fact, the scan points resulting from the acquisition of two objects or parts of them with a single impulse have been identified and removed, thus eliminating all the false points generated. The incorrect data were subsequently removed, and the noise of the surfaces, clearly altered from the point of view of general geometric coherence, was reduced. This operation allowed replacing the scanner's inconsistent values with the surrounding area's average values to obtain a more uniform surface. Considering that the instrument can acquire data up to a distance of about 350 meters, it was necessary to remove all the unnecessary and excessively redundant points to avoid a weighting of the complete cloud and, therefore, improve the general view of the three-dimensional survey. For the same purpose, it was decided not to combine all the scans into a single complete point cloud but to create three macro-groups superimposable on each other through common parts:

- Union BA_MU: it includes the scans performed at the School of Music, the School of Ballet, and all the scans in the areas next to the two buildings;
- Union PA: it includes scans performed at the School of Plastic Arts and all scans in the bordering areas of the building;
- Union MU_Rec: it includes scans performed in the eastern portion of the Music School and all scans performed along the Rio Quibù up to the Rectorate building.

On the other hand, 36 laser recordings were left single and not aligned. They were recorded only for direct and sporadic interrogations to verify the remaining area's geometry or structures. Once these operations were completed, the following phase identified the reference points to calculate each scan's rotation and translation coefficient.

Through the common points between the different clouds, it was possible to locate the scans, to align and record them, minimizing errors related to angular closure and distance errors. These operations allowed precise control of the inaccuracies, in all cases below the acceptable limits, returning a highly reliable result from the metric point of view. Once the complete clouds were generated, a second processing phase was carried out. This elaboration was able to eliminate all the redundant points to allow a significant reduction in terms of total file weight and to simplify the three-dimensional visualization of the data (Figure 4).

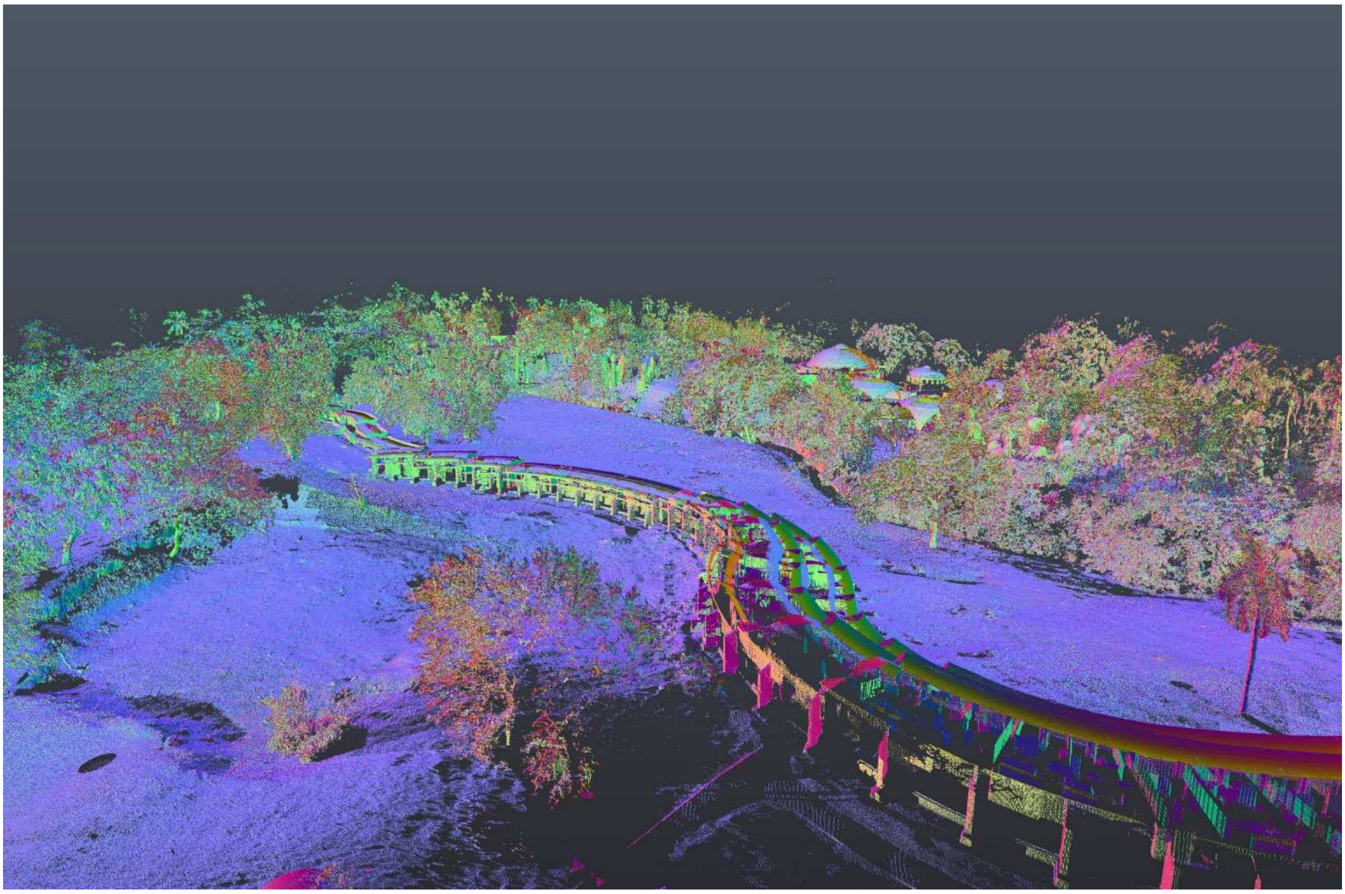


Figure 4 - Perspective view of the point cloud "Union BA_MU" with coloring determined by plan variations.

In the final processing phase, the spherical images carried out by the laser scanner were also applied to the complete cloud, thus associating the chromatic data with the geometries of the single point detected (Figure 5 - Figure 9). The scans did not consider absolute positions and levels also in this case. However, it was possible to obtain the conversion factors for each point's altimetry and the roto-translation factors to be applied to the three macro-groups, thanks to the data recorded through detailed laser scans and the association of this information with the absolute GNSS coordinates[4].

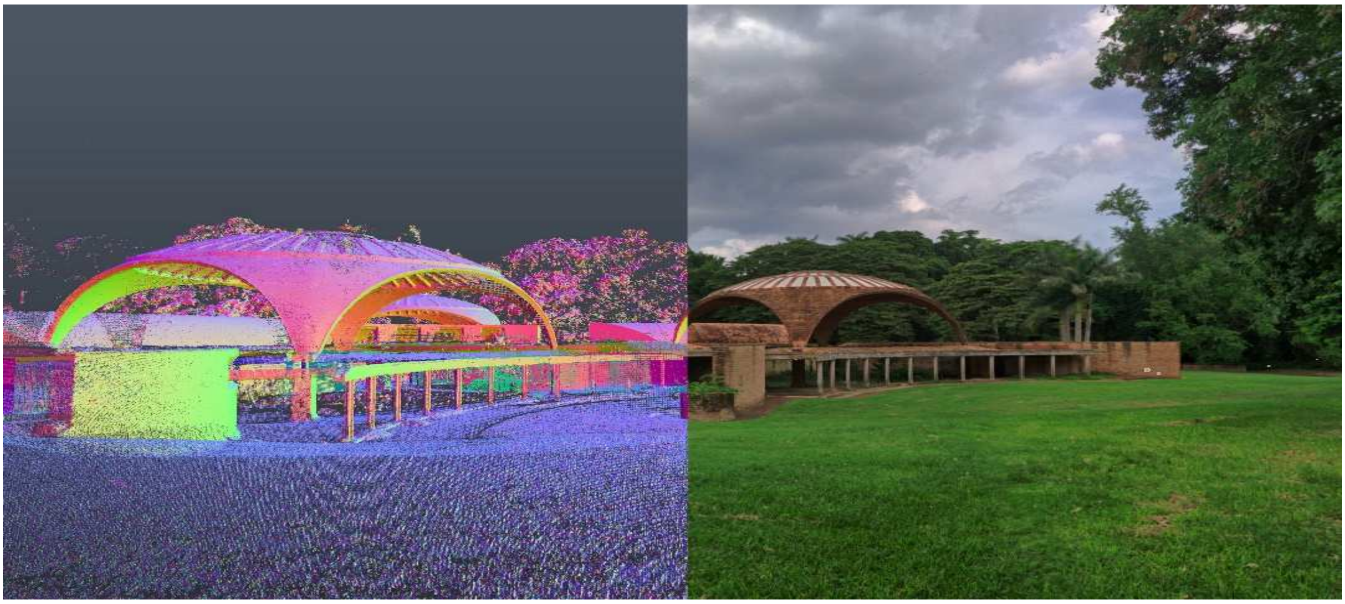


Figure 5 - Perspective view of the School of Ballet. On the left: a cloud of points with coloring determined by the plan variations. On the right: spherical color image.

Figure 6 - Perspective view of the "Union BA_MU" point cloud with the chromatic data application.

[4] See 5.1.2.3 The GPS/GNSS data and the three-dimensional acquisitions.

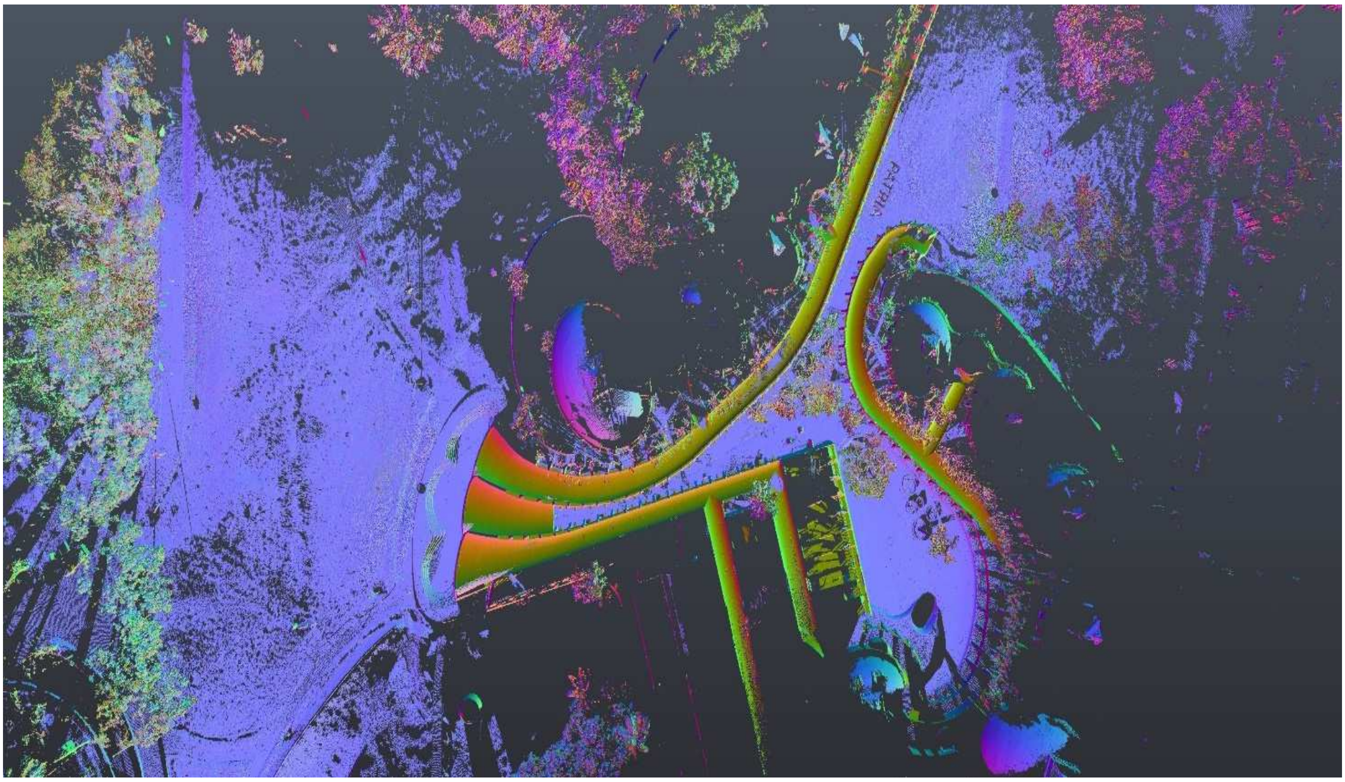


Figure 7 - Perspective view of the "Union PA" point cloud with coloring depending on the plan variations.

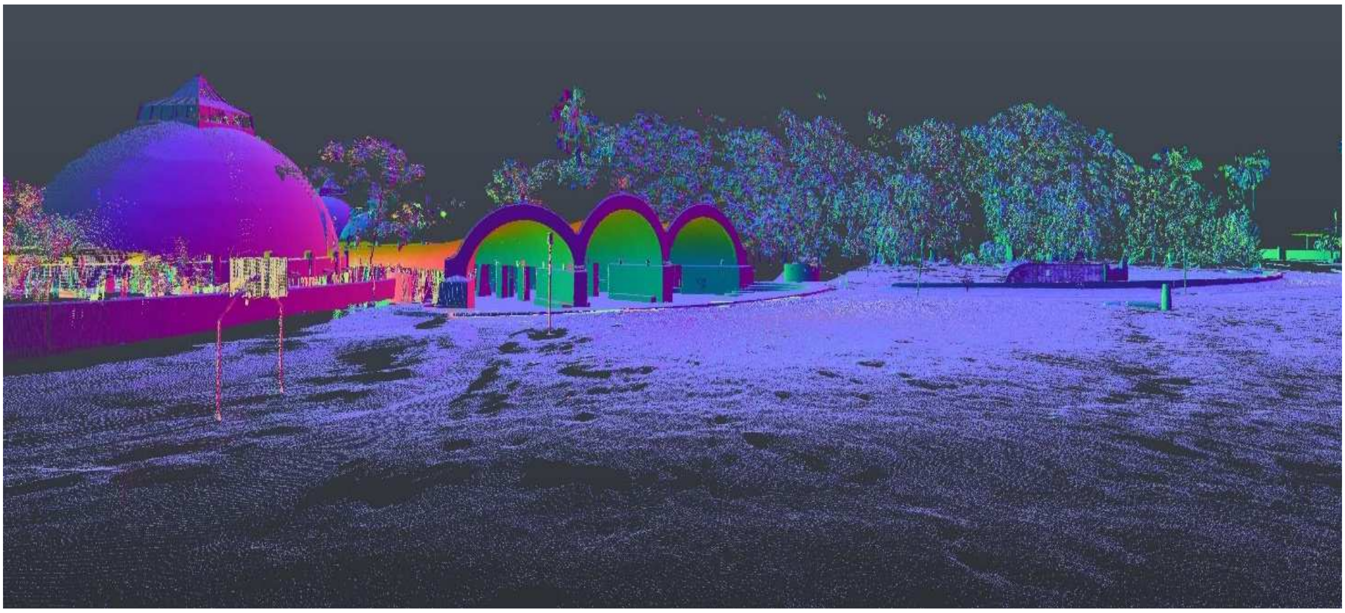


Figure 8 - Front perspective view of the "Union PA" point cloud with coloring depending on the plan variations.

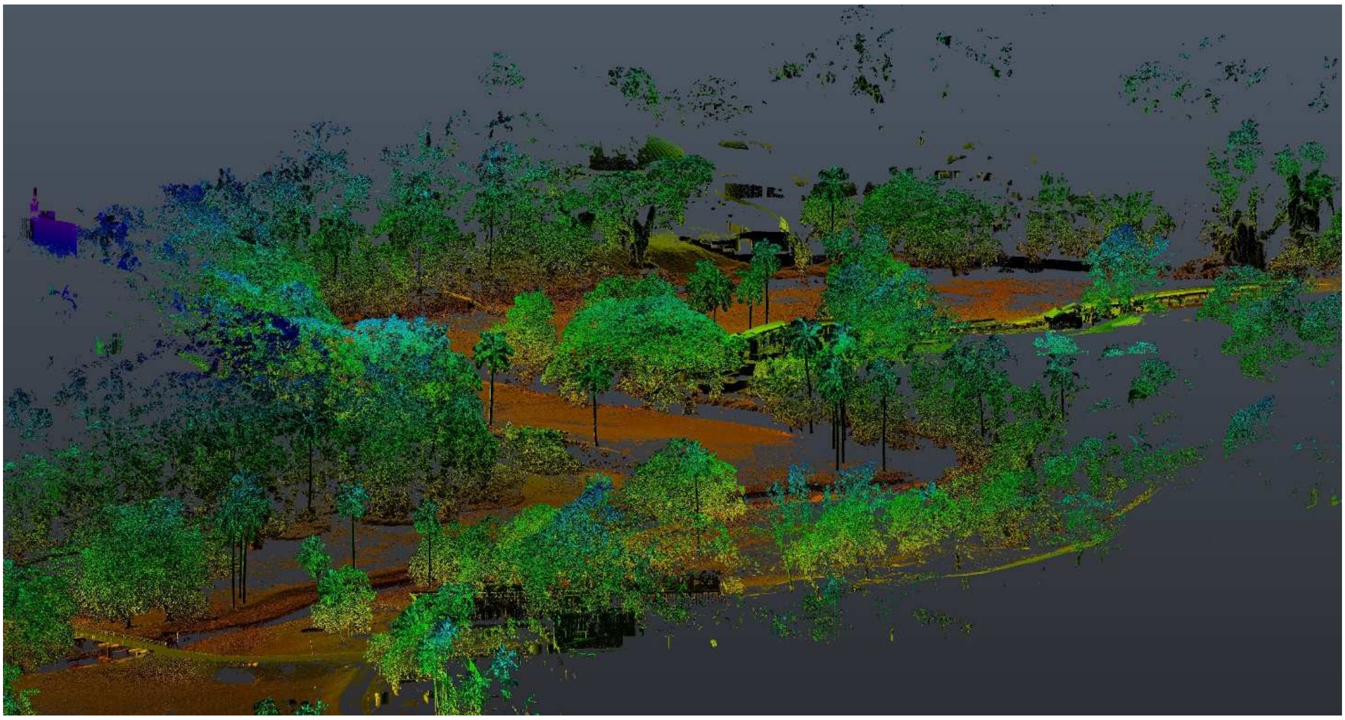


Figure 9 - Perspective view of the point cloud "Union MU_Rec" with coloring dependent on altitude variations.

Once the initial processing phase of the three-dimensional data acquired by long-range terrestrial laser scanner was completed, the information was organized and exported to generate the appropriate graphic and cartographic support bases for setting up the G.I.S. management tool and for the analysis activities of the research groups involved in the project.

Considering how various were the necessary information and the purposes for the different research activities, it was decided to generate specific documents based on the working groups' diverse needs, giving priority to the elaborations to create the cartographic bases on a larger scale. For the three identified macro-groups, we proceeded through zenith projection elaborations with a detailed scale of 1:200, both in grayscale and in color for the only scans that acquired the chromatic information (Figure 10 and Figure 11). This made it possible to significantly enrich the information baggage concerning the area's morphology, especially for the structures' correct positioning. Finally, the BA_MU and MU_Rec point clouds were post-processed through decimation filters (at 50mm and 100mm) to generate a digital terrain model capable of representing altitude changes, especially in areas closest to Rio Quibù and the Schools of Music and Ballet[5]. These data were also used to analyze the hydrographic risk and the related designing of the interventions[6].

[5] For a more detailed discussion on these activities see 5.1.2.3 The GPS/GNSS data and the three-dimensional acquisitions.
[6] See Action 3 Landscape management and flood risk assessment and mitigation.

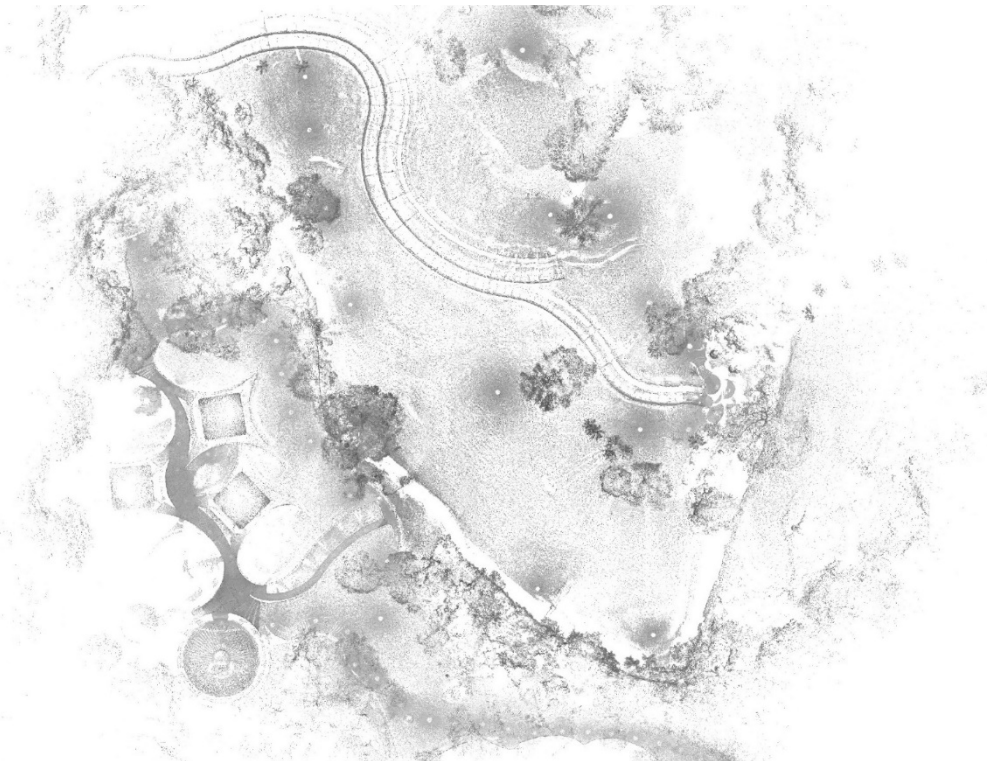


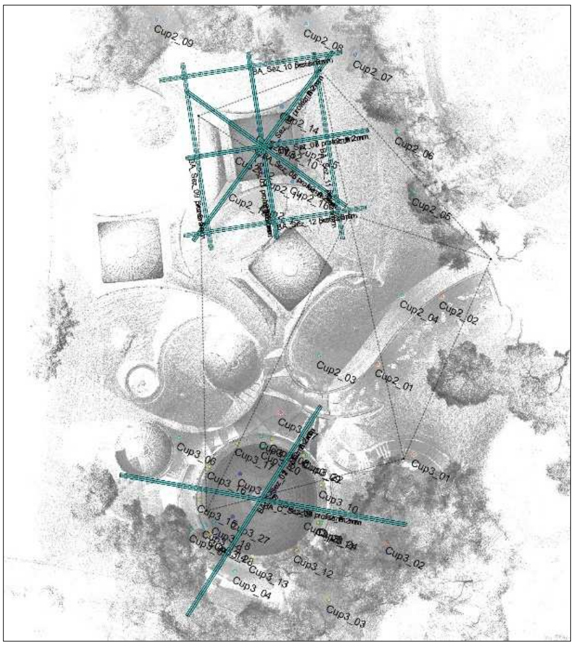
Figure 10 - Zenith view of the point cloud "Union BA_MU" with grayscale coloring.

Figure 11 - Zenith view of the "Union PA" point cloud with the application of chromatic information.

Processing phase of the detailed three-dimensional data

Regarding the detailed acquisitions, a total of 70 laser scans were recorded, 46 for the School of Ballet and 24 for the School of Plastic Arts, which led to the creation of two distinct high-density point clouds with grayscale coloring. The first concerning the School of Ballet includes two domed spaces (Figure 12). The second concerning the School of Plastic Arts contains three-dimensional information about a single domed room (Figure 13).

The instrument used for three-dimensional acquisition is a terrestrial laser scanner (Z + F IMAGER 5010c), and all the recordings were made with a 360° rotation of the instrument around the vertical axis and 300° around to the horizontal one, at a height between 1.00 and 1.80 meters from the ground, on a topographic tripod. To obtain a homogeneous result from the graphic point of view, it was preferred to use similar quality and resolution parameters, paying attention to the position and dimensional differences of the spaces to be detected[7].



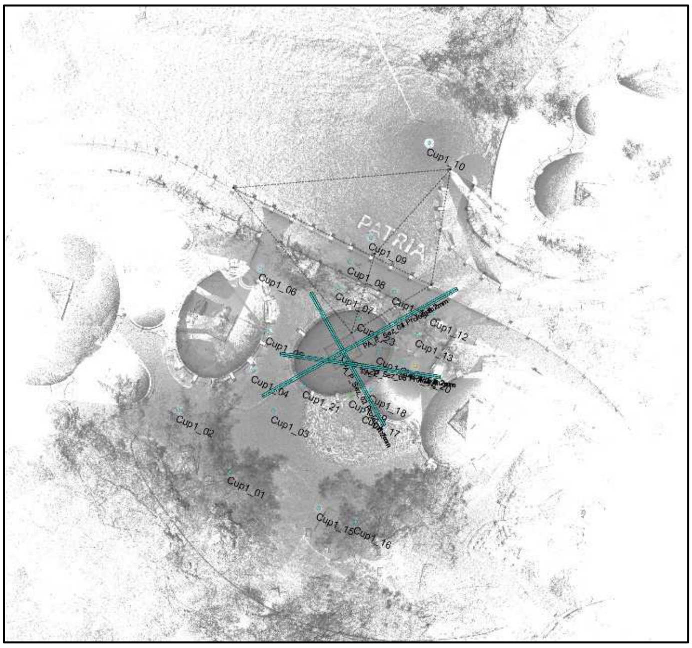


Figure 12 - Point cloud of the School of Ballet, zenith projection; Figure 13 - Point cloud of the School of Plastic Arts classroom, zenith projection.

The phase of alignment and registration of the individual clouds has led to excellent results both from the point of view of density and the point of view of the recordings' metric reliability. In fact, there are no erroneous overlaps of separate common areas or false points that could have compromised the result. For a more precise and more immediate visualization of the three-dimensional acquisitions, the clouds were cleaned and filtered from wrong points or points not correctly acquired due to problems connected to the materials (chromed portions, not entirely transparent glass, dark-colored metal foils).

[7] For further information about the scans and their parameters see Annex 2B GNSS and Laser Scanner Survey.

To keep as much information as possible, data external to investigation areas have not been removed. The coordinates and absolute dimensions recorded using differential GNSS instrumentation were subsequently associated at the two complete point clouds[8] to establish the basis for the forthcoming three-dimensional elaborations' georeferencing.

These clouds were also used to extract the section profiles in plan and elevation and the external façades (Figure 14 and Figure 15) to obtain vector-graphic drawings, at different levels of detail, useful for the structural study phase and the definition of the intervention project.

These data were subsequently implemented and enriched through partial elaborations of the geometrically more complex areas to create a fundamental information database to define the detected portions' structural behavior and better understand their morphology.

Figure 14 - Section/elevation of the School of Plastic Arts.

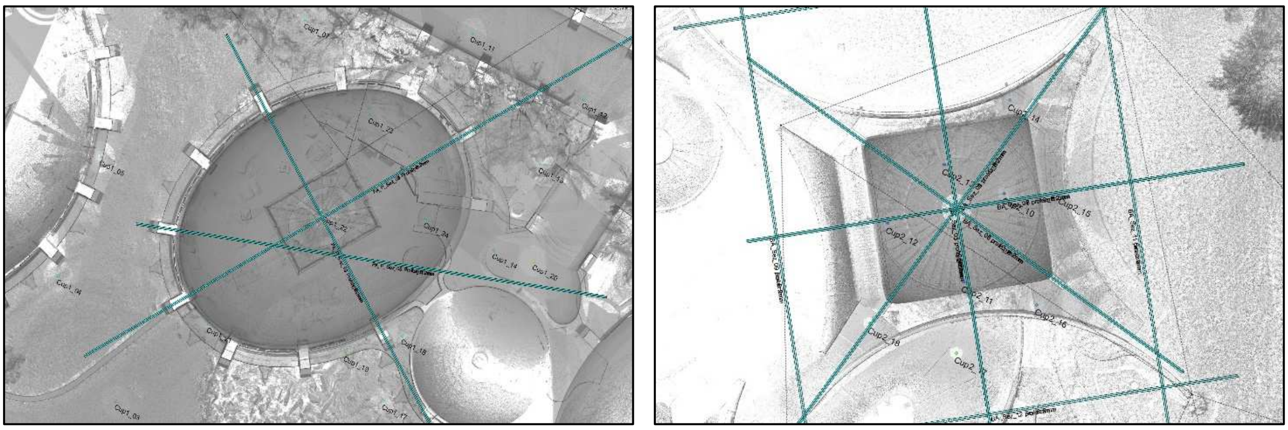


Figure 15 - Detail of the School of Plastic Arts and the School of Ballet's analyzed spaces.

[8] For a more detailed discussion on these activities see 5.1.2.3 The GPS/GNSS data and the three-dimensional acquisitions.

For the three classrooms, it was decided to represent the geometries in three different ways based on the three structures' morphological complexity. For this reason, a three-dimensional model divided by elements (partitions, beams, roofing, pillars) was created for the Ballet School's classroom, as it had very complex geometries and pronounced deformations, especially relative to the four horizontal beams and the four upper arches (Figure 16).

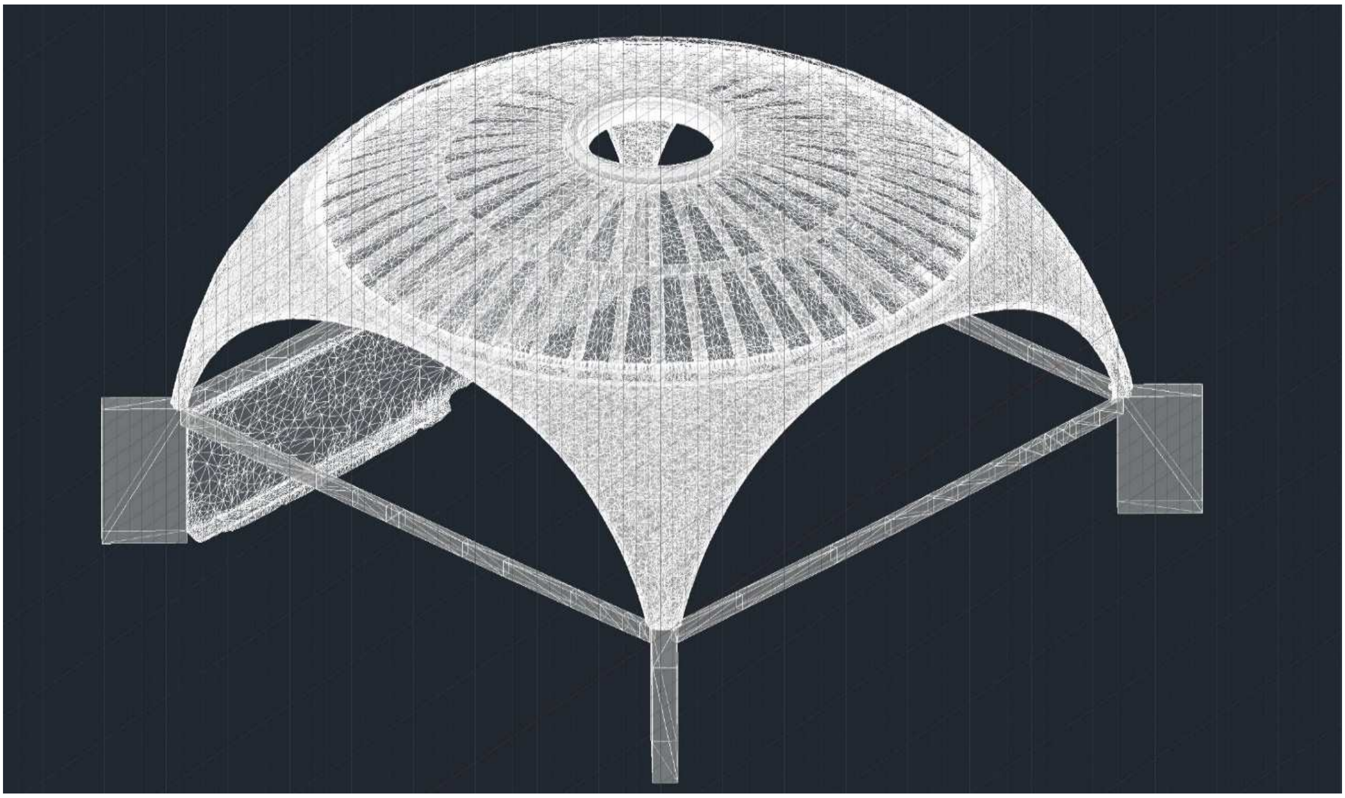


Figure 16 - Three-dimensional model of the Ballet School surveyed space.

In addition to the three-dimensional model, the following drawings were made in 1:50 scale:

- Planimetry at an altitude of + 120cm from the walking level;
- Plan with roof projection;
- 4 cross sections;
- 4 external elevations.

For the School of Plastic Arts' domed space, as previously, a two-dimensional representation in plan and section was chosen and creating an approximate three-dimensional model of the internal and external shell of the covering structure. Above all, this is to define and three-dimensional display the roof structure's deformations that are difficult to represent in two-dimensional drawings.

Finally, only two-dimensional drawings in plan and section (Figure 17) were made for the Ballet School choreography theatre. The structure is morphologically more straightforward and does not present significant deformations that would have required further graphic insights.

The plans, sections, and elevations were subsequently verified through the point cloud. The dimensions of the main elements present or may present morphological or dimensional criticalities were reported, and the clearest uneven outline was represented (Figure 18). All the two-dimensional and three-dimensional elaborations were transferred to the structural group for the three classrooms' analysis.

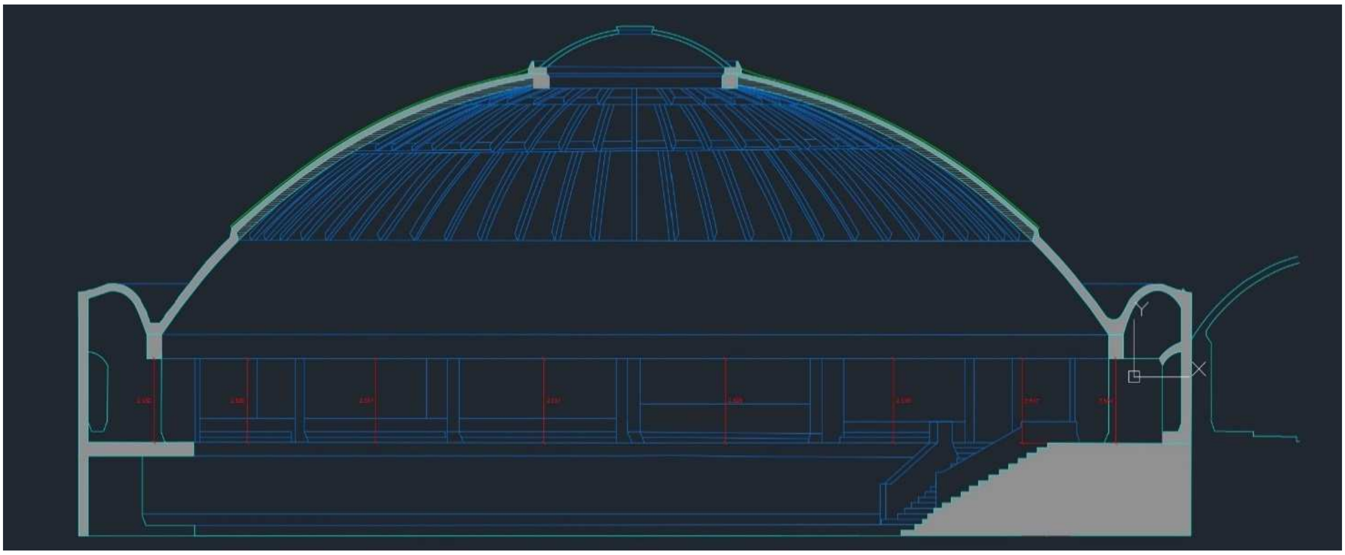


Figure 17 - Cross-section of the choreography theater of the Ballet School.

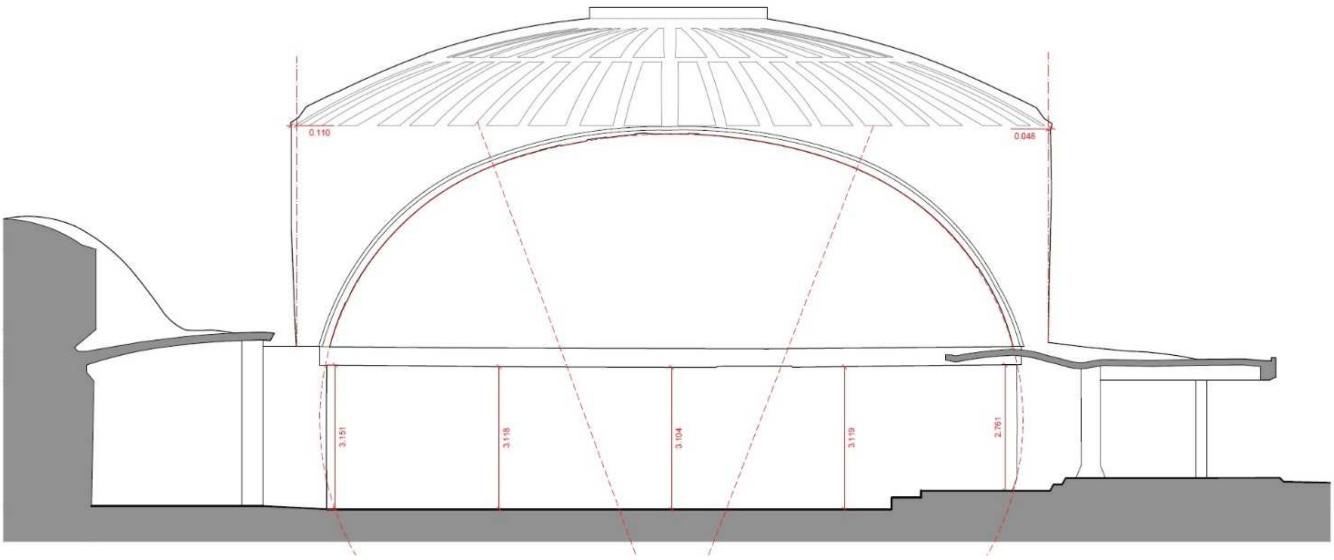


Figure 18 - Cross-section of the domed space of the Ballet School with dimensions and outlines.

5.1.2.3 The GNSS/GPS data and three-dimensional acquisitions

Considering what was done and acquired during the June 2019 mission, the data processing phases were divided based on the priorities that emerged in the research group's study and analysis. For this reason, it was preferred to begin the point clouds processing as it proved to be the most expensive time-consuming operation and, at the same time, the more useful one for the systematization of the cartographic, geometric, and planimetric information of the general area and of about the five schools.

The data obtained using differential GNSS instrumentation were processed to anchor, through absolute positions and altimetry, the two detailed surveys concerning the Schools of Plastic Arts and Ballet. The process gave excellent results as it was possible to obtain the coordinates of 7 points (Figure 19 and Table) with a maximum zenith deviation of 5 cm and 10 cm in elevation[9]. The 19 coordinates acquired with portable GPS instruments were also post-processed to verify their quality and precision. In this case, the metric accuracy was lower due to limits directly attributable to the instrumentation adopted, due to the presence of a dense and covering vegetation with tall trees, reaching a maximum difference of about 50 cm in plan (Figure 20).

Figure 19 - "Bing VirtualEarth" aerial image and positioning (in yellow) of the 7 GNSS points.

[9] For further information about the GNSS acquisition and processing see Annex 5C GNSS processing and Annex 2B GNSS and Laser Scanner Survey.

Table 1 - Coordinates of the 7 GNSS points in the WGS84 and NAD83 coordinates reference system.

	WGS84 - use ITRF2008						
	Lat N	Lon W	Ell_Ht	Northing	Easting	Zone	Elev
CHIN	24° 33' 1.72570"	81° 48' 25.65923"	-15,144	2715413,698	418257,383	17	8,365
GCEA	19° 17' 34.86951"	81° 22' 40.88361"	16,073	2133293,197	460283,030	17	31,304
GPS01	23° 5' 24.67117"	82° 26' 56.08499"	-12,658	2554239,417	351601,038	17	9,628
GPS02	23° 5' 26.78626"	82° 26' 54.08635"	-13,051	2554303,907	351658,554	17	9,242
GPS03	23° 5' 13.90150"	82° 27' 6.04003"	-12,465	2553910,985	351314,481	17	9,784
GPS04	23° 5' 13.56768"	82° 27' 8.76559"	-19,008	2553901,489	351236,822	17	3,240
GPS05	23° 5' 10.41770"	82° 26' 51.86611"	-3,339	2553799,831	351716,739	17	18,891
GPS06	23° 5' 17.97296"	82° 26' 35.62761"	-11,566	2554027,637	352181,106	17	10,687
GPS07	23° 5' 24.06053"	82° 26' 34.32496"	-8,966	2554214,506	352220,023	17	13,310
UNPM	20° 52' 6.60680"	86° 52' 5.43058"	-0,436	2307600,113	513712,372	16	11,355
	NAD83 (2011)						
	Lat N	Lon W	Ell_Ht	Northing	Easting	Zone	
CHIN	24° 33' 1.70871"	81° 48' 25.64262"	-13,515	2715413,6980	418257,3825	17	
GCEA	19° 17' 34.85745"	81° 22' 40.86883"	17,823	2133293,1967	460283,0305	17	
GPS01	23° 5' 24.65569"	82° 26' 56.06812"	-11,003	2554239,4171	351601,0382	17	
GPS02	23° 5' 26.77078"	82° 26' 54.06948"	-11,396	2554303,9071	351658,5536	17	
GPS03	23° 5' 13.88602"	82° 27' 6.02316"	-10,810	2553910,9853	351314,4807	17	
GPS04	23° 5' 13.55220"	82° 27' 8.74872"	-17,353	2553901,4889	351236,8224	17	
GPS05	23° 5' 10.40222"	82° 26' 51.84924"	-1,684	2553799,8312	351716,7394	17	
GPS06	23° 5' 17.95748"	82° 26' 35.61074"	-9,911	2554027,6368	352181,1064	17	
GPS07	23° 5' 24.04505"	82° 26' 34.30809"	-7,311	2554214,5064	352220,0226	17	
UNPM	20° 52' 6.59439"	86° 52' 5.40974"	1,209	2307600,1134	513712,3717	16	

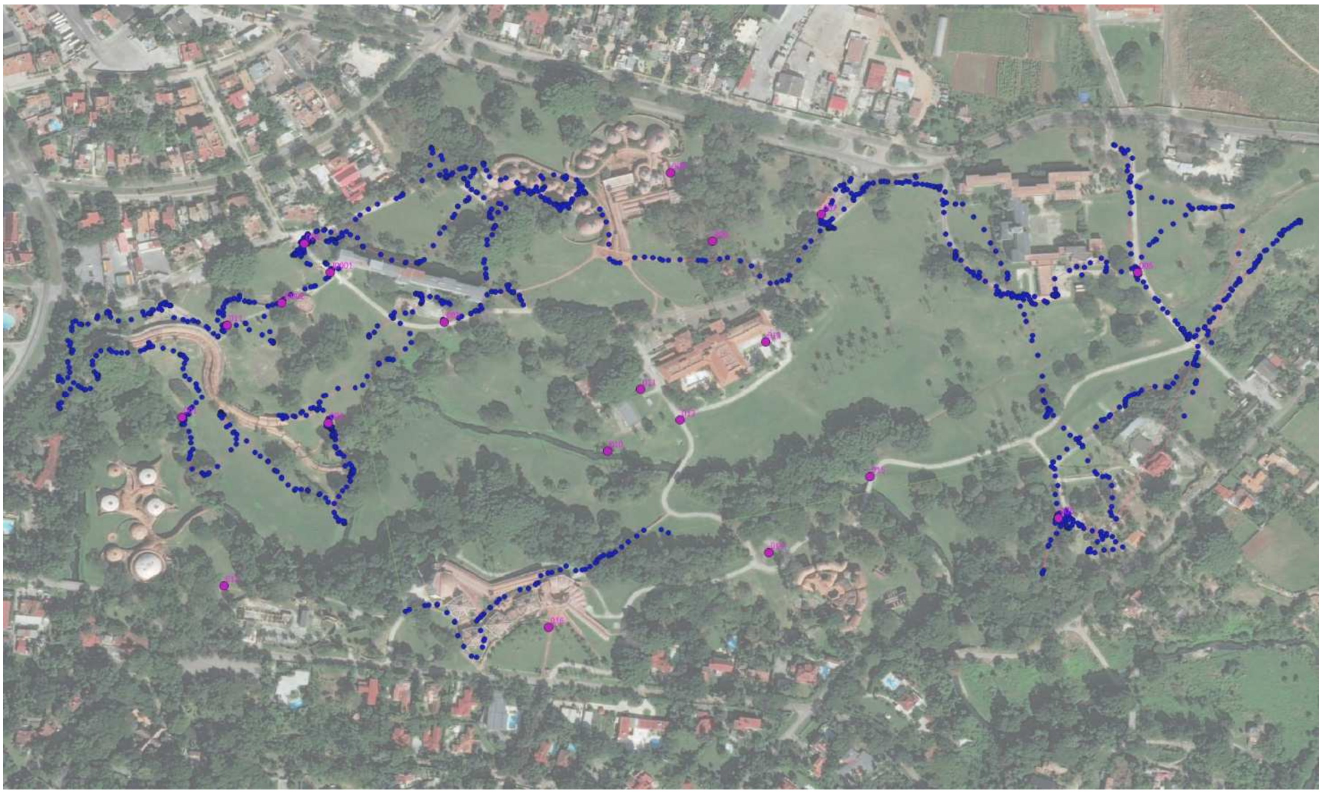
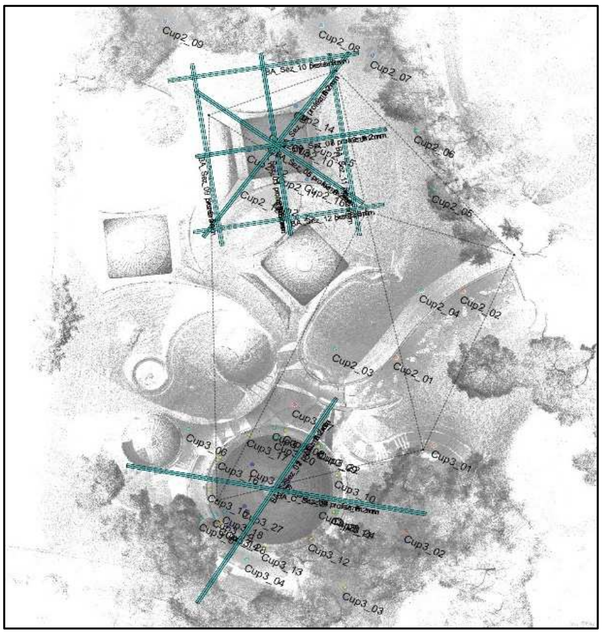


Figure 20 - "Bing VirtualEarth" aerial image, positioning of the 19 fixed GPS points (in pink) and the points acquired all over the area (in blue).

The three-dimensional information obtained by laser scanner was then roto-translated, basing the process on the GNSS points, and subsequently exported to two-dimensional plans (Figure 21 and Figure 22) ready to be inserted within the G.I.S. system.



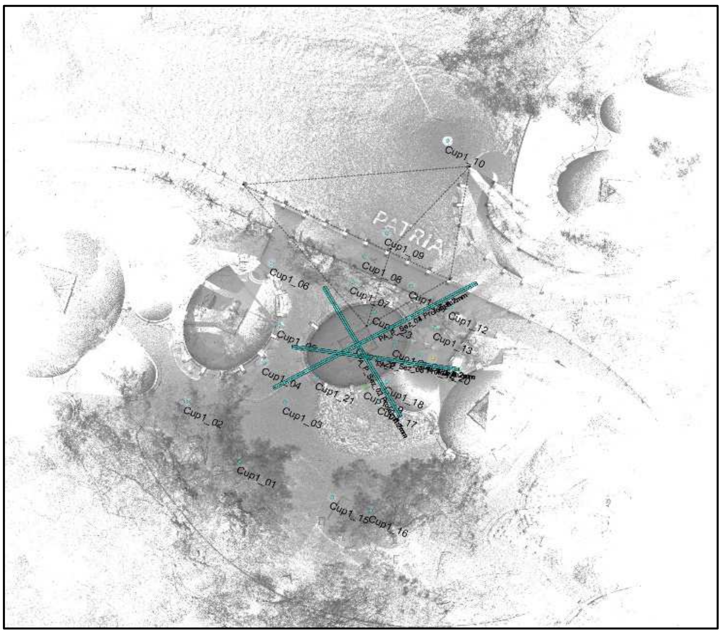


Figure 21 - Point cloud of the Ballet School, zenith projection; Figure 22 - Point cloud of a portion of the Plastic Arts School, zenith projection.

The planimetric and altimetric coordinates acquired by means of a precision GNSS antenna and the detailed point clouds of the Ballet School and Plastic Arts School were subsequently used as a basis for the long-range positioning three-dimensional elaborations performed using laser scanner instrumentation[10].
Although this instrument internally has a gyroscope, a compass, and a reliable GPS sensor (maximum planimetric deviation of 25 cm and absolute rotation of 3°), it was preferred to use the previously processed data as more consistent and due to the resulting reduced metric difference.
It was, therefore, possible to extract the common absolute coordinates between the detailed and long-range clouds to calculate the roto-translation parameter for each of the three created groups ("Union BA_MU", "Union PA", "Union MU_Rec "). This calculation is the result of an average of about 20 common points between the scans[11].
The total area of the laser scanner recordings does not entirely cover the ISA area. Still, it was possible to act on the entire plan of the site using GPS information and single long-range laser scans. Thanks to these data, all the planimetric and altimetric elaborations deriving from the acquisitions have been placed in the space, allowing us to obtain a morphologic and geometric database sufficient for the verification and correction of the planimetric drawings in our possession. It was also possible to export data useful for the validation and integration of the information collected by the other working groups, such as, for example, the altimetry of the bridge located near the Rectorate building. In this case, it was, in fact, necessary to show the elevations of elements of the bridge to allow the calculation of the depth of the Rio Quibù (Figure 23).

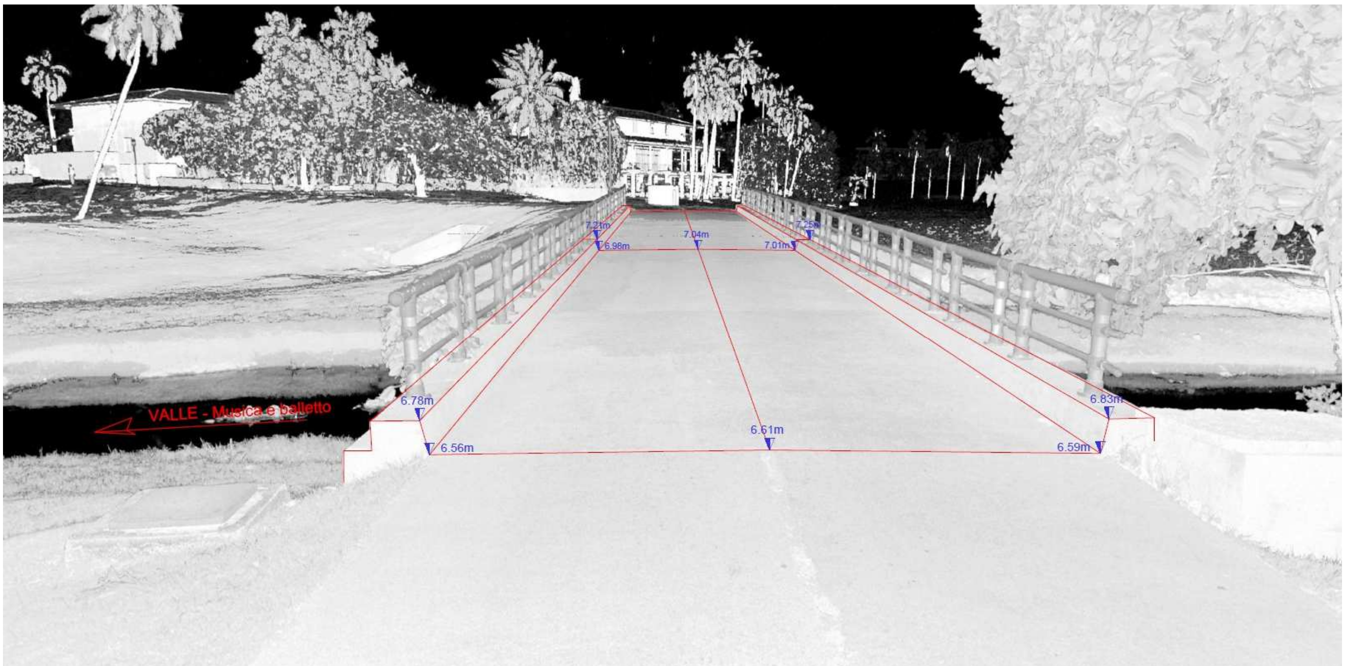


Figure 23 - Absolute elevations of some elements of the bridge near the Rectorate building.

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[10] See 5.1.2.2 3D data as support to the management system

[11] See Annex 5D Roto-translation parameters.

From this three-dimensional database, it was also possible to extract targeted sections of the terrain to better understand the area's morphology, especially regarding the most critical points. We concentrated the analysis on the space between the School of Music and the School of Ballet, where the hydrological dynamics related to the Rio Quibù were difficult to interpret without adequate and reliable graphic and metric support. The elaborations were carried out by merely extracting portions of the georeferenced point cloud (Figure 24), allowing to investigate better the changes in altitude and the points of connection between the ground and the two buildings (Figure 25). A similar methodology was applied to the central portion of the area close to the bridge near the Rectorate building and the building.

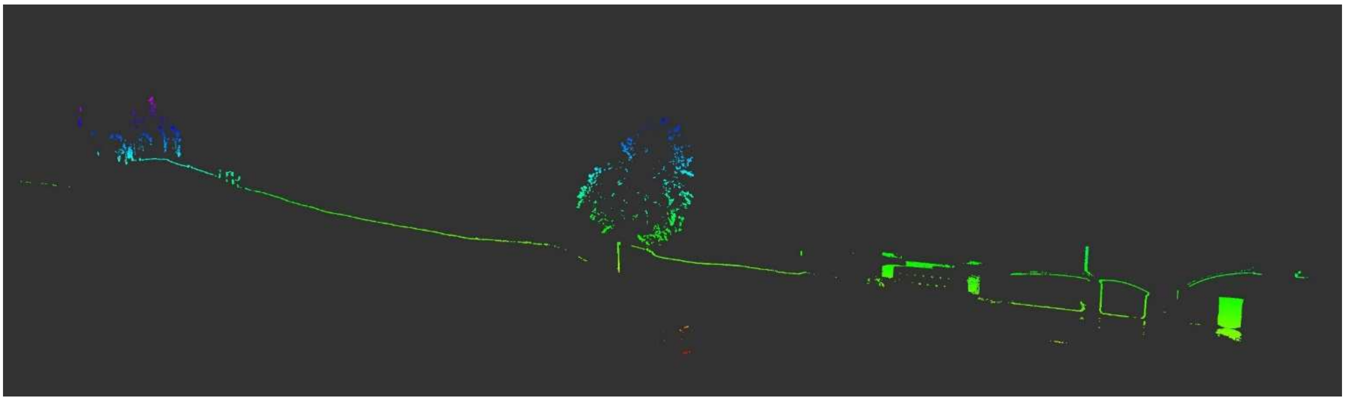

Figure 24 - East-West section of the cloud of points, the colors indicate the difference in altitude.

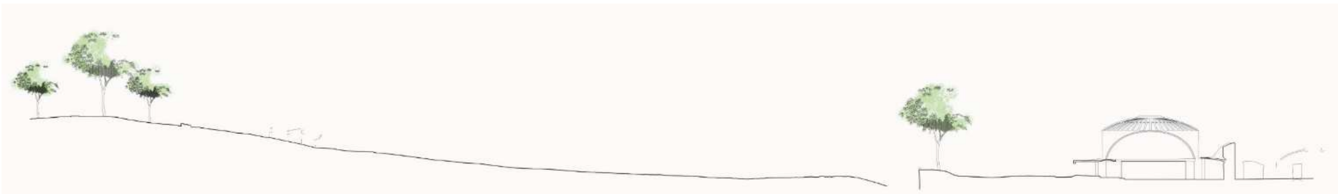

Figure 25 - Vector drawing of the East-West section.

5.1.2.4 DTM/DEM/DSM for the comprehension of the morphology

The information thus acquired and processed made it possible to understand better the morphology of the area and the buildings present, providing a conspicuous aid to the analysis activities. The aims of the project also led to further elaborations of this remarkable three-dimensional geometric database. One of the needs, especially for the flood risk analysis[12], was to understand the ground trend in all areas near the Rio Quibù, especially in the ISA's central and western part, therefore from the bridge near the rectorate building up to bridge 15. As previously indicated, the territorial sections allowed a greater understanding of the elevation changes, but only at the local level where the section plans were placed. For this reason, further elaborations have been performed starting from

[12] See Action 3 Landscape management and flood risk assessment and mitigation.

the complete cloud of points (BA_MU + MU_Rec) to obtain digital models of the terrain and surfaces. The first processing step was to classify the points into two categories: terrain and objects in elevation, including vegetation and buildings. This operation also made it possible to eliminate some points or entire areas acquired as they are not useful for creating a territorial digital model. Considering the high number of points acquired to adequately define the buildings and the spaces connected to them (about 10 billion points), it was necessary to decimate the three-dimensional database to make it more suitable for territorial-type processing without losing the essential information. The "terrain" category was then divided into squares of a 1-meter side and was decimated to contain about 150 points per square meter, more than enough to define the morphological trend. For the second category, we proceeded differently. All the points referring to this level were decimated on a percentage basis and reduced by 95% of the initial amount. This level aimed to indicate the position of these elements to be inserted on the digital terrain model. Finally, a comprehensive database was created by combining the two levels into a single generic container. The three levels were subsequently used to generate TIN surfaces (Triangulated Irregular Network) with a reasonable degree of definition and approximation concerning the starting point clouds to define the surfaces as closely as possible to reality. This operation was performed without interpolation algorithms and only on the data in our possession. Hence, the areas with undetected spaces were not modeled and therefore left empty, obtaining an accurate three-dimensional reconstruction since only areas corresponding to dense point cloud points were reconstructed. However, considering the complexity of the site and the non-homogeneous density of the complete point cloud, it was decided to create an additional set of models, excluding the level with elevation only, using both interpolation and data extrapolation algorithms in such a way as to fill the undetected spaces and generate surfaces extended to the hidden areas. This choice had the primary purpose of modeling above all the small portions of the ground not directly detected by the scanner, thus creating a continuous development of the morphology. The areas created by the algorithms were finally verified and removed in case of inconsistencies with the real trend.
These elaborations have, therefore, led to obtaining the following models:

- Digital Terrain Model (DTM) not interpolated (Figure 26);
- Digital Terrain Model (DTM) extrapolated (Figure 27);
- Digital Elevation Model (DEM) not interpolated (Figure 28);
- Digital Surface Model (DSM) not interpolated (Figure 29);
- Digital Surface Model (DSM extrapolated) (Figure 30).

To simplify reading the digital models, an artificial lighting source was added in a three-dimensional environment to create more or less marked shadows based on the ground's slope. This operation made it possible to recognize the soil's discontinuities more efficiently and, above all, the principal critical points from the point of view of flood risk. Lighting was added to all models (Figure 31 - Figure 33), and separate maps were exported in such a way as to allow them to overlap (Figure 34).

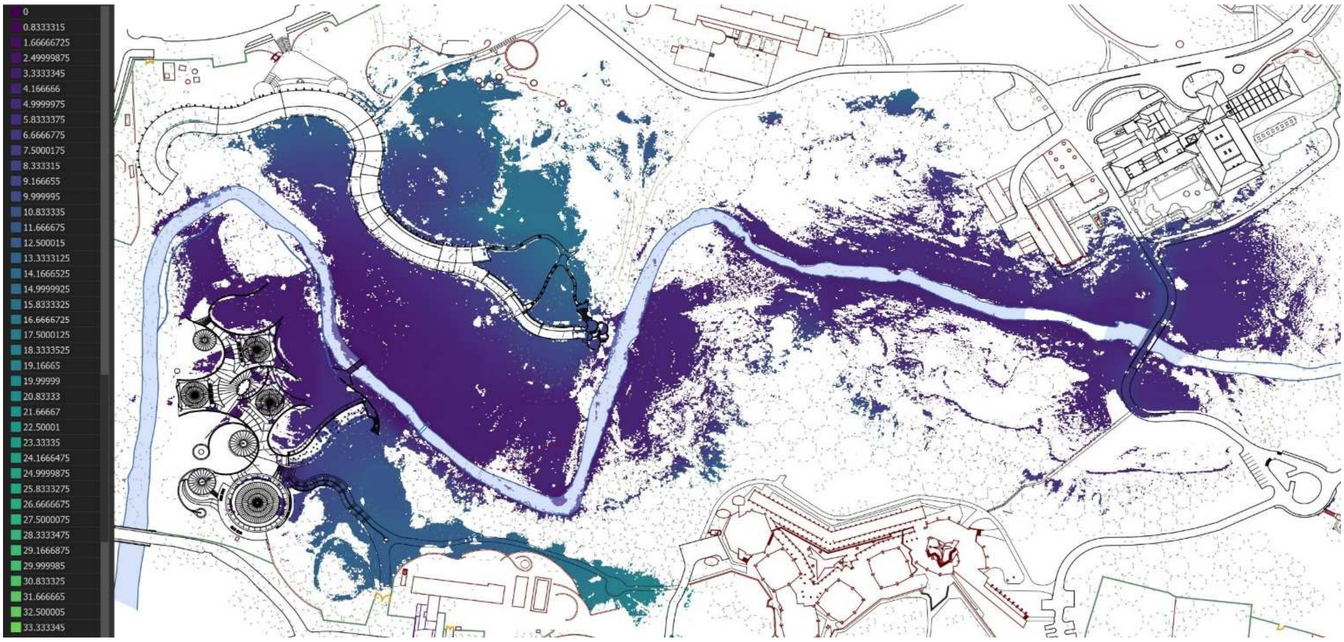

Figure 26 - "Plan Rector" map superimposed on the not interpolated DTM.

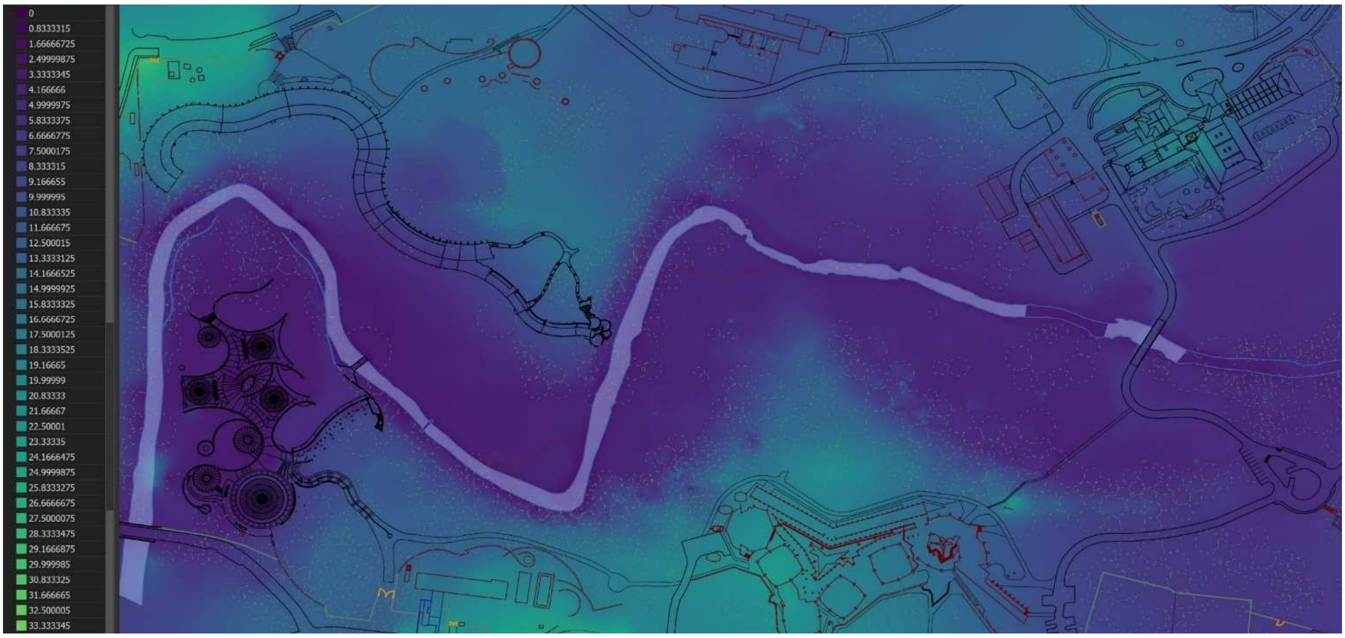

Figure 27 - "Plan Rector" map superimposed on the interpolated and extrapolated DTM.

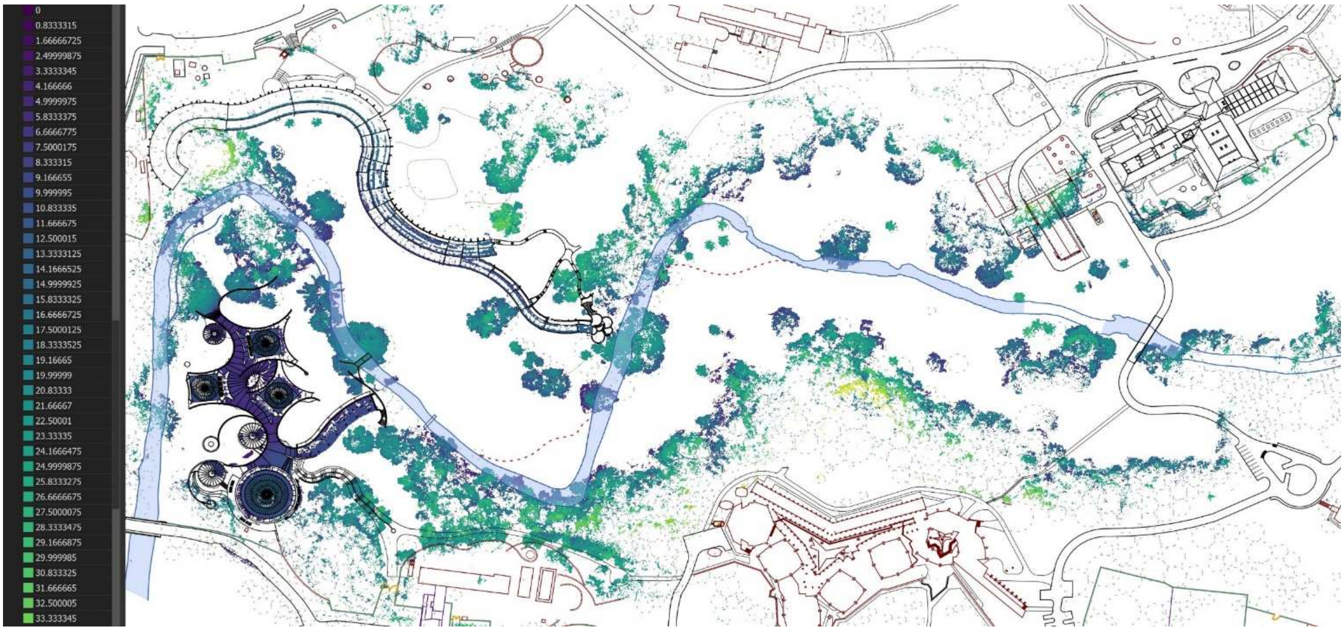

Figure 28 - "Plan Rector" map superimposed on the not interpolated DEM.

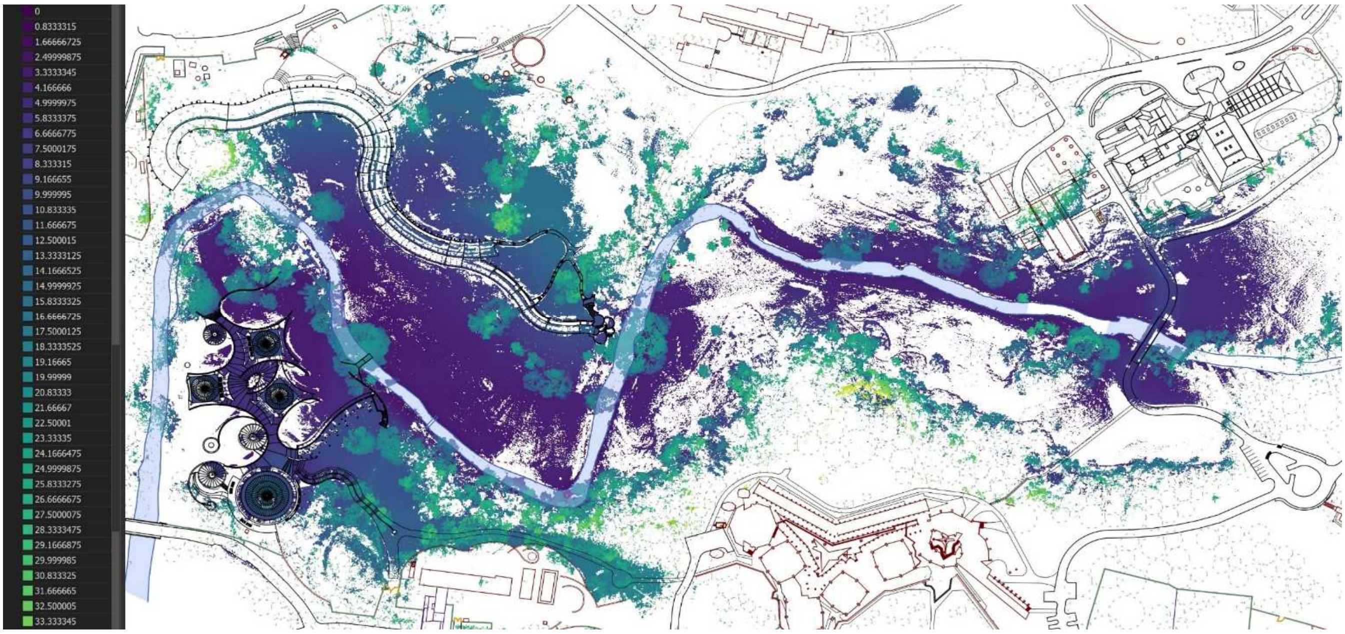

Figure 29 - "Plan Rector" map superimposed on the not interpolated DSM.

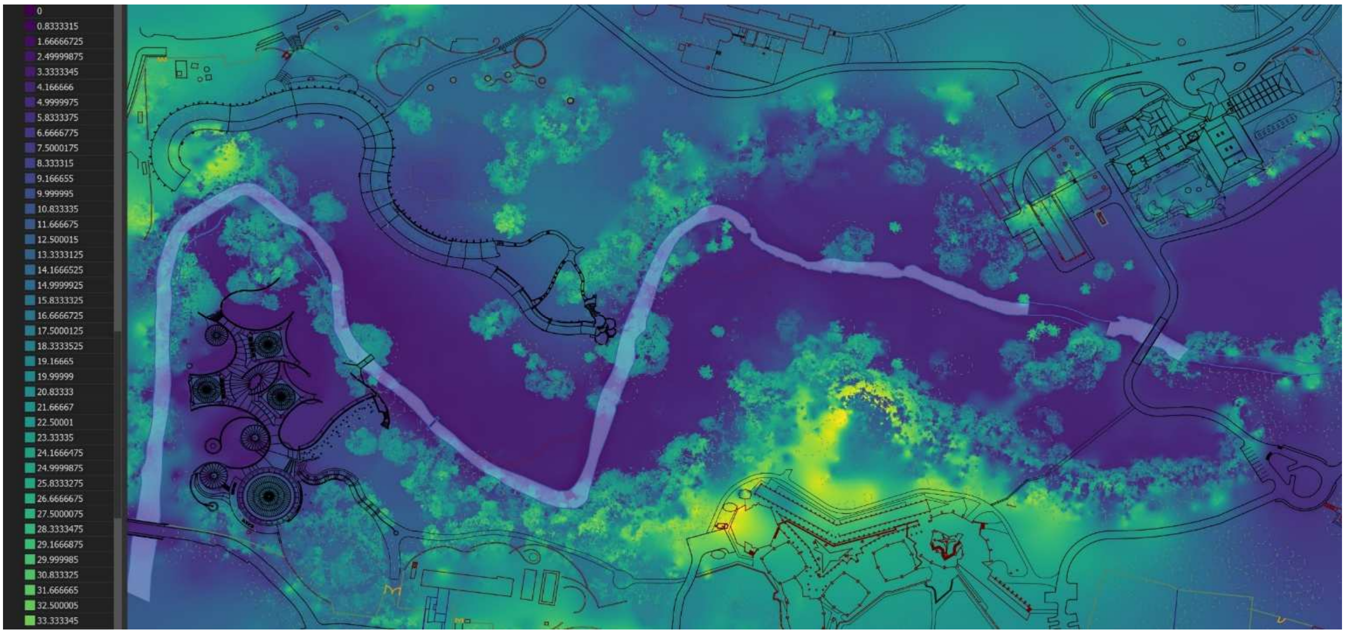

Figure 30 - "Plan Rector" map superimposed on the interpolated and extrapolated DSM.

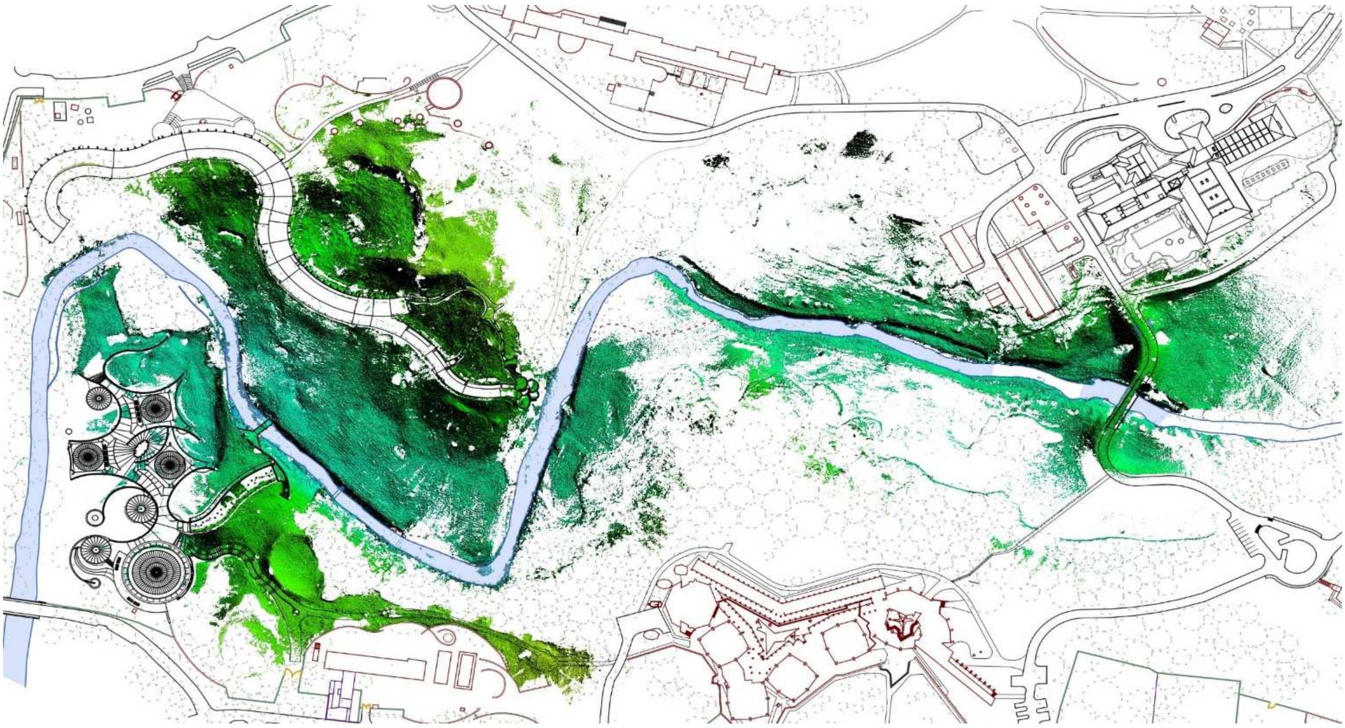

Figure 31 - "Plan Rector" map superimposed on the not interpolated shaded DTM.

Figure 32 - "Plan Rector" map superimposed on the not interpolated shaded DEM.

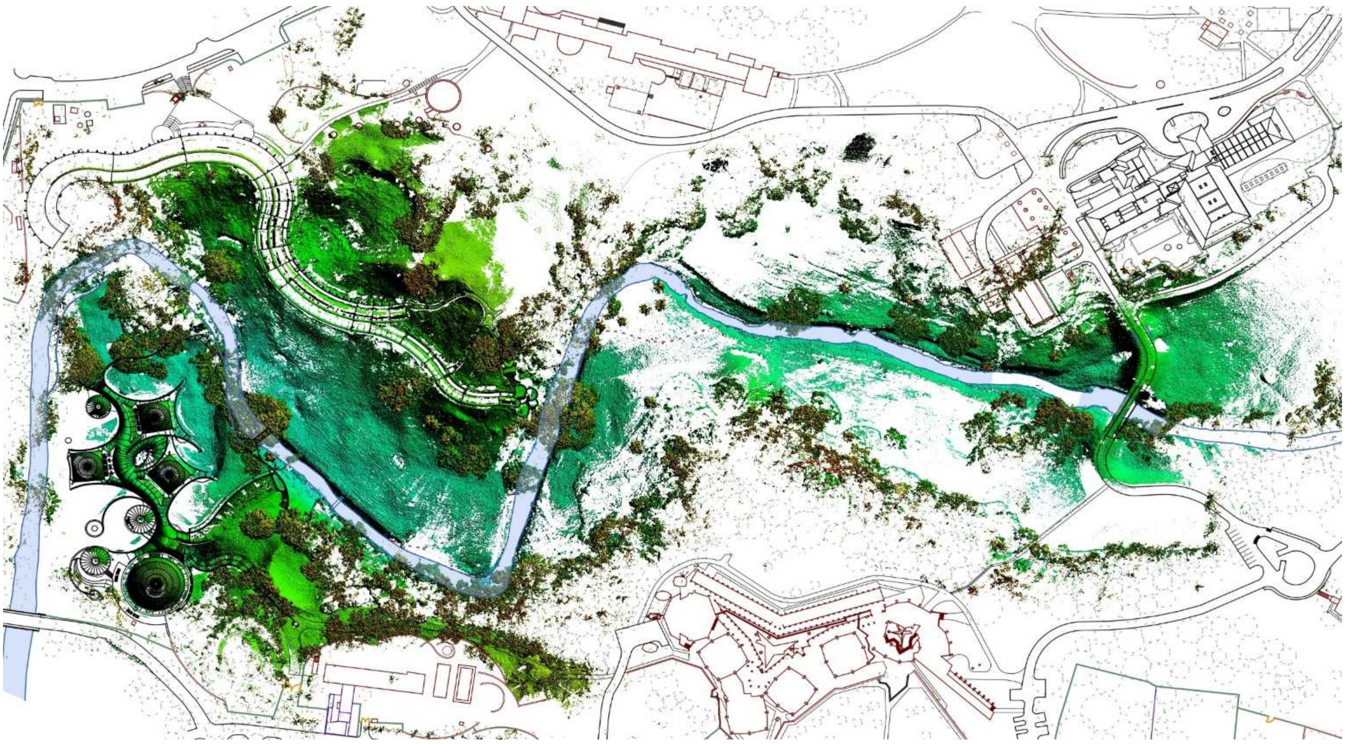

Figure 33 - "Plan Rector" map superimposed on the not interpolated shaded DSM.

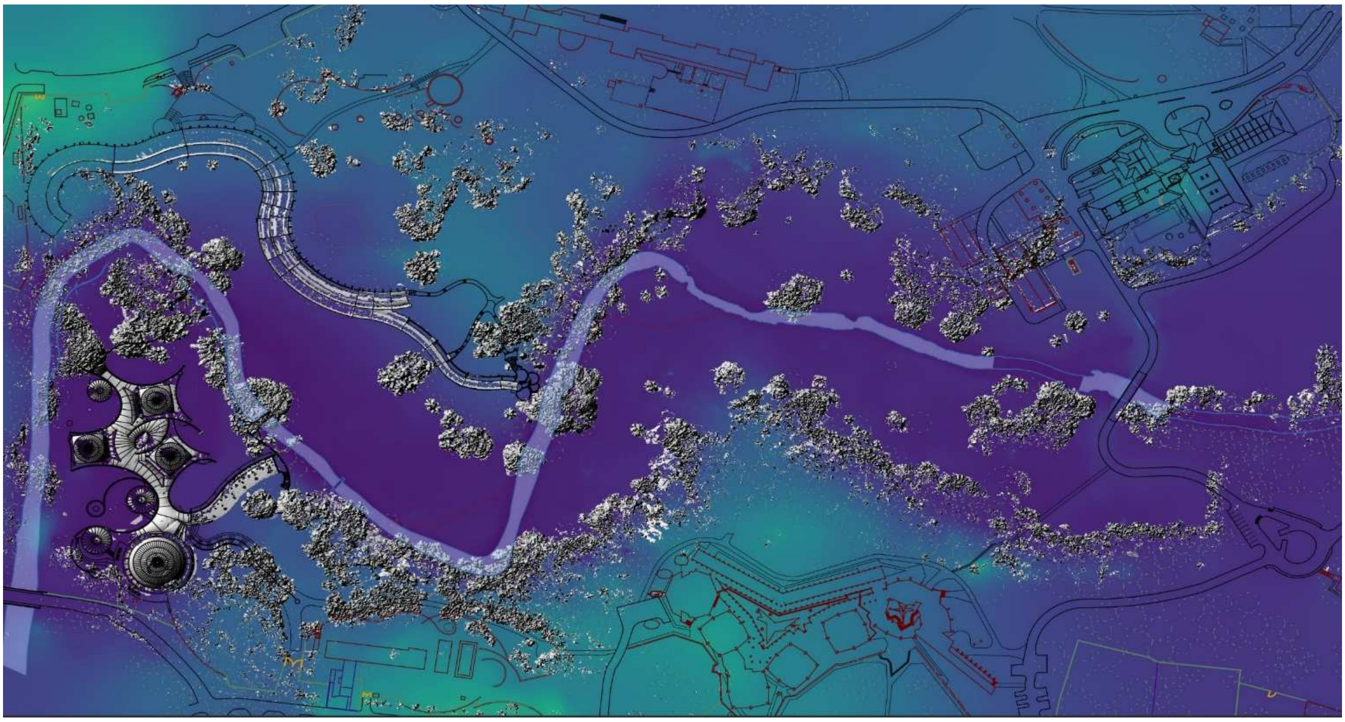

Figure 34 - "Plan Rector" map and shaded DEM superimposed on the not interpolated DTM.

The results showed that it was finally possible to simplify the DTM to obtain the contour lines' linear trend that characterizes the area. This last process permitted to create two different levels of simplification and contour, the first every 50 centimeters (Figure 35) and the second instead every 100 centimeters (Figure 36).

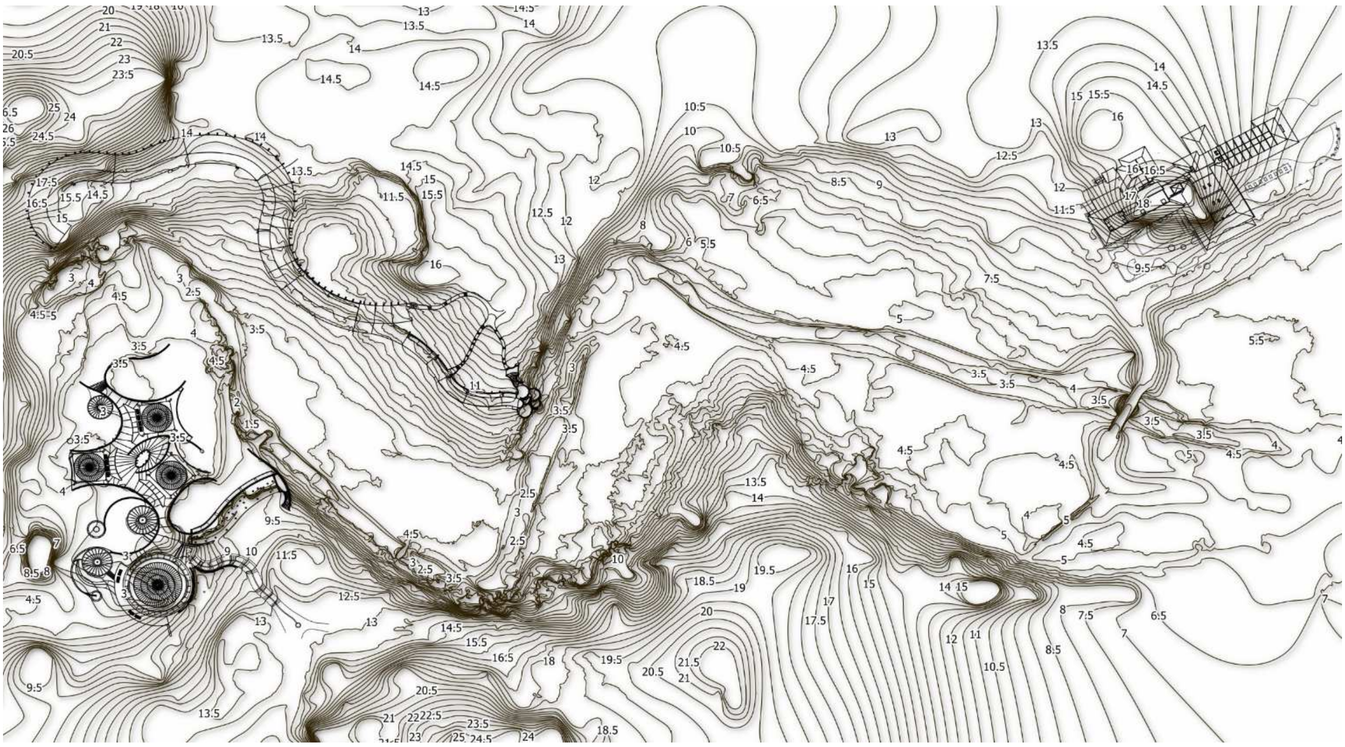

Figure 35 - Contour lines every 50 cm.

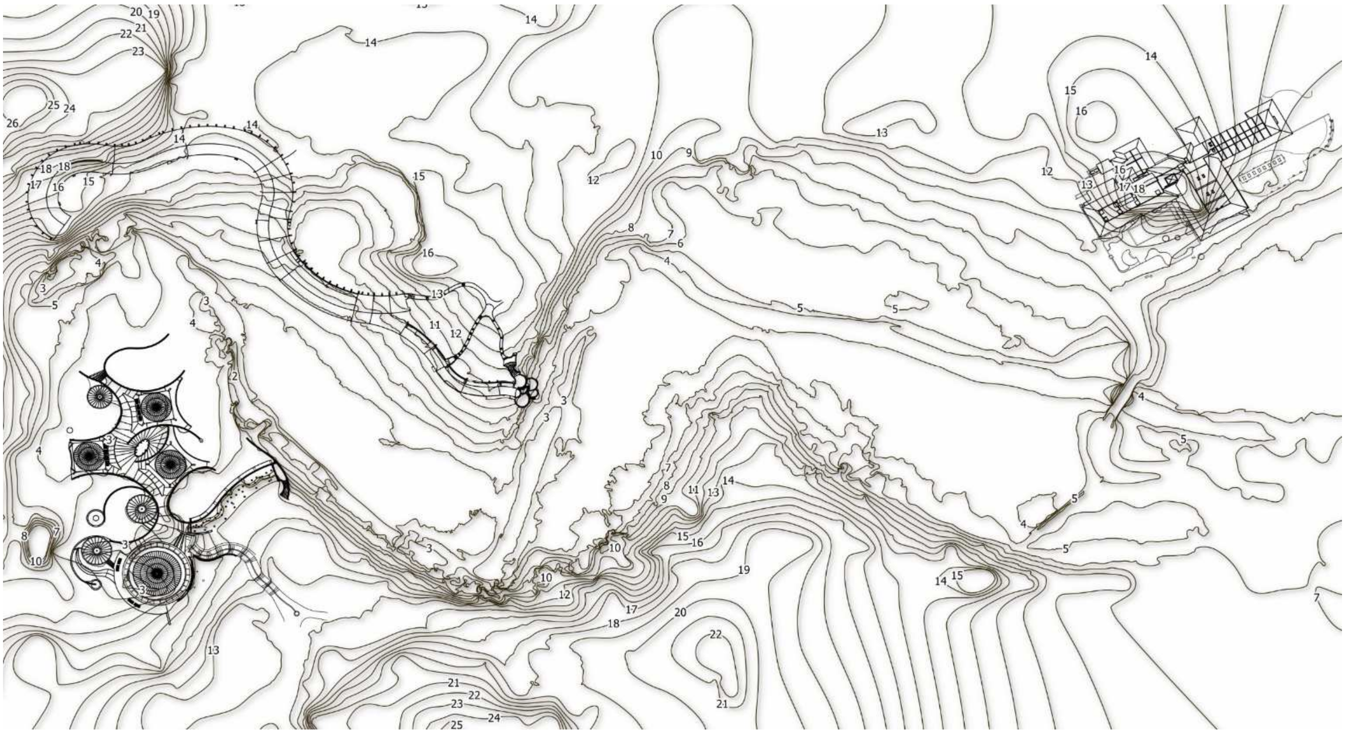

Figure 36 - Contour lines every 100 cm.

5.1.2.5 Update and correction of large- and small-scale vectorial drawings

After selecting the cartographies, elaborating the GNSS/GPS data and the three-dimensional acquisitions, the next step involved the creation of some test levels through punctual, linear, and areal "shapefiles" and the insertion of different vectorial levels created outside to the project into the draft version of the G.I.S. system. This made it possible to identify any criticism related to the reference system chosen. Besides, it allowed verifying the graphic representation options, identifying a first chromatic range to be used.

Similarly, the vector files .dwg or .dxf have been inserted within the management system to evaluate critical issues and procedures to be carried out. For this reason, some tests were conducted to import vector documentation, which manifested some compatibility problems. The drawings (both the school plans and the general plan - "Plan Rector") were made using mainly the "*sp-line*" function in the native vector software, and they cannot be imported directly into the G.I.S. as they are not correctly recognized and so not allowing adequate spatial queries.

The elaborations consequently concerned the vectorial materials already collected, starting from the general plan drawing of the area, the 2006 "Plan Rector"[13] with subsequent additions was used. This presented numerous layers, sometimes repetitive or not associated with specific elements and categories. Therefore, we chose to analyze and systematize the different spatial levels, reducing them to the minimum necessary for the representation of the elements of the area. Before the June 2019 mission, a comparison was made between the most recent aerial photo

[13] Made by EMPROY-2 Arquitectura e Ingenieria, ISA archive.

("Bing VirtulEarth", January 2019) and the ISA's vector drawing to highlight any critical interpretation issues. Many levels did not have a clearly attributable wording, resulting in complex allocation in the new coding grid, or they represented geometries and spaces that cannot be distinguished in the aerial photo.

For this reason, it was decided to move the unknown or unverifiable elements into two different levels checked directly on-site during the 2019 and 2020 inspections. This systematization has therefore led to the definition of a new list of levels divided by macro-categories (Conservation Management Plan, Plan Rector, Actual State, Topographic net, to Verify) and sublevels, to which the graphic characteristics have been associated (Table 2).

Field activities began with a first inspection concerning the areas and the elements with creating a general graphic elaboration of the site indicating the elements present. Subsequently, a planimetric register of the elements that differed from the available bases was created. The dimensions of some elements (roads, paths, buildings, or architectural elements previously identified) were acquired through the direct survey.

Finally, a general photographic survey divided by spatial elements and/or areas was created. Some panoramic spherical images (63 full color and high-definition images, 98 spherical grayscale images) were acquired for the virtual visit/inspection of the main areas and buildings[14]. A further problem encountered was related to the metric and morphological accuracy of the materials. The vector plans differed considerably from the precision measurements made during the June 2019 mission and subsequently processed. For these reasons, considering that it would have been necessary to intervene on the vector drawings, it was decided to make the required geometric and morphological changes to obtain a reliable and accurate database of geometric information (Figure 37).

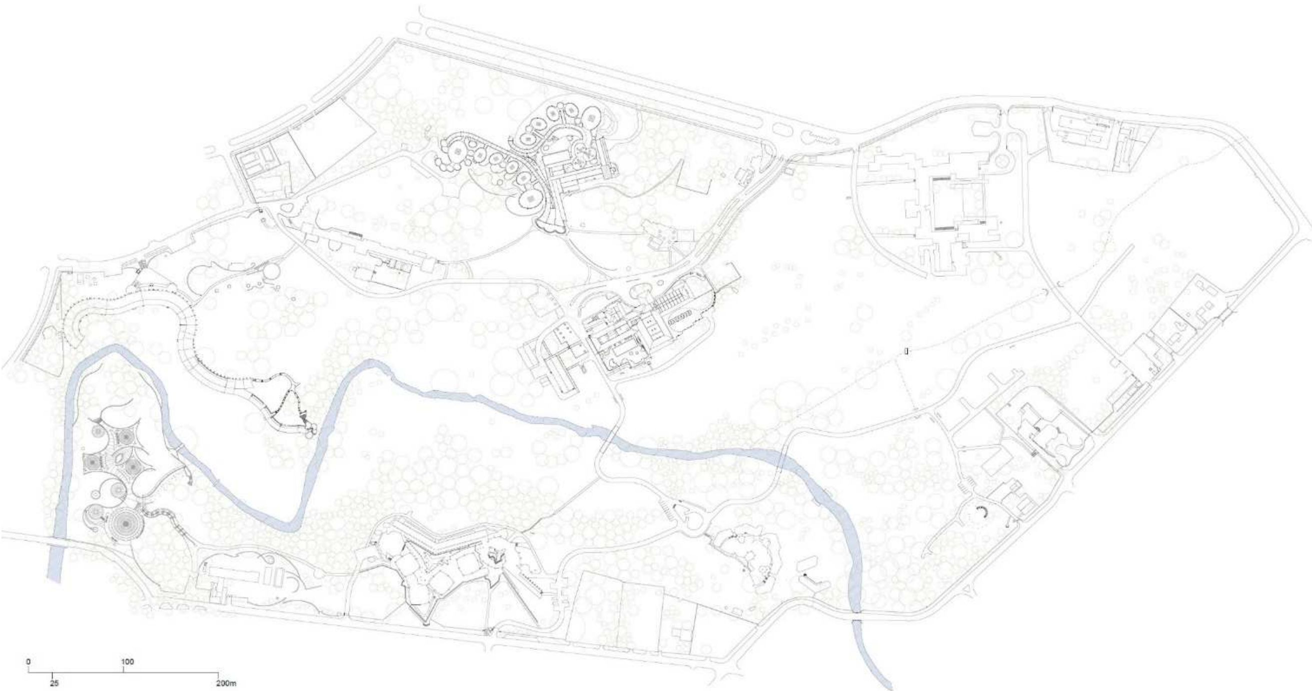

Figure 37 - New version of the "Plan Rector". In evidence, there are also the roof level plans of the four buildings detected during the inspections (Rectorate building, School of Plastic Arts, School of Music, and School of Ballet)

[14] For further details see Dissemination: The immersive visualization system.

Table 2 - List of macro-categories, layers, and brief description.

GROUP	Title	Description
CP	**Conservation Management Plan**	
	CP_codes	Categorization of the elements
	CP_picture	Aerial image of the area
	CP_school plan	Project drawings of the National Art Schools
PR	**Plan Rector**	**Project drawings**
	PR_demolitions	Demolition project
	PR_plants	Landscape project - trees
	PR_unrealized project	Project not realized
S	**Actual State**	**Actual area and building (verified on orthophoto)**
	S_bridge	Bridges over Rio Quibù
	S_buildings	Existing buildings and plan
	S_contour lines 100cm	Contour lines obtained by topographic survey every 100 cm
	S_entrance	Entries to the area
	S_external area	Definition of the area outside the ISA
	S_fencing	Fencing around the area
	S_lighting system	Lighting system in the area with description
	S_path	Existing paths in the area
	S_rio	Drawing of the Quibù river within the area
	S_rio banks	Marked perimeter of the banks of the Quibù river
	S_rio flood area	Flood areas of the Quibù river
	S_slopes	Differences in altitude near buildings
	S_streets	Existing streets in the area and around it
	S_text	Name of schools and buildings in the area and other indications
	S_trees	Existing trees in the area, unknown type
	S_tree trunks	Tree trunks in the area
T	**Topographic net**	**Topographic Survey**
	T_altitude	Value and altitude
	T_coordinates	Coordinates of the areas
	T_numbers	Numbers associated with altitudes
	T_topographic net	Topographic survey net of the area
V	**to Verify**	**Object to be verified during the 2019 and 2020 inspections**
	V_to verify	Objects connected to the actual state or the project phase
	V_unknown symbols	

The plans on which we worked concern both the larger scale, "Plan Rector", and the building scale, the three schools (School of Ballet, Music and Plastic Arts) and the Rectorate building directly detected by laser scanner instrumentation. The other buildings' plans have been modified only from the vector drawing method's point of view as they were not directly detected. The area east of the Rectorate building, on the other hand, also involved a correction of the geometric information thanks to the GPS/GNSS data and some individual laser scans.

As previously described, the cartographic documentation comes from different sources. It presents very inhomogeneous levels of detail and accuracy, not allowing to extract univocal dimensional data useful to anchor the information to specific geographical points.

Even the vector drawings of the entire area presented the same geometric problems and distortions, together with the lack of specification and characterization of some levels that make them up. The verification and systematization of these drawings and the geometric control of all the cartographic elaborations constitute a fundamental step in recovering materials that are now difficult to acquire or produce. Thus, it was possible to create a specific and univocal database to connect the project results and share materials with the entire workgroup even during the different processing phases.

Therefore, we dealt with the plans on an architectural scale, which is the second level of deepening of the CMP, particularly focusing on the School of Ballet, Music, and Plastic Arts, for which it was possible to define the building morphology based on the laser scanner survey. This operational phase aimed to obtain architectural scale planimetries (1:100 and 1:200) corresponding to the current condition (as-built), using simple and straightforward levels. The first step was to elaborate the floor plans from original vector files within the Quantum G.I.S. software to convert them into shapefiles.

To achieve this result, several operations were performed. The vector file was placed and rotated based on the georeferenced laser scanner survey to compare the vector planimetry with the point clouds and start the geometric and morphological correction operations. The plans' organization was also based on a new simplified structure of layers (Table 3).

By positioning the vector plan on the cloud, it was possible to draw with high accuracy the horizontal sections of the buildings for all the levels present in each of them. This operation was carried out through the following steps: a) correction of the vector drawings according to the corresponding cloud; b) drawing of the most complex elements through the "*poly-line*" function; c) rotation of the illustrated elements according to the position of the point cloud; d) for the areas and features not acquired by laser scanner only layer correction and drawing with "poly-line" function according to the general acquired morphology. All the elaborations in plan are represented and referred to well-defined points to place them not to lose the absolute positioning reference (Figure 38 and Figure 39).

With the same methodology, the western part of the "Plan Rector" was arranged up to the Rectorate building. In contrast, the vectorial levels were arranged for the eastern part, and the primary geometries were verified using GPS/GNSS data.

This non-marginal part of the Action 5 was necessary for the principle of in-depth knowledge of the site underlying the CMP. Knowing from an architectural point of view in order to plan interventions on the existing heritage cannot be divided from the study and the correct representation of the elements.

The next mission to the National Art Schools in February 2020 also allowed the final verification of the planimetric materials produced for the four buildings mentioned above and the area's general layout ("Plan Rector"). This verification was necessary as the graphic layouts' modification and updating have proved to be very important. It permitted to refine all the subsequent analysis of the project.

Table 3 - Layers of school plans.

LAYER	Description
Sectioned	Drawing of parts sectioned by the horizontal cutting plane
Ground Projection	Drawing of the elements in the visible projection
Window/Door Frame	Existing windows and doors
High Projection	Drawing of the elements in visible projection at upper levels (e.g., Roofing, skylights)

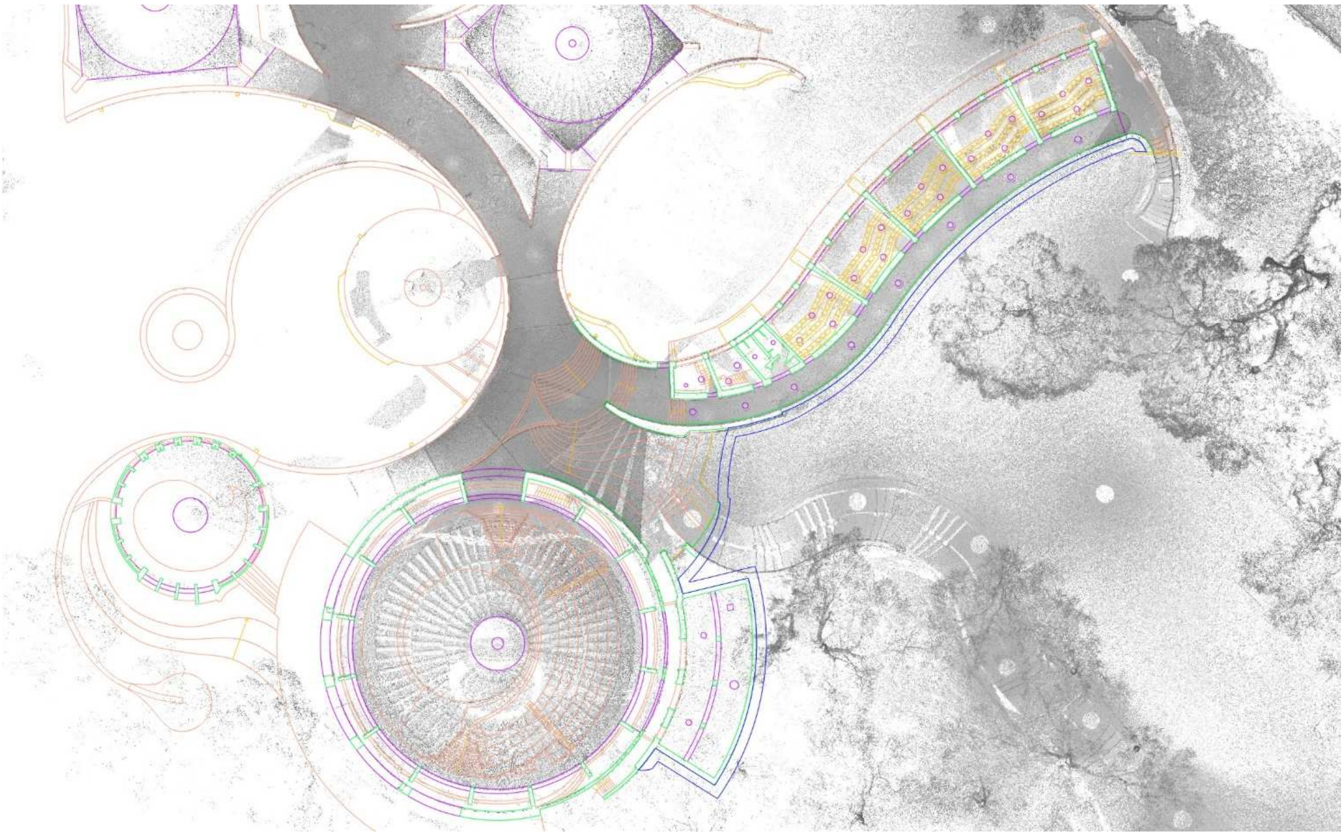

Figure 38 - Vector drawing of the School of Ballet overlapped to the georeferenced black and white cloud of points.

Figure 39 - Vector drawing of the School of Plastic Arts overlapped to the georeferenced colored cloud of points.

Briefly, these are the vector drawings produced for the four buildings:

- School of Ballet, 1:200:
    - First level;
    - Second level;
    - Roof level (Figure 40).
- School of Plastic Arts, 1:200:
    - First level (Figure 41);
    - Roof level.
- School of Music, 1:200:
    - First level;
    - Second level (Figure 42);
    - Roof level.
- Rectorate building, 1:200:
    - First level;
    - Second level (Figure 43);
    - Third level;
    - Roof level.

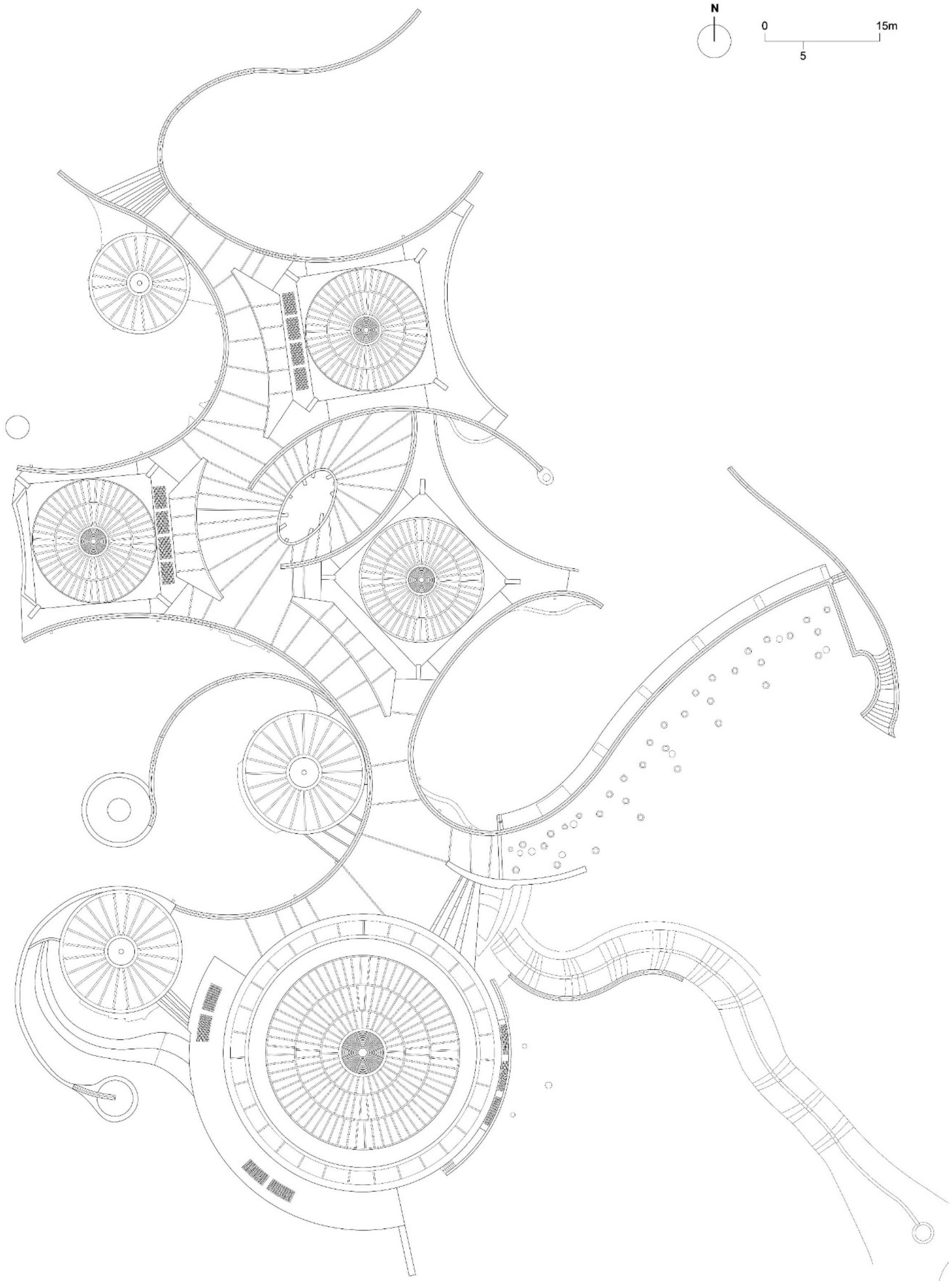

Figure 40 - School of Ballet, roof level.

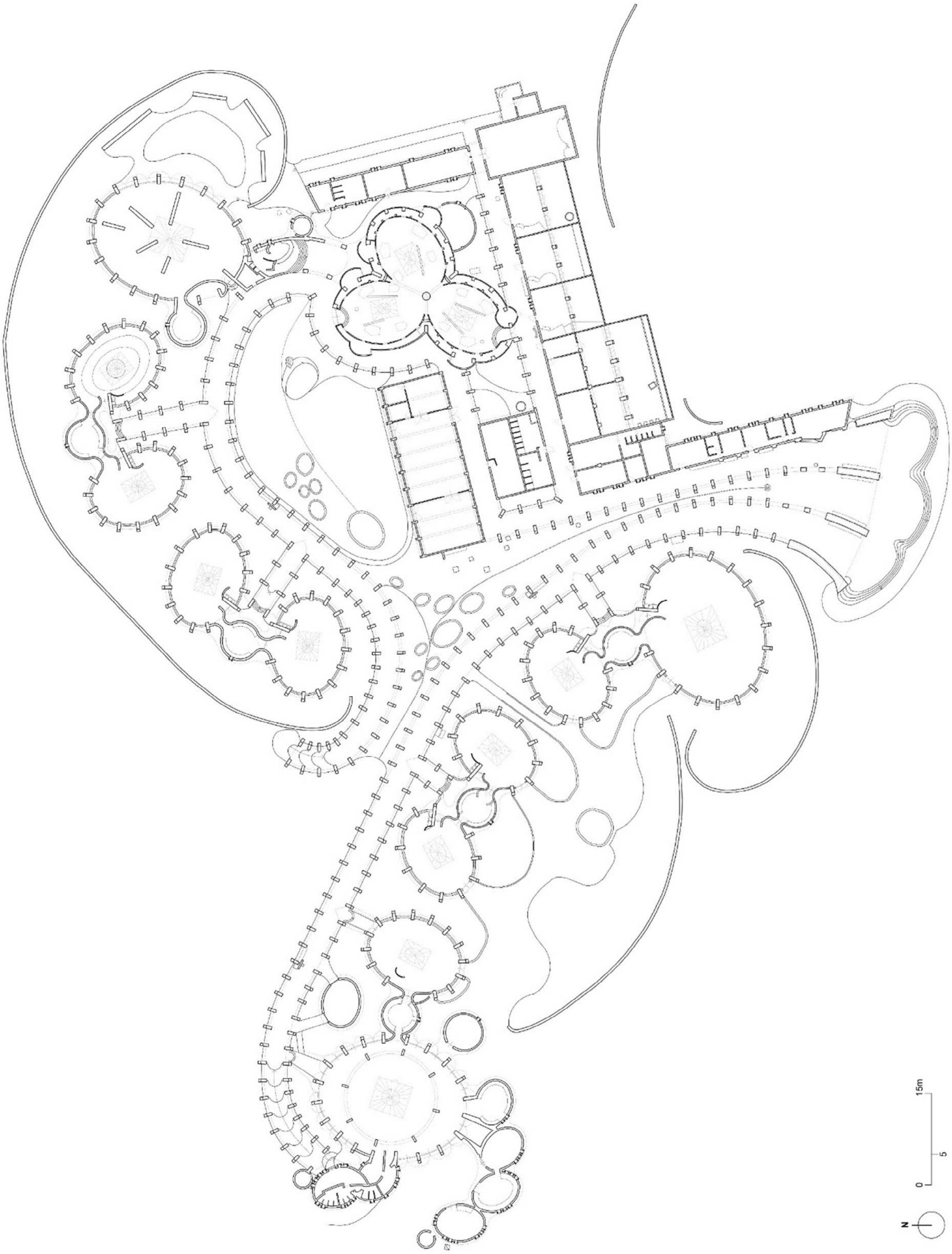

Figure 41 - School of Plastic Arts, first level.

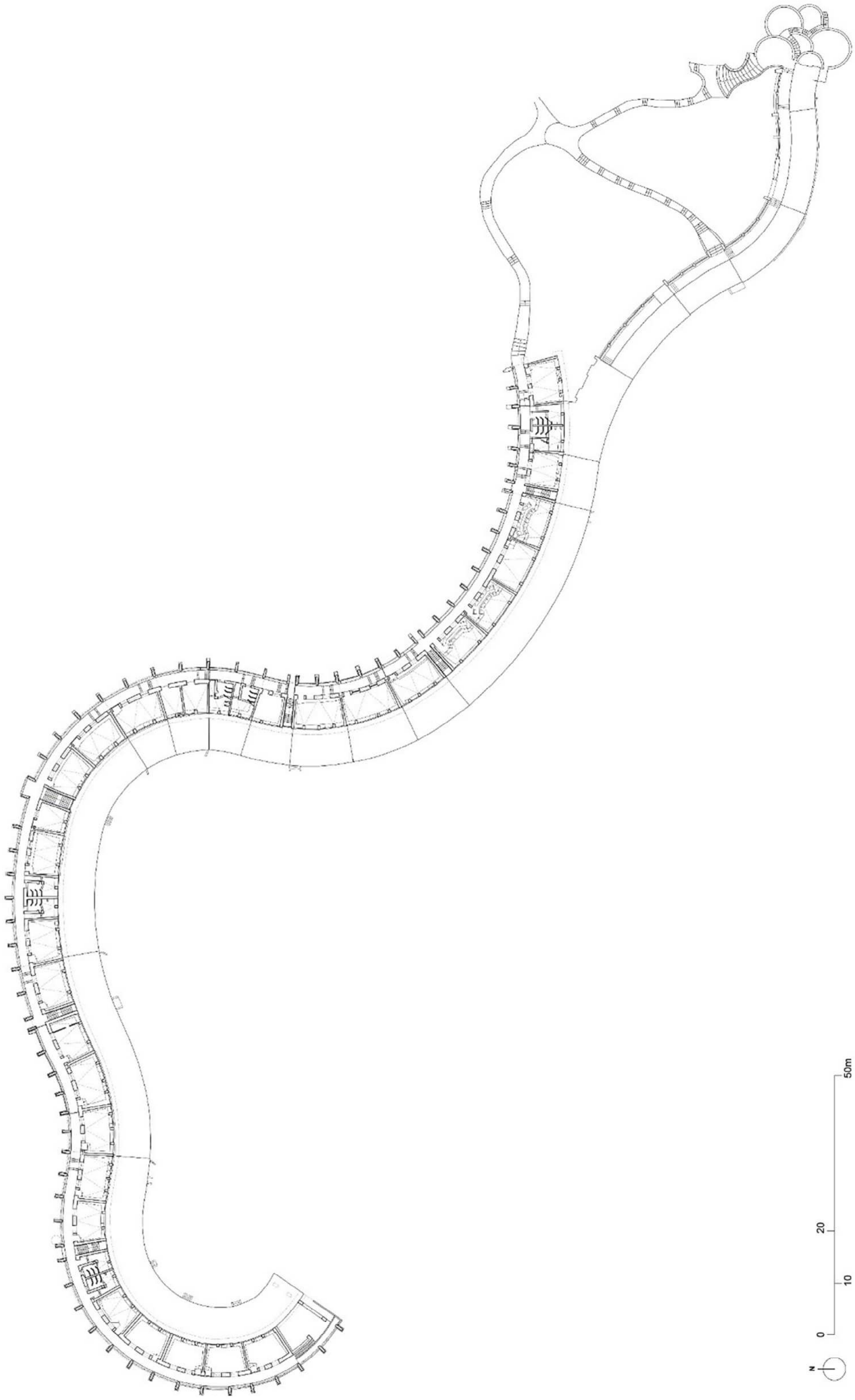

Figure 42 - School of Music, second level.

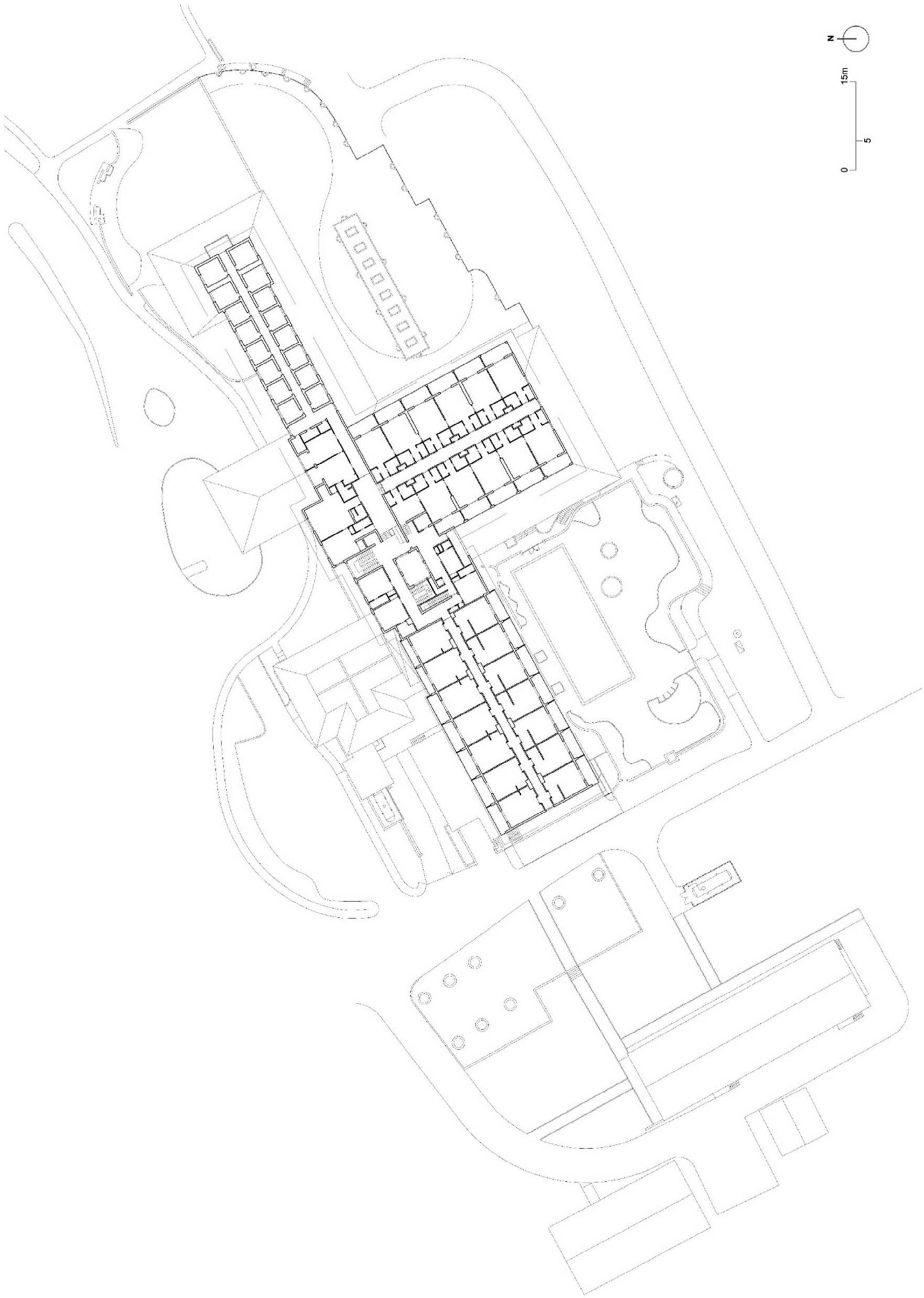

Figure 43 - Rectorate building, second level.

Finally, by comparing the large-scale three-dimensional elaborations, the new building's diagrams, and the selected maps, it was possible to quantify the distortion of the initially chosen aerial and satellite images. Therefore, these have been distorted, georeferenced, and imported into the G.I.S. based on the available data and in such a way as to uniform the supporting documentation (Figure 44 and Figure 45).

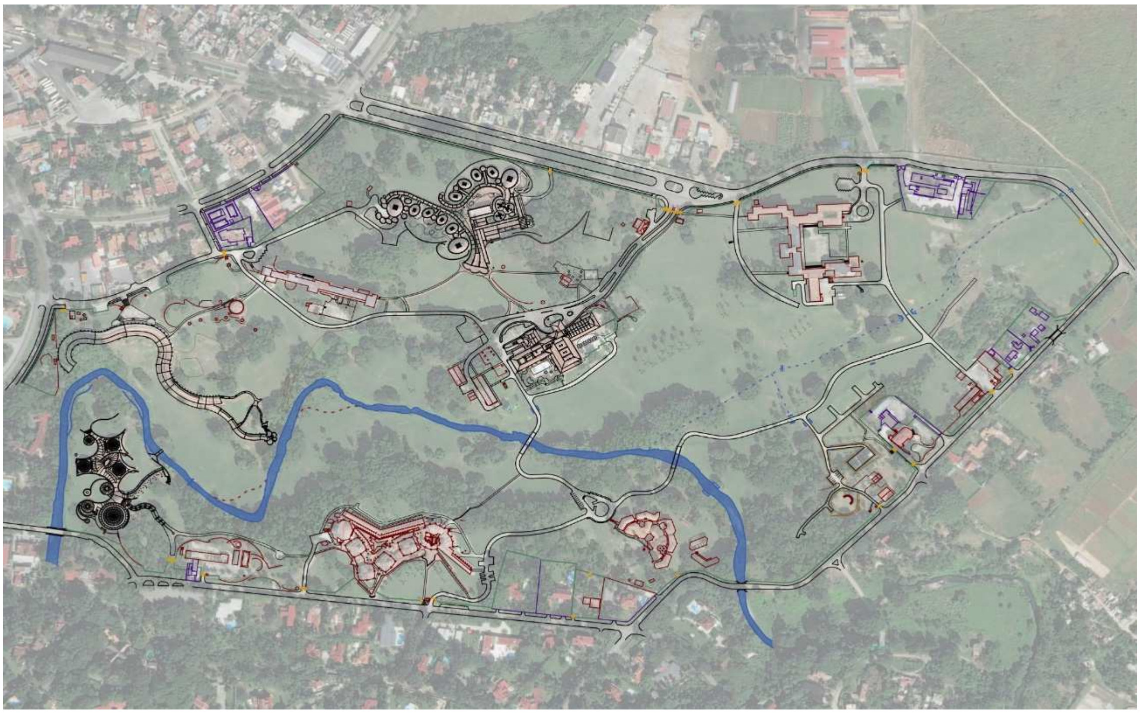

Figure 44 - The "Plan Rector" map overlapped to the Bing Virtual Earth satellite image.

Figure 45 - Detail of the School of Music's roof levels and the School of Ballet overlapped to the Goggle satellite image.

5.1.3 Organizing the information levels and hierarchies

As already mentioned, the G.I.S. was designed to collect different data and materials concerning the area in three progressive levels of detail (general/territorial level, buildings, and spaces).

Below is stated the main subdivision structure of raw and processed materials within the G.I.S. (Table 4):

Table 4 - Macro-categories and groups.

Macro-categories	Groups
00_Working layers	--
Survey - GNSS & GPS coordinates	--
Plan Rector 2020	- *Current situation* - *Topographic net*
Green areas & vegetation	- *Trees* - *Other*
Spaces	- *BA_School of Ballet* - *MU_School of Music* - *PA_School of Plastic Arts* - *RE_Rectorate building* - *MD_School of Modern Dance* - *TE_School of Dramatic Arts*
Buildings - Drawings	- *BA_School of Ballet* - *MU_School of Music* - *PA_School of Plastic Arts* - *RE_Rectorate building* - *MD_School of Modern Dance* - *TE_School of Dramatic Arts*
Thematic mapping	- *General state of conservation* - *Intensity of use* - *Use adequacy* - *Transformability* - *Level of significance*
Cartographies	- *WMS cartographies* - *Rectified aerial images*
Survey - DSM/DTM/DEM	- *DTM contour lines* - *DEM 100 cm* - *DEM 100 cm shaded* - *DTM 100 cm* - *DTM 100 cm shaded* - *DSM 100 cm* - *DSM 100 cm shaded*
Survey - Laser scanner	- *BA MU_Schools of Ballet & Music* - *MU RE_Rio Quibù (Western area)* - *PA_School of Plastic Arts*
Hydrogeological risk analysis	- *Flood area_Depth* - *Flood area_Velocity*

The categories' organization and the primary information levels made it possible to think about the elements' hierarchy to be inserted before the data loading phase[15]. In fact, the order was designed to allow operators to view multiple elements simultaneously, create overlapping mappings, and investigate numerous levels with a single operation. For this reason, the punctual, linear, or areal levels of small extension have been inserted in the first part of the system. In contrast, the medium-large extension's territorial or areal levels are located in the second part of the structure. Each group has been implemented with the data resulting from the various activities' research and is entirely independent to allow any subsequent shifts in order.

5.1.4 Descriptive data of the buildings and spaces

During the project, the G.I.S. was used to organize and have immediately available all the information relating to the buildings and individual spaces collected through desk analyzes and during the inspections.

The possibility of collecting comparable data in a single tool permits archiving a large amount of information in an organized way whilst displaying different thematic maps on single cartographic support offers an immediate and synoptic point of view of the various phenomena in such a huge and complex contest.

As mentioned in the introductory part, the G.I.S. system has been structured on two levels; the first level contains general and territorial information, whilst the second level, which describes the buildings, is further divided into two sub-levels.

The first sub-level, filled for all the buildings in the park, comprises a description, a historical resume, general information, and aggregated data, such as the overall surface, data on plant networks, and information on projects, uses, and maintenance phases carried out in the past, where these do not concern a specific space or element.

Therefore, this first phase of analysis allows the first classification and includes all the information that cannot be associated with a single environment (e.g., design and state of conservation of the prospects, plant networks, etc.).

As said, the analysis was carried out for all the buildings in the park, including the older buildings (although heavily altered over time, such as the Rectorate building or the building that hosts the *Facultad de Artes de la Conservación del Patrimonio Cultural*). Even the most recent construction of little architectural value, considering that all these buildings have a specific role from a functional and management perspective, regardless of their different level of interest and cultural significance.

Indeed, although the CMP focuses on the 5 schools realized in the '60, that requires specific strategies and conservative interventions, any decision about management and use should involve the entire complex, which includes, in addition to the constructions, pedestrian and vehicular paths, natural elements and open spaces that are often used by students for their exercises.

The second level, filled for the Schools of Ballet, Music (*Gusano*), Plastic Arts, and Modern Dance, provides detailed information and evaluations for each space[16].

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[15] See 5.1.6 Implementing the system through the information levels.

[16] Refer to Annex 5F Descriptive data of the spaces of the Schools for full specifications of each school space.

A further level of detail can be introduced, although at this stage, more detailed information was not considered useful and consistent with the purposes of the conservation management plan.

The Attribute table

Within the aforementioned organization, two main layers to collect and organize most of the data and materials have been organized (Figure 46). Unlike the other levels, in which the material is inserted as a simple layer of the system, these levels are structured to insert information according to precise schemes. In fact, both levels have been designed with the attribute table function of the selected G.I.S. software.

It allows the creation of these data collection tables (i.e., attribute tables). Moreover, it allows to equip the objects of a selected layer with pre-established information (Figure 47).

The result of an attribute table is a series of interrogable objects incorporated in the layer that allows having a check of all the data relating to them. The data that can be entered is of the alphanumeric type. Therefore, it is possible to use the attribute tables in any way that is functional to the designer, e.g., tables for collecting information and textual notes, numbers and codes, short text information, etc.

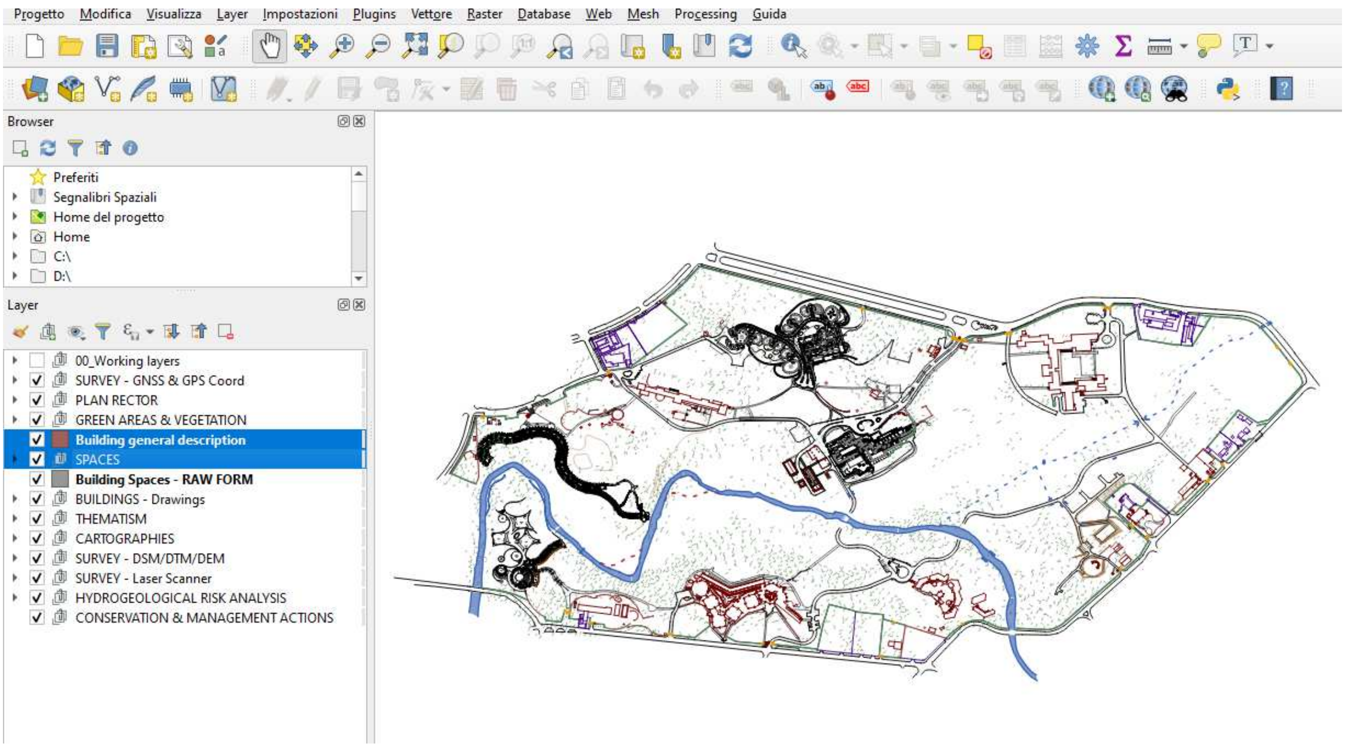

Figure 46 - Attribute layers.

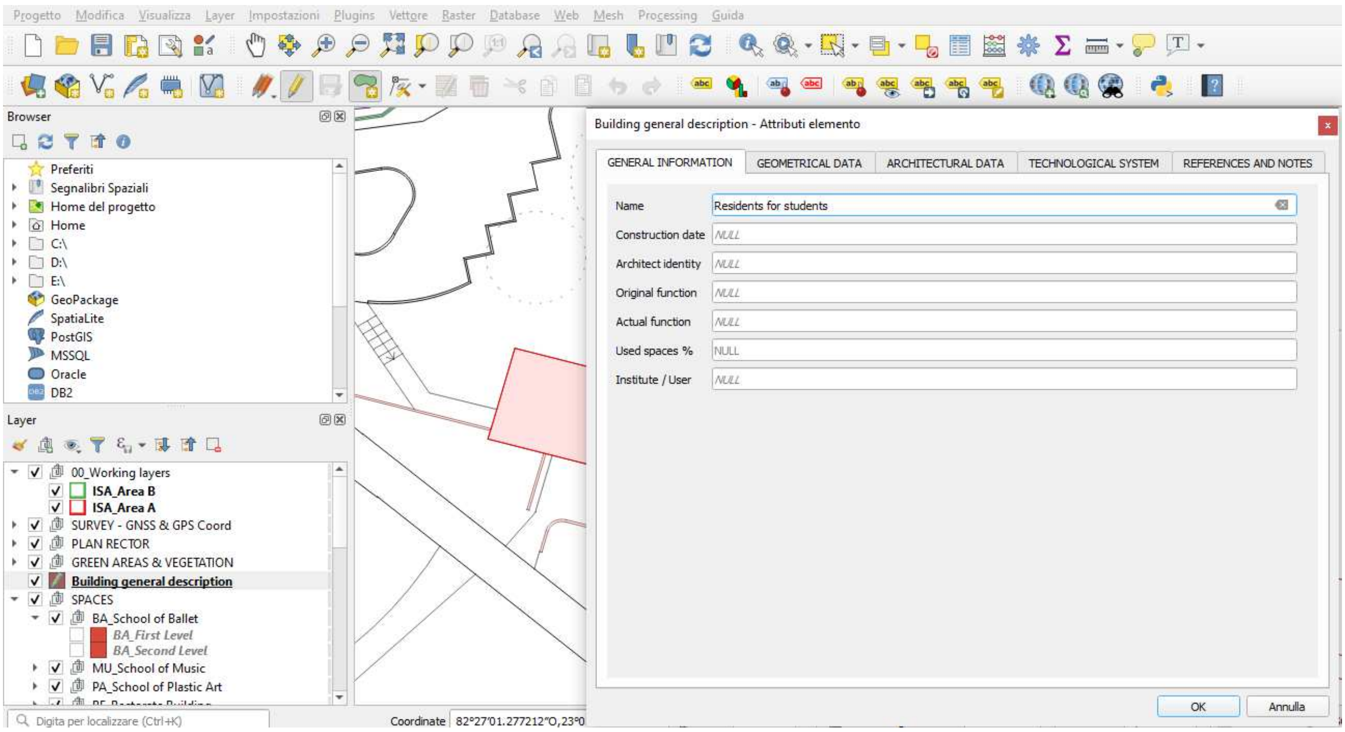

Figure 47 - Building informative form.

The First level coding

All the park buildings are identified by a 2-digit code, which corresponds to the first descriptive level of the G.I.S. The first level of coding determines the five schools:

- BA: School of Ballet (arch. Vittorio Garatti)
- MU: School of Music (arch. Vittorio Garatti)
- MD: School of Modern Dance (arch. Ricardo Porro)
- PA: School of Plastic Arts (arch. Ricardo Porro)
- TE: School of Dramatic Arts (arch. Roberto Gottardi).

The other buildings in the park area were identified similarly:

- RT: Rectorate building
- BL: Library
- PT: Heritage Faculty building
- TA: Actual School of Theatre
- ME: School of Music (ENA)
- RE: Residential building
- EA, EB, EC, …: Entrances.

Similar coding can be attributed in future implementations to other elements, which have not been cataloged, such as paths or landscape areas. In particular, this last aspect has emerged to be of great importance for the managing institution, which recognizes biodiversity as one of the characterizing elements and, therefore, worthy of protecting this place. The first level (schools and other functional units) is associated with a first descriptive form[17]

[17] See 5.1.4.1 Analysis form for the on-site inspections and 5.1.4.2 Second level form: general description of the spaces.

The First level form: general description of the buildings

The form includes the data analyzed in the previous actions (Table 5).

The information can be inserted in free fields as text or numerical data. An easy-to-read summary form is generated.

The data are organized as follows:

General data

Includes historical and management- related information, including the percentage of used and unused spaces. That data appeared to be essential to highlight unused or underused spaces within the complex and provide information that can be of significant importance for the site managers.

Geometrical data

Include both aggregate and partial data on indoor and outdoor spaces.

Architectural data

Summarizes the relevant data produced in Action 1 (general description; architectural identity; access point and accessibility; pertinences and surroundings; the general state of conservation); Action 2 (structural analysis); Action 3 and 4 (Critical external factors - flood risk); Action 4 (thermal behavior and comfort issues).

Technical system

Includes a description of the existing technical systems and installations.

References and notes

Collects a selection of significant images, archival documents, and drawings.

That first level of analysis provides a general overlook of the complex.

The data can be implemented over time, and therefore it can be updated for any forthcoming study or project. Nevertheless, with that data entry mode, the data are not connected to each other. For example, the state of conservation and the percentages of the building's use are entered manually and are not linked to the spaces' analysis results. This means that the table must be updated manually with each change in the function of the rooms.

Table 5 - Groups and attributes of the general form.

Groups	Description of the attributes
General information	- Name - Construction date - Architect - Original function - Actual function - Used spaces % - Institution/user
Geometrical data	- Total area (sqm) - Number of levels - Usable spaces area (sqm) - Connection spaces area (sqm) - Outside spaces area (sqm) - Usable spaces % - Connection spaces % - Outside spaces %
Architectural Data	- General description - Architectural identity - Structural elements - Access point and accessibility - Pertinences and surroundings - State of conservation of the building - Critical external factors affecting the building
Technological system	- Electrical system - Hydraulic system - Roof drainage system - Air conditioning
References and notes	- Images and/or photographs - drawings - documents - Indication - Notes

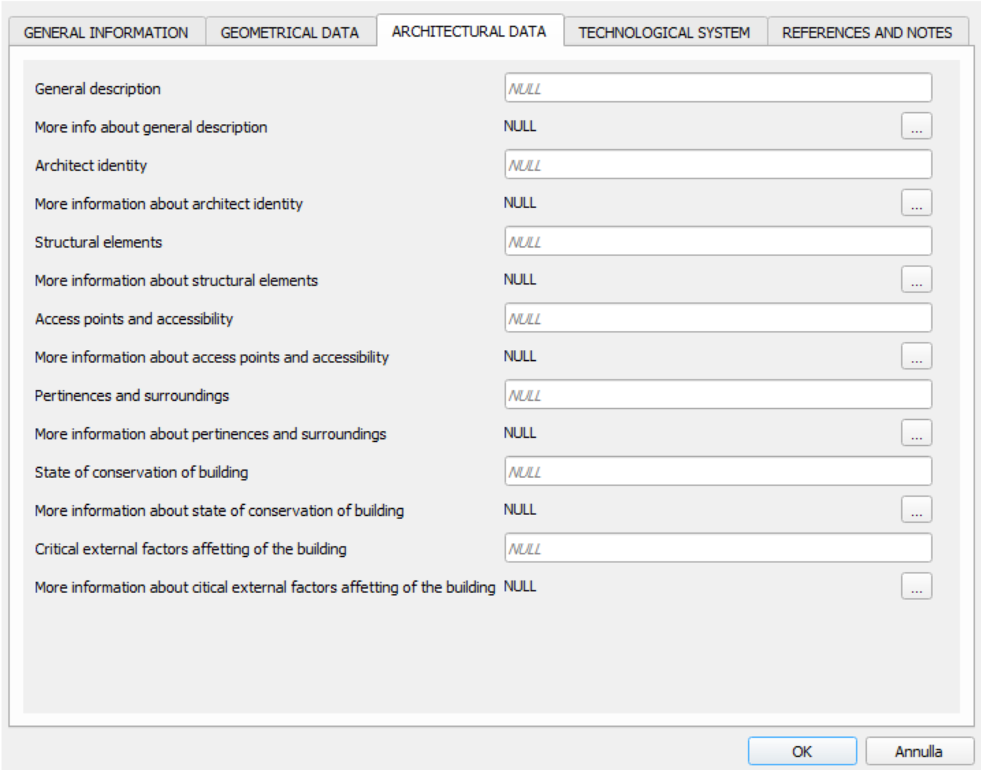

Figure 48 - General form: architectural data section.

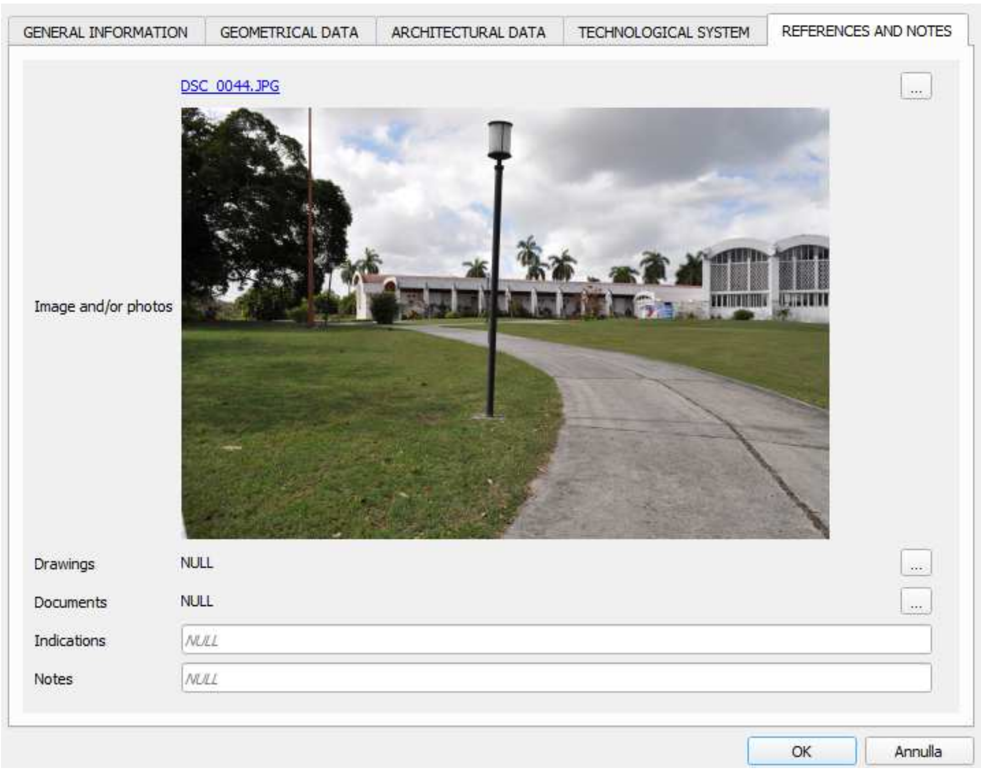

Figure 49 - General form: references and notes section.

The Second level coding

The second descriptive level refers to the single rooms or homogeneous portions of external space, which can be viewed in the plan's different levels.

In the coding of the second level of description, each space (classrooms, offices, theaters, technical spaces, etc.) that constitute the schools and other functional units has been associated with an alphanumeric code (Table 6). It uniquely identifies the G.I.S. spaces and includes the ordering element of the information entered into the system. The codes have also been attributed to open spaces, internal and external paths, and the internal areas, recognizing these elements' functional and architectural value. It was decided not to identify functional or homogeneous areas intermediate between the school and space.

This second level of coding was conceived for the five schools of Garatti, Gottardi, and Porro, starting from a typological-functional criterion, allowing compilers and managers to identify the spaces relatively intuitively.

Despite being autonomous works, the five schools, characterized by a peculiar architectural language and specificities related to the artistic disciplines that should have been taught, are characterized by a common functional scheme, which is repeated substantially identical in the different realizations and allows identifying a hierarchy of spaces.

In all schools, there are spaces for public use (e.g., the theater and the exhibition hall), which are characterized by their imposing size, the possibility of dedicated and independent access, and often associated with dedicated service spaces (e.g., the coffee bar and the ticket office). These areas should also have been created in the Schools of Dramatic Arts and Music, where spaces were also provided for performances, including external ones. Other spaces, such as those dedicated to laboratory teaching activities and exercises, are characterized by the presence of medium-large domes and are generally in direct relationship with the covered paths and with service spaces for the exclusive use of students (services, dressing rooms, spaces in which to leave equipment and materials, etc.).

The theoretical courses' classrooms are more straightforward and arranged in a line, as the offices are, which can have different sizes.

Compared to a simple numbering of the spaces (hypothesis explored in the first phase of work), the coding organized in this way allows the individual area to be identified in a reasonably intuitive way, reducing compilation errors.

The proposed coding is designed in such a way that it can be further detailed, allowing to describe, for example, each window or plant terminal. However, in this phase, such a level of detail was deemed inconsistent with the CMP's objectives, which, even considering the extension of the complex, require analysis capable of supporting a strategic vision rather than a detailed design please refer to further details.

Table 6 - Codes and description of the spaces.

Code	Description
Ae	Classroom, exhibition space (e.g., theatre)
Al	Laboratory classroom (e.g., plastic arts)
Ap	Practice classroom
At	Theoretical classroom
Ba	Toilet
Bt	Toilet for the theoretical classrooms
Bp	Toilet for the practice classrooms
Bs	Toilet for the specialized functions
Cm	Dining hall
Ct	Technical room enclosed to the dining hall (e.g., kitchen, refrigerating room)
Ea	External bounded area adjacent to the classrooms
Ec	Covered space
Ee	External exhibition space
Ep	Outdoor area / square
Of	Office / administration
Pc	Covered outdoor path
Pd	Internal path / distribution / corridor
Pe	Uncovered external path
Pf	Hallway
Pv	Vertical connection in the path
Sa	Specialized function
Sb	Specialized function / archive / library
Sc	Covered space
Ta	Technical room
Td	Technical room / storage
Te	Service room for the exhibition space
Tl	Technical room for the laboratory classrooms
Tp	Changing room for the practical classrooms
Tt	Changing room for the theoretical classrooms

5.1.4.1 Analysis form for the on-site inspection

After an initial reconnaissance phase (June 2019), which made it possible to identify the main themes of analysis (e.g., materials, elements, recurring problems) and to define the coding of the areas, a first analysis form (Table 7) was drawn up to be filled in during the inspections. The goal was to speed up both the data acquisition and elaboration phases.

During the inspections, the analysis sheet describes the main spatial, technical, and functional characteristics of the spaces and the outdoor areas. This description includes the plant equipment, the windows' features, and the fixed and mobile furnishings. For each room, the following is then specified: the designed and current function, use (used, not used), institutional or spontaneous function.

Table 7 - The analysis form for on-site inspections.

SPACE CODE		
USED	yes not	
FUNCTION	Original	
	Project	
	Actual	
		institutional spontaneous
NOTES		
DIMENSIONS	area	
	height	maximum
		average
CHARACTERIZING ELEMENTS	Level of significance: excellent good medium poor	
INTENSITY OF USE	General evaluation: excellent good medium poor	
USE	General evaluation: excellent good medium poor	
Spaces dimension	excellent good medium poor	
Environmental comfort	excellent good medium poor	
Interferences on the functions	excellent good medium poor	
Accessibility	excellent good medium poor	
EQUIPMENT	General evaluation: excellent good medium poor	
Furnishings	yes not	
	Adequacy	excellent good medium poor
	Maintenance status	excellent good medium poor
Electrical system	yes not	
	Adequacy	excellent good medium poor
	Maintenance status	excellent good medium poor
Air conditioning system	yes not	
	Adequacy	excellent good medium poor
	Maintenance status	excellent good medium poor
……………	yes not	
	Adequacy	excellent good medium poor
	Maintenance status	excellent good medium poor
STATE OF CONSERVATION	General evaluation: excellent good medium poor	
Roofs	excellent good medium poor	
Structures	excellent good medium poor	
Flooring	excellent good medium poor	
Doors and windows	excellent good medium poor	
TRANSFORMABILITY	General evaluation: excellent good medium poor	
Function	excellent good medium poor	
Internal layout	excellent good medium poor	
Plants	excellent good medium poor	
Equipment	excellent good medium poor	
INDICATIONS		

5.1.4.2 Second level form: general description of the spaces

The second level of analysis, filled for the Schools of Ballet, Music (*Gusano*), Plastic Arts and Modern Dance, provides detailed information about the indoor and outdoor spaces that includes:

- a description of the technical elements (windows, skylights, floorings, furniture);
- an assessment of the state of conservation of the technical elements;
- an evaluation of the maintenance and functionality of the technical systems;
- an analysis of the uses.

The attributes tab is organized into macro-categories, including the fields described in Table 8, and makes the data directly related to the map.

Unlike the previous level, at the second level, the data are inserted through multiple choice forced fields to maintain greater consistency in the descriptions and avoid the mistakes and unevenness due to manual data entry.

Moreover, forced fields simplify the phases of interrogation and implementation of the tool since a specific element can be retrieved and analyzed.

The form entails specific and synthetic evaluations expressed with a score ranging from 1 (LOW) to 4 (HIGH). The synthetic evaluations depend on the specific assessment and are automatically filled by the system but can always be modified to consider the assessed topics' different weights.

Table 8 - Groups and attributes of the general form for the spaces.

Groups	Description of the attributes
Location and identification	- Area identification code - Building identification code - Sector identification code - Complete identification code of the space - Space function code - Common name of the space - Areal dimension - Height dimension max - Height dimension min
Functions	- Used - Institutional, spontaneous, licensed function - Original project function - Project function - Current function
Technological elements	- T.e.: Roof - State of conservation: Roof - Priority index for structural intervention of the roof - Evaluation report of the structural analysis of the roof - T.e.: floor - State of conservation: Floor - T.e.: vertical surfaces - State of conservation: vertical surfaces - T.e.: Window frame - T.e.: number of Window frame - T.e.: Window frame project - State of conservation: Window frame
Technological system	- T.S. Electrical system - Adequacy: Electrical system - Maintenance status: Electrical system - T.S. Hydraulic system - Adequacy: Hydraulic system - Maintenance status: Hydraulic system - T.S. Air conditioning - Adequacy: Air conditioning - Maintenance status: Air conditioning - T.S. Rainwater disposal plant - Adequacy: Rainwater disposal plant - Maintenance status: Rainwater disposal plant
Equipment	- E. fixed furniture - Adequacy: fixed furniture

Groups	Description of the attributes
	- Maintenance status: fixed furniture - E. mobile furniture - Adequacy: mobile furniture - Maintenance status: mobile furniture
Use adequacy	- Dimensions of the space - Space comfort - Functional interference - Accessibility
Transformability	- Functional transformability - Layout transformability - Technological systems transformability - Furniture transformability
Evaluation	- General conservation status - Level of significance - Level of intensity of use - Level of use adequacy - Level of transformability
Hydrogeological risk	- Hydraulic priority index
References and notes	- Reference to images - Reference to drawings - Reference to documents - Indication - Notes

The data were organized in groups as follows:

Location and identification:

Includes space's code (reported on the plans), the name of space, and the main dimensional data (area, height).

Functions:

Collects information on the project and current function; the latter includes the spontaneous uses and the licensed functions (e.g., spaces granted to students or external companies).

A specific field collects the information regarding the functions foreseen in subsequent projects, even unreleased, if available. That data is important to keep track of the changes that occurred over time and evaluate the gap between the current situation and the project.

Technological element:

The item summarizes the analysis carried out I Action 1 and 2 to describe and assess the state of conservation of structures and technical elements.

Technological system:

Includes information on existing systems (electrical, hydraulic, air conditioning, rainwater disposal) and their functional status

Equipment:

Includes information on the fixed and mobile furniture, including state of maintenance and appropriateness. The purpose is twofold: to describe the elements that were realized as part of the original project, as the lighting in the School of Modern Dance or the fixed furniture in the classrooms and keep track of the present materials and objects.

Use adequacy:

Evaluation of the match between current use and characteristics of the space through functional and comfort parameters.

Functional interference (e.g., proximity to environments hosting noisy functions, which involve crowding or which generate other forms of disturbance);

Accessibility (e.g., possibility of access from the outside or independent access, presence of gaps, stairs, or other physical or perceptual barriers);

Transformability:

Evaluation of space's flexibility described as rate of changes that may affect the function, the layout (including changes that affect the size of the spaces), the implementation of the technological systems, and the furniture.

Evaluation:

That section of the form includes a general evaluation of the spaces, that includes:

- level of significance (cultural value);
- general state of conservation;
- intensity of use
- consistency of the functions performed with the characteristics of the spaces.

Hydrological risk:

The item summaries the data on hydrological risk produced in Action 3.

References and notes:

Collects a selection of significant images, archival documents, and drawings.

As in the case of the previous level, the form can be implemented over time.

The single room data can be displayed in visual sheets (Figure 50 and Figure 51) to get the information at a glance.

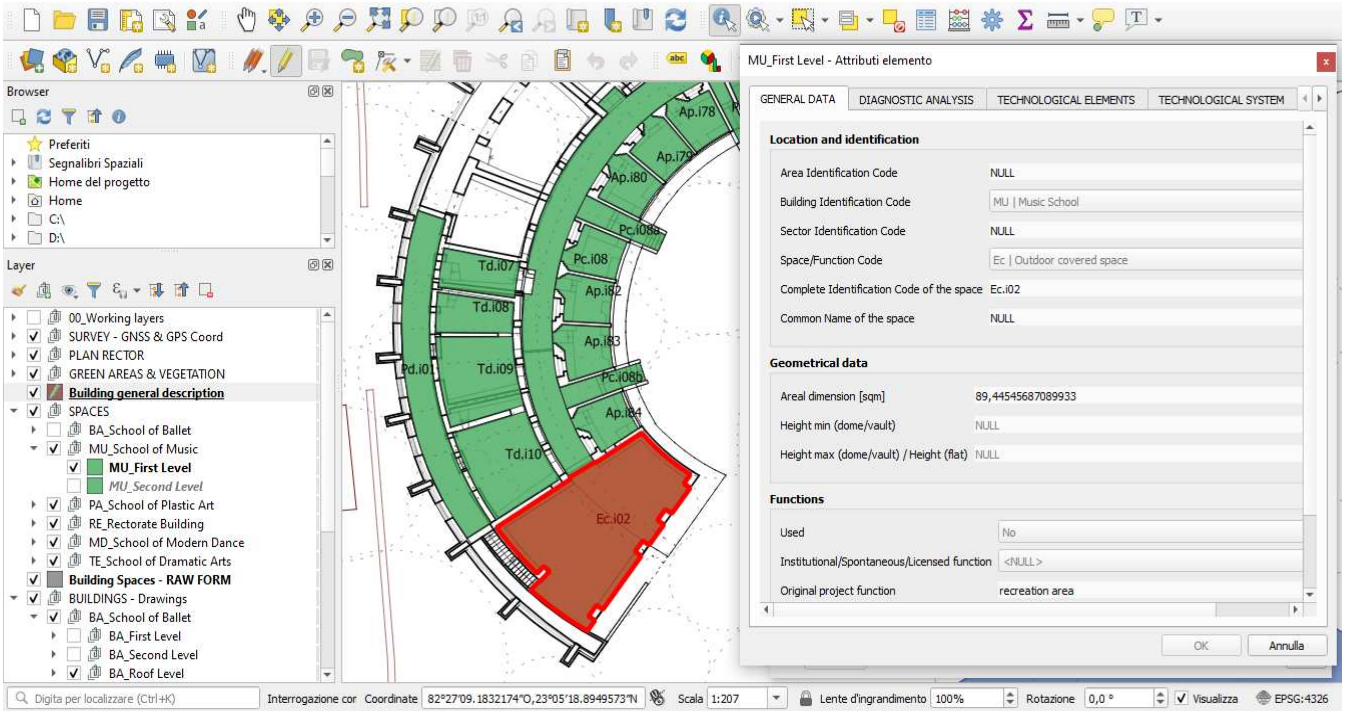

Figure 50 - Spaces' form, general data section.

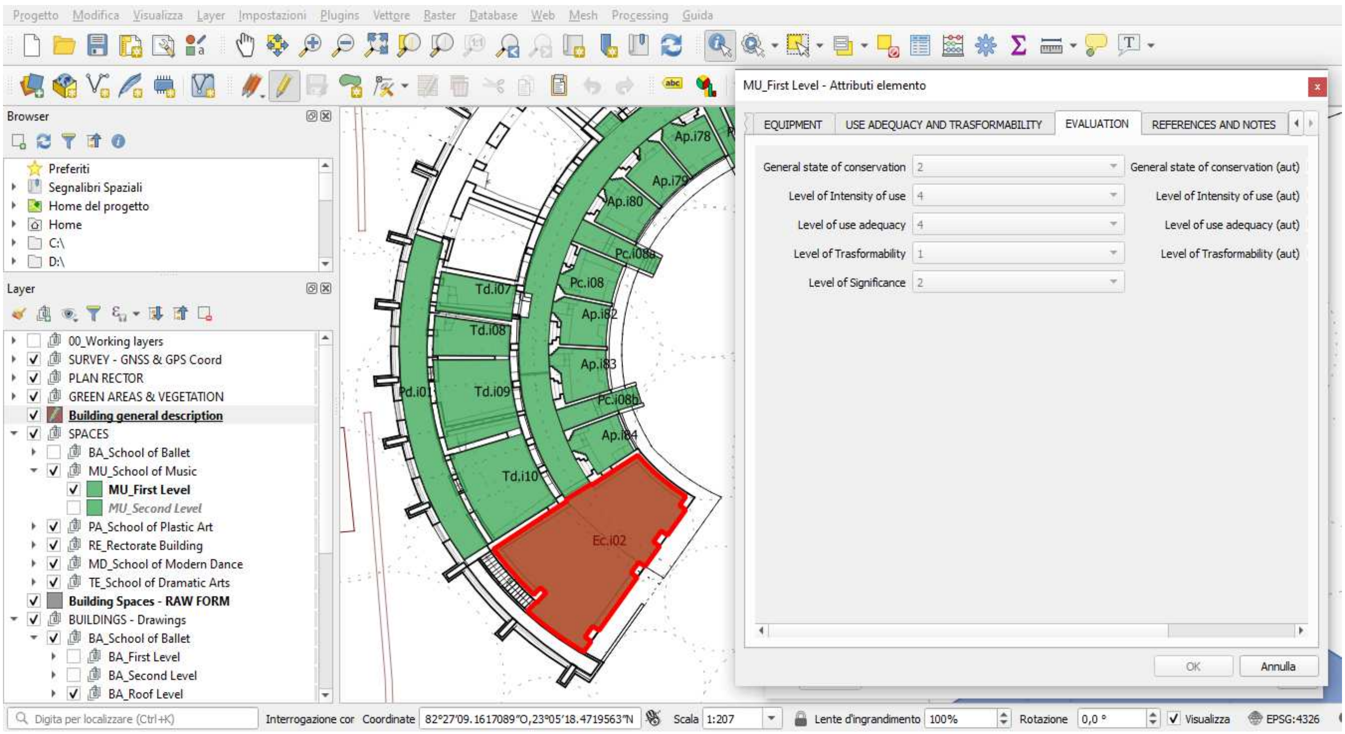

Figure 51 - Spaces' form, evaluation section.

5.1.4.3 Criteria for the evaluation of buildings and spaces

The form described above undoubtedly incorporates a discretionary aspect. Therefore, it is liable to be affected by an expert point of view, which may not entirely represent the users' point of view.

To reduce the risks deriving from an objective assessment's impossibility, the evaluation scores were assigned by applying strict criteria. For each criterion, the score is attributed as follows:

- 0 points - absent or negative;
- 0,5 points - medium;
- 1 point - high

and

- Morphology of the space and contribution to the overall composition (0 - 1 point)
- Relevance of the function in the general layout (0 - 1 point)
- Presence of characterizing elements (e.g., domes, fixed furnishings), which cannot be modified without compromising the building's overall quality. (0 - 2 points).

  Those elements are described for each school in Action 1.

General state of conservation

The general evaluation depends on the weighted sum of the partial evaluations. Specific evaluation criteria have been agreed upon with the Cuban partners to coordinate the two groups' work (see Table 9).

Table 9 - State of conservation. Evaluation criteria used for the on-site inspection.

USED	NOT USED
1. High Structure, materials, waterproofing, electrical-air conditioning systems, furniture *(e.g. oficina de Alexis)*	1. High Existing structure without particular collapses, no significant infiltrations, existing floor, partially existing windows, green maintenance, some temporary use *(e.g. Escuela de Teatro)*
2. Medium-High Structure, materials, waterproofing in need of some intervention (limited infiltrations or molds), regular or dated electrical and conditioning systems, appropriate furniture *(e.g. Escuela Artes Plasticas)*	2. Medium-High Structure with some collapses of lesser intensity, medium visible infiltrations, partial floor in medium condition, partially existing windows, some presence of vegetation *(e.g. Escuela Artes Plasticas)*
3. Medium-Low Structure with cracks, materials with medium or evident decay, repetitive and constant infiltrations, need for planned intervention (infiltrations, molds, holes, detachments), missing or non-functioning electrical systems, missing or dated furniture *(e.g. Escuela Danza Moderna ENA)*	3. Medium-Low Structure with medium intensity collapses, severe infiltrations and biological patina with saline efflorescence, missing floor, absent or destroyed windows, constant presence of vegetation in the walls or floors, medium difficulty of access, presence of garbage and dirt in medium quantity *(e.g. Escuela de Ballet)*
4. Low Cracked, fragile and/or partially collapsed structure, in an evident state of decay, always present and constant infiltrations (mold, lichens, vegetation, holes from part to part, detachment, erosion), electrical systems absent or never installed, furniture missing or totally destroyed *(e.g. Escuela de Ballet, Escuela de Música)*	4. Low Structure with collapses of load-bearing elements (beams, pillars, partitions), severe and continuous infiltrations, biological patina, mold, saline efflorescence, missing floor, absent and/or destroyed windows, constant presence of vegetation in the walls and/or floors, not used and of medium difficulty in accessibility, presence of garbage and dirt in large quantities *(e.g. Escuela de Música)*

Intensity and consistency of the uses

It's important to notice that the use-related analysis entails both the intensity of use and the actual uses' consistency with the spaces' peculiar characteristics.

The intensity of use is evaluated:

- LOW for the spaces that are unused or closed;
- MEDIUM/LOW for the spaces that are used occasionally (e.g., the paths that lead to unused or closed spaces);
- MEDIUM/ HIGH for the spaces that are continuously used by a few people or in defined time slots. (e.g., the practical classrooms in the School of Plastic Arts, that are only used by 1- 2 students, that also use them as residences);
- HIGH for spaces that are intensively used (e.g., the spaces of the rectorate).

The consistency evaluation weights the match between current use and characteristics of the spaces. The score depends on the results of the interviews and the spontaneous behaviors observed.

In the not currently used spaces, the consistency evaluation weights the intended uses' feasibility without significant changes. E.g., the exhibition space in the School of Plastic Arts, despite being unused, has all the features and plant equipment that are needed to host temporary exhibitions; the function fits well into space, but it is not implemented due to organizational problems.

Quite different is the case of the School of Music (*Gusano*), almost entirely unused, except for a few spaces that are used by local companies (ESIC - "*Empresa de Seguridad de Instituciones de Cultura*" and "*Empresa de Gastronomia - Municipio de Playa*"), maintenance staff and young artists. The original project envisaged a series of small spaces for individuals or small groups, for musicians playing different instruments. Today these classrooms are decaying, and there are no windows, furniture, or equipment. Besides, musical instruments' practice should require technical plants, soundproofed surfaces to reduce noise disturbance, and larger rooms for greater flexibility. For this reason, the classrooms on the lower level have a low level of matching with the intended use.

The spaces rented to artists and artisans have a higher consistency rating in the same building than those used as storage rooms. Indeed, with small changes, like a straightforward electrical system, a layer of paint, or a handmade fence, those tenants make these spaces alive.

The synthetic evaluations are expressed with a variable score from 1 to 4, whose criteria are indicated in and Table 10.

Table 10 - Evaluation criteria used for the on-site inspection, consistency of use.

Consistency of use (only for used spaces)	Fundamental elements
1. High Suitable space, furniture, and plant system	Iconic elements that must not be modified changed or replaced because they are fundamental for the image and the architectural function of the schools to be preserved (*e.g. Escuela de Ballet: las cúpulas, Escuela de Música: el techo a bóveda catalana, Escuela de Teatro: los recorridos internos)*
2. Medium-High Suitable space and furniture, unsuitable plant system	
3. Medium-Low Suitable space, Unsuitable furniture, and plant system	
4. Low Unsuitable space	

Finally, these assessments lead to an overall evaluation of the viable transformation rate that can be introduced without compromising the space's specific value.

As explained above, that evaluation depends on the weighted sum of the previous assessments and is expressed in the following 4 scores:

- LOW.

  No changes are required or admitted.

  That score applies to both the most significant spaces and the spaces that cannot be modified as they are specifically designed for a specific use, like the water tanks in the School of Plastic Arts.

  Considering that the systems' inefficiency and the roofs' deterioration are recurring problems, technical adaptations and conservative interventions are always permitted.

- MEDIUM-LOW

  Limited transformations are needed or different use without changes.

- MEDIUM-HIGH

  Building works are required with or without a change of use;

- HIGH

  Significant intervention is required that affects the whole structure and entails substantial changes in the layout and function.

As said above, the tool provides an automatic filling of some fields, such as the metric data (e.g., area of the space) and the overall evaluations, that depends on the scores attributed in the partial evaluations applying the criteria.

However, to avoid the mix-ups that may result from the impossibility of weighting the different items to be taken into account (as occurs in multi-criteria assessments), the items can always be edited, and a different score can be inserted into the form.

The significance evaluation always prevails over the other assessments and determines the level of suitable change that can be deemed acceptable.

For example, suppose space is rated with a high level of significance. In that case, even if it is underused or unused, change can be allowed as long as it doesn't affect all the elements that underlie significance, including function.

Therefore, if the original function is strictly associated with the value and has been maintained over time, this should not be changed; nevertheless, if the function is no longer present, a new use can be identified, as long as it doesn't require partition walls, demolitions or other inadmissible changes.
This is the case of the choreography theatre in the School of Ballet, which presents a very high level of interest despite being unused and in very poor condition; the admissible transformation is medium-high, as the unique character of that space and the relationships with other rooms should be maintained. In the same school's practical classrooms, a higher level of transformation is allowed, despite a very high significance level. In that case, a different function should be identified, and another relationship with the covered path and the outdoor spaces.
When dealing with a low level of cultural significance, significant transformations will be acceptable, even if not motivated by strict functional or maintenance reasons but, for example, suggested by an overall functional reorganization.

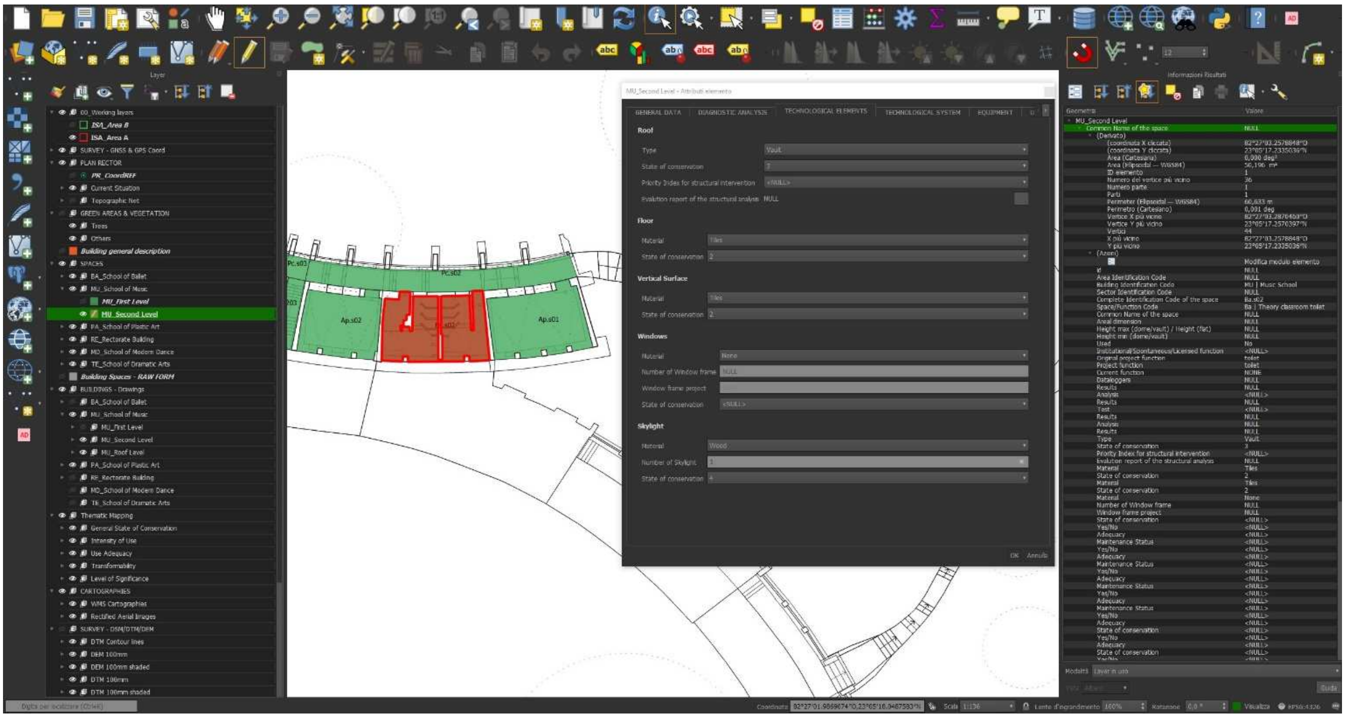

Figure 52 - School of Music, evaluation of the state of conservation of the Technological elements.

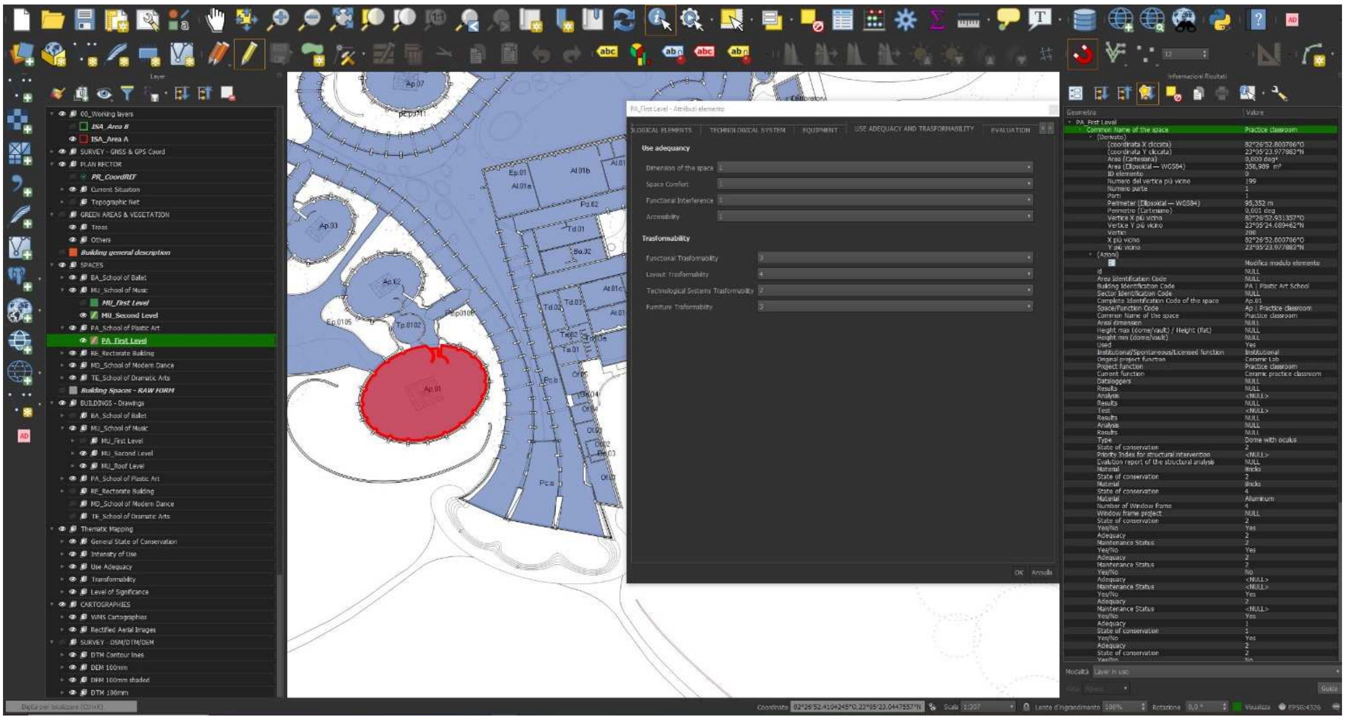

Figure 53 - School of Plastic Arts, evaluation of the use adequacy and the transformability.

5.1.5 Identifying the queries to create thematic maps

The management system's organization has considered the possible requests that a database set up in this way can foresee as part of a Conservation Management Plan. This tool has the ability to interact and operate with other systems for most of the information it contains, in addition to its function as a container and data viewer. The designed structure of the G.I.S. allows full interaction between the different levels, whether these are spatial or contain numerical and textual information. The most important aspect is the design and organization of these data and fields, an operation that can significantly facilitate the creation of queries and thematic maps. This organization considered the possible outputs that the tool could or should have generated based on the project's needs and the partners involved. For this reason, parallel to the structuring of the information levels and descriptive cards, the main queries have been designed thinking about their formulation and their graphic output. The operation inevitably led to changes to the structure initially conceived, however making it more consistent with the CMP's purposes.

The most basic spatial analysis form consists of the synoptic visual rendering of a phenomenon's spatial distribution, made possible by the cartographic system's technical nature designed and implemented. G.I.S. systems enhance this ability by automating even complex calculation operations and analyzing one or more thematic layers and their associated attributes. The possibilities of constructing spatial analyzes are strongly conditioned by the specific form of modeling and recording of the information. Instead, the queries' outcome can be a new dataset extracted from the one tested or a new thematic map utterly independent from the initial information.

Essentially, the analyzes are divided into three categories: querying, proximity analysis, and overlay analysis. The querying operates an internal selection of the objects in the analyzed theme by defining an objective output, for example, classification or spatial selection of a particular attribute. The proximity analysis allows a selection through spatial relationships. In contrast, the overlay analysis applies operations of intersection between overlapping themes, giving back data or thematic maps resulting from multiple interactions and calculations.

Among the querying operations, the functions of identification, interactive selection, and examination must be indicated as real query operations. The user can, in fact, select elements by writing a query that automatically identifies the objects that correspond to a specific selection criterion, based on the table information. The simplest type of query in a database is the association through a relationship operator (such as "=") between a table field and a particular value. The queries are built using the SQL (Structured Query Language), which allows formalizing the examination criteria in a table field. Simple questions can be created by imposing more than one selection condition. The Boolean operators "AND" and "OR" are used for this purpose. “AND” imposes that all the required conditions are verified, while “OR” imposes that at least one of the necessary conditions must be confirmed. "NOT" instead requires that the condition that follows in the expression of the query, mono or multi-criteria, is not verified.

On the other hand, the proximity analysis allows to explore the space surrounding the objects and possibly create new layers based on the analysis. Instead of selecting the objects according to a value in the table attributes, it is possible to set selections based on their spatial relationship with the other items belonging to the same layer. On the other hand, buffering allows to create a polygonal area surrounding a specific object and then visualize that area and use it for other forms of spatial analysis. Finally, the overlay analysis integrates simple queries with operations on spatial relations. For example, the layers derived from a proximity analysis can relate to the attribute fields' querying operations, thus generating a specific thematic map.

For the National Schools of Art of Cuba's management system, the main analyzes concerning the five schools surveyed have been structured using mainly direct or complex querying functions (identification, selection, or research) and proximity analysis functions. The groups involved in the analyzes were: Location and identification, Functions, Technological elements and systems, Evaluation (Table 11). These first questions arose from the research group's needs to continue with the CMP activities and test the system in its complexity. These queries have allowed us to calibrate the G.I.S. structure better and refine the attribute tables regarding buildings and spaces.

Table 11 - List of queries and their typology.

Group	N	Query	Typology
Location and identification	1	Spaces macro code from the classification	Direct query
	2	Areal dimensions	Proximity analysis
	3	Height dimension [dome/vault/flat slabs max]	Direct query
	4	Height dimensions [dome/vault min]	Direct query
	5	Height dimensions [average]	Complex query
Functions	6	Project function if not used	Complex query
	7	Function of the space if used differently concerning the project	Complex query
	8	Function of the space if used spontaneously / with license	Complex query
	9	Institutionalized licensed spaces	Direct query
Technological elements	10	State of conservation: Roofs	Direct query
	11	State of conservation: Floors	Direct query
	12	State of conservation: Vertical surfaces	Direct query
	13	State of conservation: Windows frame	Direct query
Technological systems	14	Level of adequacy of technological systems: Electrical system	Direct query
	15	Level of adequacy of technological systems: Hydraulic system	Direct query
	16	Level of adequacy of technological systems: Air-Conditioning system	Direct query
	17	Level of adequacy of technological systems: Rainwater disposal plant	Direct query
	18	Level of maintenance of technological systems: Electrical system	Direct query
	19	Level of maintenance of technological systems: Hydraulic system	Direct query
	20	Level of maintenance of technological systems: Air-Conditioning system	Direct query
	21	Level of maintenance of technological systems: Rainwater disposal plant	Direct query
Evaluation	22	General conservation status	Direct query
	23	Level of significance	Direct query
	24	Intensity of use	Direct query
	25	Adequacy of use	Direct query
	26	Level of transformability	Direct query

5.1.6 Implementing the system through the information levels

After the system's organization phase and the queries, the previously arranged cartographic, geometric, and informative materials were introduced. Priority was given to large-scale cartographic materials to verify the selected reference system and provide context for subsequent insertions. In addition to aerial photos with WMS reference or integrated locally[18], digital models of the terrain (DTM), elevations (DEM), and surfaces (DSM)[19] and the survey of significant points acquired with GPS and GNSS technology[20] have been added. Once their correct positioning was verified, it was possible to implement the data concerning the buildings in the ISA area, therefore the school plans in vector and raster format coming from the laser scanner survey[21]. Consequently, it was possible to outline the buildings and individual rooms by adding all the information recorded and processed in the organized forms[22]. Finally, the results of the Action 3 were added to the system before the thematic maps were created[23].

5.1.6.1 Cartographic records

The selected cartographic materials have been imported directly via WMS (Web Map Service) connection. A selection of these has been inserted through traditional georeferencing hem always available locally without an internet connection (Figure 54 and Figure 55). On the other hand, WMS maps are accessible only through stable internet connections and allow to view areas outside the survey area. The groups and information levels implemented are shown below in Table 12.

Finally, the results of the three-dimensional territorial elaborations have been added. Therefore it was possible to implement the cartographic materials with contour lines and digital models of the terrain (DTM), elevations (DEM), and surfaces (DSM), as per the diagram in Table 13 (Figure 56 - Figure 59).

[18] See 5.1.2.1 Reference system and cartographic basis.
[19] See 5.1.2.4 DTM/DEM/DSM for the comprehension of the morphology.
[20] See 5.1.2.3 The GNSS/GPS data and the three-dimensional acquisitions.
[21] See 5.1.2.2 3D data as support to the management system.
[22] See 5.1.4 Descriptive data of the buildings and the spaces.
[23] For the whole list of macro-categories, groups and information levels see Annex 5E List of macro-categories, groups and information levels.

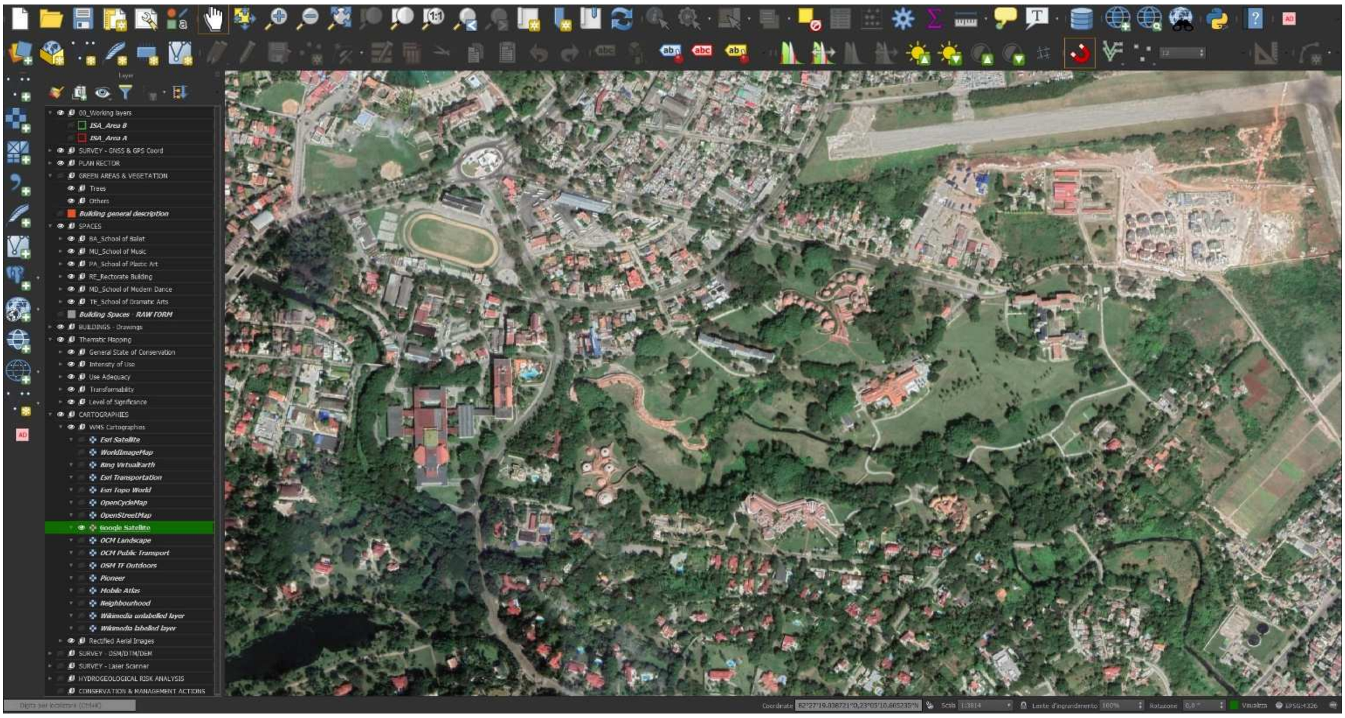

Figure 54 - Google Satellite aerial image through WMS connection.

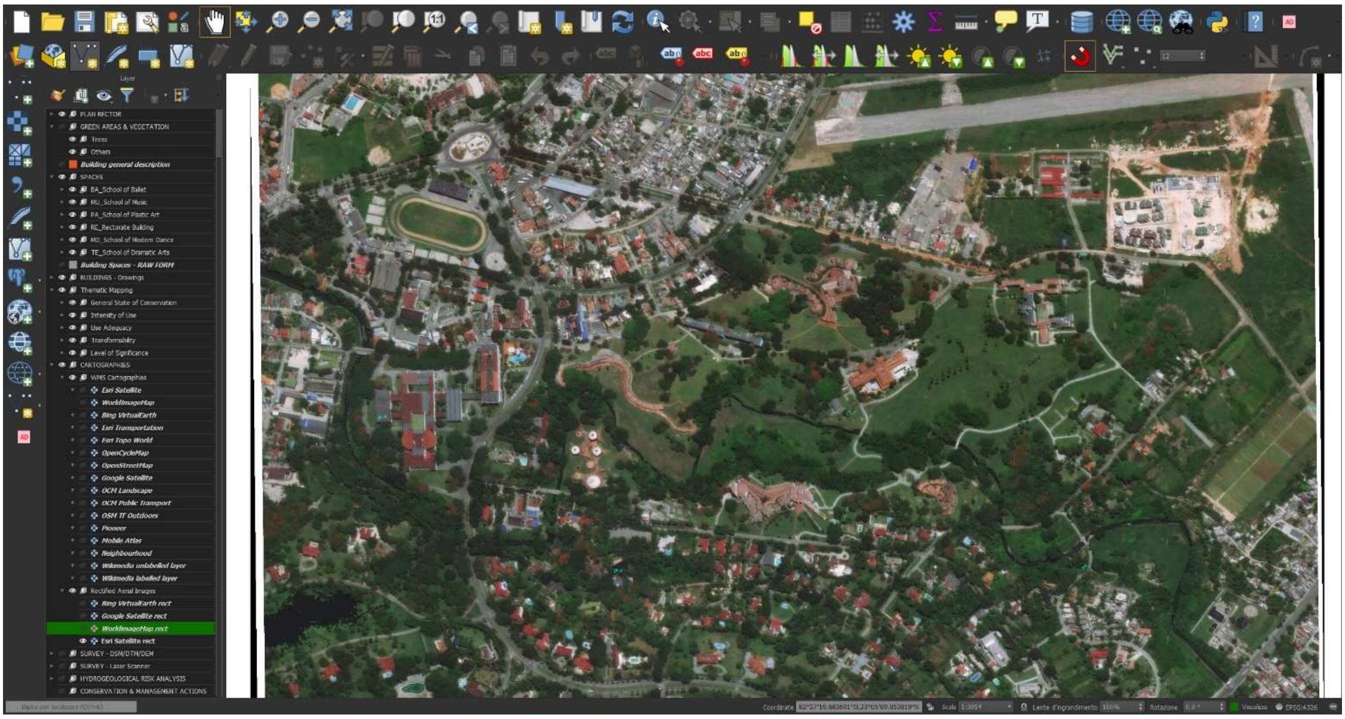

Figure 55 - World Image Map rectified stored into the system.

Table 12 - List of cartographic records.

Macro-category	Groups	Information levels
Cartographies	WMS Cartographies	ESRI Satellite
		WorldImageMap
		Bing Virtual Earth
		ESRI Transportation
		ESRI Topo world
		OpenCycleMap
		OpenStreetMap
		Google Satellite
		OCM Landscape
		OCM Public Transport
		OSM TF Outdoors
		Pioneer
		Mobile Atlas
		Neighborhood
		Wikimedia unlabeled layer
		Wikimedia labeled layer
	Rectified Aerial Images	Bing Virtual Earth rectified
		WorldImageMap rectified
		Google Satellite rectified
		ESRI Satellite rectified

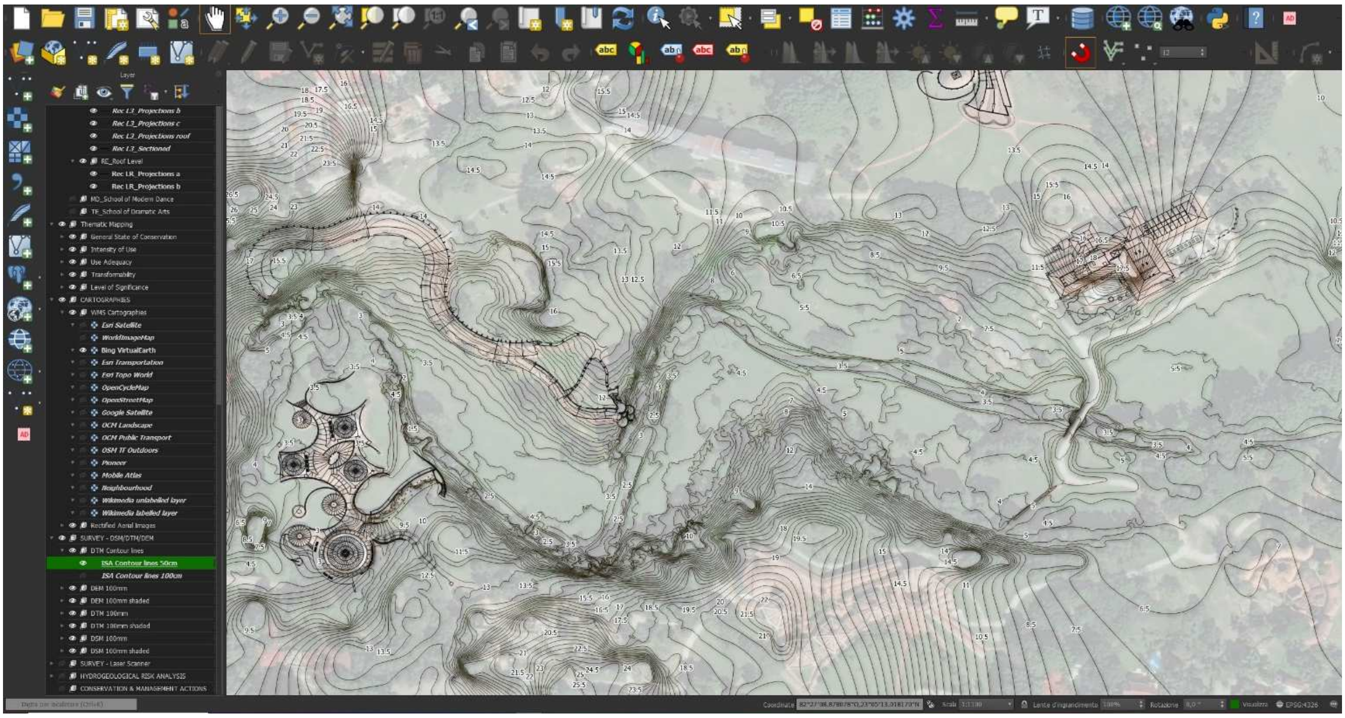

Figure 56 - Contour lines every 50 cm.

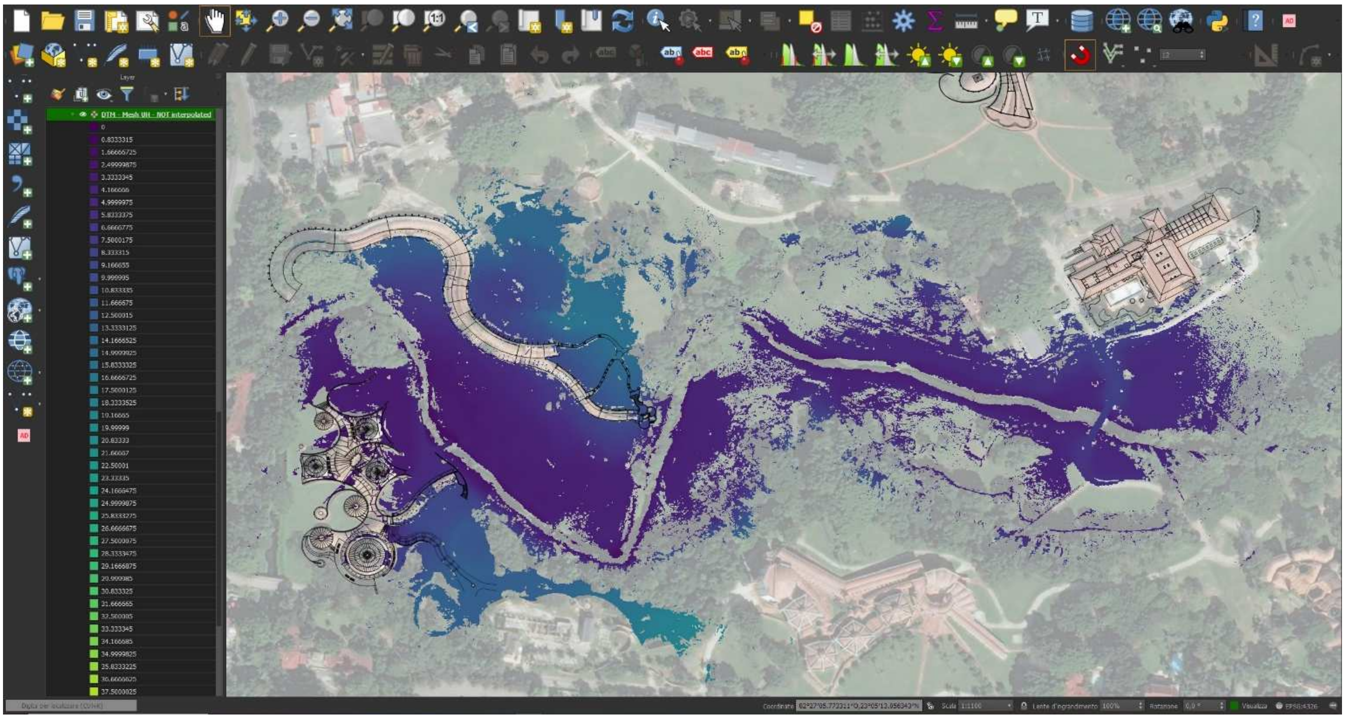

Figure 57 - Not interpolated Digital Terrain Model (DTM) on the Bing Virtual Earth map.

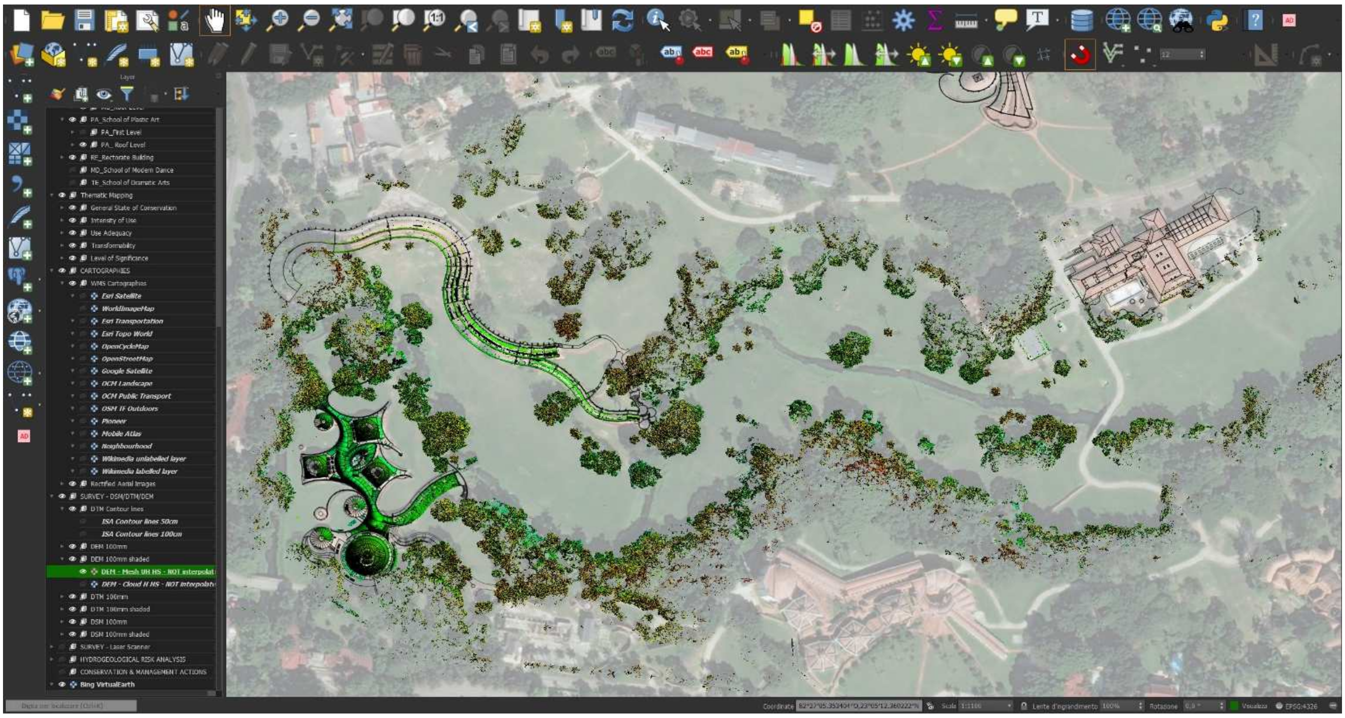
Figure 58 - Shaded Digital Elevation Model (DEM) on the Bing Virtual Earth map.

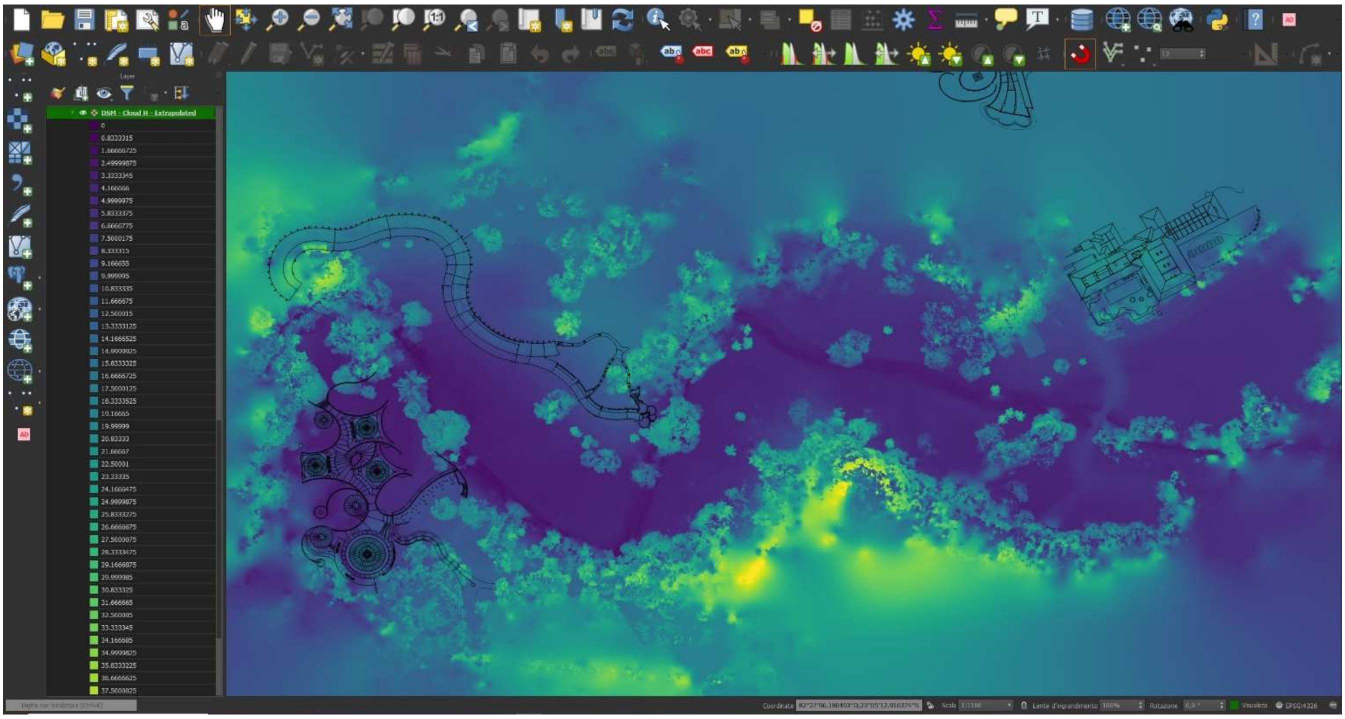
Figure 59 - Extrapolated Digital Surface Model (DSM).

Table 13 - List of digital elaborations.

Macro-category	Groups	Information levels
Survey DEM/DTM/DSM	DTM Contour lines	ISA Contour lines 50cm
		ISA Contour lines 100cm
	DEM 100mm	DEM - Mesh UH - NOT interpolated
		DEM - Cloud H - NOT interpolated
	DEM 100mm shaded	DEM - Mesh UH HS - NOT interpolated
		DEM - Cloud U HS - NOT interpolated
	DTM 100mm	DTM - Mesh UH - Extrapolated
		DTM - Mesh HU - NOT interpolated
		DTM - Cloud H - Extrapolated
		DTM - Cloud H - NOT interpolated
	DTM 100mm shaded	DTM - Mesh UH - Extrapolated
		DTM - Mesh HU - NOT interpolated
		DTM - Cloud H - Extrapolated
		DTM - Cloud H - NOT interpolated
	DSM 100mm	DSM - Mesh UH - Extrapolated
		DSM - Mesh HU - NOT interpolated
		DSM - Cloud H - Extrapolated
		DSM - Cloud H - NOT interpolated
	DSM 100mm shaded	DSM - Mesh UH - Extrapolated
		DSM - Mesh HU - NOT interpolated
		DSM - Cloud H - Extrapolated
		DSM - Cloud H - NOT interpolated

5.1.6.2 GNSS/GPS survey elaborations

The territorial cartographic documents were integrated with the points acquired through precision GPS and GNSS technology (Figure 60 and Figure 61) in different groups and levels, as shown in the diagram in Table 14.

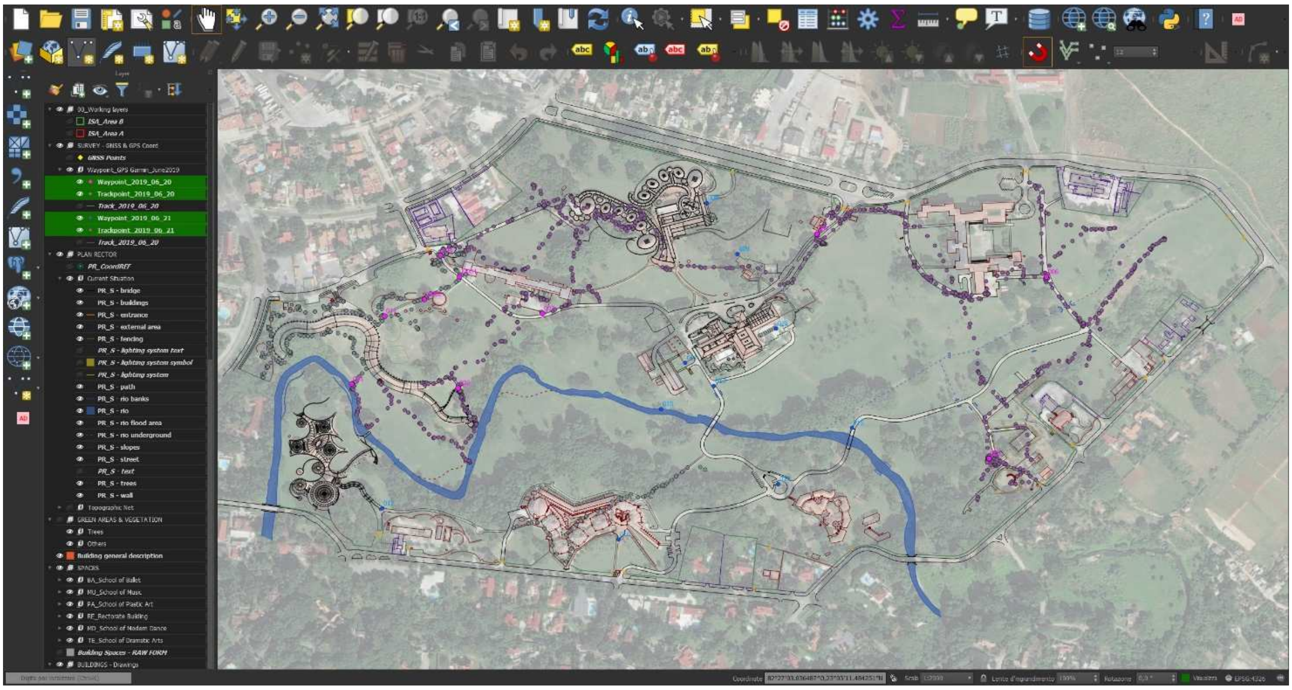

Figure 60 - GPS point (in purple) on the Bing Virtual Earth map.

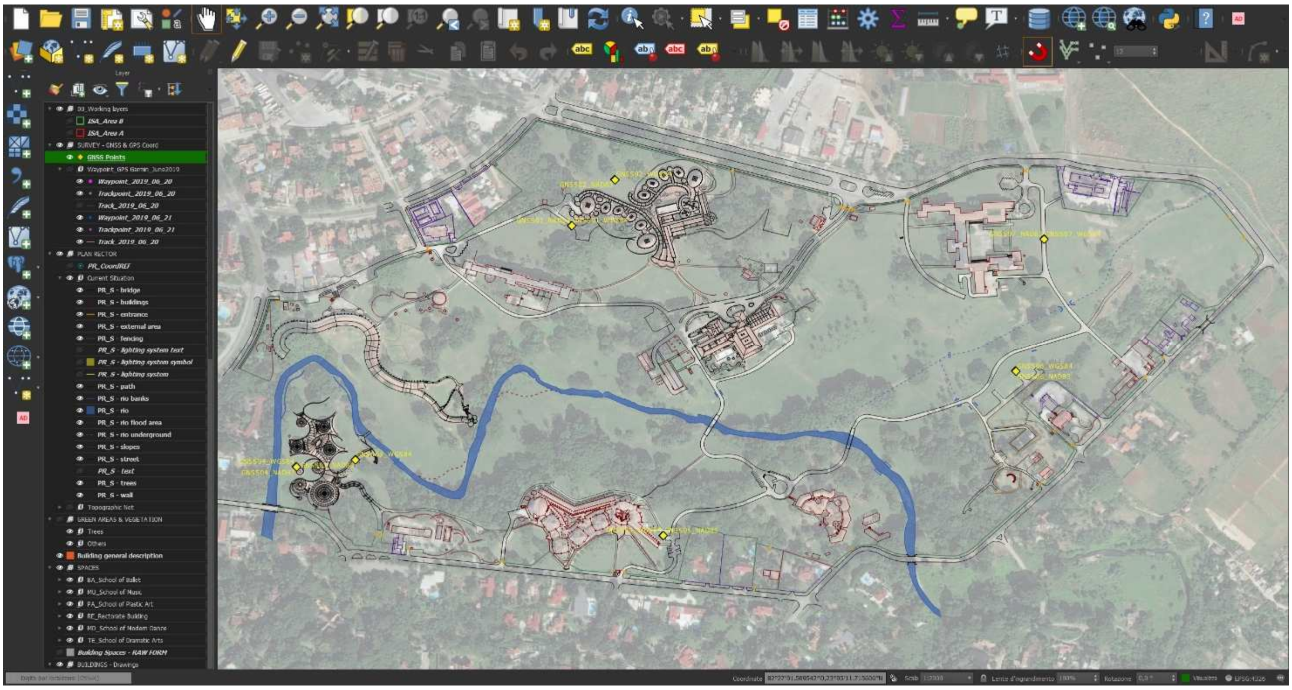

Figure 61 - GNSS points (in yellow) on the Bing Virtual Earth map.

Table 14 - List of GNSS/GPS levels.

Macro-category	Groups	Information levels
Survey GNSS & GPS	Waypoint GPS June 2019	Waypoint - 2019_06_20
		Trackpoint - 2019_06_20
		Track - 2019_06_20
		Waypoint - 2019_06_21
		Trackpoint - 2019_06_21
		Track - 2019_06_21
	GNSS Points	GNSS points - June 2019

5.1.6.3 Laser scanner results

Once the levels with territorial detail were created and implemented, after verifying the system's correct functionality, it was possible to link the elaborations concerning the area and the buildings. In fact, the cartographic materials and the GPS/GNSS points, in addition to contextualizing the information, play the fundamental role of connection, allowing a perfect superimposition of the different elaborations. Thus, it was possible to insert the point clouds in zenith view and raster format from the laser scanner survey, as shown in the diagram in Table 15. These are divided by area and characterized by different detail levels based on the instrumental acquisitions performed. In fact, it is possible to view point clouds that geometrically describe the area or buildings (Figure 62 and Figure 63) or portions of these (Figure 64 - Figure 66). Subsequently, it was possible to implement the system with vector processing. In this case, it was connected to the entire area (Figure 67 and Figure 68) and the buildings surveyed (Figure 69 - Figure 71), as shown in the diagrams in Table 16 and Table 17.

Table 15 - List of Laser Scanner records.

Macro-category	Groups	Information levels
Survey Laser Scanner	BA-MU School of Ballet & Music	BA Zt_CoordREF
		BA MU_CoordREF
		BA Zt_BW pt1 Detail Practice room
		BA Zt_BW pt2 Detail Choreographic Theater
		BA MU_BW pt1
		BA MU_BW pt2
		BA MU_BW pt3
		BA MU_BW pt4
		BA MU_COL pt1
		BA MU_COL pt2
		BA MU_COL pt3
		BA MU_COL pt4
	MU-Rec Rio Quibù (Western Area)	MU Rec_CoordREF
		MU Rec_BW pt2
		MU Rec_BW pt3
		MU Rec_BW pt4
		MU Rec_BW pt5
	PA School of Plastic Arts	PA Zt_CoordREF
		PA_CoordREF
		PA Zt_BW Detail Practice room
		PA_BW pt1
		PA_BW pt2
		PA_COL pt1
		PA_COL pt2

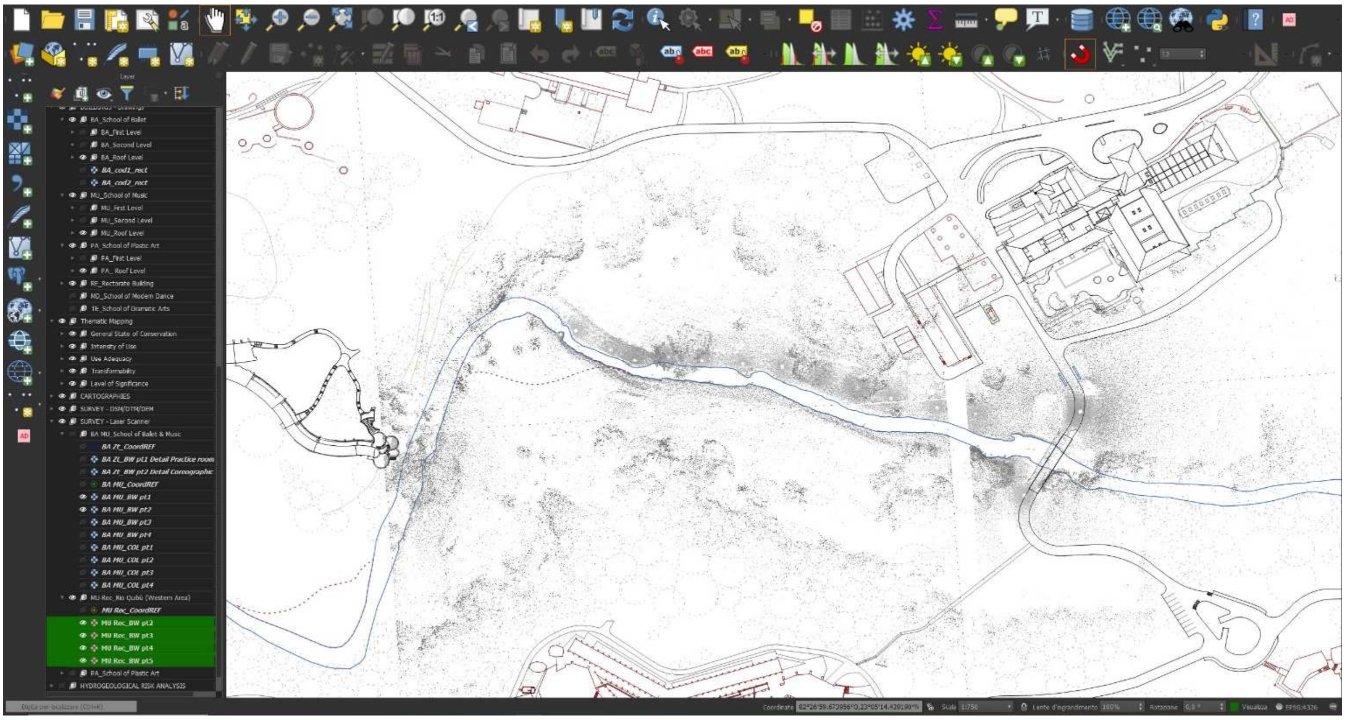

Figure 62 - Grayscale cloud of points of the central area of the ISA.

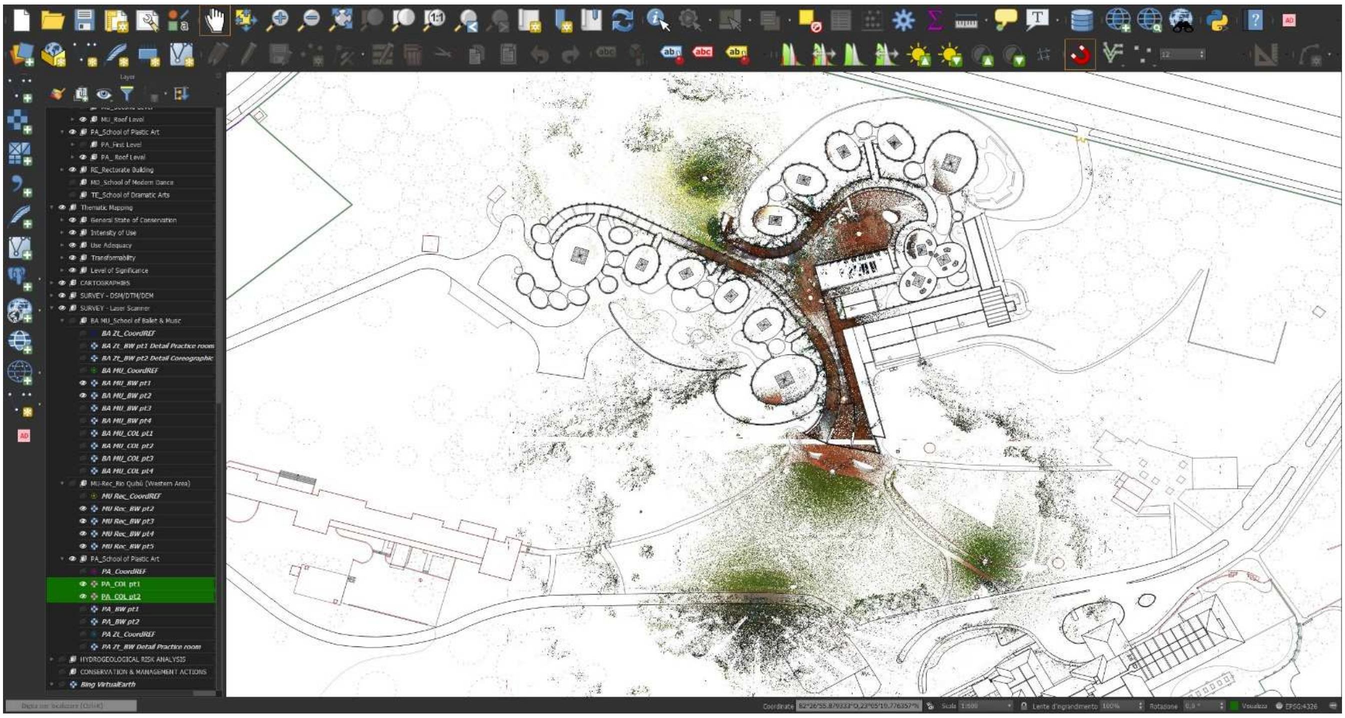

Figure 63 - RGB cloud of points of the School of Plastic Arts.

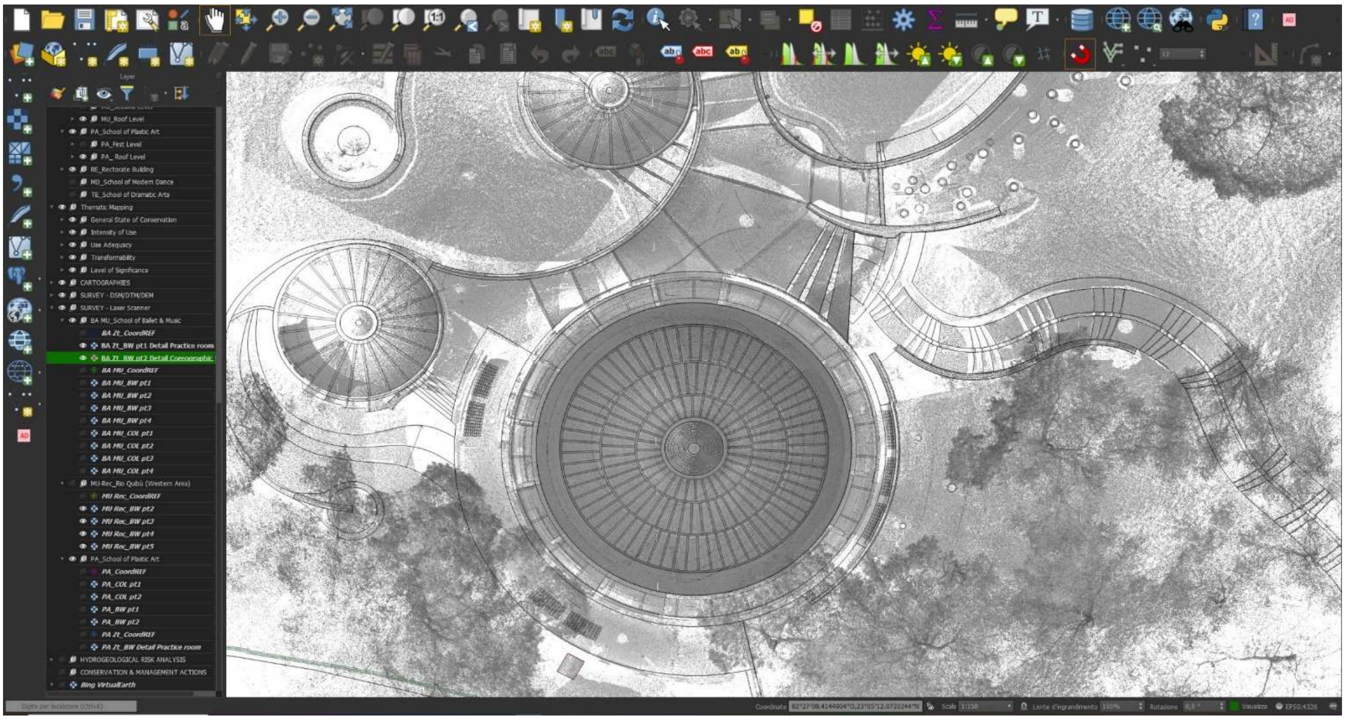

Figure 64 - Grayscale cloud of points of the choreographic theatre of the School of Ballet.

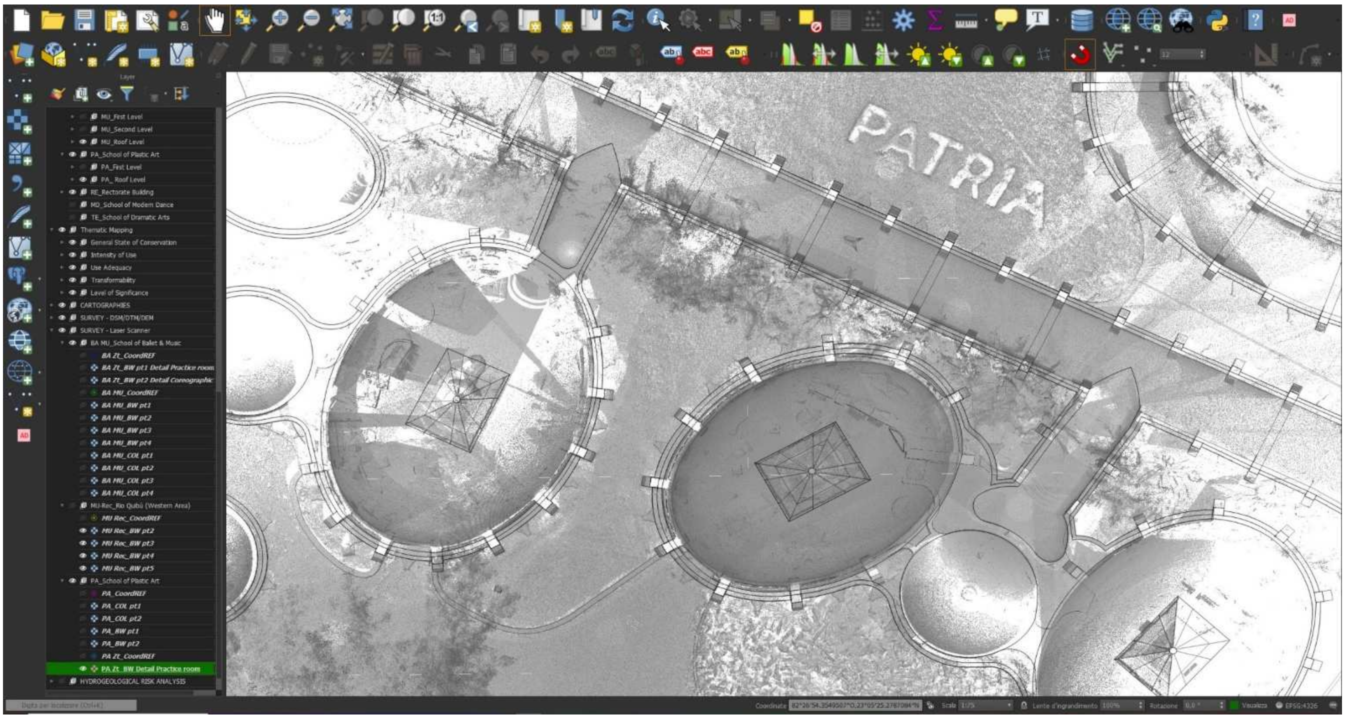

Figure 65 - Grayscale cloud of points of a practice classroom of the School of Plastic Arts.

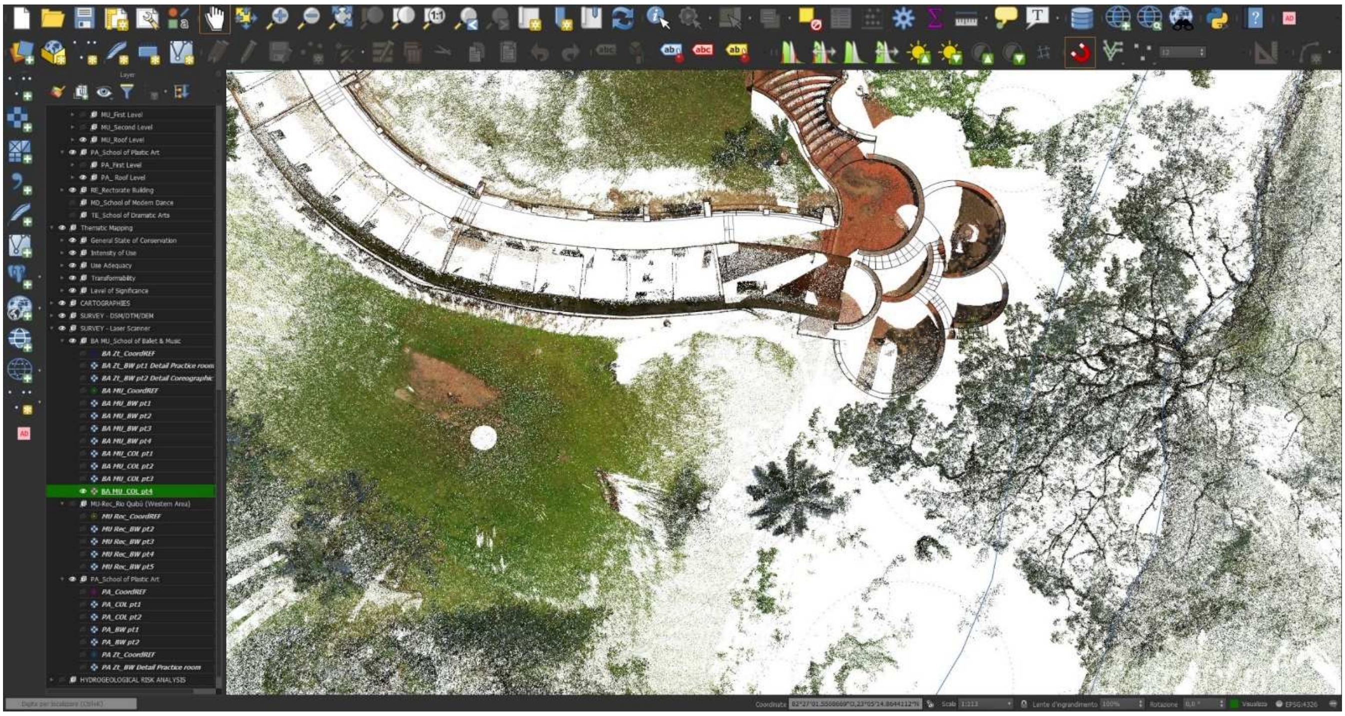

Figure 66 - RGB cloud of points of the eastern part of the School of Music.

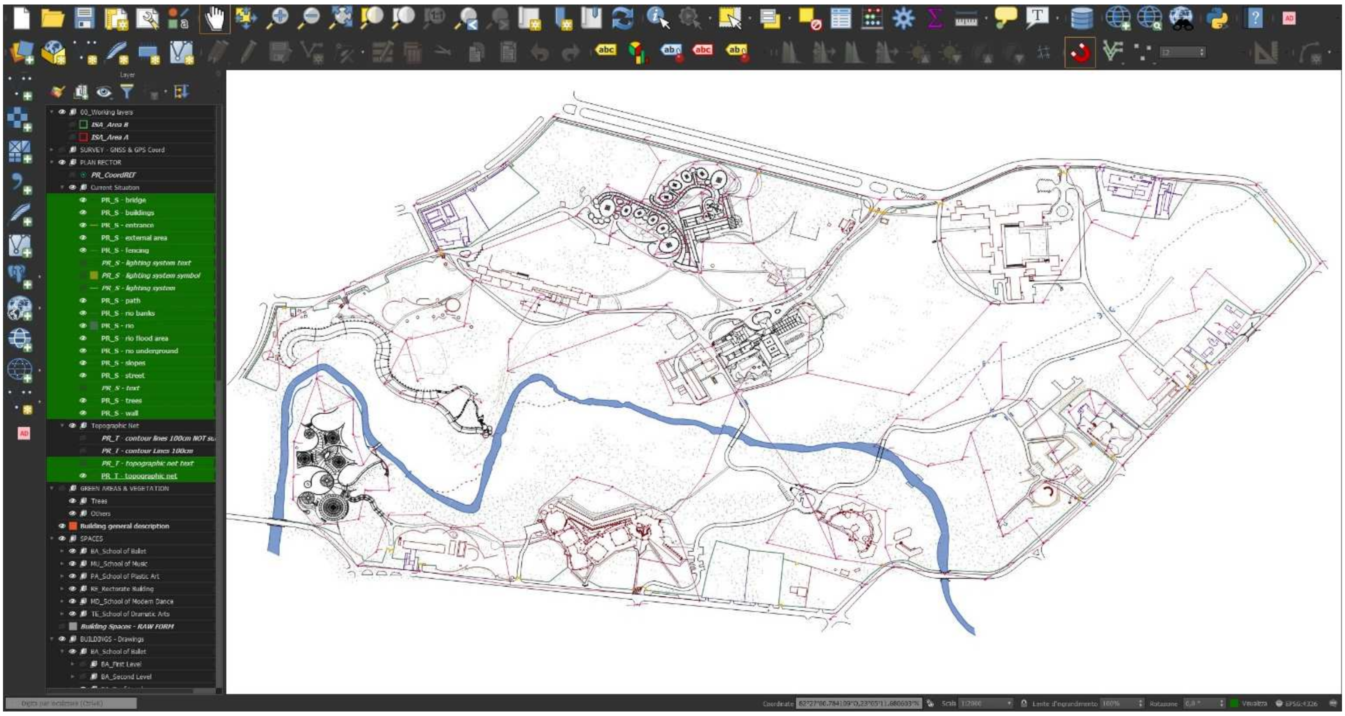

Figure 67 - Vector graphic drawing of the “Plan Rector”.

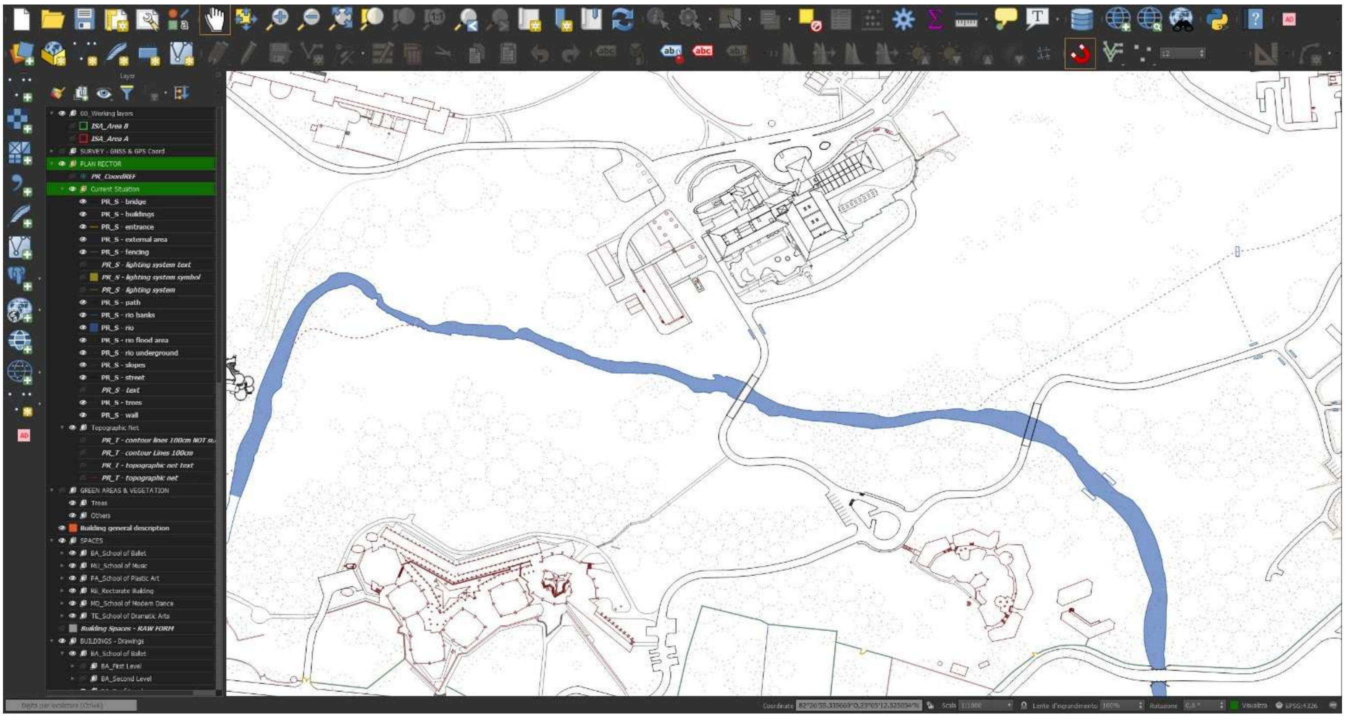

Figure 68 - Detail of the vector graphic drawing of the “Plan Rector”.

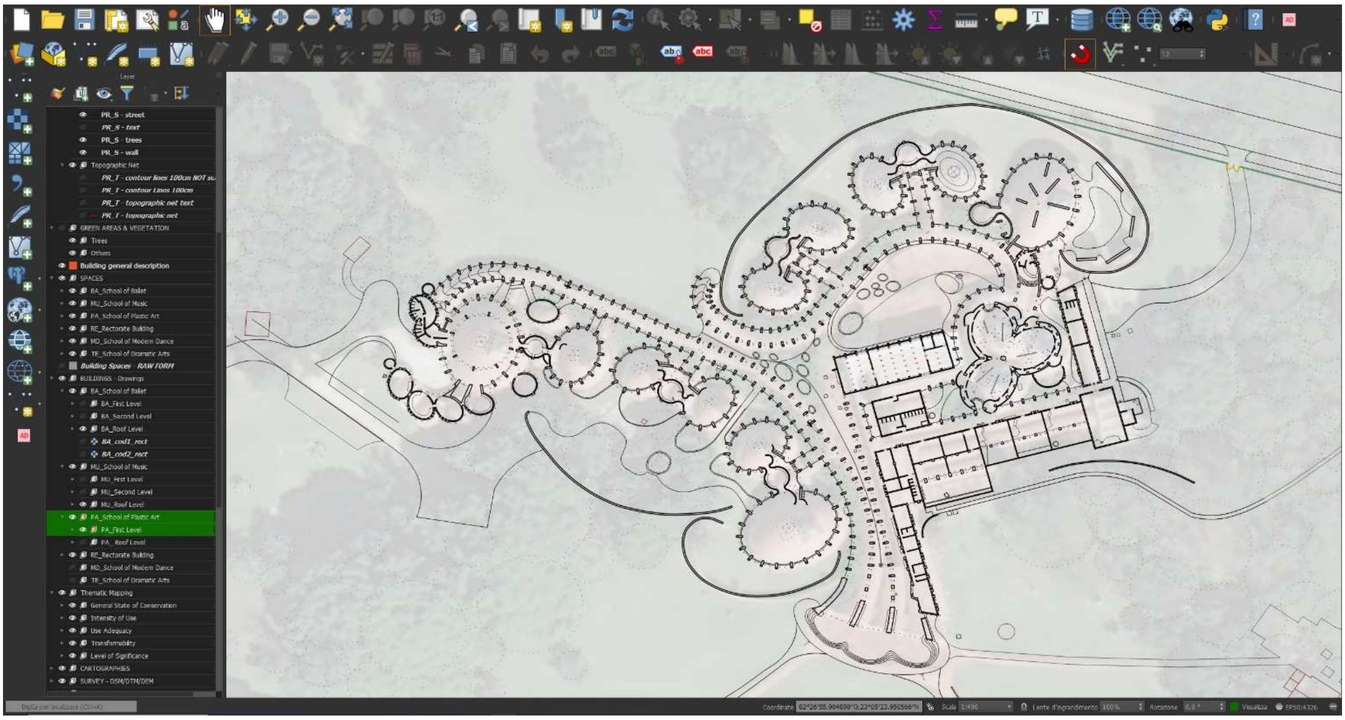

Figure 69 - Vector graphic drawing of the School of Plastic Arts on the Bing Virtual Earth map.

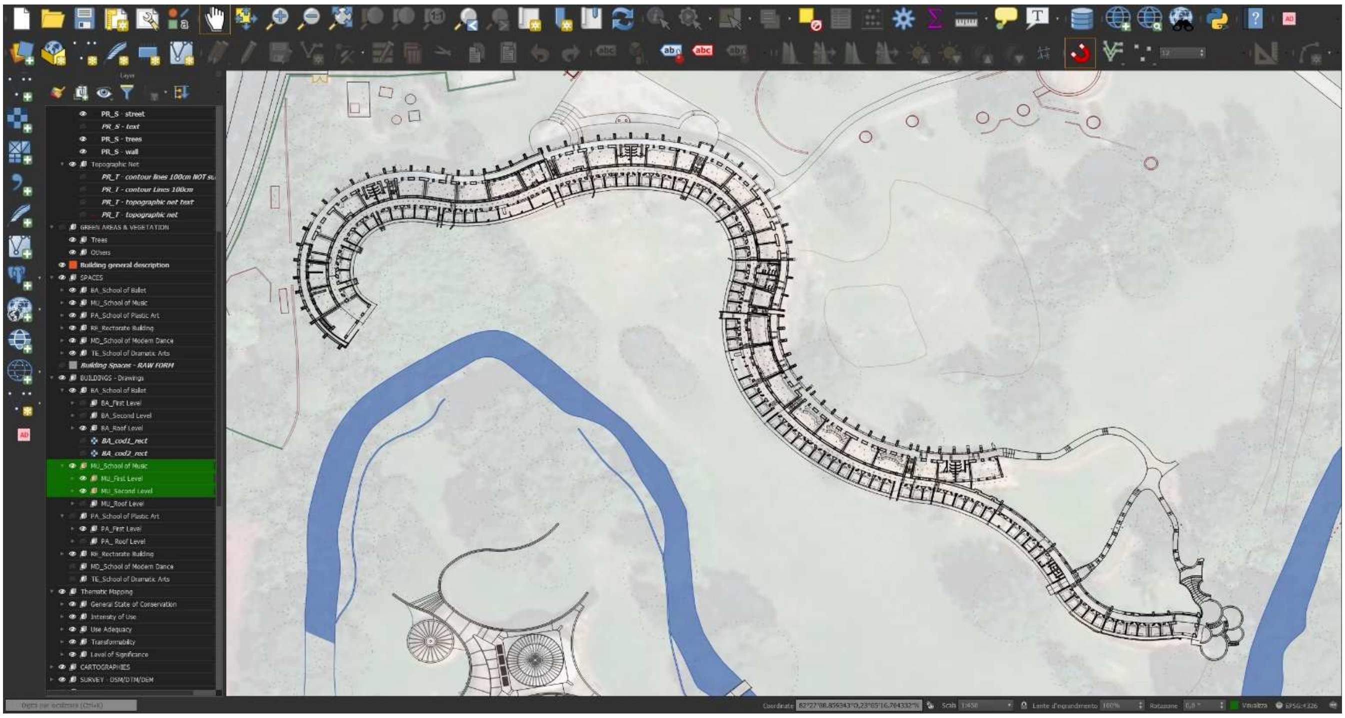

Figure 70 - Vector graphic drawing of the School of Music on the Bing Virtual Earth map.

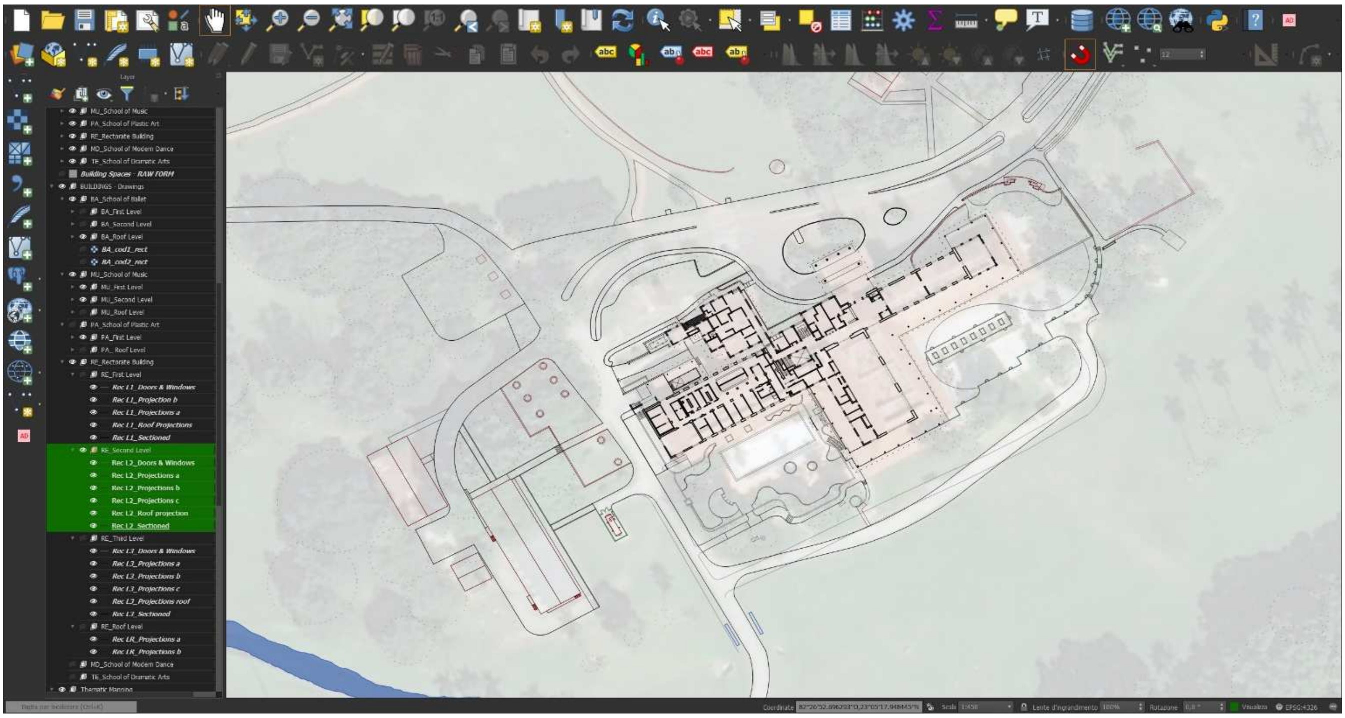

Figure 71 - Vector graphic drawing of the Rectorate building on the Bing Virtual Earth map.

Table 16 - List of levels related to the general plan of the area.

Macro-category	Groups	Information levels
Plan Rector	Current Situation	PR_S - bridge
		PR_S - buildings
		PR_S - entrance
		PR_S - external area
		PR_S - fencing
		PR_S - lighting system
		PR_S - lighting system symbols
		PR_S - path
		PR_S - rio
		PR_S - rio banks
		PR_S - rio flood area
		PR_S - slopes
		PR_S - streets
		PR_S - text
		PR_S - trees
		PR_S - wall
	Topographic net	PR_T - contour Lines 100cm
		PR_T - topographic net text
		PR_T - topographic net
		PR_T - contour lines 100cm NOT surveyed
	PR_CoordREF	PR_CoordREF

Table 17 - List of the vector-graphic levels of the buildings.

Macro-category	Groups	Information levels
Buildings Drawings	BA_School of Ballet	BA_First Level
		BA_Second Level
		BA_Roof Level
	MD_School of Modern Dance	MD_First Level
	MU_School of Music	MU_First Level
		MU_Second Level
		MU_Roof Level
	PA_School of Music	PA_First Level
		PA_Roof Level
	RE_Rectorate Building	RE_First Level
		RE_Second Level
		RE_Third Level
		RE_Roof Level

5.1.6.4 Descriptive data of the buildings and spaces

Finally, to complete the knowledge background, we proceeded to characterize the buildings' spaces for the analysis, as shown in the diagram in

Table 18. Thanks to vector graphic support, it was, in fact, possible to outline the buildings of the ISA complex and subsequently identify each relevant area or space, such as rooms, classrooms, corridors, and open spaces directly connected to a structure (Figure 72 and Figure 73). This operation also allowed to anchor the data from the inspections of June 2019 and February 2020 to each object as established in the specially designed attribute tables (Figure 74 - Figure 76)[24]. Therefore, the implementation of this information provided all the useful data to characterize the spaces for creating thematic maps[25].

Table 18 - List of records related to the building spaces.

Macro-category	Groups	Information levels
Spaces	BA_School of Ballet	BA_First Level
		BA_Second Level
	MD_School of Modern Dance	MD_First Level
	MU_School of Music	MU_First Level
		MU_Second Level
	PA_School of Music	PA_First Level
	RE_Rectorate Building	RE_First Level
		RE_Second Level
		RE_Third Level

[24] See 5.1.4 Descriptive data of the buildings and the spaces.
[25] See 5.1.7 Thematic maps to support the understanding of the site and the CMP's draft.

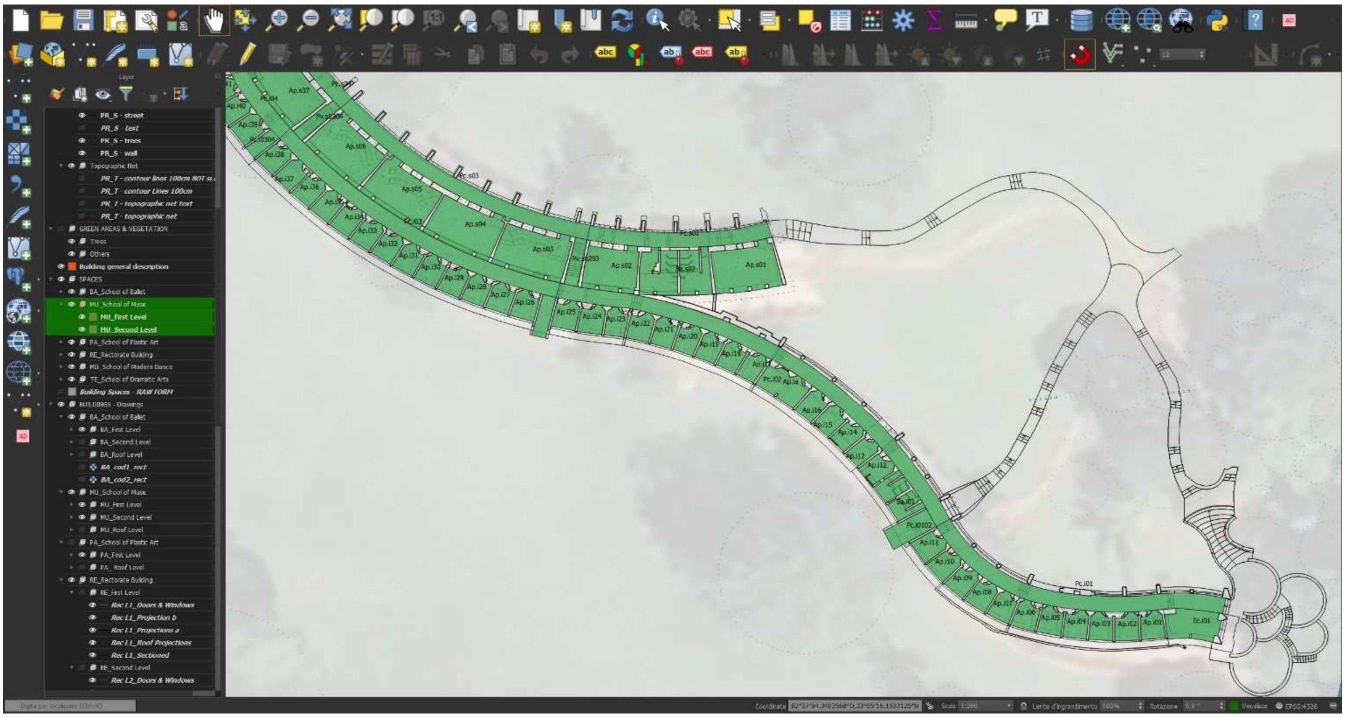

Figure 72 - The descriptive data of the Scholl of Music spaces.

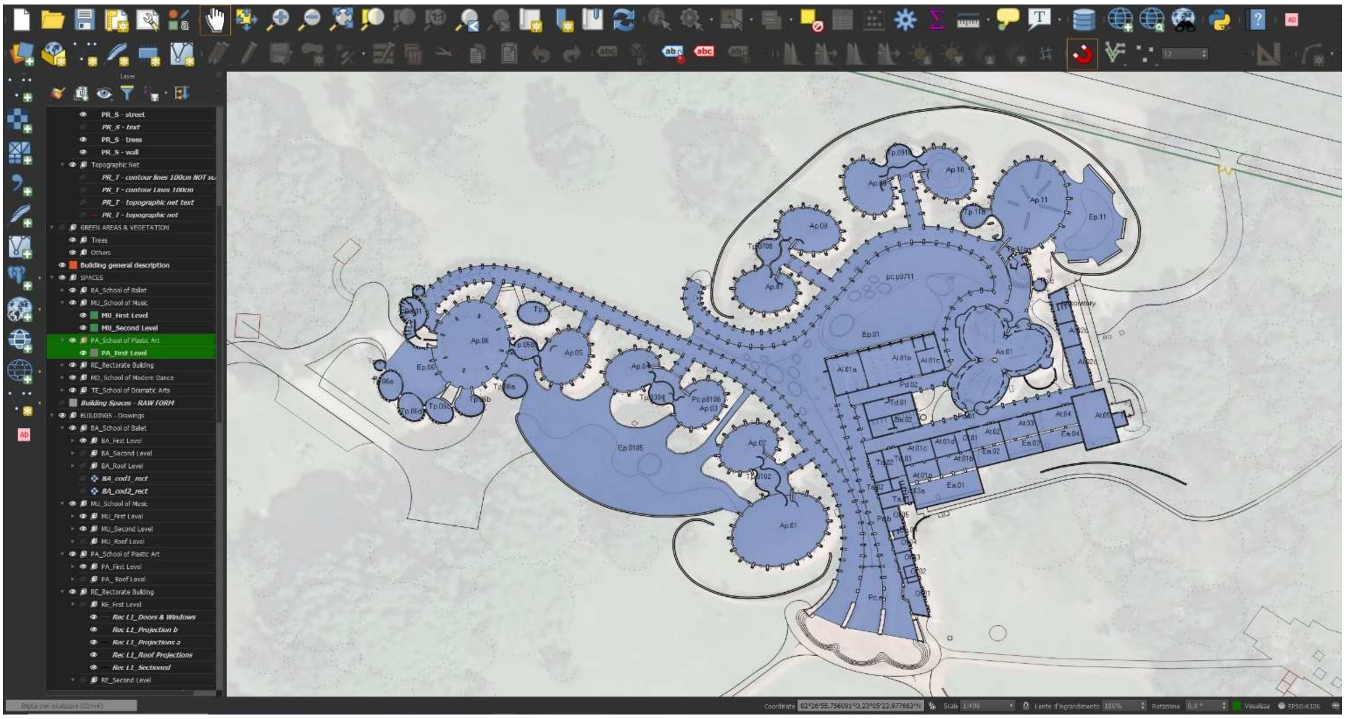

Figure 73 - The descriptive data of the School of Plastic Arts spaces.

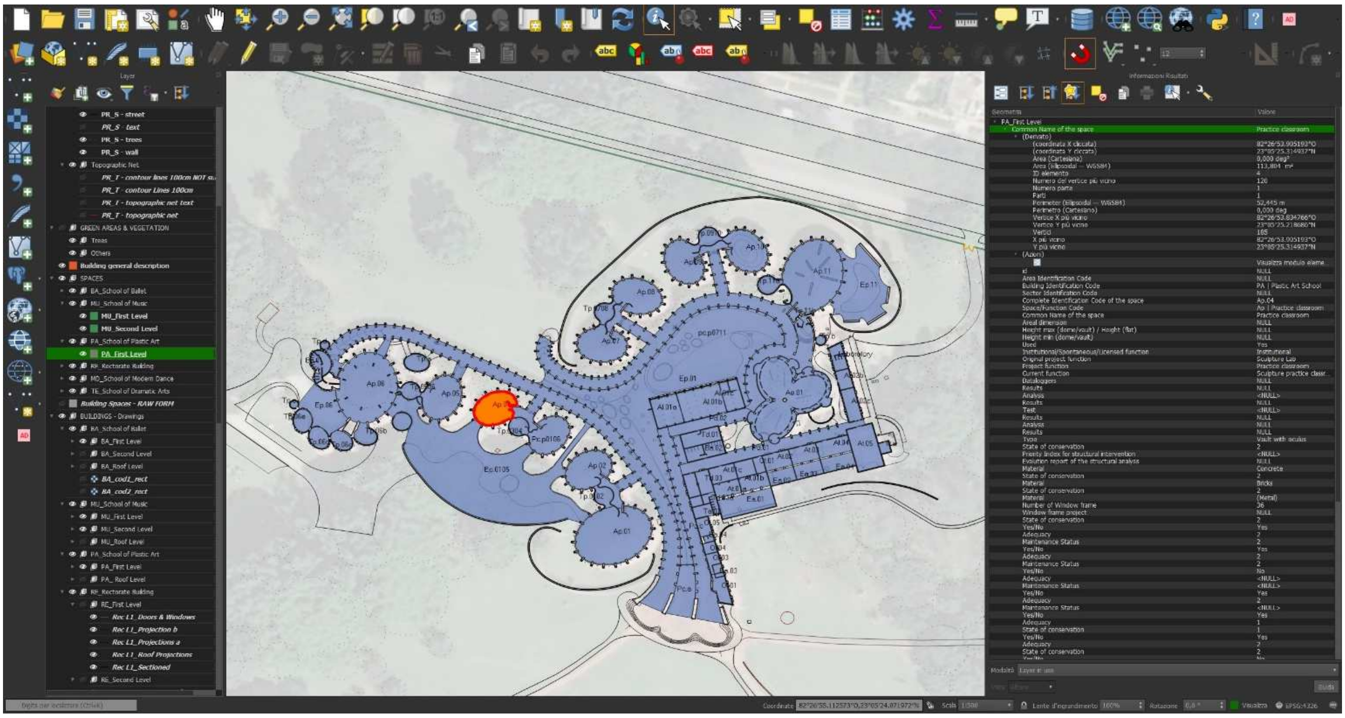

Figure 74 - The descriptive data of a School of Plastic Arts practice classroom.

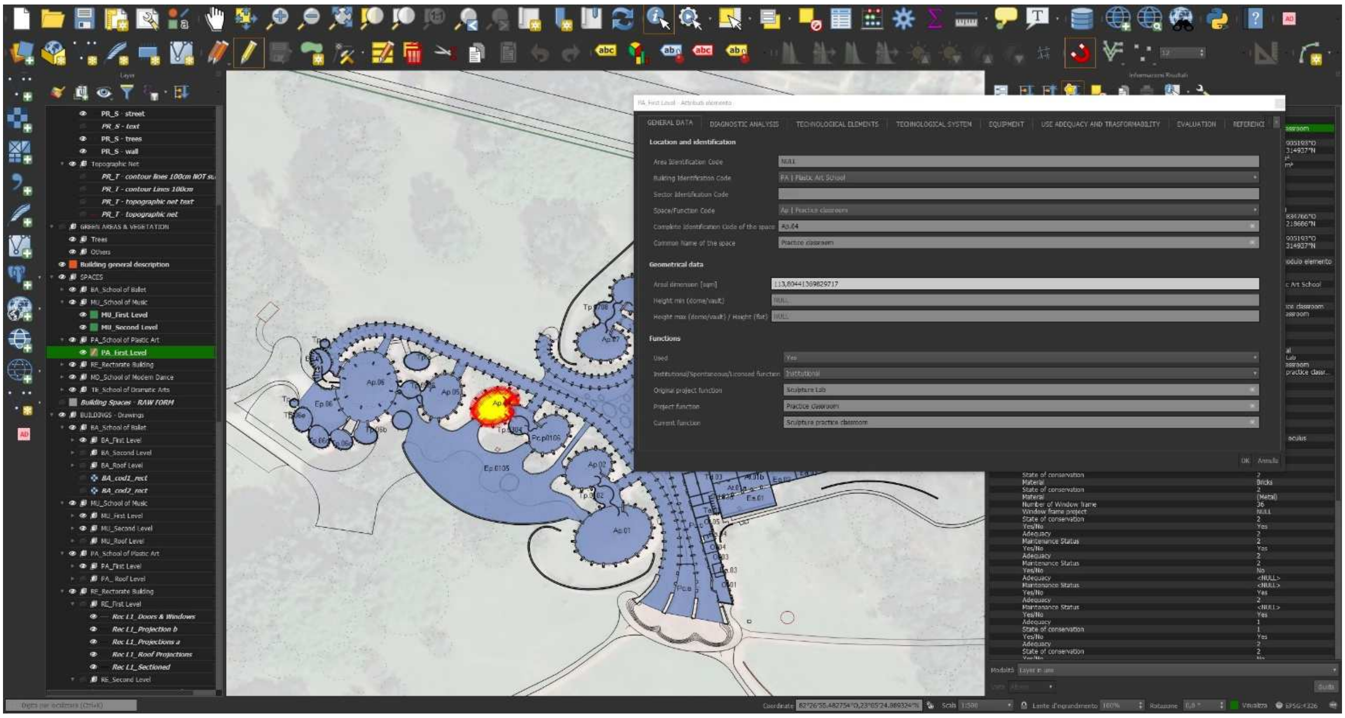

Figure 75 - The descriptive data of a School of Plastic Arts practice classroom.

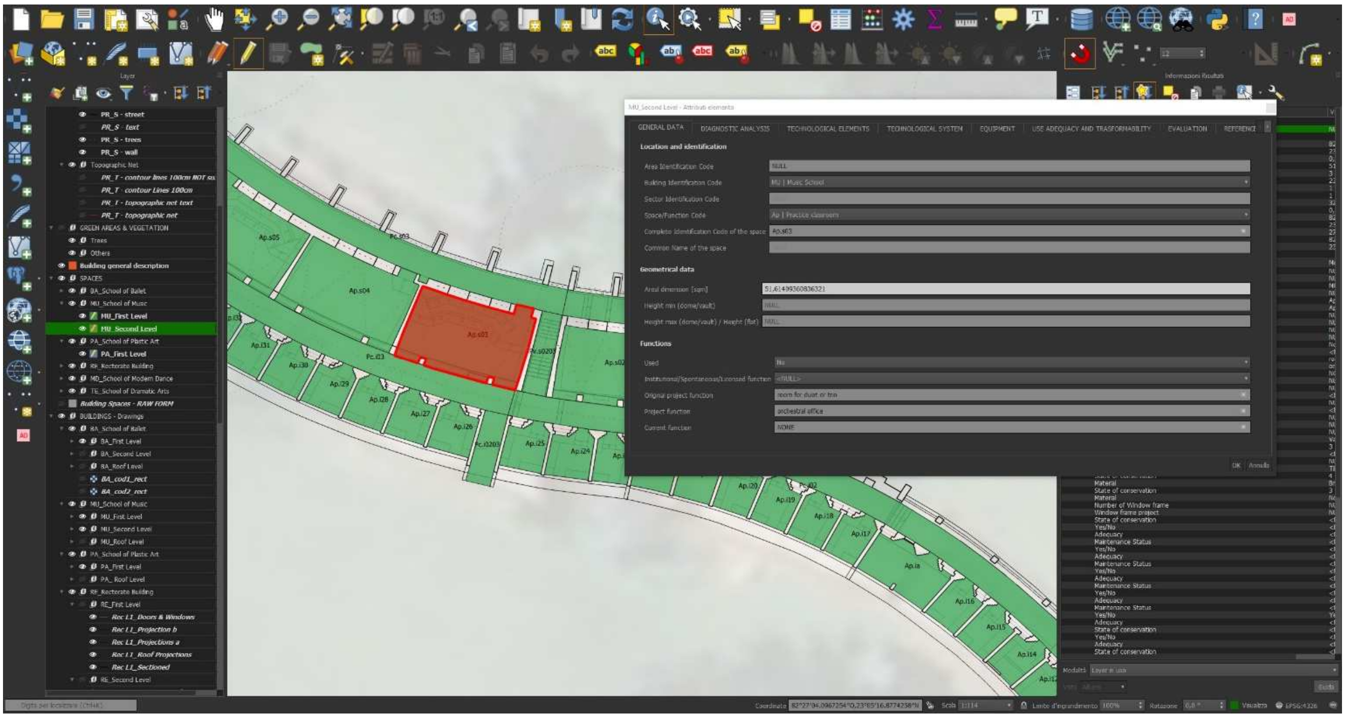

Figure 76 - The descriptive data of a School of Music classroom.

5.1.6.5 Visualization of the hydrogeological risk analysis' results

Finally, the first results of the investigations concerning the "Landscape management and flood risk assessment and mitigation"[26] were included in the system as per the scheme in Table 19. The working group that dealt with these analyses used the cartographic documentation generated by the three-dimensional territorial survey[27] . Therefore, it was possible to insert the processed information by automatically placing it in the correct position (Figure 77 - Figure 78).

Table 19 - List of levels related to the hydrogeological risk analysis.

Macro-category	Groups	Information levels
Hydrogeological Risk Analysis	Flood areas DEPTH	Depth [m]_*Recurso Idraulico* 2005_T=100 years
		Depth [m]_*Recurso Idraulico*-Wall 2005_T=100 years
		Depth [m]_T=5 years
		Depth [m]_T=10 years
		Depth [m]_T=20 years
		Depth [m]_T=100 years
	Flood areas VELOCITY	Velocity [m/s]_*Recurso Idraulico* 2005_T=100 years
		Velocity [m/s]_*Recurso Idraulico*-Wall 2005_T=100 years
		Velocity [m/s]_T=5 years
		Velocity [m/s]_T=10 years
		Velocity [m/s]_T=20 years
		Velocity [m/s]_T=100 years

[26] See Action 3 Landscape management and flood risk assessment and mitigation.
[27] See 5.1.2.4 DTM/DEM/DSM for the comprehension of the morphology.

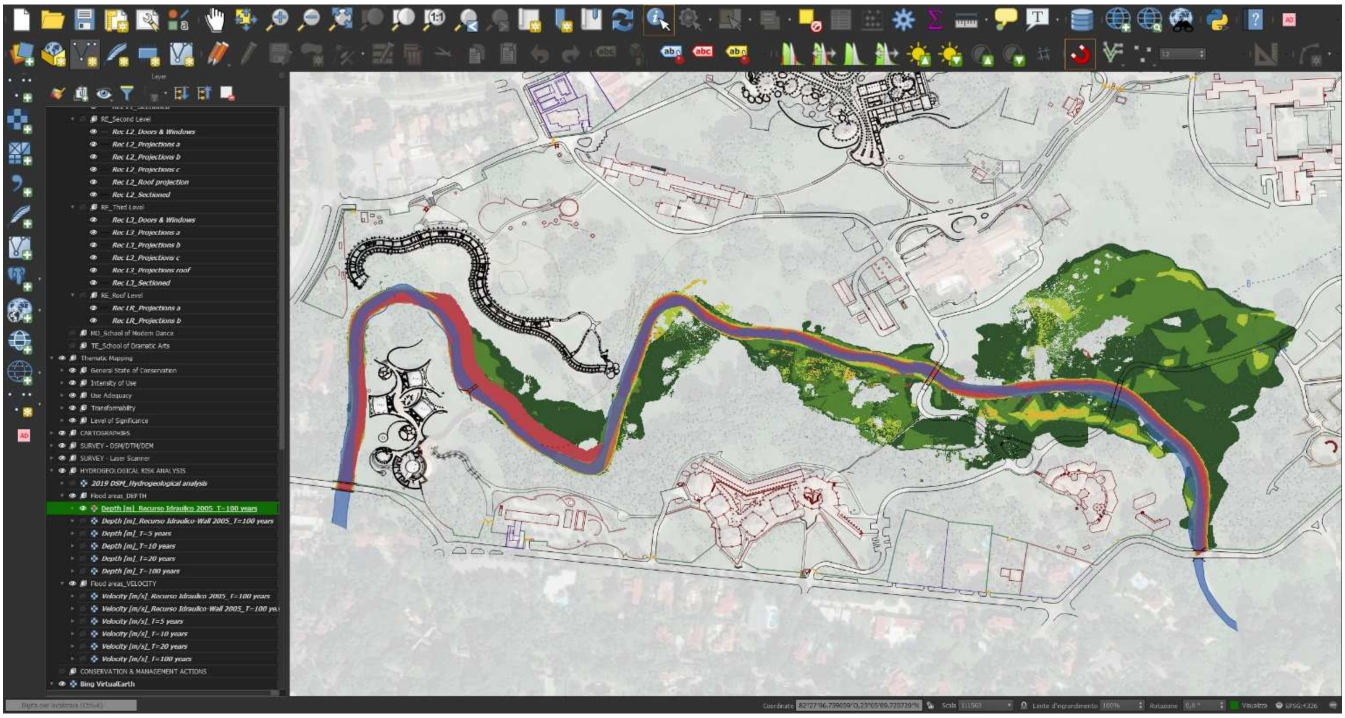

Figure 77 - Depth map based on the analysis of the *Instituto Nacional de Recursos Hidraulicos*, 2005.

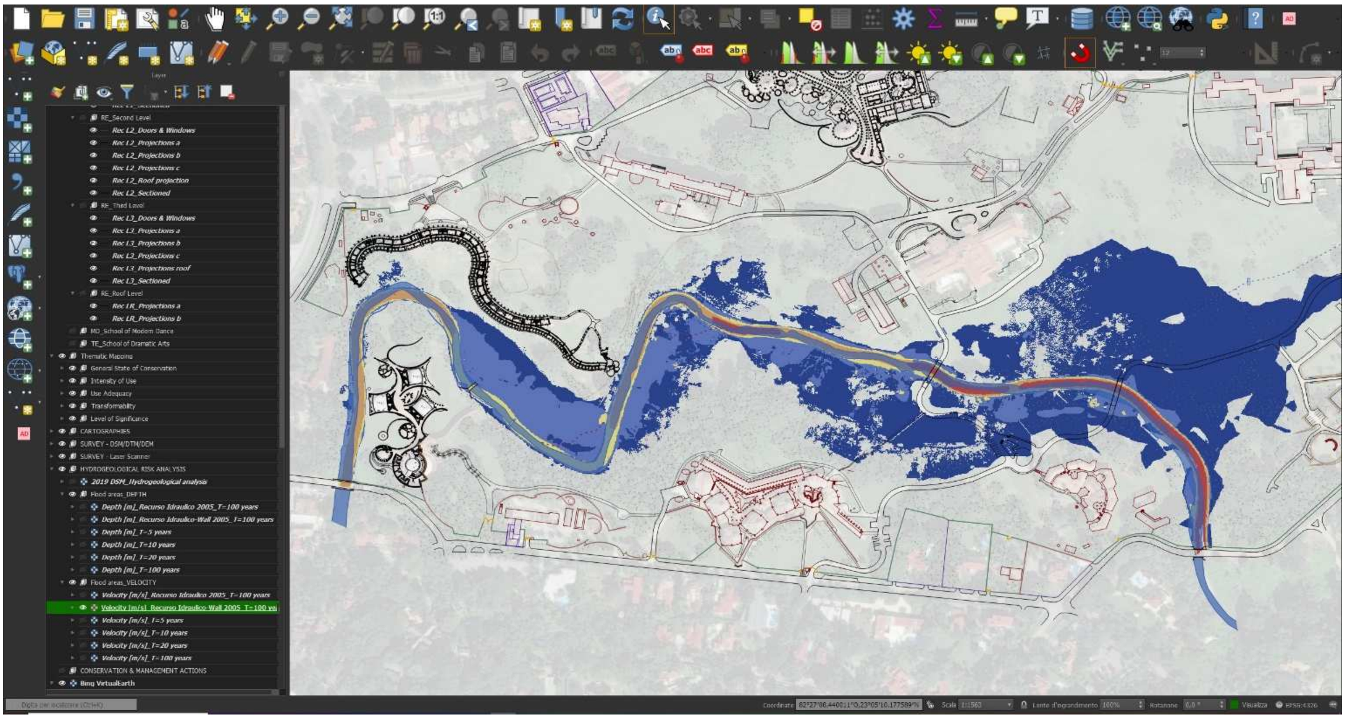

Figure 78 - Velocity map based on the analysis of the *Instituto Nacional de Recursos Hidraulicos*, 2005.

5.1.7 Thematic maps to support the understanding of the site and the CMP's draft

The data implemented in the system made it possible to obtain an advanced database of cartographic, geometric-morphological, and descriptive elements[28]. This information was used for two different purposes: the first for their direct consultation, the second for data analysis through the querying system.

Consultation is provided for all categories, groups, and informative levels with the possibility of varying the display parameters to overlay the available graphic outputs. The application of the querying system[29], on the other hand, has allowed the creation of real synthesis documents, also called thematic maps, showing graphically the result of queries made to the database. The results reflect the type of spatial analysis, therefore simple querying, proximity analysis, and overlay analysis. For all the three research categories, the output consists of the synoptic visual rendering of the spatial and non-spatial distribution of a specific phenomenon. The thematic maps created both as a result of a study and in support of the research group are actually new concluded levels of the G.I.S. or the levels on which further analysis and improvements can be made.

As reported in Table 20, the questions were divided by topic or group in such a way as to cover the main aspects of the activities carried out. In addition to the structuring that uses the SQL language, allowing to formalize the search criteria in a table field, the visual aspects have been defined to characterize the queries' outcome elements. In fact, it was crucial to associate an adequate graphic output to the type of request made to the database so that a clear thematic map was obtained, not requiring specific clarifications or textual additions.

Among the thematic maps created, those relating to the evaluation of the spaces of schools and buildings in the ISA area are of great interest (in Table 20, n. 22-26). The database associated with the "Spaces" level was interrogated for their creation, allowing each school space to be categorized based on the related evaluation. For each evaluation category (General conservation status, Level of significance, Intensity or use, Adequacy of use, Transformability), an equivalent color range was set in order to compare the data coming from different buildings with the same evaluation criteria (Figure 79). The graphic choices and the chromatic ranges can be varied according to the needs. It was, in fact, essential to be able to superimpose the themes in such a way as to create summary maps capable of showing multiple results in a single representation (Figure 80).

A similar categorization method was used to create thematic maps associated with the analyses addressed in "Landscape management and flood risk assessment and mitigation" (Figure 81 - Figure 84). All the thematic maps and the querying system results can be viewed directly within the system or can be exported to external documents.

[28] See 5.1.6 Implementing the system through the information levels.
[29] See 5.1.5 Identifying the queries to create thematic maps.

Table 20 - List of queries and their typology.

Group	N	Query	Typology
Location and identification	1	Spaces macro code from the classification	Direct query
	2	Areal dimensions	Proximity analysis
	3	Height dimension [dome/vault/flat slabs max]	Direct query
	4	Height dimensions [dome/vault min]	Direct query
	5	Height dimensions [average]	Complex query
Functions	6	Project function if not used	Complex query
	7	Function of the space if used differently concerning the project	Complex query
	8	Function of the space if used spontaneously / with license	Complex query
	9	Institutionalized licensed spaces	Direct query
Technological elements	10	State of conservation: Roofs	Direct query
	11	State of conservation: Floors	Direct query
	12	State of conservation: Vertical surfaces	Direct query
	13	State of conservation: Windows frame	Direct query
Technological systems	14	Level of adequacy of technological systems: Electrical system	Direct query
	15	Level of adequacy of technological systems: Hydraulic system	Direct query
	16	Level of adequacy of technological systems: Air-Conditioning system	Direct query
	17	Level of adequacy of technological systems: Rainwater disposal plant	Direct query
	18	Level of maintenance of technological systems: Electrical system	Direct query
	19	Level of maintenance of technological systems: Hydraulic system	Direct query
	20	Level of maintenance of technological systems: Air-Conditioning system	Direct query
	21	Level of maintenance of technological systems: Rainwater disposal plant	Direct query
Evaluation	22	General conservation status	Direct query
	23	Level of significance	Direct query
	24	Intensity of use	Direct query
	25	Adequacy of use	Direct query
	26	Level of transformability	Direct query

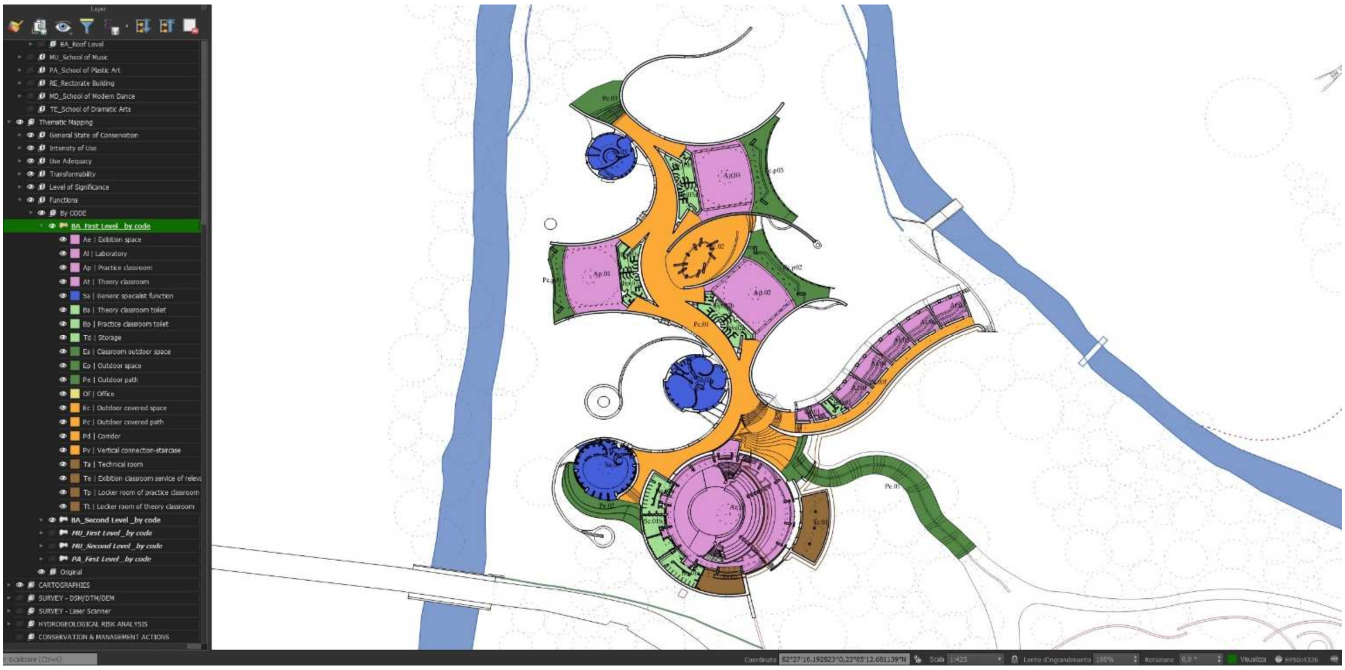

Figure 79 - School of Ballet, first- and second-level, Thematic map: Functions by code.

Figure 80 - School of Plastic Arts, Thematic map: General conservation status and Level of significance.

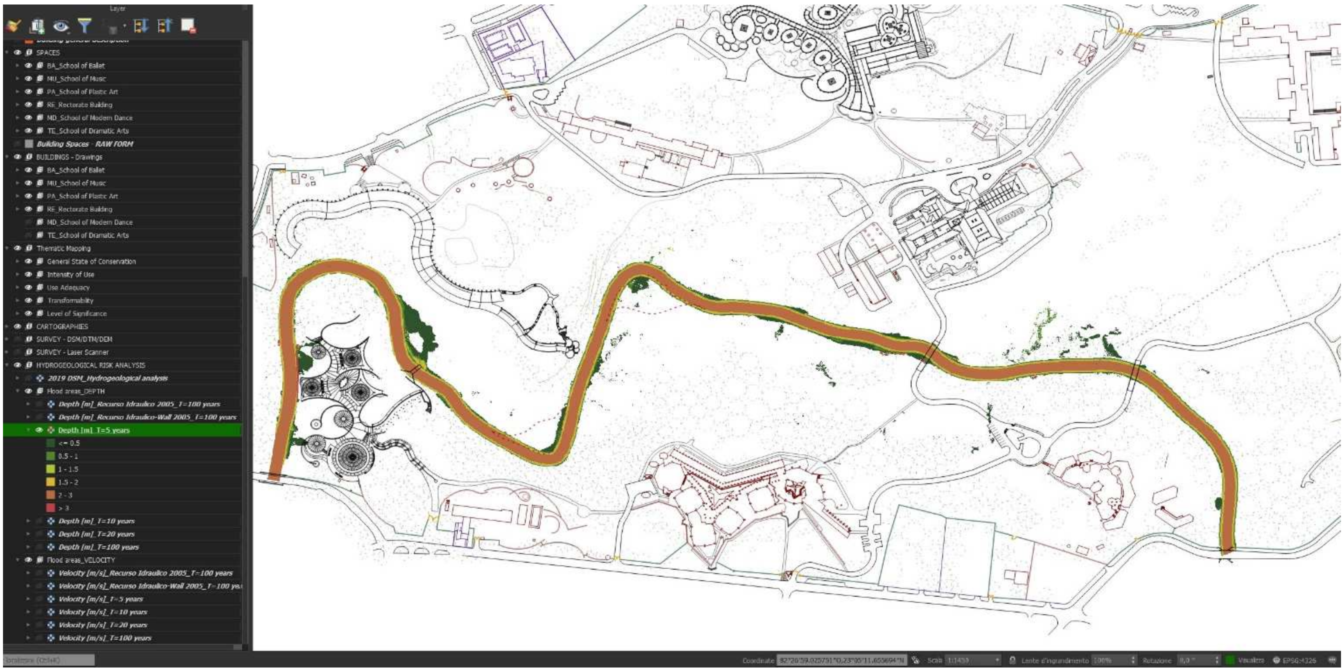

Figure 81 - Hydrogeological risk analysis: Depth [m]_T=5 years.

Figure 82 - Hydrogeological risk analysis: Depth [m]_T=100 years.

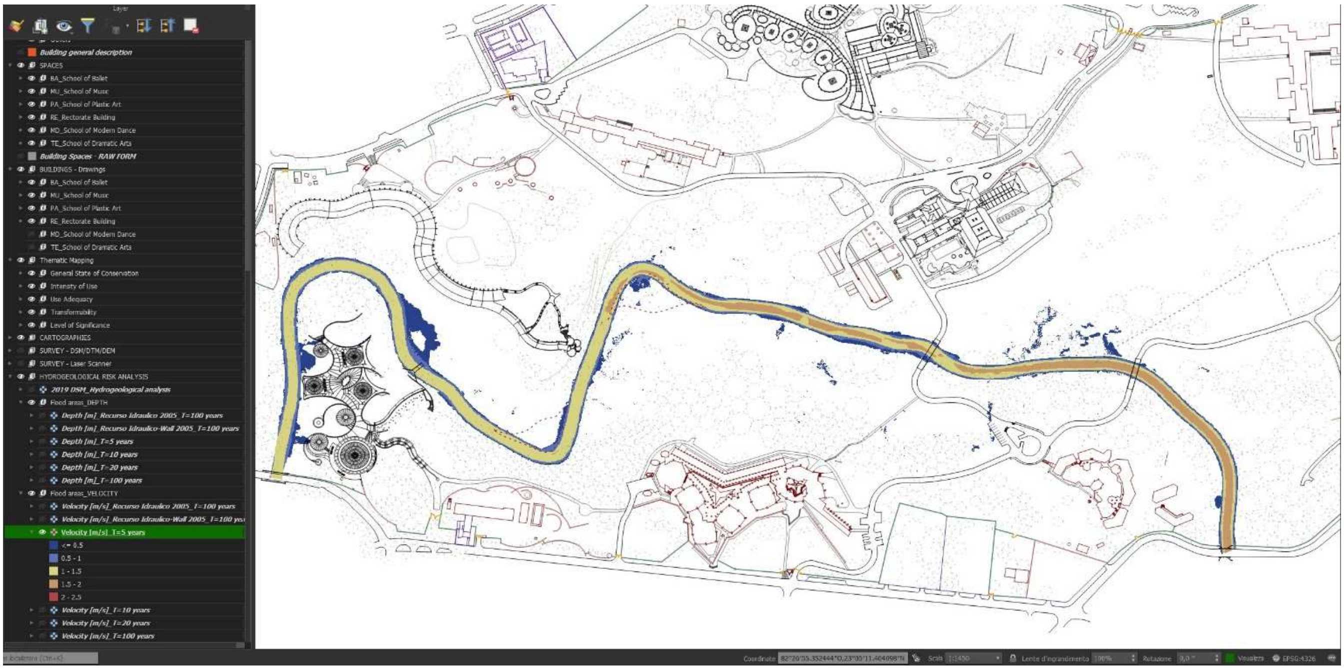

Figure 83 - Hydrogeological risk analysis: Velocity [m]_T=5 years.

Figure 84 - Hydrogeological risk analysis: Velocity [m]_T=100 years.

5.2 Guidelines for the management of the site

5.2.1 Thematic maps

5.2.1.1 School of Ballet

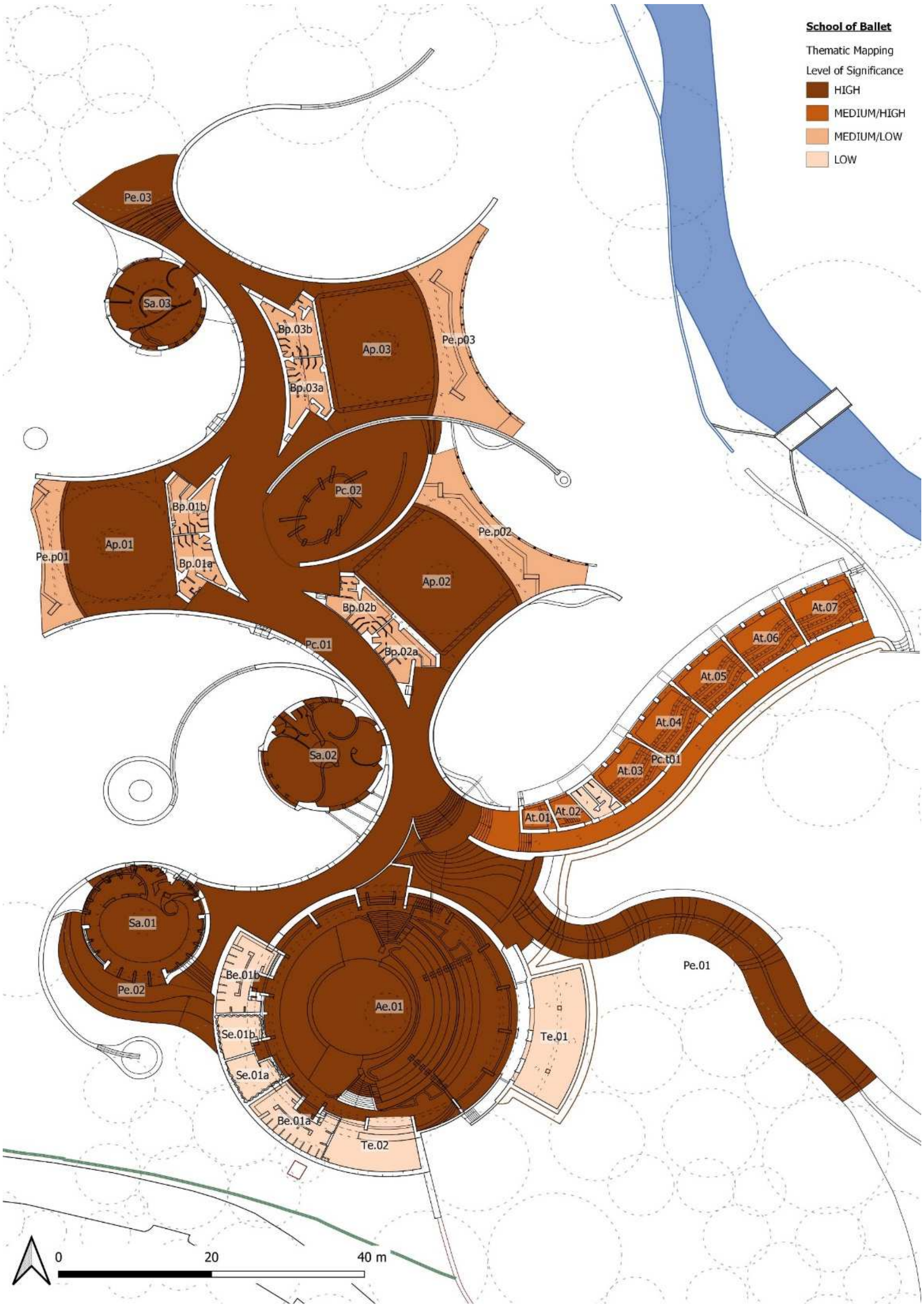

Figure 85 - Levels of significance, first and second levels.

Figure 86- State of conservation, first and second levels.

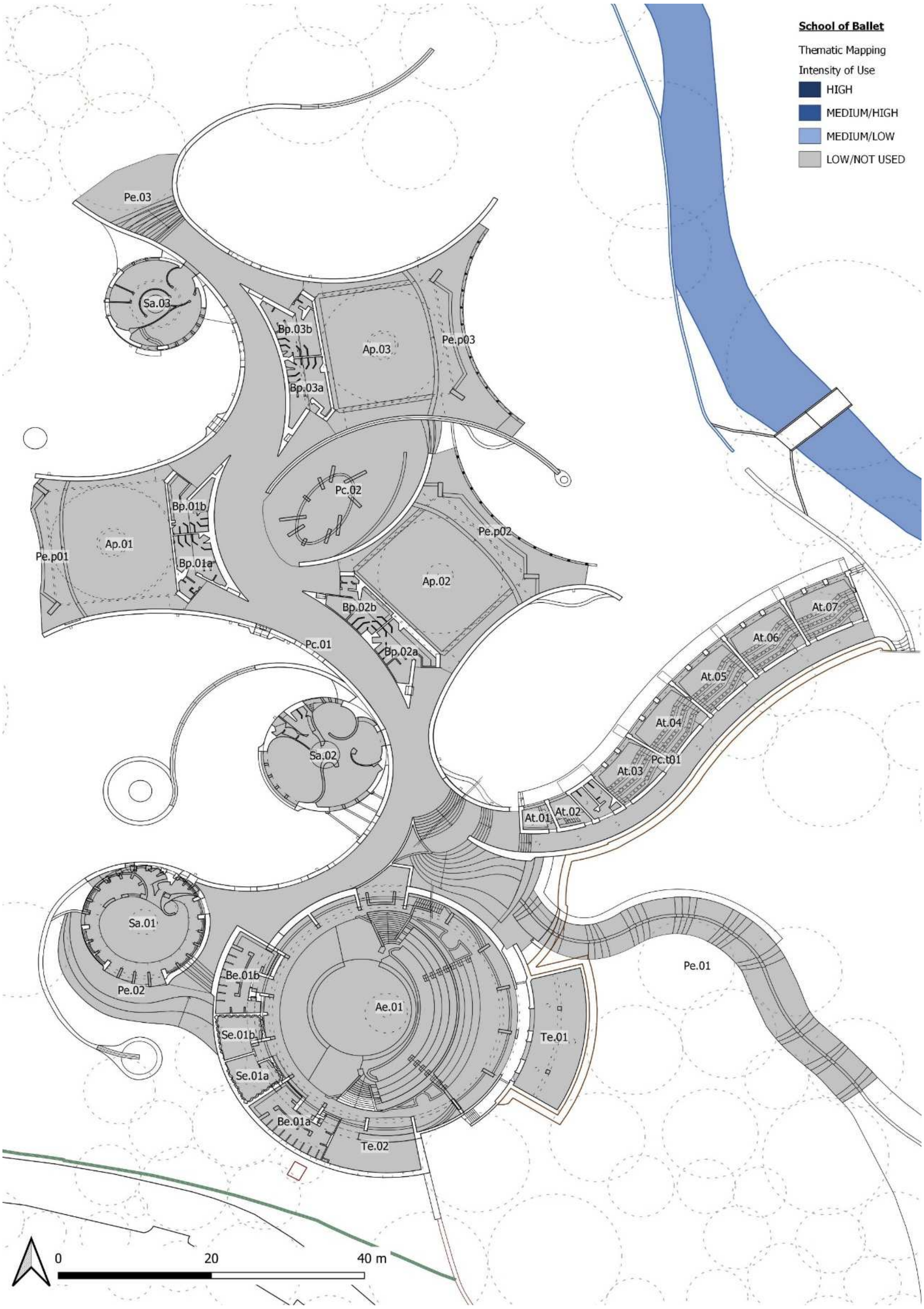

Figure 87 - Intensity of use, first and second levels.

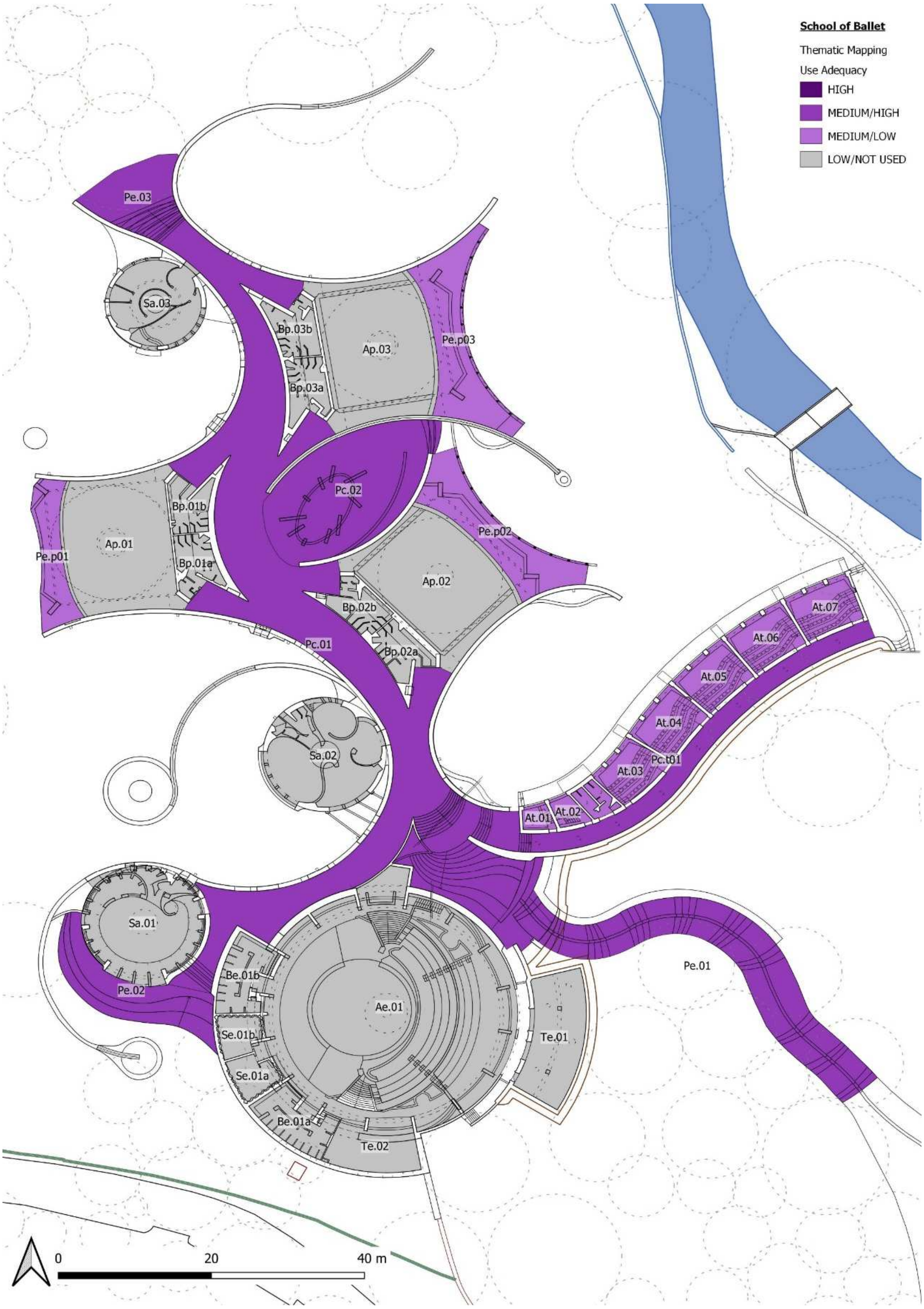

Figure 88 - Adequacy of use, first and second levels.

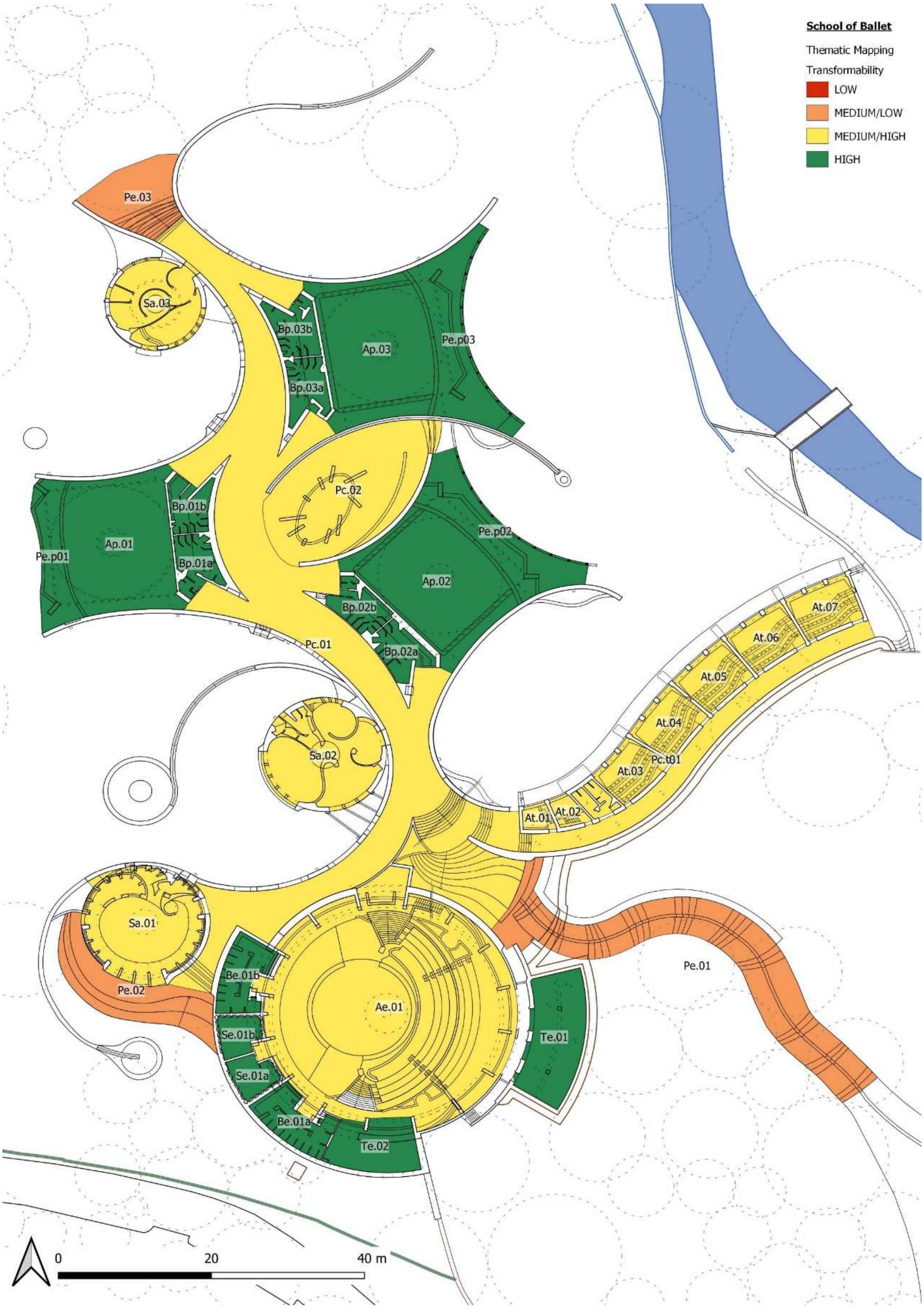

Figure 89 - Tolerance for change, first and second levels.

5.2.1.2 School of Music

Figure 90 - Levels of significance, ground floor.

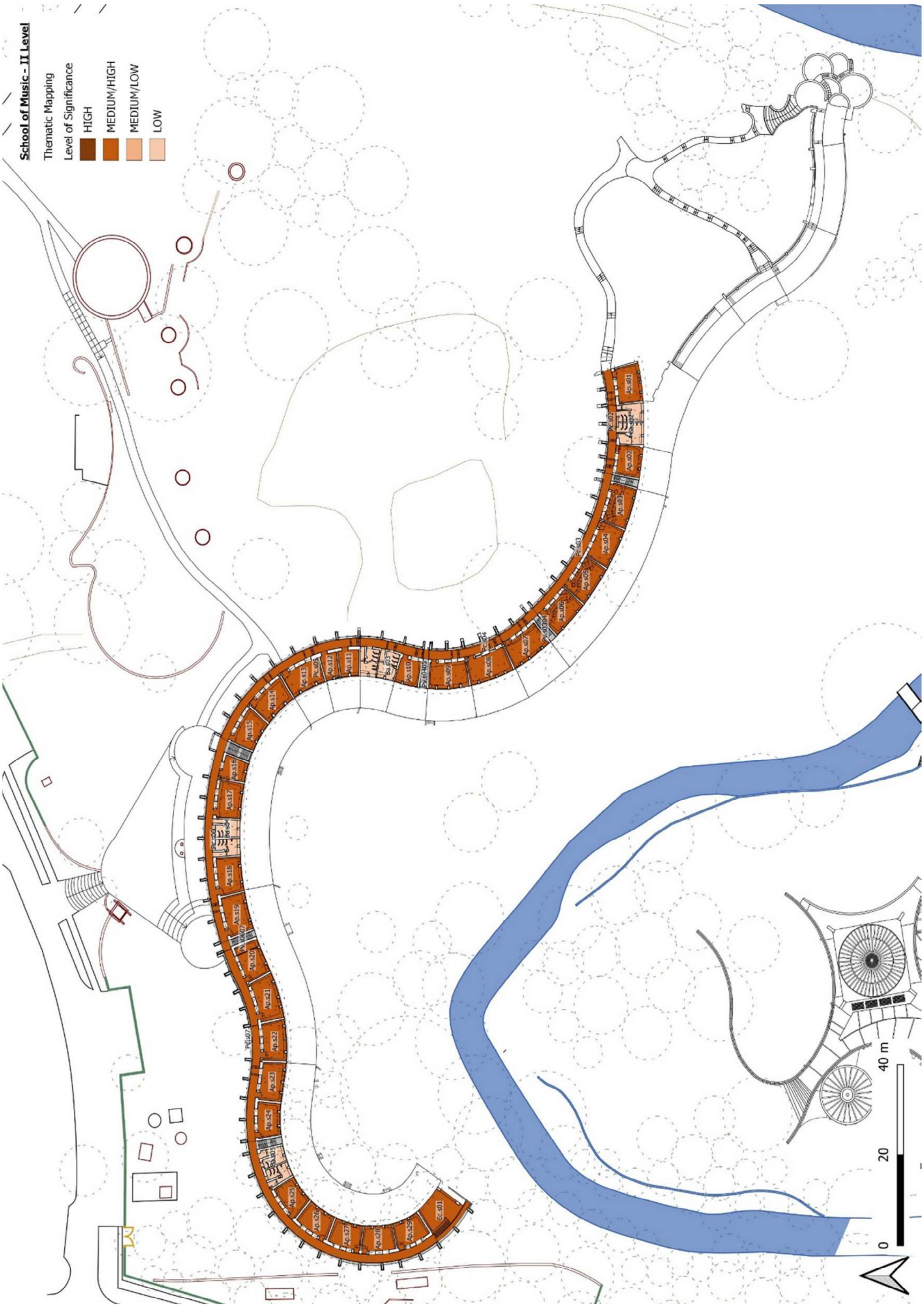

Figure 91 - Levels of significance, first floor.

Figure 92- State of conservation, ground floor.

Figure 93- State of conservation, first floor.

Figure 94 - Intensity of use, ground floor.

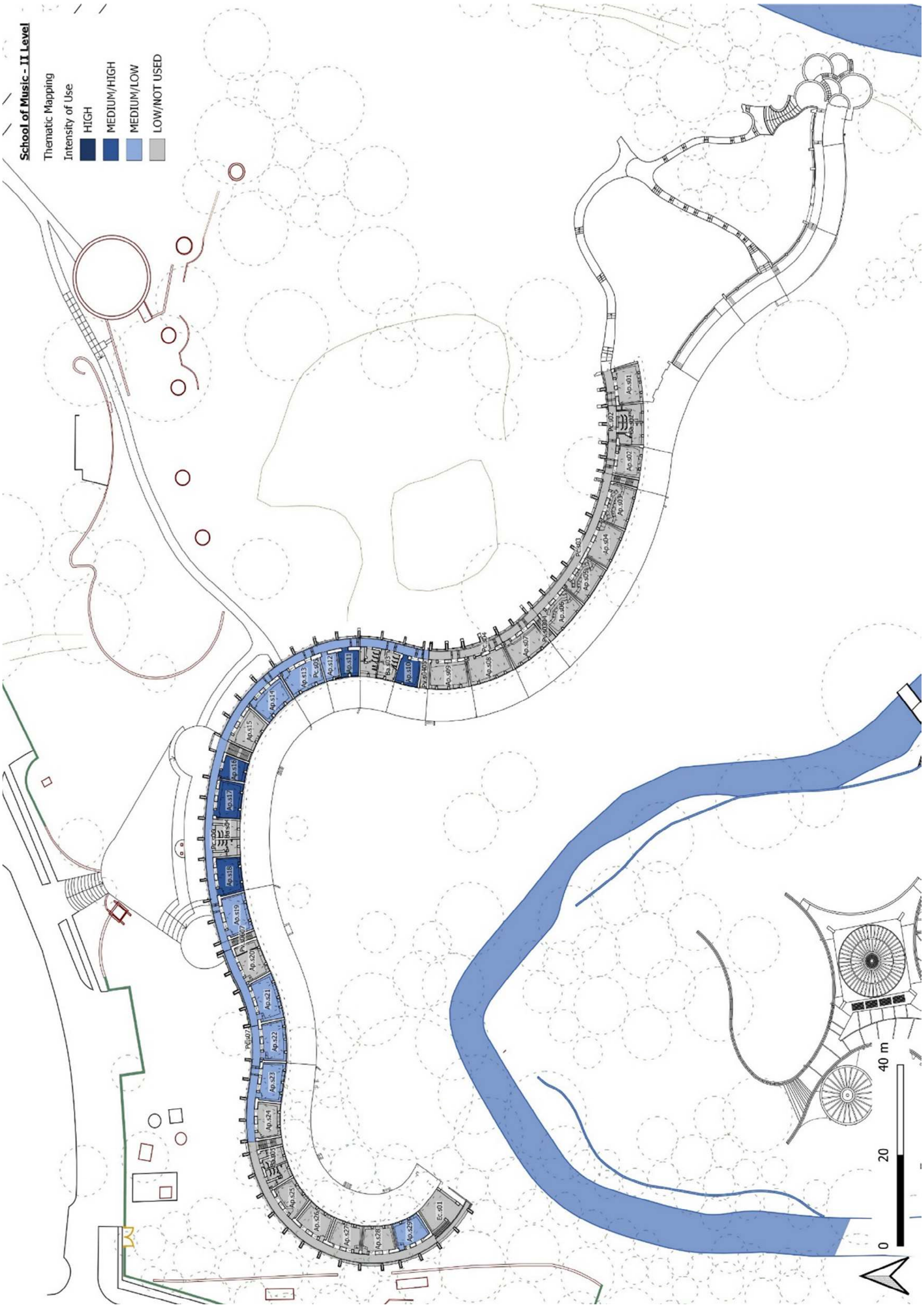

Figure 95 - Intensity of use, first floor.

Figure 96 - Adequacy of use, ground floor.

Figure 97 - Adequacy of use, first floor.

Getty Foundation

Figure 98 - Tolerance for change, ground floor.

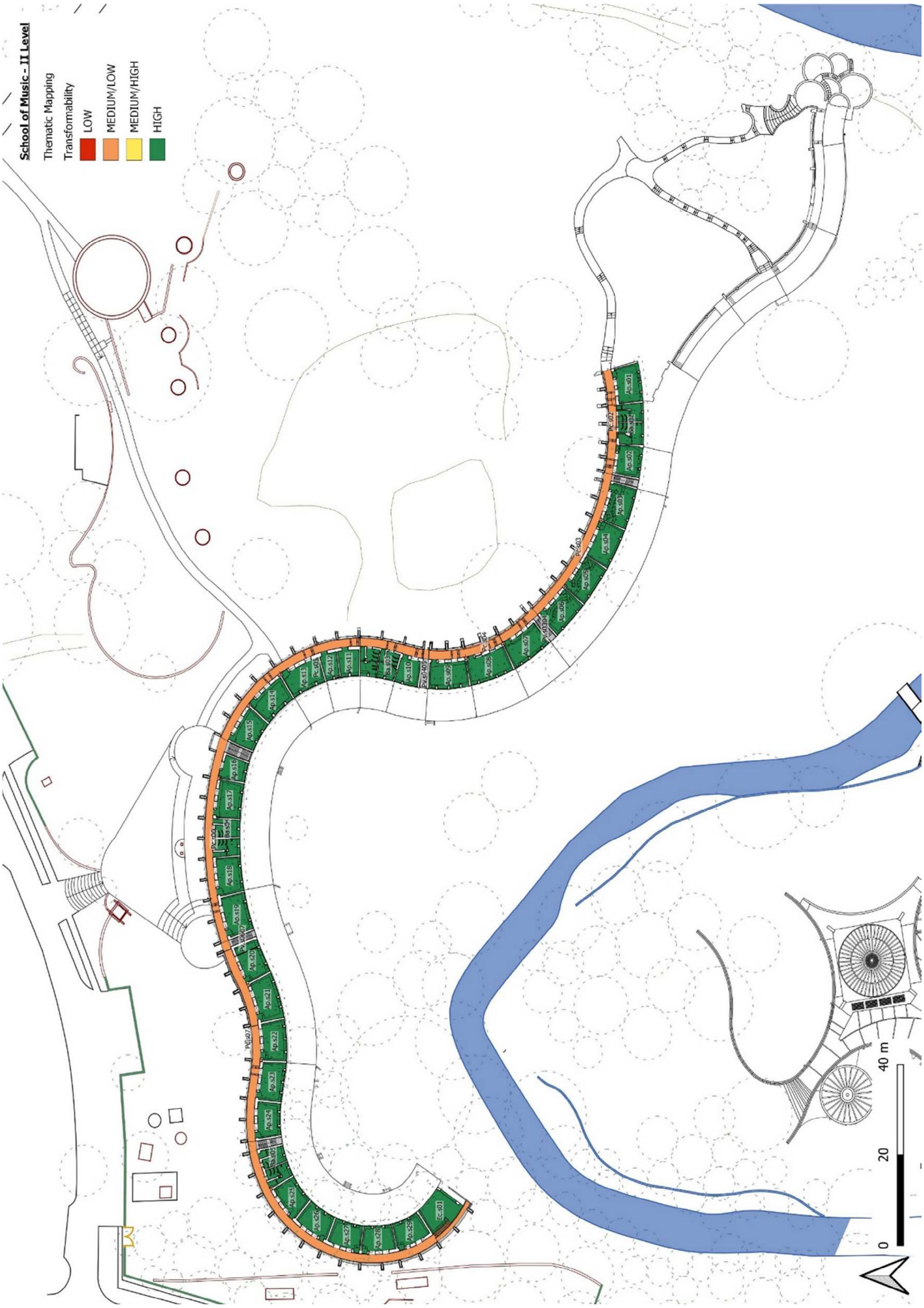

Figure 99 - Tolerance for change, first floor.

5.2.1.3 School of Modern Dance

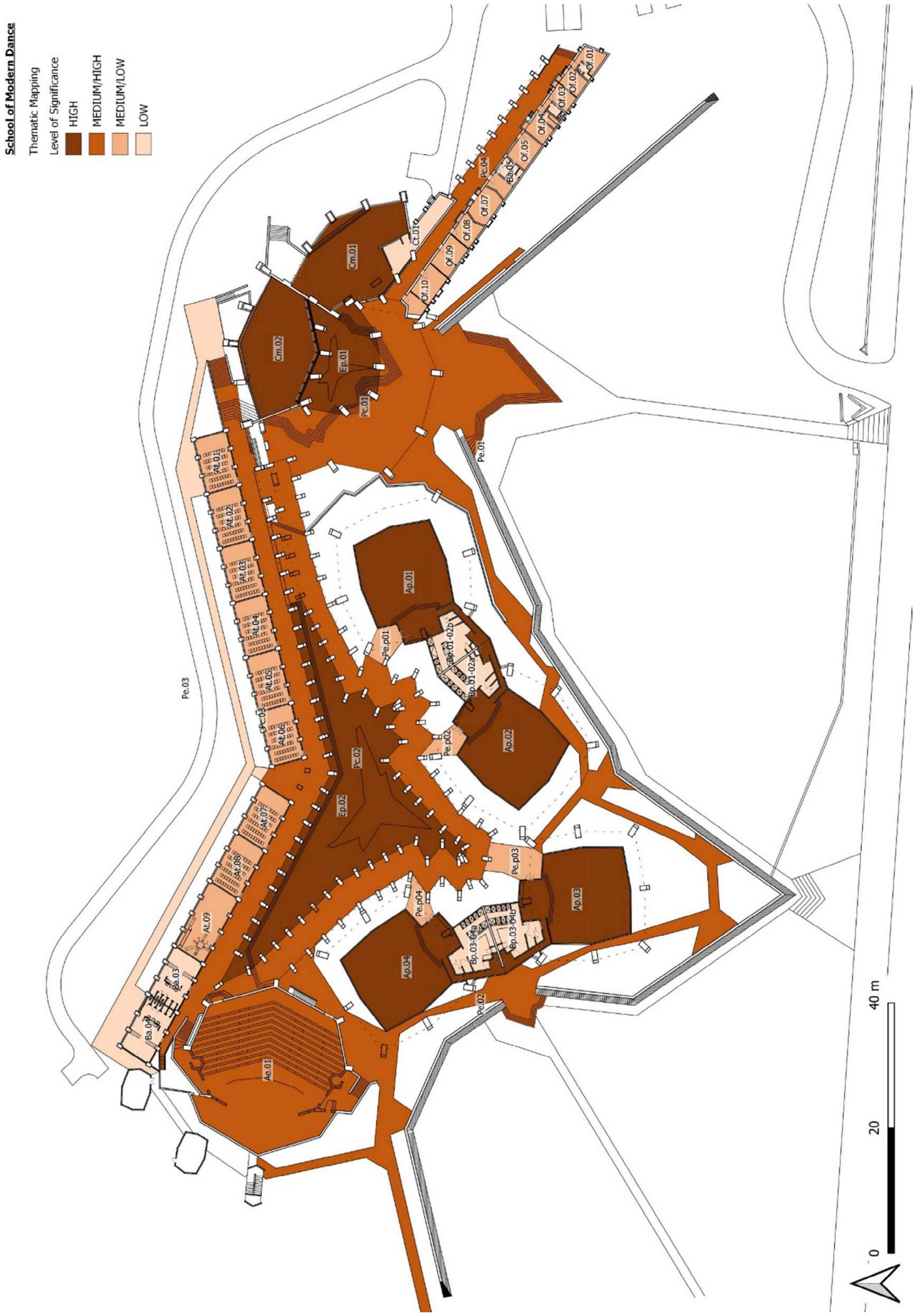

Figure 100 - Levels of significance.

Figure 101 - State of conservation.

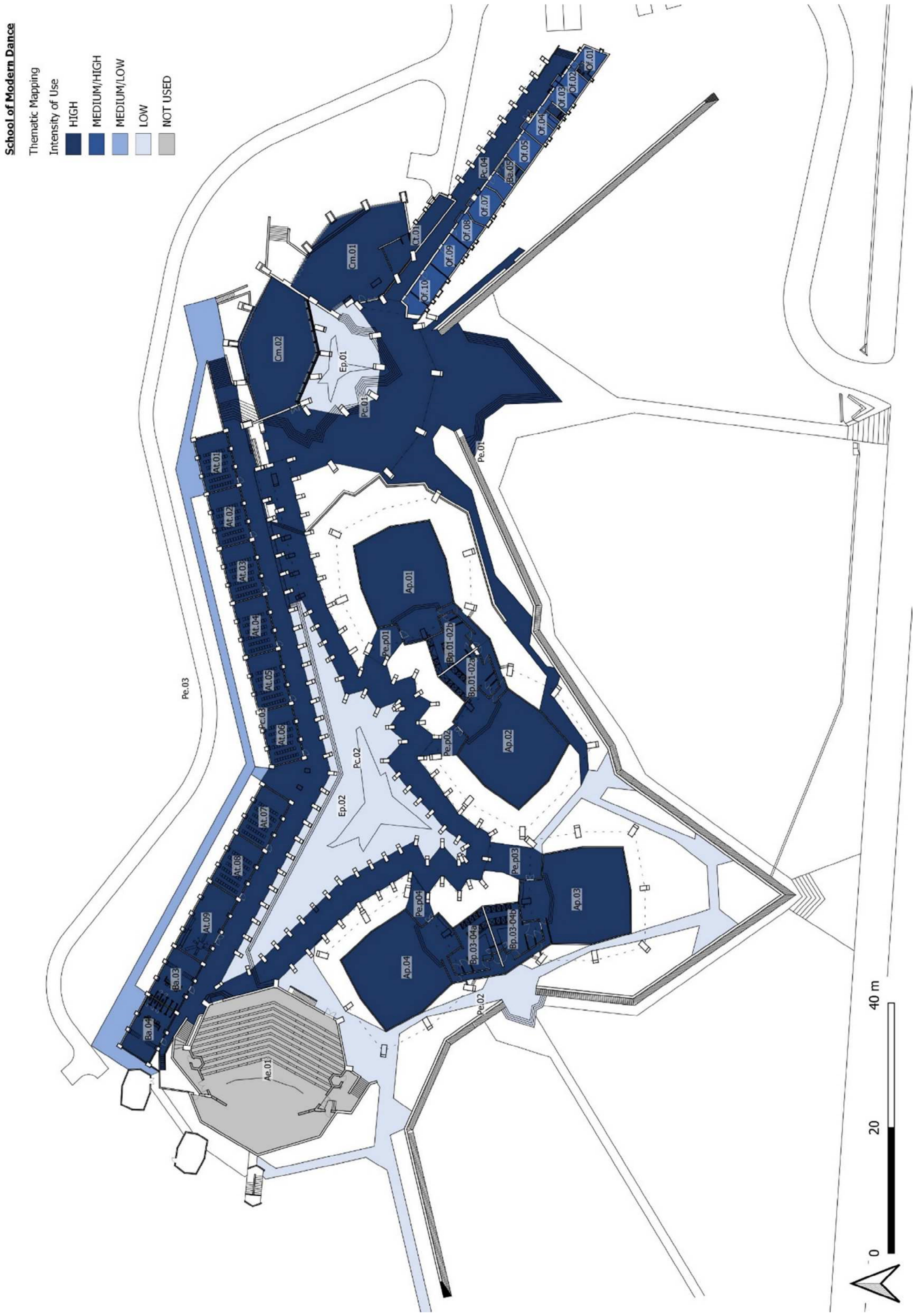

Figure 102 - Intensity of use.

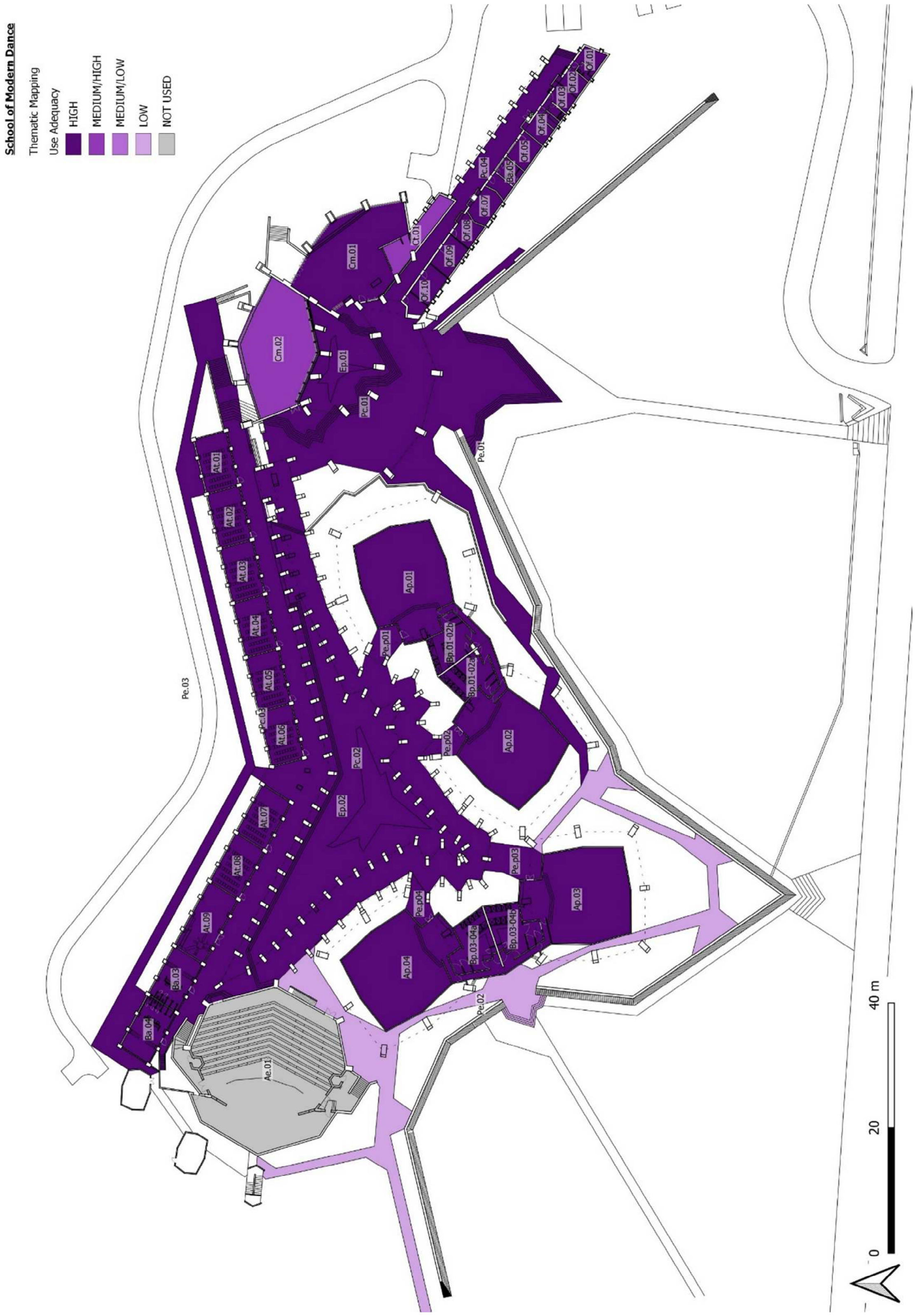

Figure 103 - Adequacy of use.

Figure 104 - Tolerance for change.

5.2.1.4 School of Plastic Arts

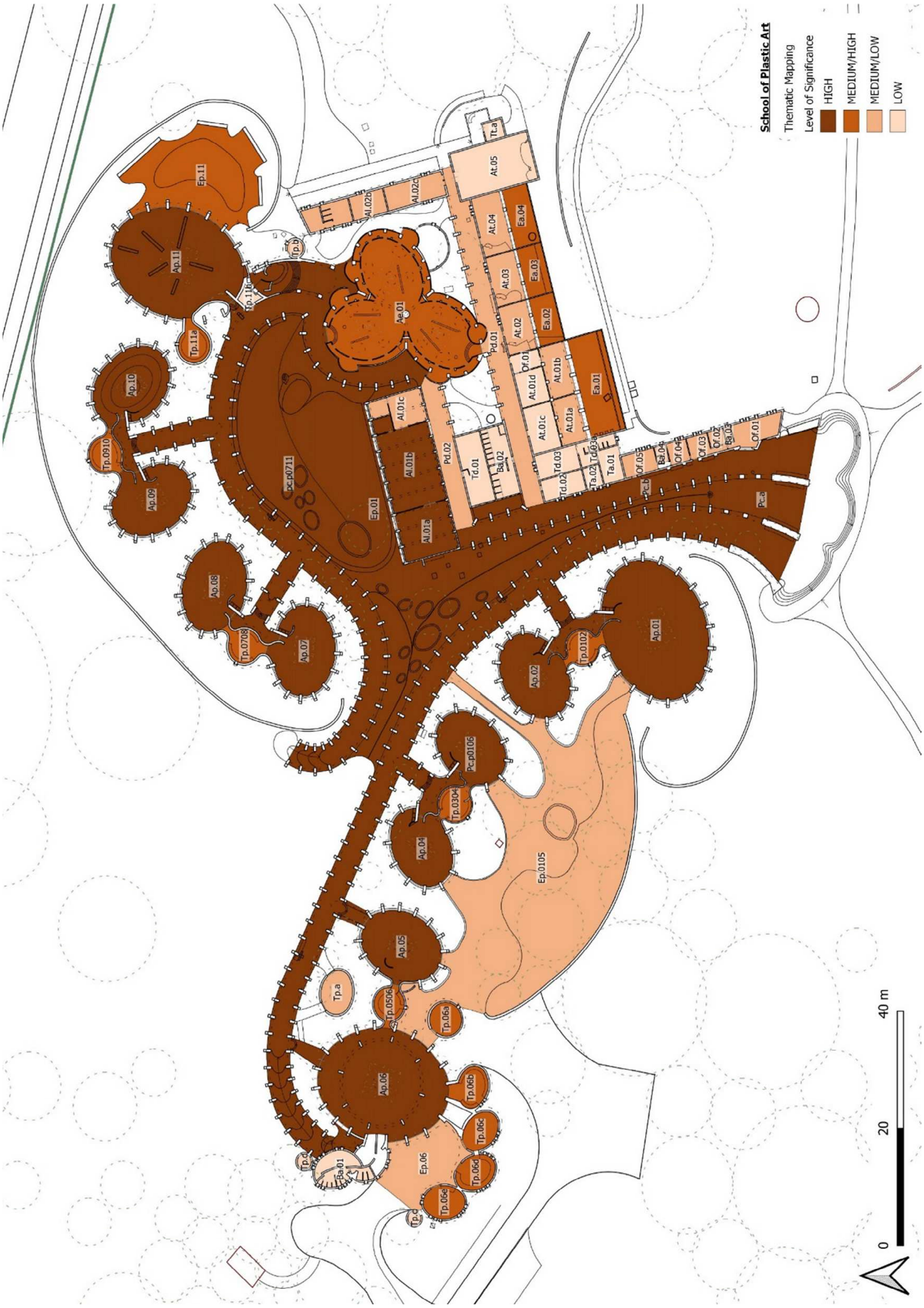

Figure 105 - Levels of significance.

Figure 106- State of conservation.

Figure 107 - Intensity of use.

Figure 108 - Adequacy of use.

Figure 109 - Tolerance for change.

5.2.2 Guidelines for an adaptive reuse

As mentioned before, the same hierarchy of spaces can be recognized in the five schools.

This typical structure is easily recognizable both in the schools that have been completed but have never been used (School of Ballet) and in those that, being completed, are currently in use (Modern Dance, Plastic Arts). In the School of Music and the School of Dramatic Arts, only partly built, only some of the components can be identified while others remained on paper.

These spaces - or sets of spaces - share a number of features and issues and have a similar significance level, albeit with different state of repair and use.

5.2.2.1 Spaces for public performances and exhibitions

Each of the five schools had to be provided with at least a theater or exhibition hall for public performances (identified as Ae in the coding).

Such large spaces were realized in the Schools of Ballet, Plastic Arts, and Modern Dance. Two massive theaters connected by a walkway - one for chamber music and opera, the other for symphonic music – were supposed to be built for the Schools of Music. Two further halls were foreseen in the School of Dramatic Arts.

Exhibition areas have direct access from the outside and were provided with public services, like the cafeteria, the ticket office, and hang-out spaces. The artists had private access from the inside and had dressing rooms and services for exclusive use. Despite their great potential, these emblematic spaces are systematically underutilized, not only because of a poor state of repair. The School of Ballet’s choreography theater, which is covered by an impressive dome that overlooks the interior space, has lost all the windows and almost all the original elements that have been removed over time. Frequent floods make the situation worse, and some of the ancillary spaces are cluttered with mud and debris and, therefore, quite challenging to access. The theater is unused, except for some occasional artistic performance. The theater of the Modern Dance school is unused and inaccessible, and shows minor maintenance problems, as the common water seepage from the roof.

The same goes for the School of Plastic Arts exhibition space that is substantially locked, despite being in excellent repair condition and equipped with adequate systems, including a modern air conditioning system. The external exhibition space adjacent to the 5th year workshop is also unused.

This condition of disuse depends on the objective difficulty of organizing events within the schools and teaching. It is indeed hardly believable that a simple program of public events could grant new life to all these spaces in the next future.

The schools are located in a peripheral area, far from the city center and poorly connected by public transport, especially in the evening. The schools' original design included multiple access points to the park, which did not have any fences. Today access to the campus is limited thanks to strict control both at the entrances of the park and of individual schools. Today, safety needs have increased and are particularly high in the lower-level schools (ENA School of Music and School of Modern Dance), which are attended by very young students. Along the park's perimeter, all the entrances are controlled, and many of the secondary entrances to the Schools have been closed or excluded from the main routes.

The distribution of the entrances needs to be improved since most accesses are located near the rectorate and residences whilst the western area of the park, where there are some deposits and other functional units that should be refurbished, is less served and controlled.

A second aspect that makes the theaters and exhibition spaces little used is linked to their dimension and morphology, which does not allow for partitions or other substantial changes. However, it is possible to think of mobile or temporary structures that allow greater flexibility for these spaces. The theater of the school of Modern Dance and the related spaces could be used as a classroom for the lessons that are currently held at the School of Music and in the former *Casa Colonial*. Both spaces lack adequate service and equipment and are not very suitable for dancing. The spaces at the Music School could instead be appointed in rotation to students as rooms for rehearsal or other group activities. At the same time, the *casa del protocolo* could host a small documentation/archive center. The School of Plastic Arts' exhibition space is adjacent to other unused or underused spaces, such as the photography laboratory, the offices of the faculty of Art Theory, and the conference room, also known as the "enchanted deer theater". These spaces could accommodate part of the *Facultad de Artes de la Conservación del Patrimonio Cultural* activities, which currently take place in a small building located along the western border of the park. The faculty has an increasing number of enrolled students and has an educational offer covering various fields (restoration of paintings, stone materials, photographs, archaeological remains). Practical training is an essential part of teaching and is performed on museum objects on loan to the faculty for diagnostic and restoration activities. The spaces currently used by the Faculty are small and do not meet the environmental and safety requirements that are needed to preserve the works being restored. Those activities can be relocated in the spaces of the former Department of Theoretical Studies. In contrast, the former photographic laboratory could host a specialized laboratory and training center for the conservation and restoration of photographs. The theater/conference room could host a classroom equipped with workstations for the international projects in which ISA participates. The reorganization of this part of the building should usefully involve the theoretical classroom At.01, which has been divided to create four different rooms; the continuity of the space should be restored, although it is possible to provide movable walls or other light partitions to ensure greater flexibility.

A similar reorganization should concern the adjacent technical spaces. As mentioned, given the current needs and mission of ISA, it is hardly credible to expect that each school can keep its own theater. The exhibition space of the schools of Plastic Arts and the theater of the school of Modern Dance, now nearly unused, could be used for educational activities with very limited interventions. Events, concerts, and performances could instead be relocated to the Ballet School. Environmental protection is, in any case, a priority, and any other intervention should be carried out in progressive stages and with minimal interventions. One of the three practical classrooms could be recovered to host exhibitions and shows, rethinking the access from the outside and the relationship with the external spaces.

Figure 110 - School of Ballet; choreography theater.

Figure 111 - School of Plastic Arts; exhibition space.

5.2.2.2 Practical classrooms

The practical classrooms (Ap) recalls - on a smaller scale - the morphology of the spaces for public performances and exhibitions and are among the National Schools' most relevant and recognizable spaces.

They configure as large spaces covered by domes, flanked by service spaces (changing rooms, laboratories, storage spaces for materials and works in progress, bathrooms...) that are exclusively used (as in the School of Ballet) or shared by two classrooms (as in the Plastic Arts and Modern Dance schools). They may have external workspaces (Ea). They do not have direct access from the outside but can be reached from the school's paths.

In the Plastic Arts and Modern Dance schools, these classrooms are currently used for teaching activities (group lessons and rehearsals). The large size and the presence of auxiliary facilities are strong points, while the lack of air conditioning and other technical systems and some maintenance issues are limiting factors.

In the Modern Dance School classrooms, numerous percolations from the roof and skylight caused the deterioration of the wooden floor.

In the Plastic Arts school, the classrooms are less than required, namely at least a classroom for each year. To meet this need, the former canteen's (*comedores*) is being used as an additional classroom, whilst the canteen has been relocated in the former library. Some lessons are held in the School of Music and in the *Casa Colonial*, even though these spaces do not have the characteristics of privacy and proximity to dedicated service spaces that are instead typical of the practical classrooms.

In the School of Plastic Arts, some of the domes are used by 1-2 students who also live in these spaces, served exclusively by a room with a washbasin. Other domes are used by 7-8 students who display their artworks here.

A critical point is related to maintenance, which mainly concerns the domes and skylights and the absence of adequate systems, in particular air conditioning systems. The envelope's characteristics and the windows (metal, replacement) do not guarantee adequate internal comfort conditions, especially during summer.

The School of Music (*Gusano*) has never been completed or used for teaching.

The maps that report the evaluations related to the state of repair of the spaces (classrooms and paths) show that the building's state of conservation is, generally speaking, bad. Nevertheless, the rooms on the upper floor are in better conditions than those on the lower level, where the rooms are rather small in size, and most spaces are in a severe state of disarray and therefore inaccessible.

This is probably the result of some maintenance interventions that have been carried out over time on the upper level, which allowed these spaces to be used as storage and offices by external companies (*Empresa de Gastronomia del Municipio de Playa; ESIC Empresa de Seguridad de Instituciones de Cultura*). The main works concerned the plaster covering the brick vaults and the partitions, which were partly rebuilt.

Most of the cubicles are used as storage. Although this use led to a minimum level of care and control, it is not consistent with the building's value and the ISA's overall artistic teaching mission.

Besides, a few cubicles have been successfully converted into artistic workshops. Minor inexpensive interventions were made to adapt the rooms, such as providing an electrical system, installing a water tank, and placing windows and door frames.

Given the positive outcomes, more students and young artists could set a multidisciplinary artistic space that could also host public and external artists. This would also help overcoming the lack of spaces for individual practice in the School of Plastic Arts.

Besides, some spaces in the *Gusano* could also be granted to groups of students of the School of Theater who are currently forced into excessively small and cramped spaces that are quite unsuitable for the practical lessons. This solution should however be temporary as it will become superfluous once the restoration of the School of Theater will be over. It is essential to notice that in the *Gusano,* the practical classrooms are relatively small compared with the other schools. There are two different typologies of classrooms, for individual practice or a small group of performers. This depends on the extreme articulation of musical teaching, which encompasses about 40 different instruments, mainly with individual lessons or small groups.

In some spaces, the armchairs' brick structure has been preserved; these elements should be kept and completed wherever possible. Music lessons are currently located in the Rectorate building, where there are also the administrative offices and the conference room, ordinarily used in occasion of meetings and public events.

The classrooms are currently located on the lower floor and the building's first floor, while the rector's offices are on the first floor. The conference room is located on the ground floor where there is also the bar, currently under renovation. There are other music classrooms, the canteen, the kitchen, and some offices (newspaper and technical direction) on the lower floor. Unused spaces can be found in the former gymnasium, in front of the swimming pool, and in the entire west wing, where the bar is located. The classrooms are necessarily noisy, but the absence of soundproofing results in the disturbance of the nearby administrative offices. However, due to the availability of spaces within the Rectorate, there is room for a reorganization of the building to reduce the two functions' interference.

Currently, out of 6735 sqm, in the Rectorate building, 1614 sqm are unused or under renovation, which corresponds to 23,9% of the available surface. The spaces that allow greater functional flexibility are those of the former gymnasium (levels -1 and ground level). The east wing has been unused for a long time and thus requires significant renovation. That refurbishment could also be an opportunity to rethink the vertical connections (stairs and elevator) and provide independent access. Historical images document a structure that shaded the swimming pool, which has been demolished over time. The bar and the kitchens on the lower level could be connected, improving the service in case of institutional events in the conference room. The School of Plastic Arts' graphic and lithography lab is a sort of exception if compared to the practical classrooms described above. It is a large and bright space, with direct access from the square. Here an interesting collection of dies for lithographic printing and some machinery are stored.

Figure 112 - School of Music (*Gusano*); workshops.


Figure 113 - Rectorate – gymnasium and pool.


Figure 114 - School of Plastic Arts: lithography workshop.

5.2.2.3 Spaces for specialized functions

In the School of Ballet, there are three small spaces for specialized functions: infirmary, library, office.
The access is from the same inner path that leads to the practical classrooms.
These spaces have a high architectural value level due to the design's quality, the importance in the overall design, and the characterizing elements that are still present, like the domes and the double level, which must be maintained.
In the School of Plastic Arts, a small library is located near the theoretical classrooms. In the School of Modern Dance, the former library and the storage spaces are now occupied by the canteen ad kitchen. The former canteen was converted into a practice classroom.

5.2.2.4 Theoretical classrooms

The theoretical classrooms, the labs, and the offices are less significant from an architectural point of view. The theoretical classrooms (in the schools of Ballet, Plastic Arts, and Modern Dance) are directly accessed from the covered and regularly shaped paths. The wooden seats have been removed everywhere, while the seats' masonry structure and the teacher's desk's raised space are still visible.
The façade is marked by the regular rhythm of the windows and reflects the rooms' regular shape. The theoretical rooms are not provided with dedicated service spaces, and the toilets are freely accessible from the internal route.
The three classrooms of the School of Plastic Arts have a small paved patio; nowadays, these spaces are scarcely used because of the hot weather and can be revised by providing shading elements that would help manage the solar gain. All the theoretical classrooms have maintained their function over time, and the only changes concerned the furnishings and windows, which have been completely replaced. All the classrooms are equipped with air conditioning units, which, however, cannot be used.
The only exception is the classrooms in the school of Plastic Arts, which has been divided into four smaller spaces, two of which without direct access from the external corridor. In this case, the continuity of space should be restored, and the classroom could be used for practical activities.

Figure 115 - School of Modern Dance - theoretical classrooms.

5.2.2.5 Offices

The offices have regular shape like the theoretical classrooms. Where built (Schools of Modern Dance and Plastic Arts), the offices are located in a single linear building, connected to the internal path but with direct access from the outside.

Compared to the theoretical classrooms, which have the same size, the offices have different sizes depending on the function (meeting room, administration, dean's office, …). Nevertheless, just like in the theoretical classrooms, the windows on the façade follow a regular rhythm, unrelated to internal divisions. The air conditioning system exists but is not used. The School of Music's offices were built, with the only exception of the student office inside the *Gusano*. The main administration should have been placed in an independent building (n. 17-18-19-20), next to the general services. The spaces of the Photography laboratory and the Department of Theoretical Studies in the School of Plastic Arts – which are currently inaccessible for safety reasons – are also similar to the offices.

5.2.2.6 Covered and external paths

The covered paths (Pc) giving access to the rooms are of particular importance and should not be modified.

In the Plastic Arts and Modern Dance schools, the hallways flank a paved outdoor space (Ep External space/square). In the school of Plastic Arts and Ballet, a small cafeteria was placed along the path. In the school of Dramatic Arts, narrow outdoor lanes lead to the classrooms. Due to the dimension, and to the non-linear shape of the path, these spaces can be perceived as open-air rooms. In the Music School, there are two covered paths, one for each level. The upper corridor is partially open towards the external landscape, whilst the lower path is underground. Little light comes from brick diaphragms on the vault. The two paths are connected by a series of internal staircases and were supposed to be provided with water fountains.

The conservation of the roofs is a critical issue; over time, given the delamination of the bricks on the vaults' inner surface, waterproofing interventions were carried out. At the upper level of the *Gusano*, layers of cladding were superimposed on the inner surface. The uncovered external paths (Pe) are minor ones and can be modified as needed in a general reorganization of the park's paths. Indeed, some of these paths lead to secondary entrances, which are now locked.

Figure 116 - School of Modern Dance, covered paths.

Figure 117 - School of Modern Dance, covered paths, and square.

Figure 118 - School of Modern Dance, covered paths, and square.

Figure 119 - School of Plastic Arts, cafeteria.


Figure 120 - School of Music (*Gusano*), lower-level path.

Figure 121 School of Music (*Gusano*), upper-level path.

Figure 122 - School of Music (*Gusano*), the covered path.

Figure 123 - School of Music (*Gusano*), external paths.

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Dissemination and communication

Dissemination and communication

Website

The National Art Schools Conservation Plan website[1] is the main public and up-to-date source of information and communication. The website is aimed to enhance our project's identity. Besides the domain, logo, and graphic features, it contains information about all the institutions and people involved, the various related activities, and further links and resources. It also includes a summary of the schools' past and recent history, and it summarizes the five main actions of the Conservation Plan. The website has also been used as a continuous record of each on-site step of the project and every related event. This will lead up to an accessible complete version of the Conservation Plan final document (Figure).

The website breaks through geographical barriers and is accessible as our presentation brochure from any place in the world. This aspect is essential for a project that involves interdisciplinary and international partnerships. Placing our project on a website has helped us gaining exposure and encouraging further collaboration channels. Sharing is now also possible through the website's social media profiles.

Due to the broad group of institutions involved, it was preferred to choose a sober and neutral style. For the layout aspect, a mix of two templates was chosen: a single scrolling page and a simple article-like template.

A single scrolling page template enables the user to scroll through the titles and the summary of the entire project without tricky navigation or opening many pages. This facilitates the comprehension of the project as a coherent flow of ideas. This kind of template works efficiently across platforms and mobile devices and provide a more intuitive experience.

The main page is composed of a static main menu containing the home link together with the links to our team, activities, Spanish language option, and a search box. Moreover, the top menu contains icons linking social media profiles.

The user can scroll down until the "icon menu" composed of image buttons containing information about the history, architecture, the architects, alumni, the schools today, and the conservation plan.

By continuing scrolling down, the user finds the five main actions of the "conservation plan", a virtual gallery and finally, an embed map showing the Art Schools location.

The home page ends with a "Contact us" link and a footer containing a second social media menu (Figure 2 - Figure 8).

[1] http://www.keeping-isa-modern.com/

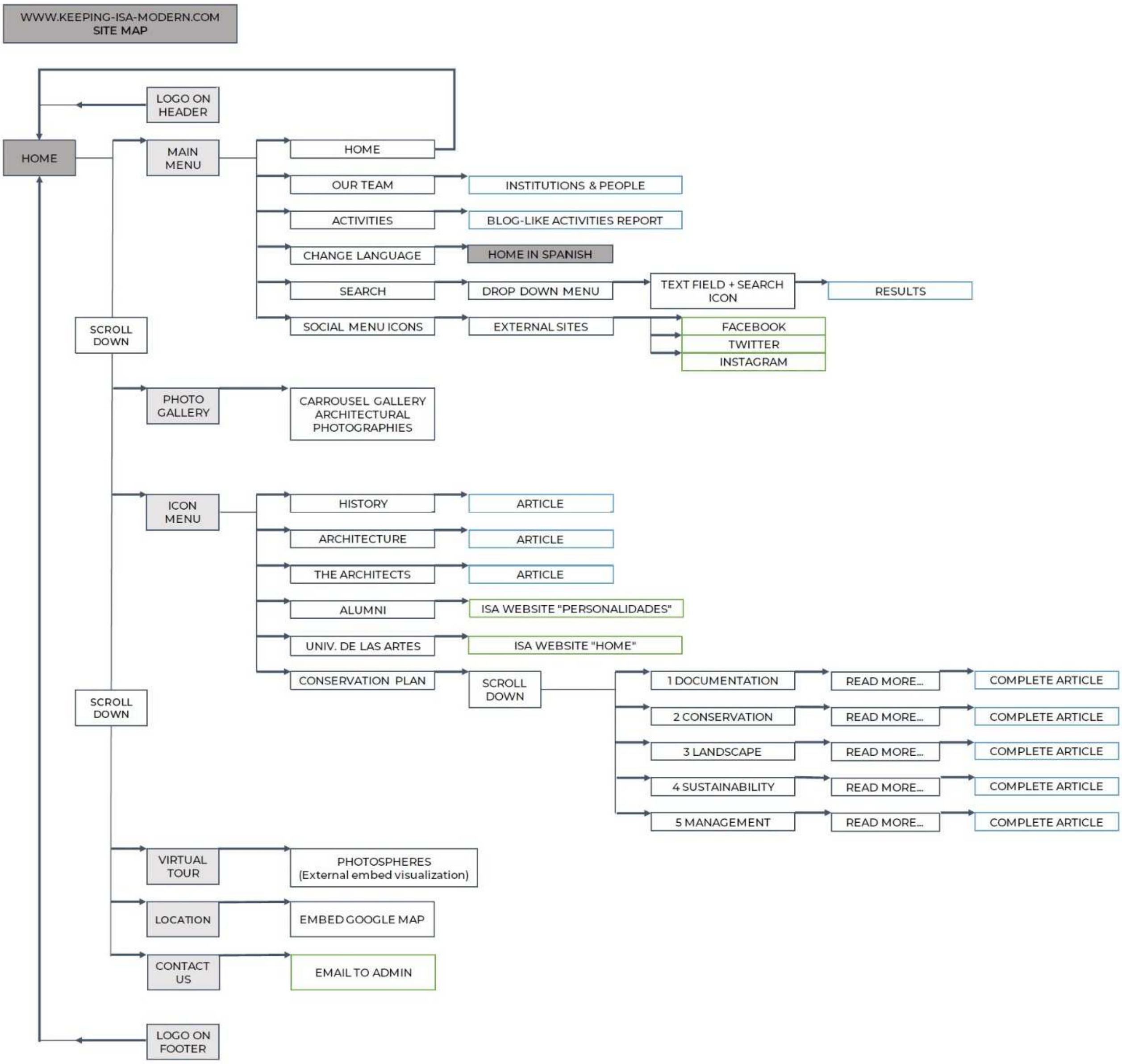

Figure 1 - Structure of the website

An article-like template has been used for both the icon menu and the five actions (through a "Read more" link). This page is versatile and is well-suited to the topics of the project. A picture can be placed as the header of the article, and additional images and graphics can be positioned along with the text.

A WordPress free profile was chosen for hosting our website. It was agreed that such a choice represented many advantages and was sufficient for our website needs.

The only critical issue that we encountered was the fact that the considerable amount of multimedia reflected in slightly longer loading times. This issue was encountered, especially when visiting the website from places or countries with slower internet connections. This was faced with a freeware cache plugin for WordPress that enhanced the loading experience, together with an image compression plugin.

To further improve the website performance, the latest updates such as videos and photospheres (virtual tour section on the Home page) were hosted on external services.

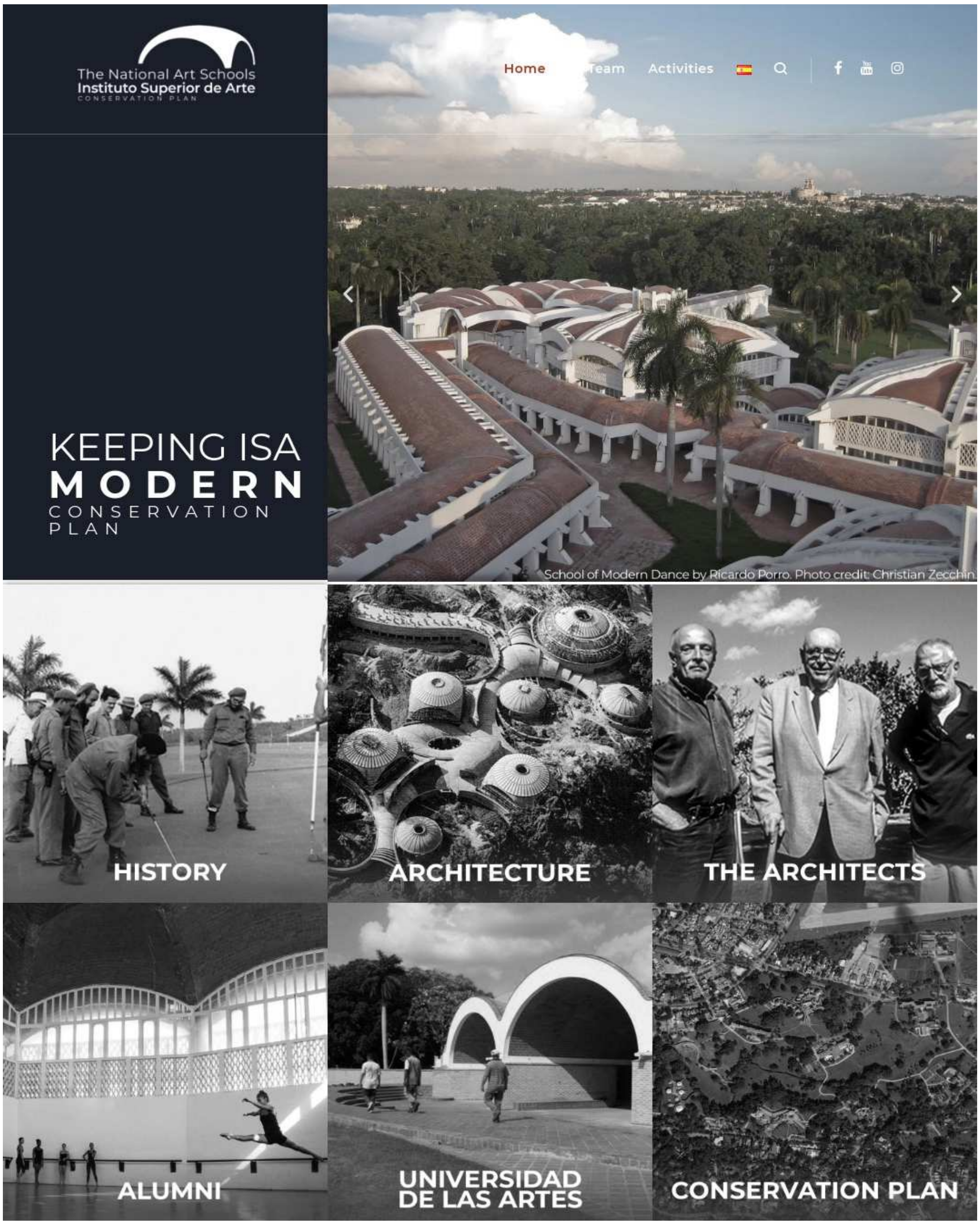

Figure 2 - Homepage, upper section.

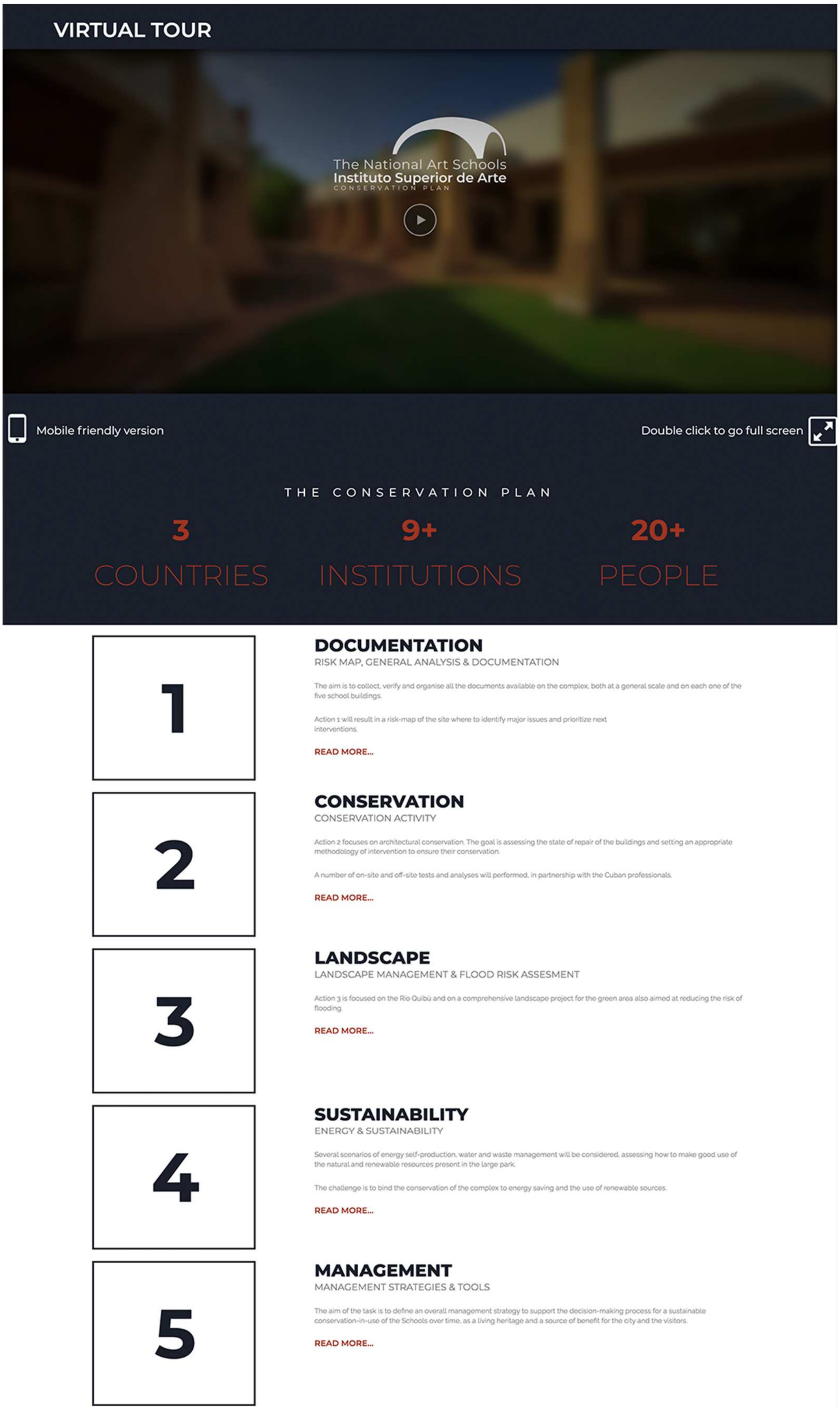

Figure 3 - Homepage, central section.

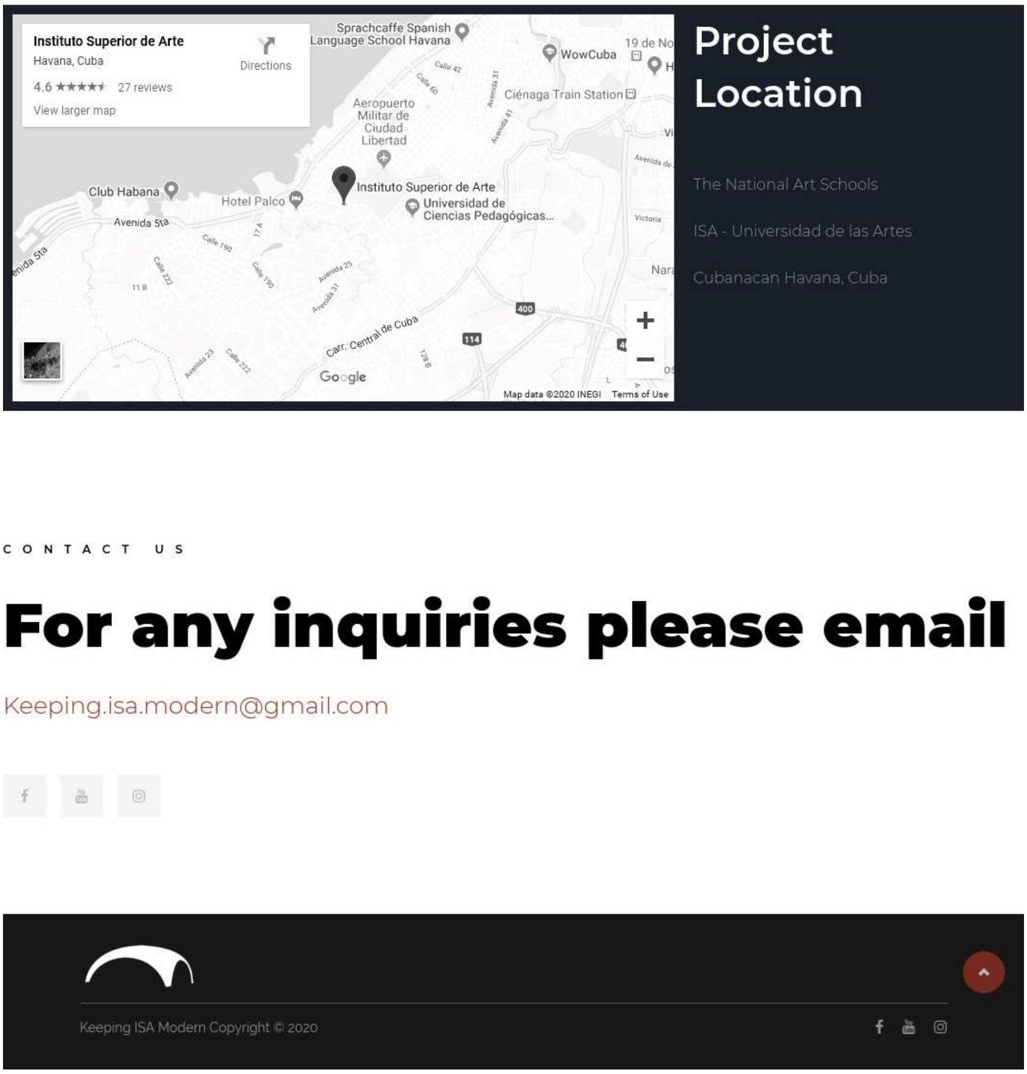

Figure 4 - Homepage, lower section.

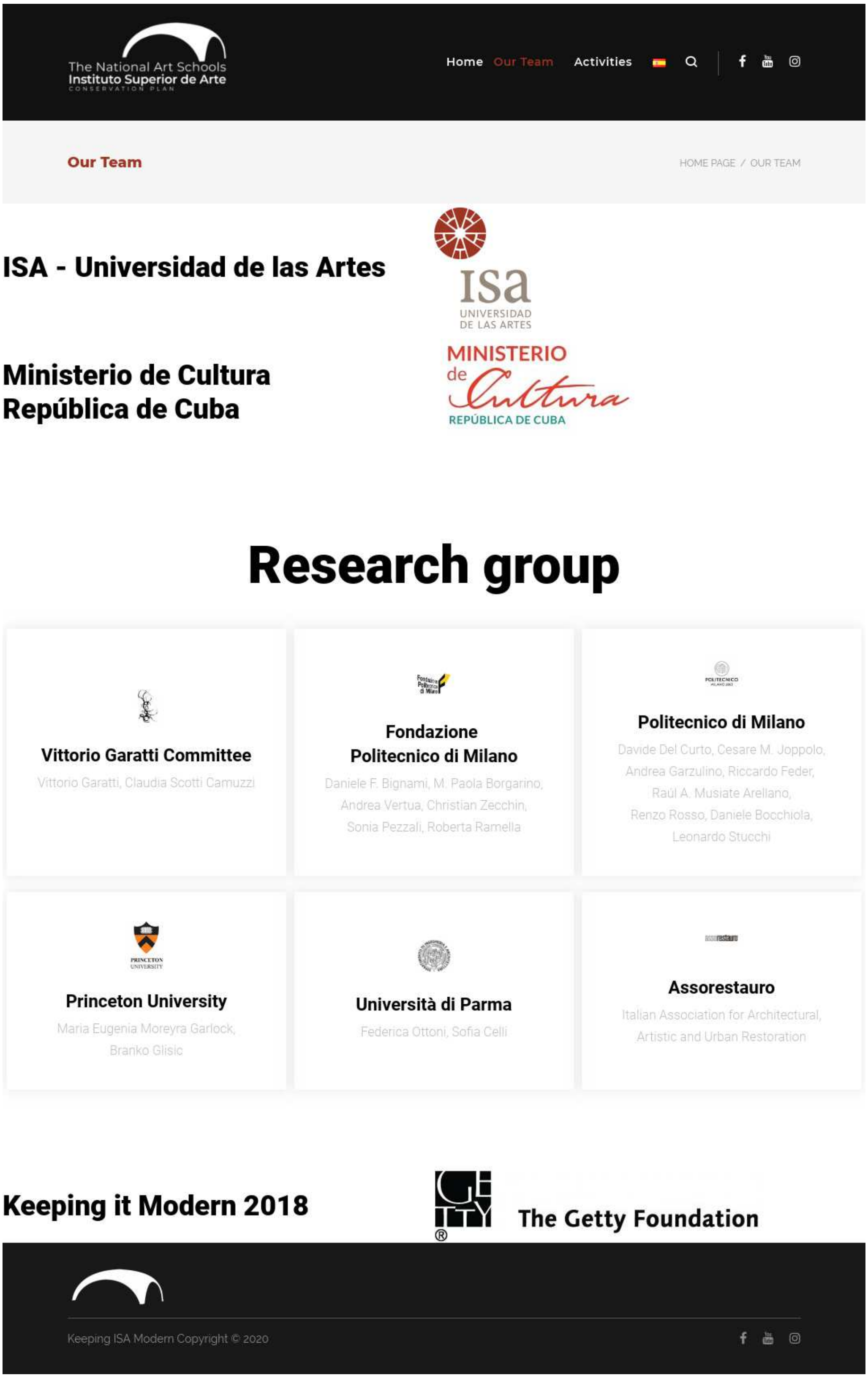

Figure 5 - Research group section.

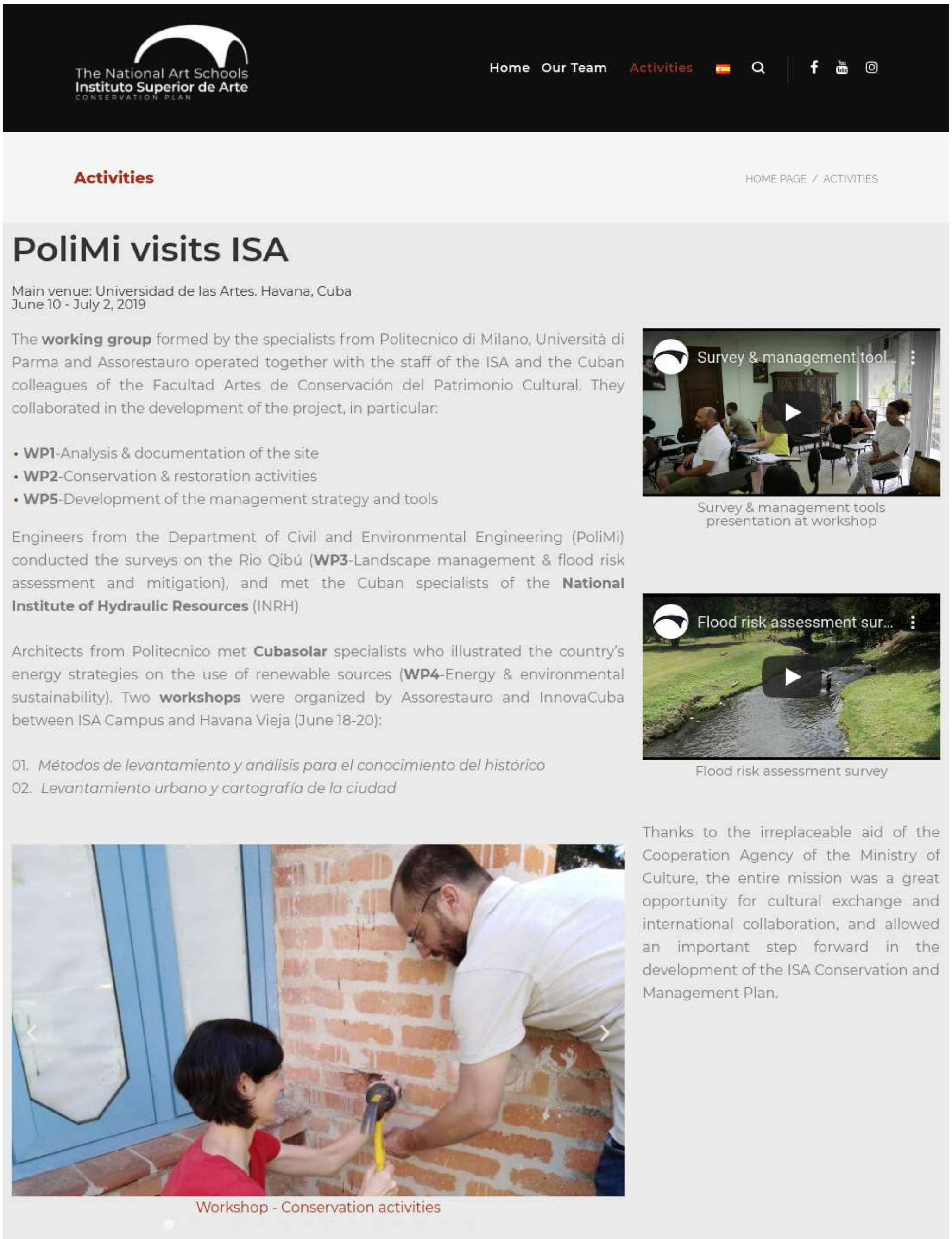

Figure 6 - Activities section.

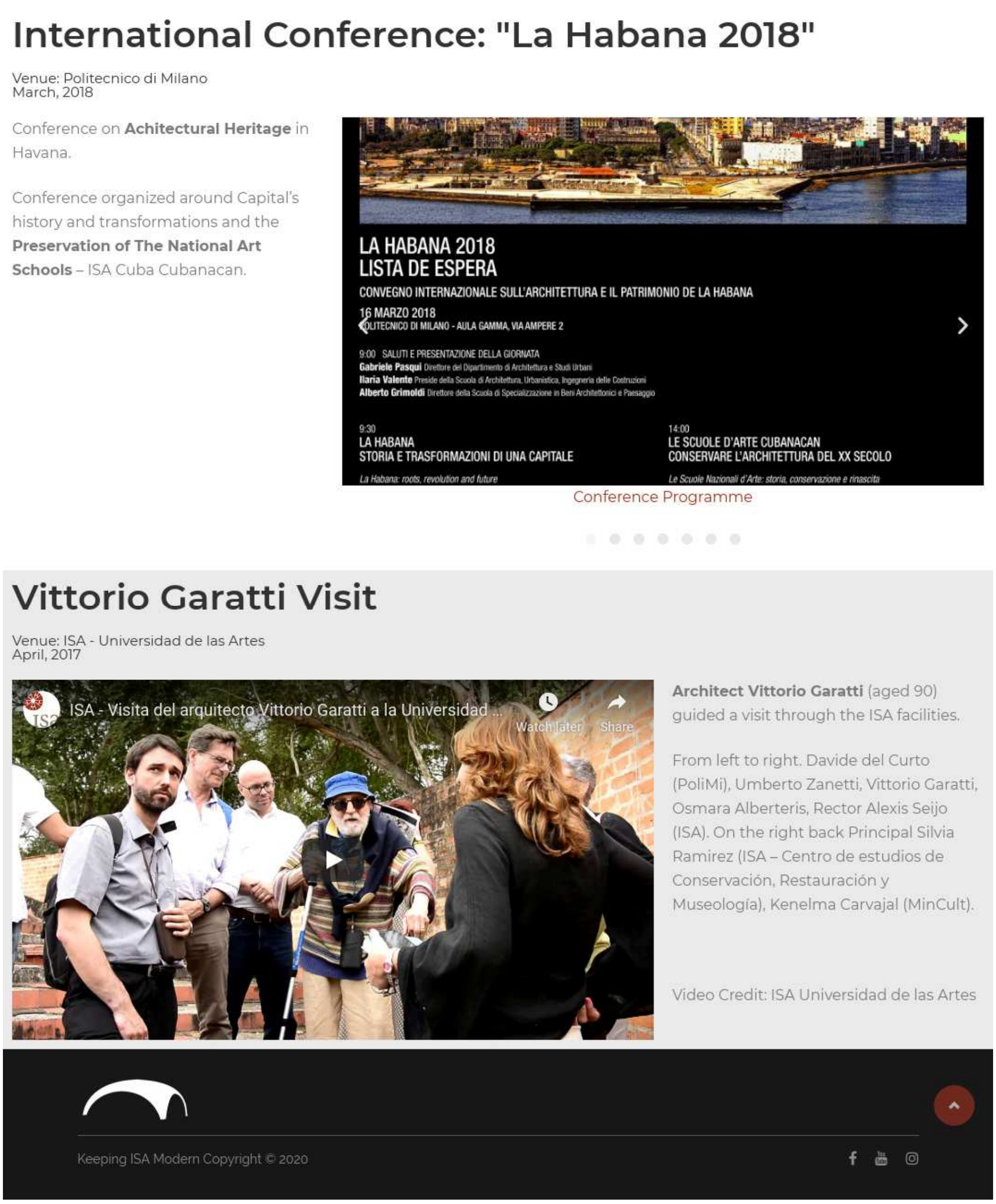

Figure 7 - Activities section.

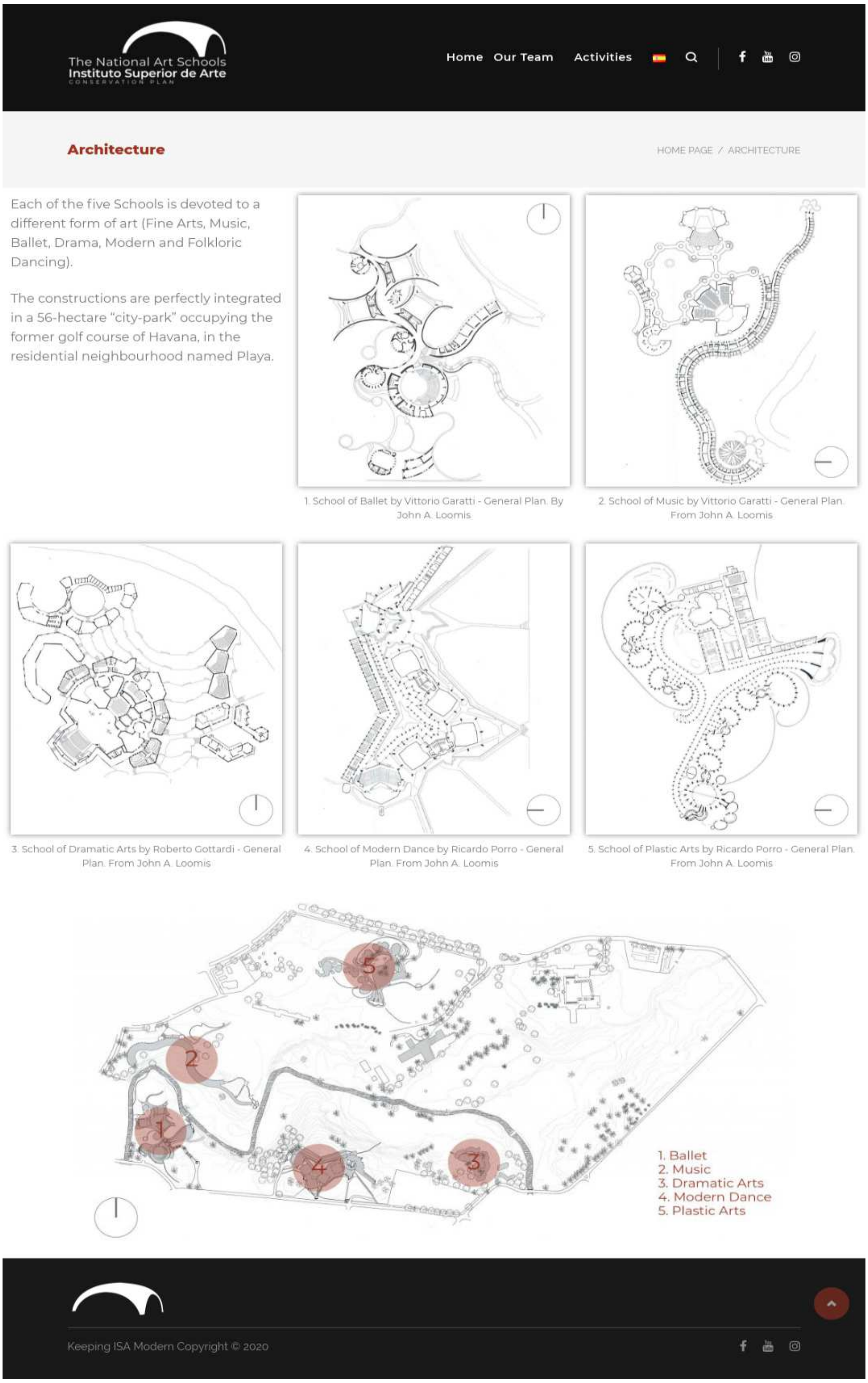

Figure 8 - Architecture section.

The immersive visualization system

During the inspection in June 2019, a considerable amount of information was acquired, which served above all to support the activities of the different working groups involved. On the other hand, however, the geometric and morphological acquisitions carried out through the use of a laser scanner equipped with a photographic camera have allowed for further processing than the more strictly technical and dimensional ones[2]. Given the considerable potential of this system, it was decided to use the photographic material produced for two additional purposes with respect to the morphological analysis of the area and buildings. The first for internal use to document objects and allow inspections through the simple vision of spherical images, and the second to make the National Schools of Art and the park virtually available through immersive navigation of the elaborations.

The laser scanner used (FARO S350) is able, in fact, to record a series of photographic images in such a way as to cover an entire scene from the point of acquisition.

Therefore, in addition to the geometric data, small-sized images are taken (about 3MB, 3264 x 2448 pixels) to be processed as a mosaic to create a unitary spherical image. As previously indicated, 161 laser scanner recordings were made. Of these, 63 are associated with the RGB chromatic data while the remaining 98 with the grayscale photographic acquisition (Figure 9).

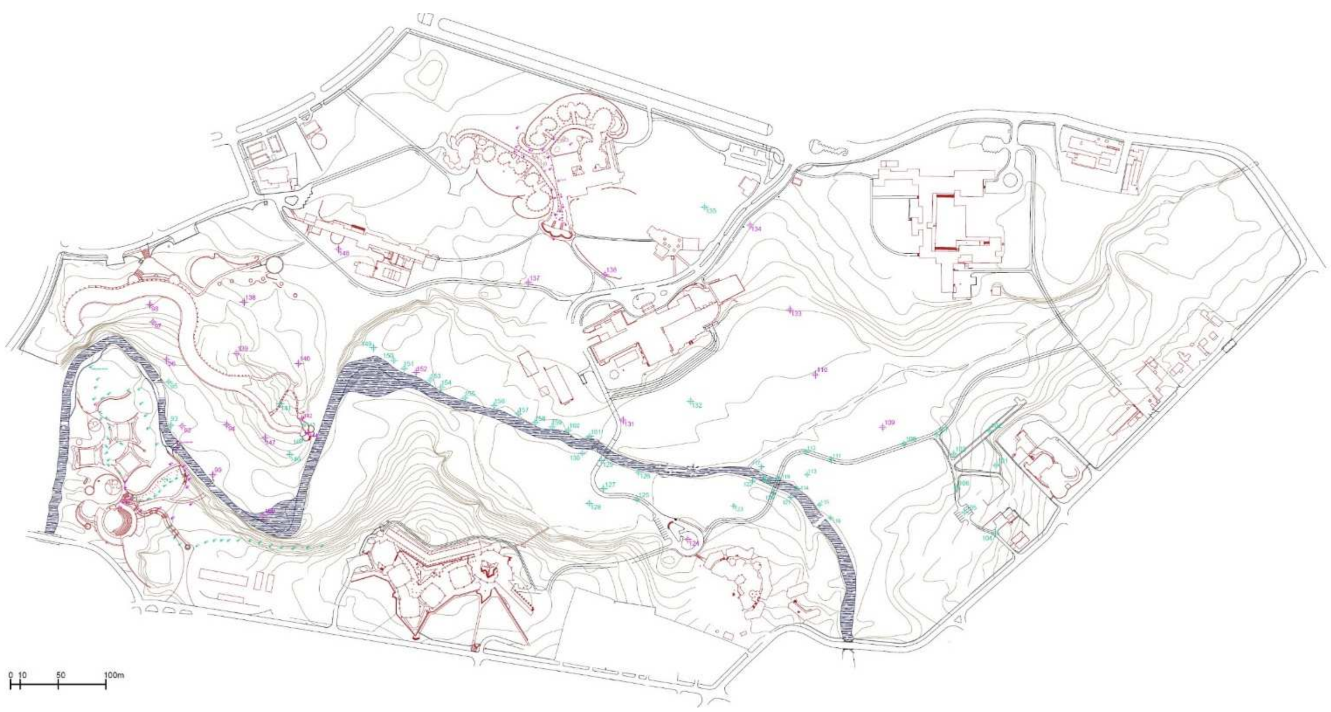

Figure 9 - General plan of the ISA with the location of the scan points (in green, the scans registered in grayscale, color scans are in purple).

[2] See *5.1.2.2 3D data as support to the management system.*

Observed a strong irregularity of lighting sources both inside and outside the buildings, the photographic acquisitions were mostly carried out using the HDR 3X function of the instrument, which allowed to record three distinct photographic shots with a different exposure (- 1.5, 0, +1.5). In each registration point, 198 single images (Figure 10) were acquired following the instrument's scanning pattern and were associated with the corresponding point cloud constituting the first output.

The 198 images were subsequently subdivided on the basis of their exposure creating three macro-groups (Figure 11) and were assembled in such a way as to form three spherical images (Figure 12 - Figure 14). These were post-processed through the High Dynamic Range (HDR) function, allowing you to view a richer range of colors, brighter whites, and very deep blacks (dynamic range) in a single spherical shot (Figure 15 - Figure 22) compared to Standard Dynamic Range (SDR). With SDR technology, shaded areas are often reproduced with a granular black level, and the bright regions have very noticeable shades of white. With HDR technology, on the other hand, it is possible to capture the differences in brightness with greater liveliness and in a much more realistic and immersive quality, without however neglecting all the gradations in the light and dark areas. As for the images acquired in grayscale, we proceeded with a simple mosaic of the individual portions of space in order to create a unitary image (Figure 23 and Figure 24).

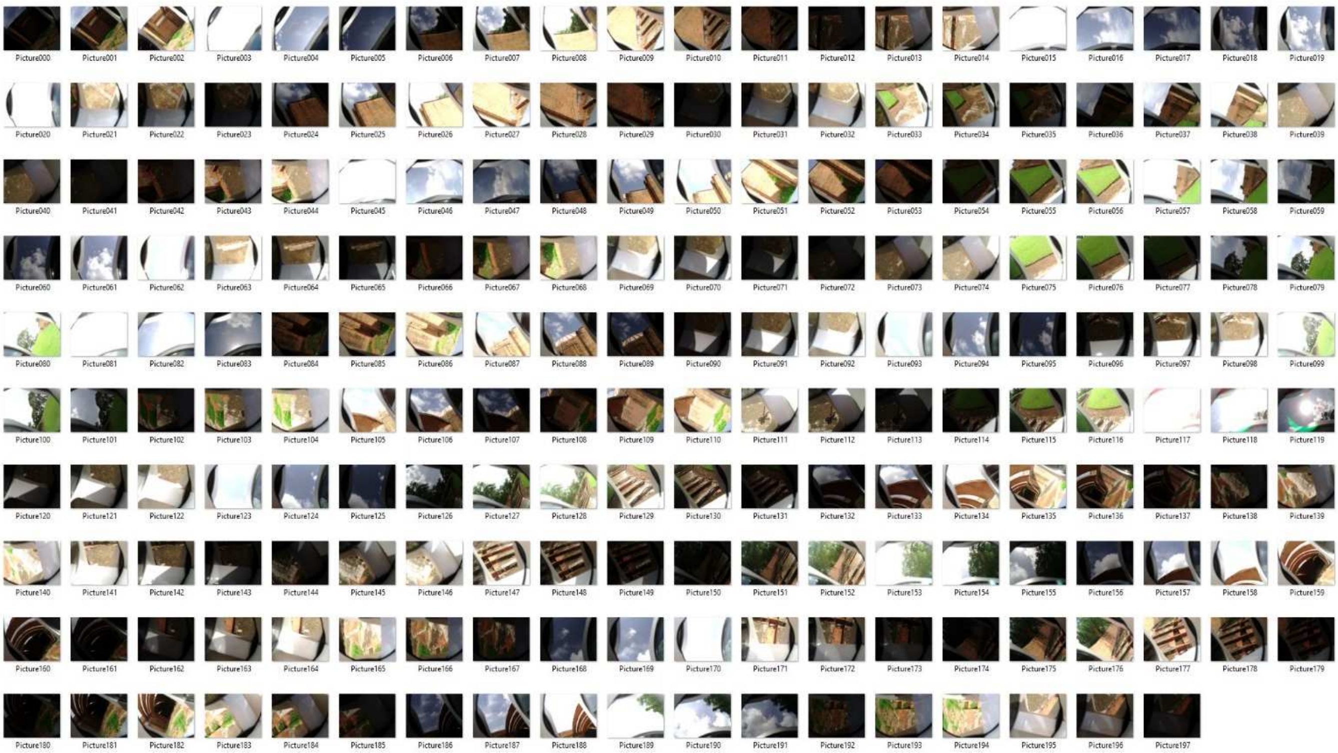

Figure 10 - List of images taken for each single acquisition point with three different exposure levels.

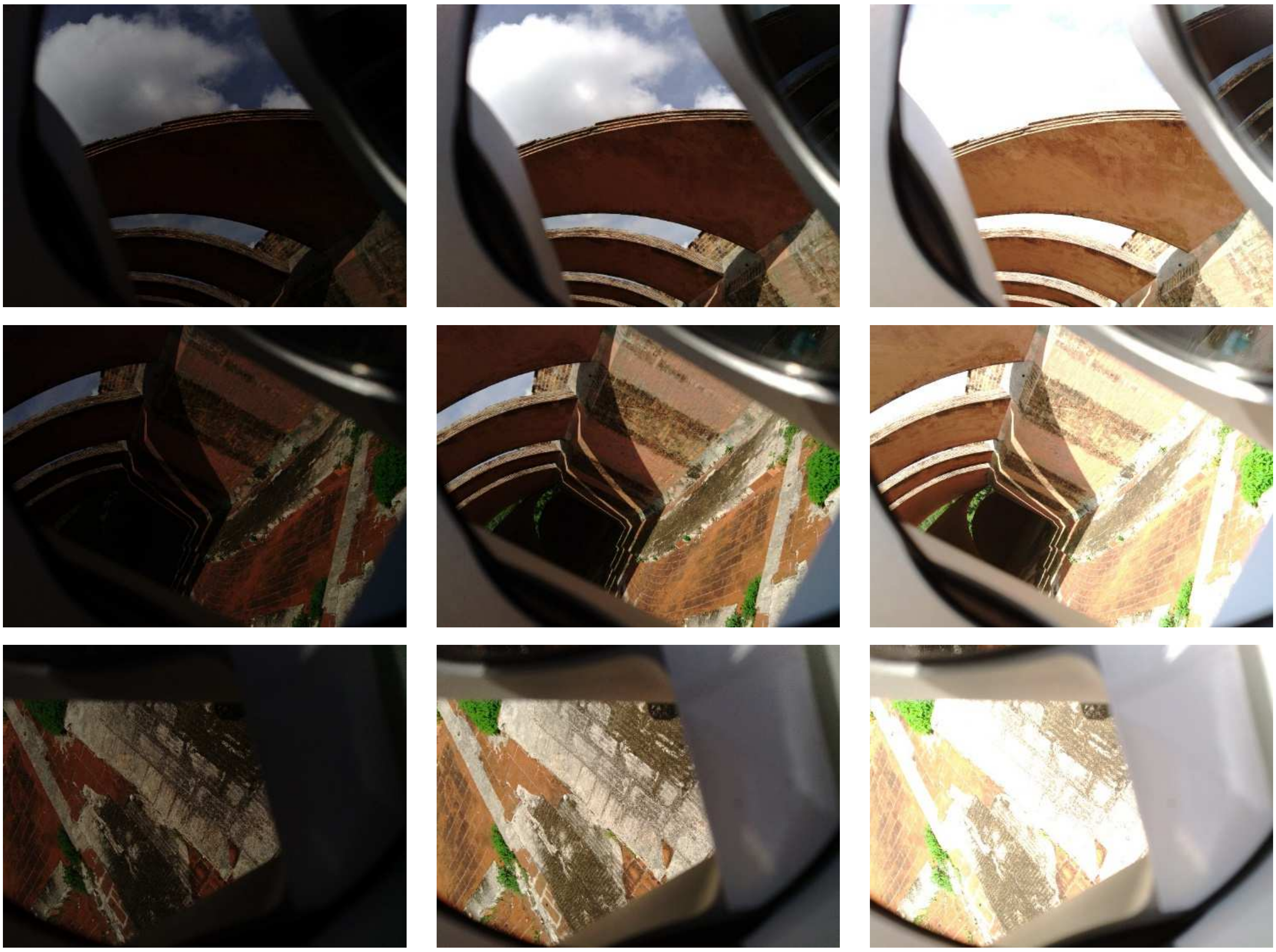

Figure 11 - Three sample frames of a portion of the Ballet School. On the left shot with exposure -1.5, in the center exposure 0, on the right exposure + 1.5.

Figure 12 - Spherical image of the Ballet School with exposure -1.5.

Figure 13 - Spherical image of the Ballet School with exposure 0.

Figure 14 - Spherical image of the Ballet School with exposure +1.5.

Figure 15 - HDR spherical image of the Ballet School with exposure.

Figure 16 - Spherical image of the Ballet School after the final graphic post-processing.

Figure 17 - Spherical image of the Ballet School after the final graphic post-processing.

Figure 18 - Spherical image of the Ballet School after the final graphic post-processing.

Figure 19 - Spherical image of the School of Plastic Art after the final graphic post-processing.

Figure 20 - Spherical image of the School of Plastic Art after the final graphic post-processing.

Figure 21 - Spherical image of the School of Music after the final graphic post-processing.

Figure 22 - Spherical image of the School of Music after the final graphic post-processing.

Figure 23 - Grayscale spherical image of the School of Ballet.

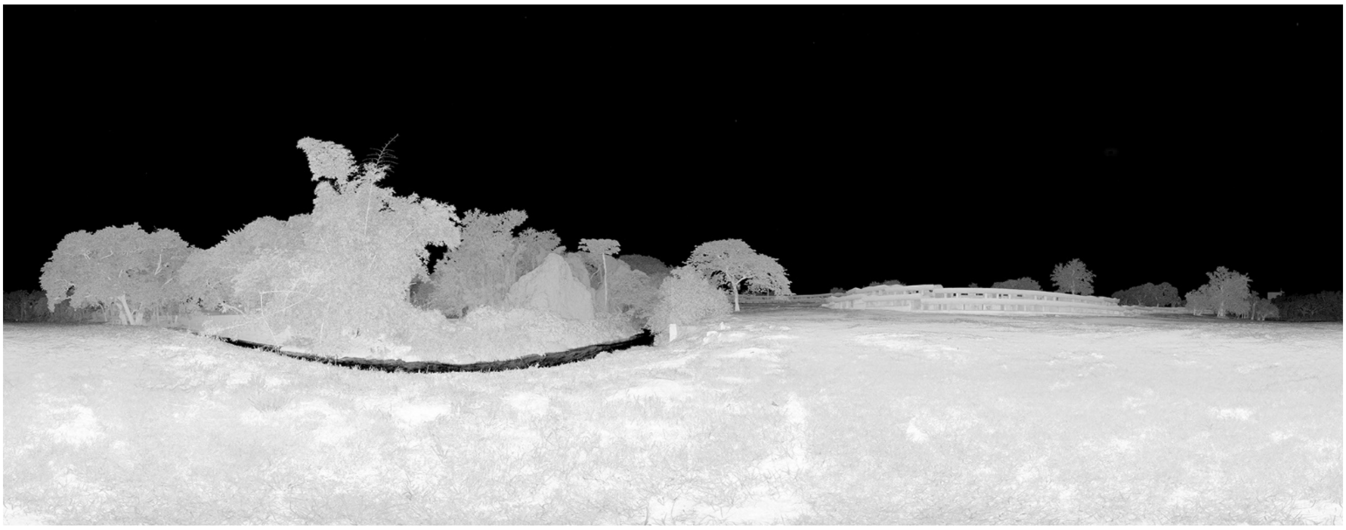

Figure 24 - Grayscale spherical image of the School of Music.

At the end of the photographic processing phase, we moved on to the structuring of the image display system. Using the analysis of the available aerial images, an appropriate aerial photo was selected on which to place the individual shooting points for selective navigation. All 63 color spherical images were then georeferenced in known space and were subsequently connected to each other in such a way as to be able to switch from one image to another without having to start again from the initial point (Figure 25).

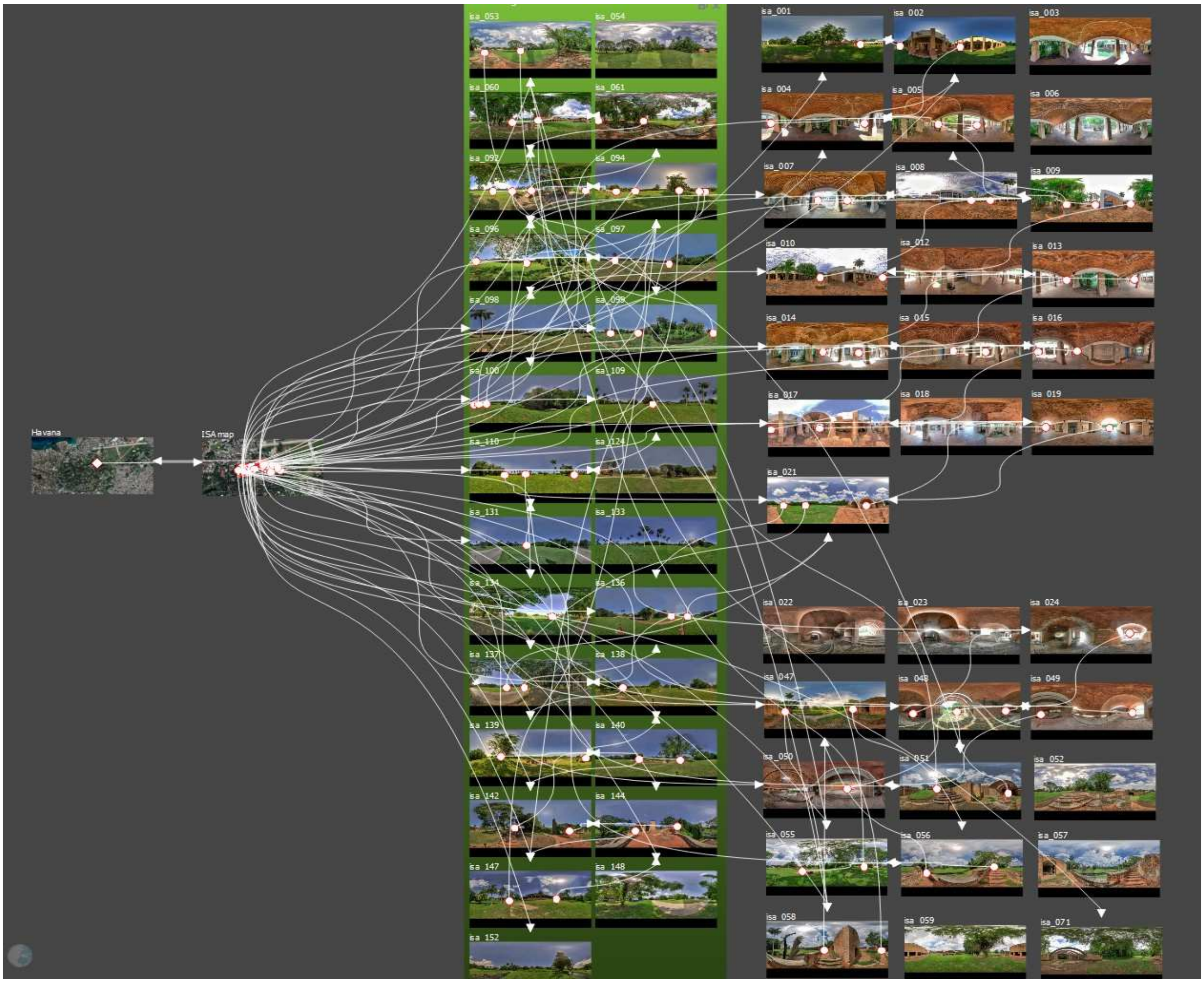

Figure 25 - Connection diagram between the aerial photo and the spherical shots.

The organization of these materials was performed through software capable of exporting the system to an HTML environment in order to be incorporated and viewed directly from all internet browsers. To improve the usability of the system and to implement its functions, it was also decided to use an external advanced hosting and visualization service. This made it possible to add further navigation possibilities and also to be inserted via embed within the project website (Figure 26 and Figure 27). The designed interface is straightforward and agrees with what has been created for the website. On the right, an aerial photo appears with the indication of the interactive spherical shots, while on the left, most of the screen is occupied by the interactive image. However, the possibility of selecting other pictures from the scrolling menu located in the lower part of the space is left.

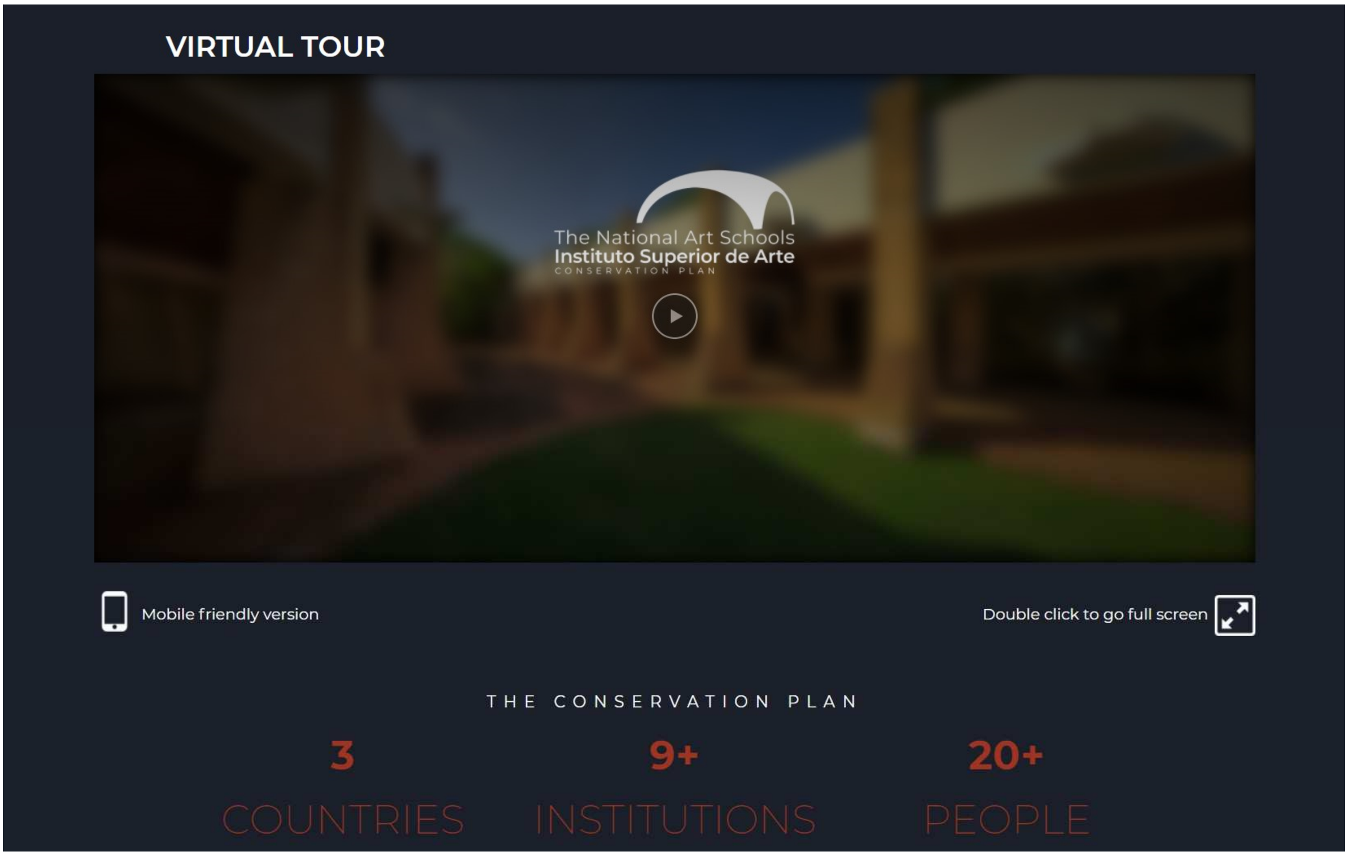

Figure 26 - Website area for access to the immersive navigation system.

Finally, it is possible to change the display functions through the drop-down menu at the top right. In addition to the traditional navigation of spherical images, it is, therefore, possible to activate the following options:

- VR mode: immersive stereoscopic navigation through cardboard for mobile devices or VR viewers. In this case, a device is not required to move within the spherical images. The internal gyroscope of mobile devices is used to understand the user's movement and consequently turn the frame as if you were on the spot. It is also possible to change the viewing point by merely framing the connection points between the images;
- Autorotation: the spherical images selected move in random directions to allow viewing without user interaction. This mode was specially designed for events, expositions, or demonstrations;
- Auto-follow: the spherical image moves following the mouse cursor;
- Slideshow: some portions of the spherical image are projected automatically. In this case, this function was specially designed for events or demonstrations.

Immersive navigation can be viewed on all devices that have an internet connection, i.e., computers (Figure 28 and Figure 29), tablets, and mobile phones. For the latter, a slightly different interface has been designed in order to better adapt to the vertical and reduced format of the screens (Figure 30). The system is able to evaluate the quality and speed of the internet connection, consequently modifying the detail of the images, thus allowing complete usability for all conditions. The immersive visualization system, therefore structured, remains open to future implementations and modifications. It will, in fact, be possible to add interactive content as well as images, videos, or documents linked to specific points of the spherical images.

The latter is an essential condition for the reconstruction of a unitary picture of the National Schools of Art of Cuba. The buildings and areas dispersed in different states of conservation and with other accessibility conditions are quickly brought back to a single narration. Standardizing the supports of conveying the information related to them and the channels through which such information is accessible to the user is, therefore, a priority. Basing on such premises, the web portal "www.keeping-isa-modern.com" and the immersive visualization system were meant to be the main gate to quickly approach the results produced by the research team.

Figure 27 - Navigation system welcome screen.

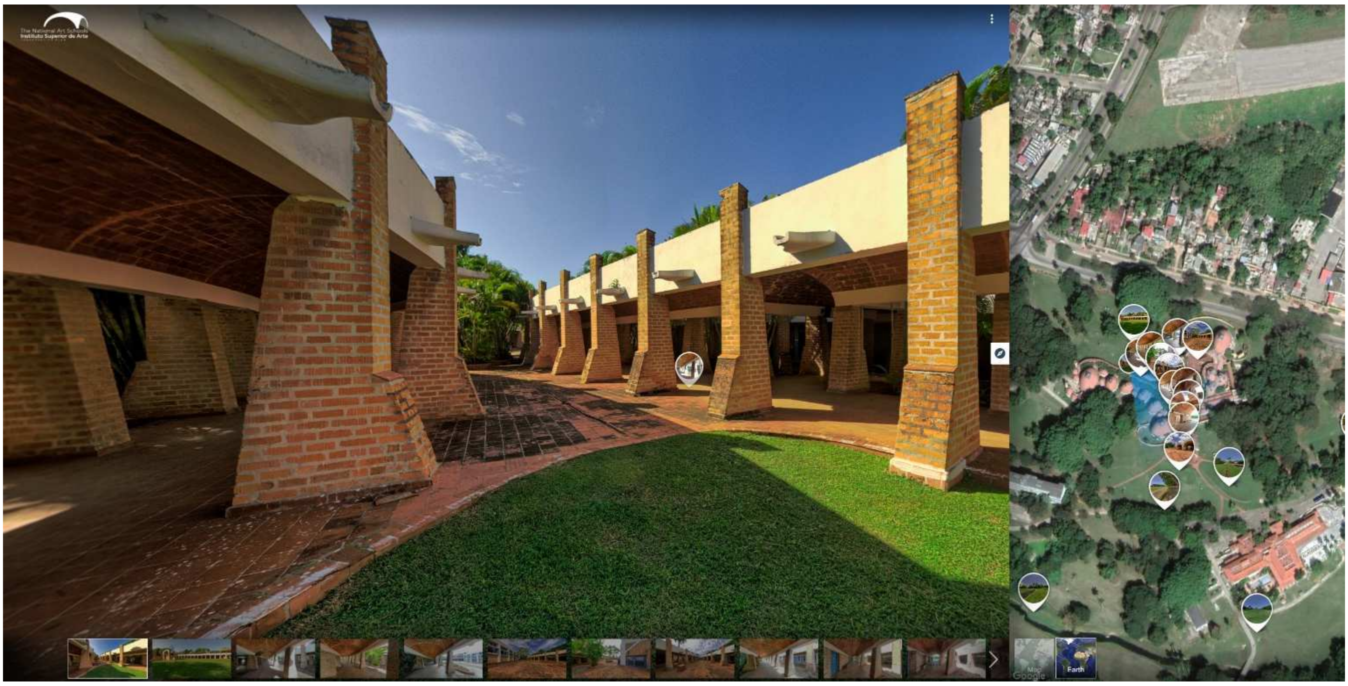

Figure 28 - Navigation system interface for computer or tablet.

Figure 29 - Navigation system interface for computer or tablet.

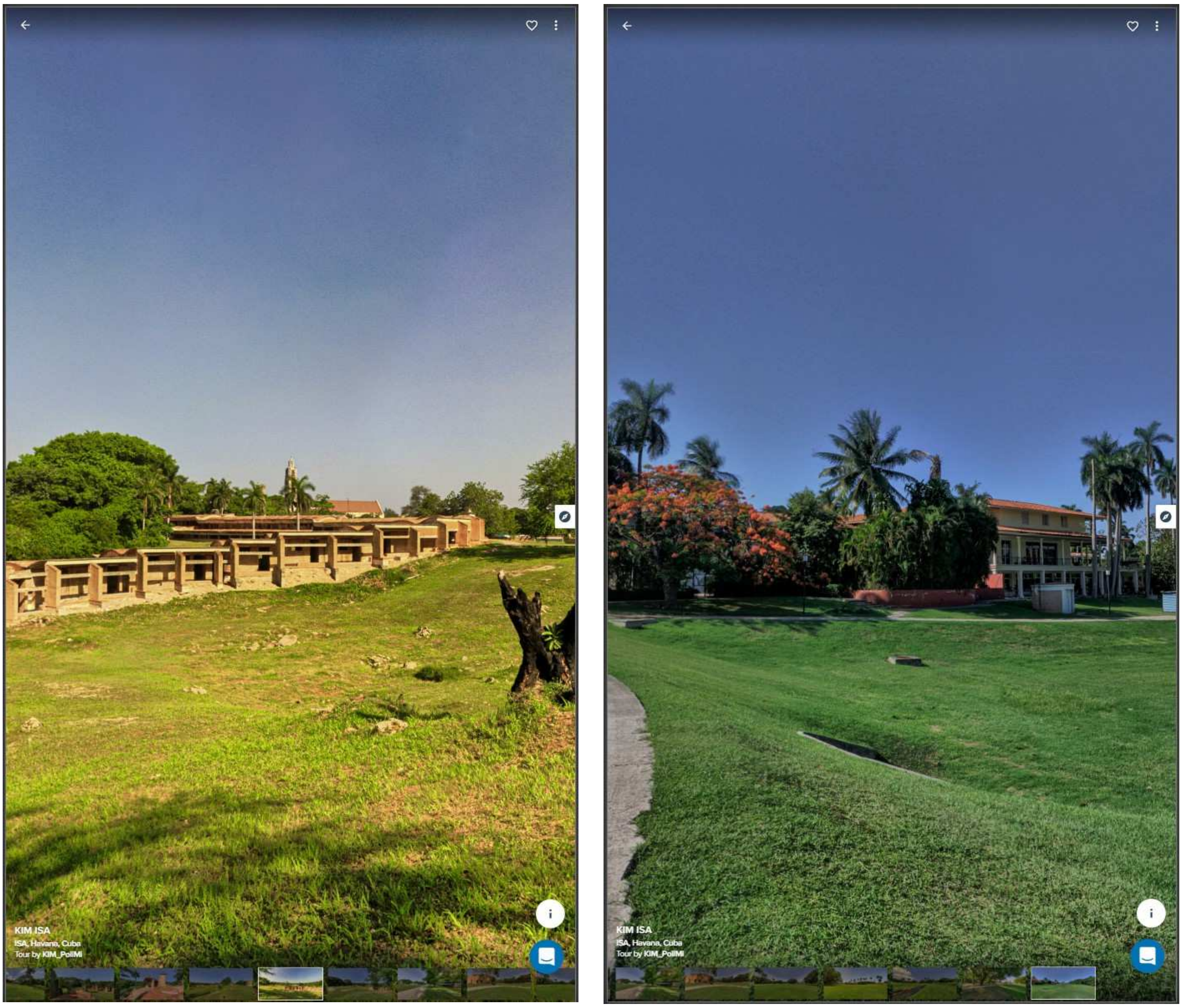

Figure 30 - Navigation system interface for mobile devices.

The communication of the CMP’s actions: a snapshot in video

To guarantee the maximum diffusion of the results and reproduce the entirety and complexity of the CMP easily and directly, a summary video was created. Starting from the material produced and collected, video, images, and photographs were selected to tell a story with an in-depth and engaging approach.

The produced video is directed to a broad audience, not necessarily specialized. It aims to present the National Art Schools, the criticalities of the area that hosts them, and the process that led the working group to formalize a conservation and management plan. The work explains the CMP's objectives, the choice of the G.I.S. tool, and all the actions carried out on-site and remotely by the working group.

The video has been structured in seven different parts, like the CMP. Video retraces CMP scheme and basic concepts. There is a first introductory part in which the user can understand where the Art Schools are, who and when designed them. The following five parts summarize the objectives of CMP and the five actions that have contributed to CMP's realization. In the seventh and last part, the experiences of sharing and dissemination are collected during the work (exhibitions, conferences, meetings, on-site meetings) to get the information and the tool available to the widest possible audience.

Thanks to this, the relationship between the five actions of the CMP, their wealth of work and material produced, and the variety of the results and outputs achieved emerge more clearly. It also shows the strength of the team's multidisciplinary nature: several collaborating institutions, each with their skills, shared the study's phases to open a 360° view of the National Art School of Havana. For the first time, the images tell us the places' reality and the analysis carried out.

The video was made with Final Cut Pro software, and photographic materials, videos acquired during on-site inspections, archival and bibliographic studies were collected. The difficulty in keeping together materials coming from different sources, often realized for other purposes, was overcome by setting the entire presentation with the website's graphics.

A short video collects and tells the salient points of a two-year work and opens to new reflections towards the future of this extraordinary place for art and life.

Publications, exhibitions, and collaborations

Scientific publications

The preliminary results of the research activity have fueled a series of scientific publications, hitherto focused on structural issues (Action 2) and on the architecture of the CMP (Action 5):

- Allegretti, F., Del Curto, D., and Mazza, S.: ADVANCED GEOMATICS AND CONSERVATION MANAGEMENT PLAN FOR PRESERVING 20th CENTURY ARCHITECTURAL HERITAGE, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W11, pp. 63-70, https://doi.org/10.5194/isprs-archives-XLII-2-W11-63-2019, 2019.
- Del Curto, D., Garzulino, A., Allegretti, F., and Mazza, S.: GIS OR BIM? A COMPARISON APPLIED TO THE CONSERVATION MANAGEMENT PLAN OF A 20th CENTURY ARCHITECTURAL HERITAGE, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLII-2/W15, pp. 365-372, https://doi.org/10.5194/isprs-archives-XLII-2-W15-365-2019, 2019.
- Douglas, I., Napolitano, R.K., Garlock, M., Glišić, b.: RECONSIDERING THE VAULTED FORMS OF CUBA'S NATIONAL SCHOOL OF BALLET, in Augilar, R. et al. (Edited by), "Structural Analysis of Historical Constructions, RILEM Bookseries, Volume 18, RILEM, pp. 2150-2158, https://doi.org/10.1007/978-3-319-99441-3_231, 2019.
- Douglas, I., Napolitano, R.K., Garlock, M., Glišić, b.: CUBA'S NATIONAL SCHOOL OF BALLET: REDEFINING A STRUCTURAL ICON, in Engineering Structures, Volume 204, Elsevier, https://doi.org/10.1016/j.engstruct.2019.110040, 2020.

The general contents and objectives of the conservation plan are summarized in Del Curto, D.: TOWARDS A CONSERVATION PLAN FOR NATIONAL ART SCHOOLS, pp. 234-243, in:

- Del Curto, D. (Edited by): UNA RIVOLUZIONE DI FORME. LE SCUOLE NAZIONALI D'ARTE DI CUBA, Mimesis Edizioni, Milano 2019.

This chapter concludes the Italian edition of John Loomis' book, which is finally available in Italian twenty years after the first edition.

Exhibitions

Conservation Management Plan joins TRIENNALE (January-August 2019)

The 22nd Architecture Triennale will be inaugurated in Milan on February 28th, 2019. Triennale is a cultural institution of relevant prestige and international resonance on the issue of fine arts, architecture, and design. The exhibition is named "Broken Nature: Design takes on human survival" (see brokennature.org) and will highlight the concept of restorative design and study the state of our connection with the natural environment, exploring architecture and design objects and concepts at all scales and in all materials.

Cuba will join the Triennale 50 years later. In fact, the last time was 1968. The Cuban pavilion will be entirely dedicated to the National Schools of Art of Havana that will then have the chance of representing Cuba in this international exhibition about the controversial relationship between architecture and nature. The curator of the pavillon is Mr. Jorge Fernandez, director of the Museum of Fine Arts in Havana. The Politecnico, through its Foundation, is co-responsible for the project of the Cuban pavilion.

An entire wall of the pavilion will be dedicated to the K.I.M./Getty project, thanks to an exhibition panel of 240x240 cm (a draft is attached). A number of meetings have already occurred for this exposition. Two in particular affected the K.I.M. project:

1) January 22nd, 2019. Triennale di Milano.

Items: preparation and contents of the pavilion

People: Christian Zecchin, Italian co-curator (Vittorio Garatti committee), Umberto Zanetti, Italian co-curator (UZ Design), Davide Del Curto (Milan Politecnico), Laura Agnesi, Stefano Boeri (Milan Triennale), Rodrigo Rodriquez (Pavilion sponsor), Alexis Sejio Garcia (Rector of the Universidad de Las Artes, Cuba).

2) February 4th, 2019. Museum of Fine Arts in Havana

Items: preparation and contents of the pavilion

People: Christian Zecchin, Italian co-curator (Vittorio Garatti committee), Davide Del Curto (Milan Politecnico), Sofia Celli (Parma University), Jorge Fernandez, Cuban curator (Museum of Fine Arts in Havana), Norma Derivet (Consejo Nacional de Bellas Artes), Alexis Sejio Garcia (Rector of the Universidad de Las Artes, Cuba).

Figure 31 - Layout of The Cuban Pavillon, XXII Triennale / Broken Nature (front view)

Figure 32 - Layout of The Cuban Pavillon, XXII Triennale / Broken Nature (side view)

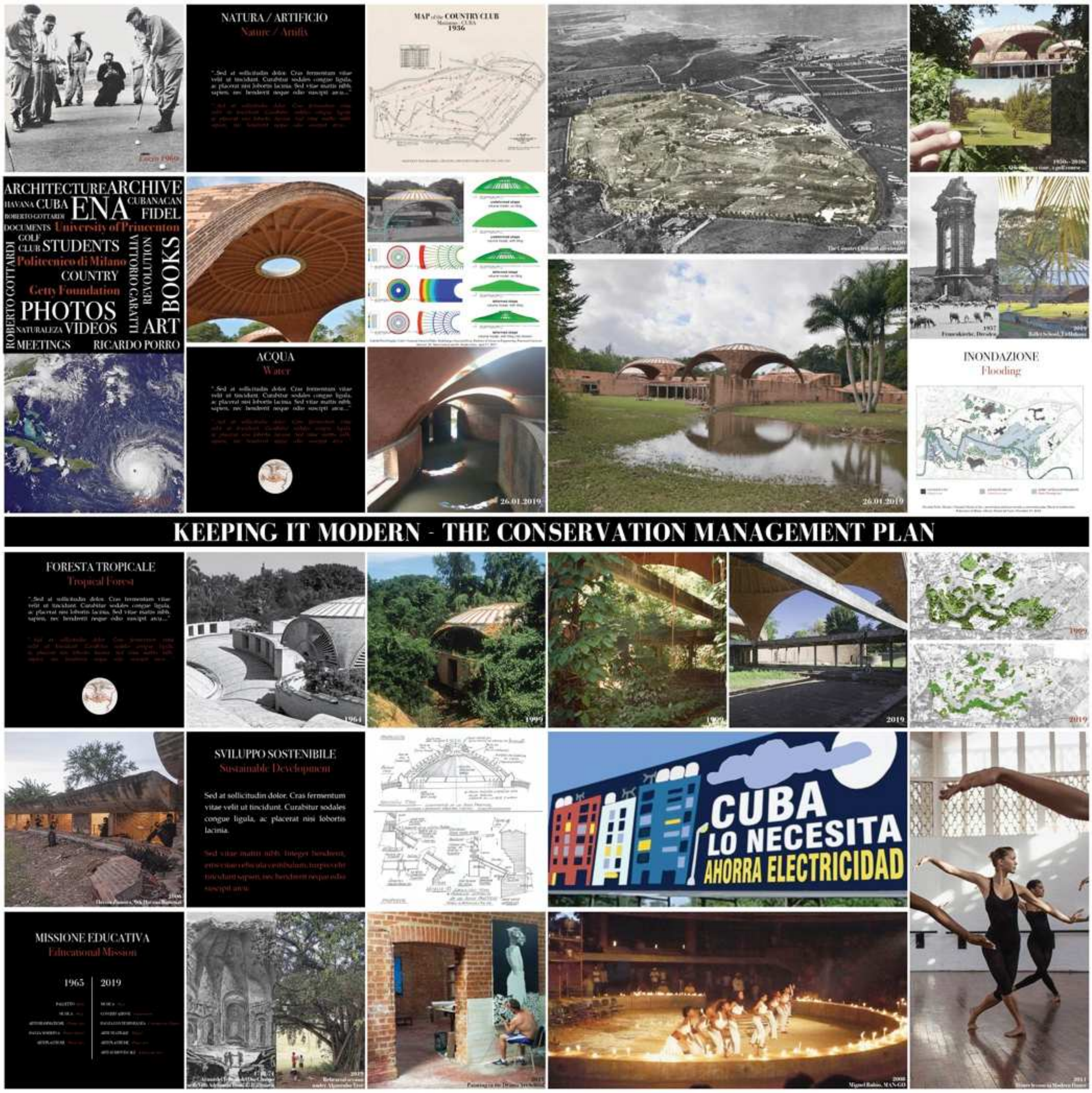

Figure 33 - Panel illustrating items and structure of the Conservation Management Plan (Politecnico di Milano / Keeping it Modern program)

Collaborations and networking

Conservation Management Plan joins the POST-TRIENNALE (October-November 2019)

The exhibition "Broken Nature: Design takes on human survival" (see brokennature.org) as a part of the 23rd Architecture Triennale in Milan closed on February 28th, 2019.

The Cuban pavilion was entirely dedicated to the National Schools of Art of Havana, and an entire wall was dedicated to the K.I.M./Getty project, thanks to an exhibition panel of 240x240 cm.

After the excellent public response to the Milan exhibition, the Cuban pavilion was re-installed at the University of Florence on the occasion of the week of Italian culture in Cuba. On October 16th, a day of study entitled "ARTE Y REVOLUCIÓN, LAS ESCUELAS NACIONALES DE ARTE DE LA HABANA" accompanied the inauguration of the pavilion in Florence. It represented a new opportunity for collaboration between the Keeping it Modern initiative and the International Cooperation project "Que no baje el telon", dedicated to the restoration of the Drama School.

On November 15th 2019 the exhibition was inaugurated again at the headquarters of the University of Rome TRE, in the spaces of the former slaughterhouse. The conference that inaugurated the exhibition took place in the presence of the Cuban ambassador in Italy, of the professors of the University of Rome3 responsible for the international cooperation project OCSHC - Oriental Cuban Small Historic Centers. The leaders of the international cooperation project "Que no baje el telon" of the University of Florence were also present. It was, therefore, a very positive opportunity for networking and discussion among three initiatives from Italy that aim to take care of Cuba's historical architectural heritage and its social and cultural background.

Prof. John Ochsendorf, present director of the America Academy in Rome, joined the conference and expressed his interest in the KIM project.

"ARTE Y REVOLUCIÓN, LAS ESCUELAS NACIONALES DE ARTE DE LA HABANA", Università degli Studi di Firenze (October - November 2019)

UNIVERSITÀ DEGLI STUDI FIRENZE | DIDA DIPARTIMENTO DI ARCHITETTURA

inaugurazione dell'esposizione

Arte y Revolución
las Escuelas Nacionales de Arte de La Habana

Mercoledì 16 ottobre 2019 si inaugurerà, nel Plesso Didattico di Santa Teresa, l'esposizione del *Padiglione Cuba*, realizzato per la XXII Triennale di Milano 2019 dal titolo "Broken Nature". Il *Padiglione Cuba* è totalmente dedicato alle *Scuole Nazionali d'Arte dell'Avana*. Sarà l'occasione anche per accennare alle iniziative che stanno interessando il complesso de *Las Escuelas Nacionales de Arte*, con particolare risalto al valore cultural-pedagogico oltre che al valore architettonico-artistico del complesso. *"Le Scuole sono più che mai vive"*, come ci ricorda il Rettore della ISA Alexis Seijo García, *"hanno e continuano a formare i migliori artisti cubani nel mondo, oltre a rappresentare un modello unico di formazione ed insegnamento artistico".*

L'evento fiorentino fa parte delle **giornate** della **cultura cubana** in **Italia**.

#CubaCulturaItalia2019

16 ottobre 2019 | 15–18

aula 401 | Santa Teresa

via della Mattonaia 8, Firenze

Interverranno

Saverio Mecca
Direttore del DIDA

Lisset Argüelles Montesinos
Addetto Culturale dell'Ambasciata di Cuba in Italia

Jorge Antón Fernandez Torres
Direttore del Museo de Bellas Artes de La Habana e Curatore del Padiglione Cuba

Rodrigo Rodriquez
Imprenditore del Design

John A. Loomis
California State University, Firenze

Davide Del Curto
Politecnico di Milano

Christian Zecchin | Umberto Zanetti
co-curatori del Padiglione Cuba

Michele Paradiso
Dipartimento DIDA, coordinatore dell'evento

A seguire l'inaugurazione dell'esposizione

L'evento si concluderà in serata, alle ore 20.30, presso il **Cinema Stensen**, in Viale Don Minzoni 25c, con la **proiezione in anteprima nazionale**, del film ***YULI danza e libertà*** *di Icíar Bollaín (Spa/UK/Ger/Cuba, 2018 - 110'), vincitore al Festival di San Sebastian del Premio come Miglior Sceneggiatura*, sulla vita del ballerino cubano Carlos Acosta, che tanta relazione ha avuto ed ha con Las Escuelas Nacionales de Arte.
La proiezione sarà preceduta da una breve introduzione di Jorge Antón Fernández Torres e Michele Paradiso. Seguirà un dibattito conclusivo.

Figure 34 - Poster and program of the opening day.

Figure 35 - Poster of the opening day.

Figure 36 - Entrance to the Exhibition.

Figure 37 - Picture of the Exhibition.

"ARTE Y REVOLUCIÓN, LAS ESCUELAS NACIONALES DE ARTE DE LA HABANA",
Università degli Studi di Roma Tre (November 2019 - January 2020)

ARTE Y REVOLUCIÓN
LAS ESCUELAS NACIONALES DE ARTE DE LA HABANA

In occasione dei 500 anni dalla fondazione (16 novembre 1519) della città de L'Avana, si inaugurerà, presso il Dipartimento di Architettura dell'Università degli Studi Roma Tre, l'esposizione del Padiglione Cuba, realizzato per la XXII Triennale di Milano 2019 dal titolo "Broken Nature". Il Padiglione Cuba è totalmente dedicato alle Scuole Nazionali d'Arte dell'Avana. Sarà l'occasione anche per accennare alle iniziative che stanno interessando il complesso de Las Escuelas Nacionales de Arte, e l'intera Cuba, con particolare risalto al valore cultural-pedagogico oltre che al valore architettonico-artistico del complesso, e alle attività che Roma Tre e il Dipartimento di Architettura stanno svolgendo a Cuba. "*Le Scuole sono più che mai vive*", come ci ricorda il Rettore della ISA Alexis Seijo García, "*hanno e continuano a formare i migliori artisti cubani nel mondo, oltre a rappresentare un modello unico di formazione ed insegnamento artistico*".

Dipartimento di Architettura
Aula Adalberto Libera
15 novembre 2019 | ore 15.00
Largo Giovanni Battista Marzi, 10 - Roma

ROMA TRE
UNIVERSITÀ DEGLI STUDI
DIPARTIMENTO DI ARCHITETTURA

Figure 38 - Poster of the opening day.

15 novembre 2019

ARTE Y REVOLUCIÓN

LAS ESCUELAS NACIONALES DE ARTE DE LA HABANA

15:00 Saluti istituzionali
Giovanni Longobardi Direttore del Dipartimento di Architettura
José Carlos Rodriguez Ruis Ambasciatore della Repubblica di Cuba in Italia
Luca Pietromarchi Rettore dell'Università degli Studi Roma Tre
Rodrigo Rodriguez Presidente di Material ConneXion Italia

15:30 Il Dipartimento di Architettura a Cuba. Il Progetto OCSHC Oriental Cuba Small Historical Centres
Mario Cerasoli Università degli Studi Roma Tre

15:50 Il ruolo della Cooperazione italiana nella tutela e valorizzazione del patrimonio culturale a Cuba
Emilio Cabasino Responsabile per Cuba dell'Agenzia italiana per la Cooperazione allo Sviluppo

16:10 Il ruolo dell'IILA nei progetti di conservazione del Patrimonio Storico Costruito in Cuba
Augusto Chiaia Istituto Italo Latino-americano

16:30 Las Escuelas Nacionales de Arte
John A. Loomis California State University

17:00 Il progetto Getty Fundation per le Escuelas de Arte de La Habana
Davide Del Curto Politecnico di Milano

17:30 Las Escuelas Nacionales de Arte: 1960-1995
Cristian Zecchin Co-curatore del Cuban Pavilion alla XXII Triennale di Milano

18:00 Las Escuelas Nacionales de Arte: storia recente e punti focali del progetto *Que no baje el telón*! (AICS-DiDA-MinCult Cuba)
Michele Paradiso Università degli Studi di Firenze

18:30 Inaugurazione della mostra, visitabile fino al 29.11.2019
Arte y Revolución Allestimento curato dagli studenti

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Dipartimento di Architettura
Aula Adalberto Libera
Largo Giovanni Battista Marzi, 10 - Roma

Figure 39 - Program of the opening day.

Figure 40 - Pictures of the Exhibition.

Figure 41 - Picture of the Exhibition.

Figure 42 - Picture of the Exhibition.

Collaboration with the Cooperation Project ¡QUE NO BAJE EL TELON! (2019-2020)

We have continued to share our progress with the Cooperation Project ¡QUE NO BAJE EL TELON! / Università degli Studi di Firenze focusing on the restoration of the School of Drama.

The Cooperation project is now concluding the first phase dedicated to the training activities on site.
We joined an on-site workshop about the structural assessment of the domes during the last mission in Cuba (November 2019)
We had the chance of a joint seminar during the next mission to Havana in February 2020, when our group met the UNIFI group in Cuba again.
On January 14th, 2020 we had a coordination meeting at DiDa Dept. (Department of Architecture), Università degli Studi di Firenze. We kept sharing and progress of the works of the two projects (The National Schools of Art / Politecnico di Milano and the Cooperation Project ¡QUE NO BAJE EL TELON! / Università degli Studi di Firenze). We coordinated the 2020 on-site agendas, and we scheduled a scientific conference for the discussion of the results of the KIM project and of the intermediate outcomes of the Cooperation Project (autumn 2020 - winter 2020).

Networking with other Kim Grantees
At the beginning of December 2020, we have been contacted by the working group that is working on the Conservation Management Plan for the Buzludzha complex in Bulgaria.
We had a positive conversation and email with the project coordinator arch. Anna Nevrokopska. We illustrated our progress and shared our previous experiences with the drafting of the Conservation Management Plan for the "Collegi" in Urbino. We are going to arrange a meeting in Sofia and a visit to the Buzludzha site.
On July 24th 2019, student YOUSSEF ALMEZERAANI defended a master thesis entitled "Rashid Karame international fair in Tripoli, Lebanon. Towards a conservation management plan", Politecnico di Milano, School of Architecture and Society, supervisor: prof. Davide Del Curto. The thesis allowed the student to get in touch with the Lebanese group operating on the CMP for the Tripoli Fair, in particular with Mr. George Arbid.
Here is the abstract of the thesis:
"This thesis proposes an analytical process to dealing with the neglect and misuse of a particular modern heritage site, the Rashid Karame International Fair in Tripoli, Lebanon. The "Adaptive Reuse" emerges from the goal of reintegrating spatially and temporally the mostly abandoned place, adapting what remains to the actual contexts in the hope that it may clarify the horizons of its best adapted future. Revitalizing this site is a critical and delicate task because it is dealing mainly with the process of unblocking correctly what was suspended half a century ago. With such a monumental project that was barely present for communities and that never, in essence, existed, does one keep its construction incomplete, frozen in time, while preserving the fabric and materiality of its architecture? Or does one discover its potential in order to transform the space, proposing a new program? Such obvious questions remain open-ended. The thesis is an academic attempt to try answering these dilemmas kept unsolved till nowadays threatening the site with irreversible consequences. The work process will come to a conclusion that will guide us towards the conservation and reuse of the fair."

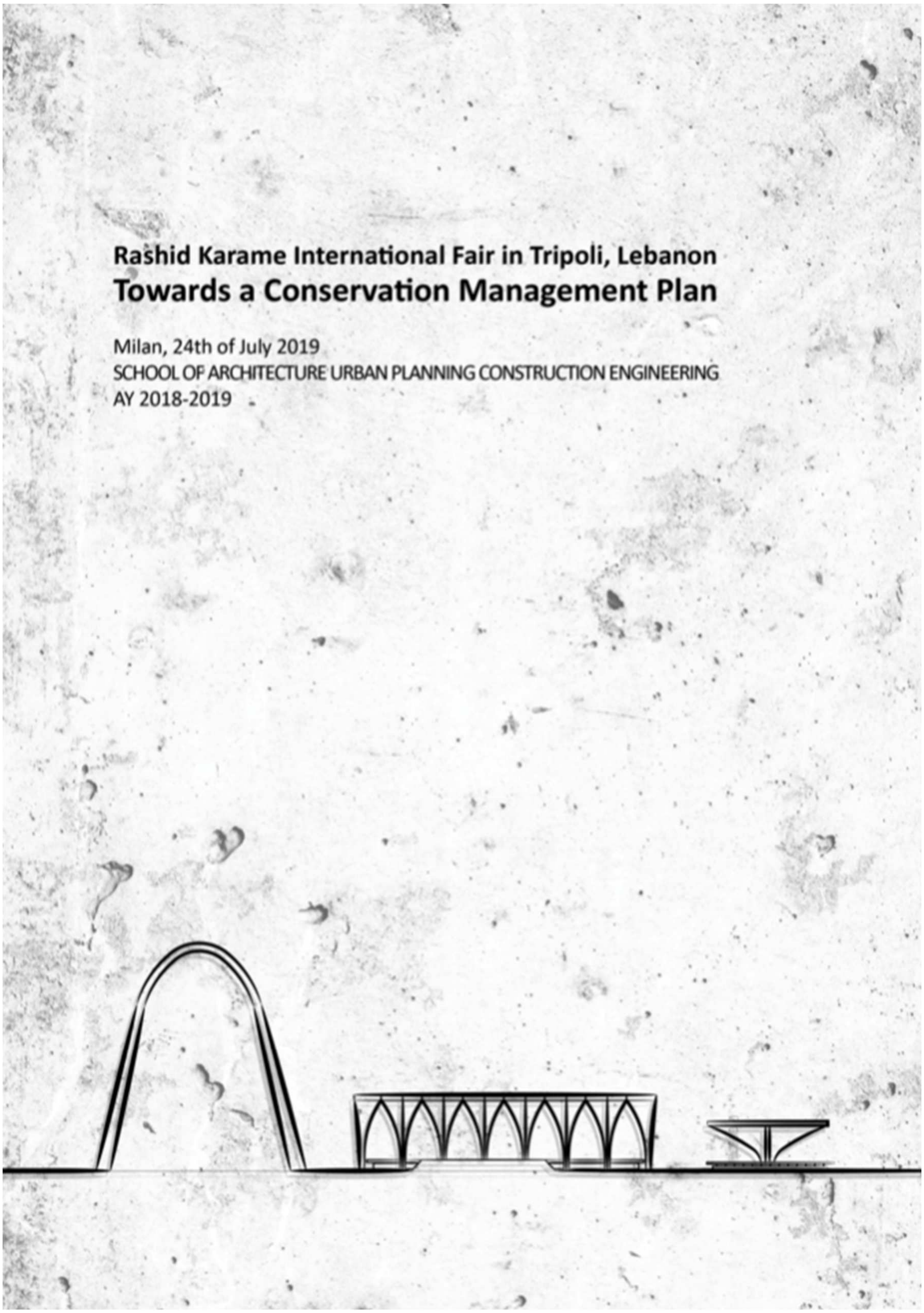
Rashid Karame International Fair in Tripoli, Lebanon
Towards a Conservation Management Plan
Milan, 24th of July 2019
SCHOOL OF ARCHITECTURE URBAN PLANNING CONSTRUCTION ENGINEERING
AY 2018-2019

Figure 43 - Almezeraani Msc thesis about the CMP of the International fairground in Tripoli, Lebanon.

Teaching activities

As part of the project, some teaching activities have been introduced to investigate specific issues addressed by the research. Specifically, the activity concerning Action 3, Landscape management and flood risk assessment and mitigation, was the subject of the "Progettazione territoriale per la gestione dei rischi" course held by Prof. Daniele Fabrizio Bignami in the AA 2019/2020 within the Master's Degree course in "Construction Architecture" of the Politecnico di Milano. Six Master thesis in Architecture also started, four of which were completed in 2018, 2019 and 2020:

- Riccardo Feder, *Havana's National Schools of Art. Preservation and reuse towards a conservation plan*, Master's Thesis, A.Y. 2017/2018, Politecnico di Milano

  ABSTRACT: This thesis proposes an architectural research on National Schools of Art of Havana. It investigates the history of the construction, use and degradation of the main buildings with a spirit of objectivity. The work starts from an evaluation of the current state, analysing the physical conservation of the building and bringing out for each of them the functional program, the permanent/temporary use and the material-structural decay also caused by the abandonment. The highlighting of critical issues and still unexpressed potentials of the site form a starting base on which it is possible to plan, for the first time, the recovery and reorganisation of the unused buildings and the park as elements which are part of a whole, in a global vision. The functional analysis is specified in the project for the recovery of the School of Music, called "Gusano", showing a possible scenario of reuse and conservation of the abandoned building. The proposal is to reconfigure the building as students residence, with the intention to reclaim to a full use one of the symbols of neglect and unfinished that has affected this area for many years.

- Giuseppe Abbattista, *Il suono dell'architettura a L'Avana. Restauro e riuso della Scuola di Musica di Vittorio Garatti-ENA (Escuelas Nacionales de Arte)*, Master's Thesis, A.Y. 2018/2019, Università degli Studi di Parma

  ABSTRACT: Nonostante il forte accento posto da "Revolution of forms" di J.L (1999) e l'inserimento nella "World Monuments Watch List 1(2002)" abbiano già ampiamente evidenziato il problema dello stato di abbandono di tali scuole, proprio la scuola di musica, su cui si concentra il focus di questa tesi, resta orfana di fonti di finanziamento, destinato al restauro, a differenza di quelle teatrale e coreutica. Perciò uno degli intenti di questa tesi è quella di dare a tale struttura la visibilità che essa merita. Alla base di questo studio vi è l'analisi del linguaggio dei tre architetti. In particolare, si è posta l'attenzione sui punti di contatto e le differenze tra i tre "protagonisti" in un quadro storico-culturale estremamente variegato che offre numerosi spunti di analisi. Il restauro di un edificio come quello della Scuola di Musica è un'operazione basata sulla conoscenza. La scuola possiede un alto valore storico, paesaggistico e rappresentativo di quell'ideale di architettura cubana "rivoluzionaria" dei primi anni 60'. Nel rispetto della Scuola di Musica e dell'architetto, in questa tesi non si è voluta trasformare la funzione del

complesso, sono state interventi atti a conservare il progetto originale. La finalità di questa tesi di laurea è di fornire un'analisi accurata attraverso i dati raccolti sul campo, in dettaglio, sulla scuola di musica, mettendo in evidenza l'importanza della sua presenza all'interno del campus e la funzione che rivestirebbe in condizione di utilizzo attivo, ponendo dove possibile l'accento sul problema dell'accessibilità. La tesi si articola in sette capitoli: nel primo viene fornita un'introduzione attraverso un excursus storico e sociale, che ha portato alla nascita delle scuole e all'incontro dei tre architetti all'Avana, il secondo e il terzo capitolo descrivono le cinque Scuole, contestualizzandole, il quarto e il quinto capitolo sono i capitoli della conoscenza, si concentra sull'indagine effettuata sulla Scuola di Musica in loco, mentre il sesto e il settimo capitolo si occupano degli interventi di consolidamento e riuso.
Grazie a questo lavoro di tesi, (che si è inserito all'interno di un percorso di studio finanziato dalla fondazione Getty con il progetto "Keeping it Modern") è stato possibile analizzare importanti aspetti legati alle Scuole e alla Scuola di Musica. In questo progetto di restauro della scuola di Musica si è voluto conservare la memoria del luogo e della costruzione, senza stravolgimenti, così da tramandare ai posteri il pensiero e il volere dell'architetto Vittorio Garatti.

- Camille Heubner, *Refinement of Form: A New Analysis of Cuba's National School of Ballet,* Bachelor's Thesis, A.Y. 2019/2020, Princeton University
  ABSTRACT: Originally constructed in 1965, the modernist and experimental structures of the National School of Arts (ISA) in Havana, Cuba have attracted renewed scholarly and architectural interest in the last two decades. A recent grant from the Getty Foundation in rehabilitation of the ISA schools has compelled investigation into the structural performance of the school buildings, especially the reinforced-concrete and thin-tile domes of the Ballet School. The purpose of this investigation is to evaluate the structural behavior and failure states of the Choreography Theater, the largest dome in the Ballet School, in order to inform preservation and rehabilitation efforts to the structure. In order to analyze the Choreography Theater's structural performance, the dome was modeled in ABAQUS, a finite element analysis (FEA) software, and subjected to three load cases which represent realistic extreme loading of the structure: simple gravity loading, hurricane wind loading combined with gravity loading, and settlement of foundation pillars through the removal of boundary conditions. The FEA results indicated that the dome has sufficient structural capacity to withstand gravity and hurricane wind loads without long-term structural damage; while the removal of two boundary conditions will induce local structural damage, it will not produce global structural failure. The FEA results also identified the connections of the lower ribs as the most at-risk elements in the structure, which was validated by observed damage in the dome. The findings of this analysis have identified restoration priorities in the proposed preservation of the Ballet School as well as determined future topics for investigation of the Choreography Theater.

- Federico Taravella, *Teaching the Arts beyond Modern Architecture. Adaptive reuse of Havana's former Clubhouse as a contemporary School of Music*, Master's Thesis, A.Y. 2019/2020, Politecnico di Milano
  ABSTRACT: This thesis presents a proposal for the adaptive reuse of Havana's former clubhouse into the seat of the music school of the Instituto Superior de Arte (ISA). ISA was born from the ashes of the National Art Schools, the Revolution's educational dream hosted into an internationally recognized masterpiece of modern architecture. The thesis is part of the international research project led by Politecnico di Milano drafting a conservation management plan for the National Art Schools of Havana, within the "Keeping It Modern" initiative by the Getty Foundation. The schools were designed in the aftermath of the Cuban revolution of 1959 by the Cuban architect Ricardo Porro and the Italian architects Vittorio Garatti and Roberto Gottardi. This complex is nowadays one of the most significant and well-known examples of modern architecture in Latin America. Today, the ruins of this revolutionary dream stand as a backdrop to the activities of the Instituto Superior de Arte (ISA), taking place in contingency buildings. One of these is the former clubhouse of Havana's Country Club Park, which hosts today multiple functions by ISA (rectorate, classrooms, canteen) given the lack of space and safe buildings. The thesis investigates the specific features of music teaching spaces by studying and comparing several music schools around the world, with a focus on the cases where existing buildings were converted into schools of music. Follows an investigation on design strategies to reduce sound transmission and improve the acoustic quality of music classrooms using smart solutions and sustainable natural materials. Finally, two proposals for such adaptive reuse are presented. Conclusions open to further developments towards an executive design and sustainable implementations of such a proposal.

Havana's National Schools of Art.

Preservation and reuse towards a conservation plan

By Riccardo Feder, Master Thesis, A.Y. 2017/2018, Politecnico di Milano

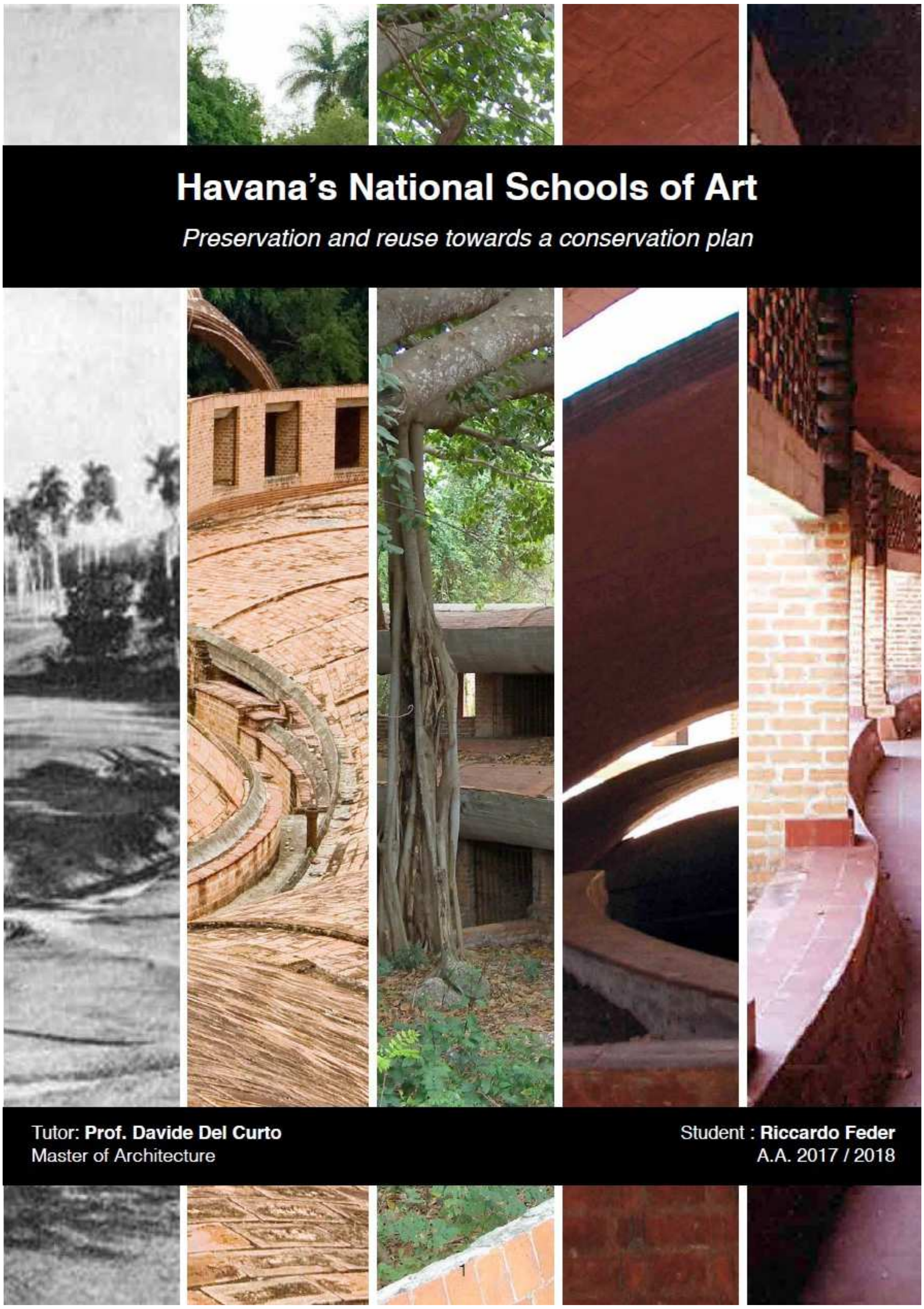

Figure 44 - Frontispiece of the Thesis.

Summary

6

Figure 45 - Summary of the Thesis, first page.

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Figure 46 - Summary of the Thesis, second page.

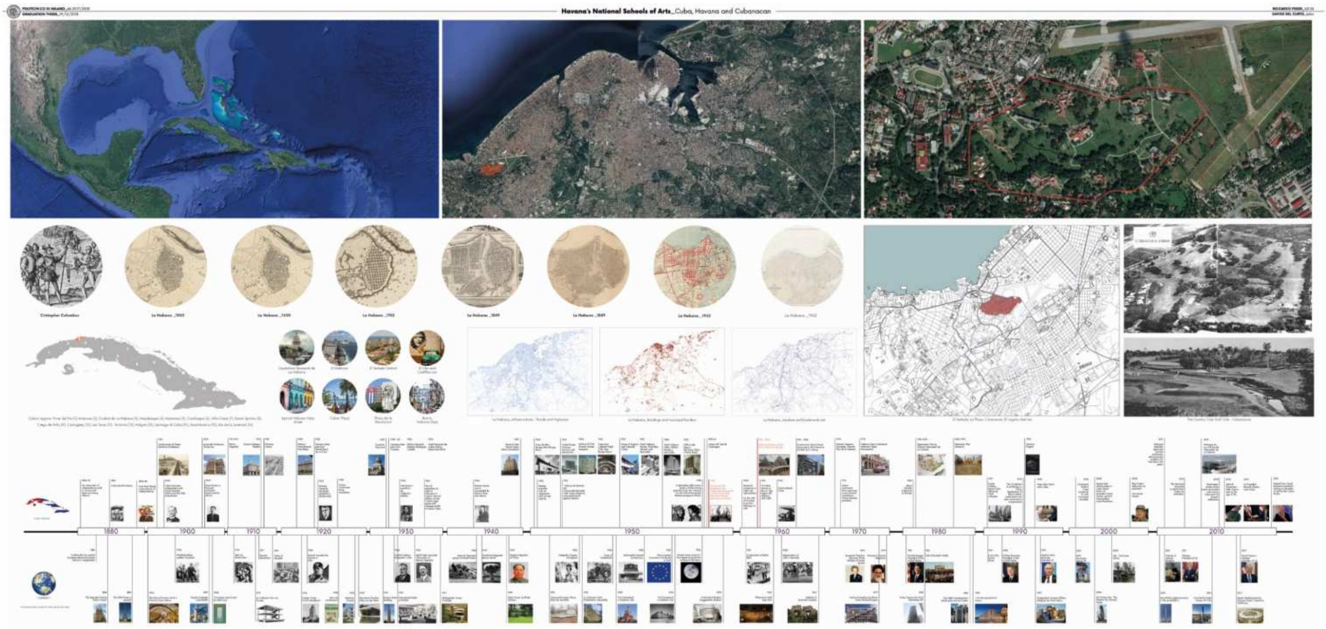


Figure 47 - Panel n. 1: Cuba, Havana and Cubanacan. Historical survey.

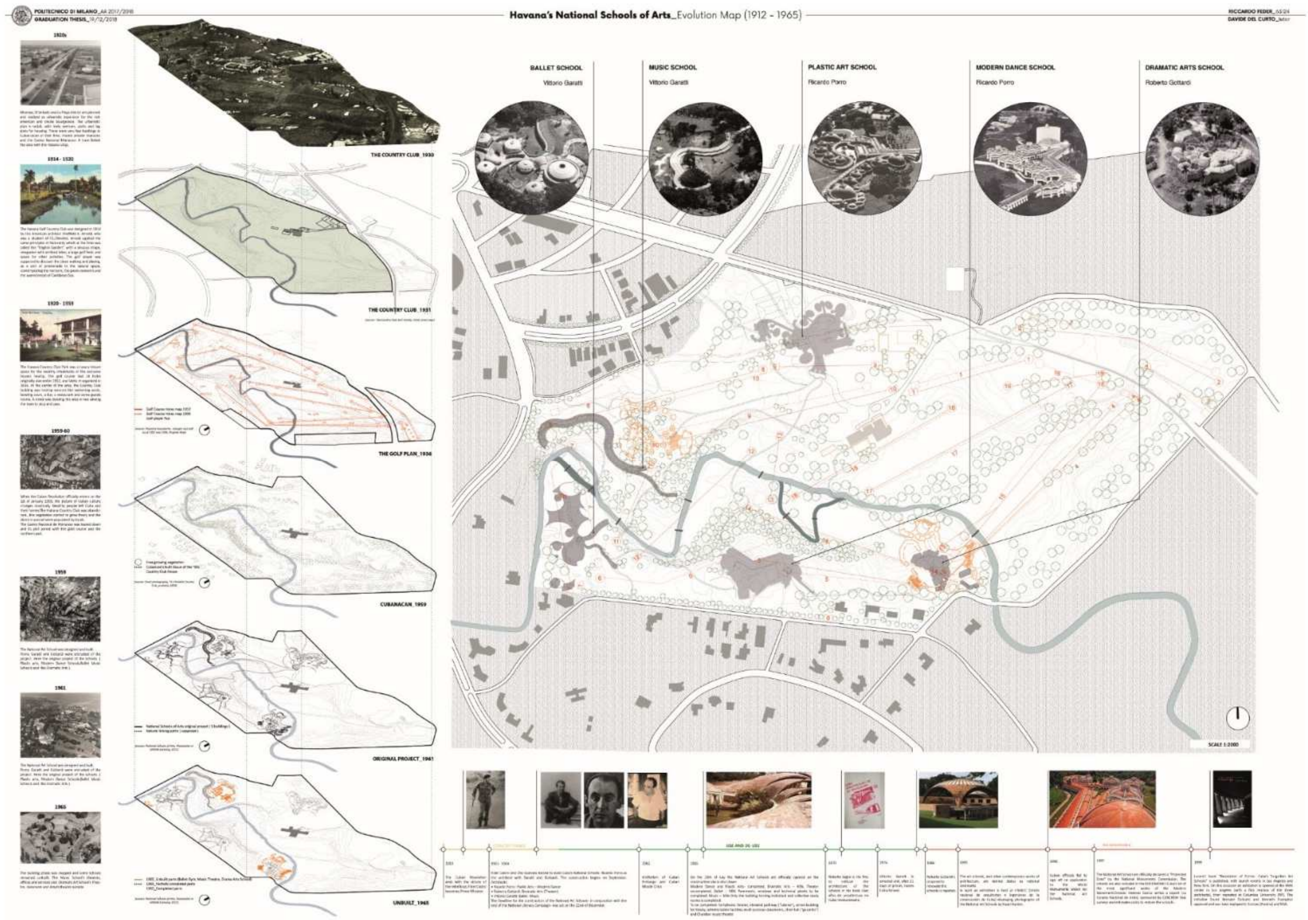


Figure 48 - Panel n. 3: The Evolution Map of Cubanacan. First stage (1912 - 1965).

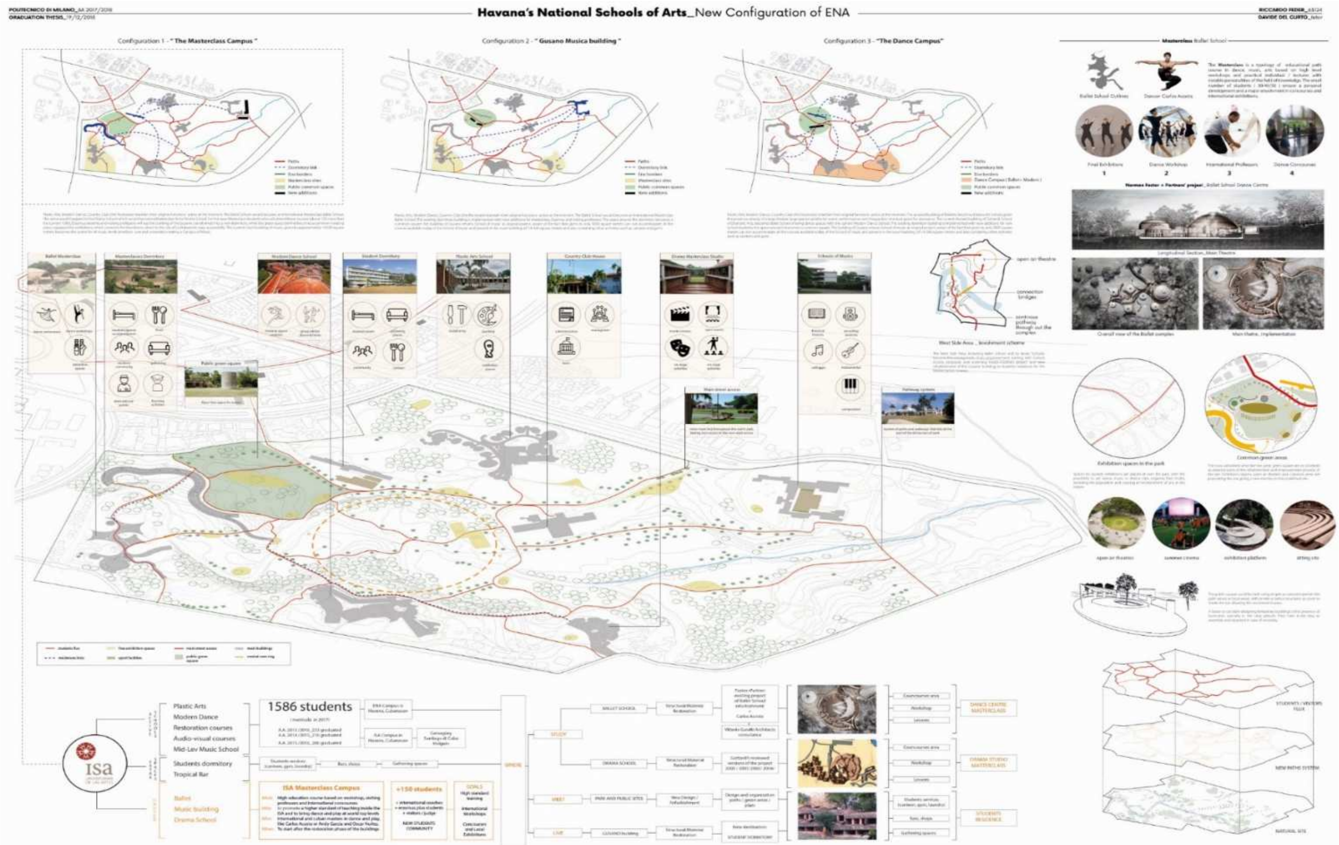


Figure 49 - Panel n. 7: Masterplan. The new configuration for ENA and proposals of transformation.

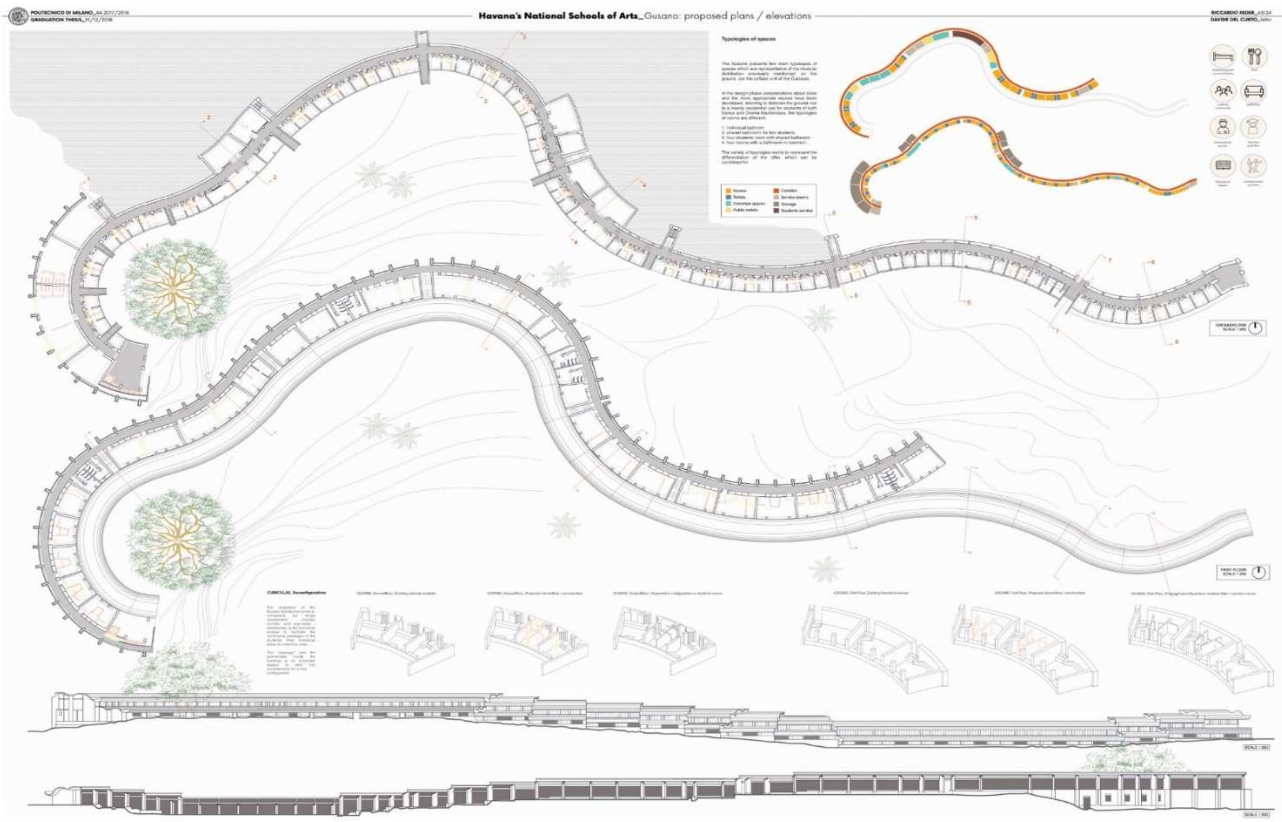
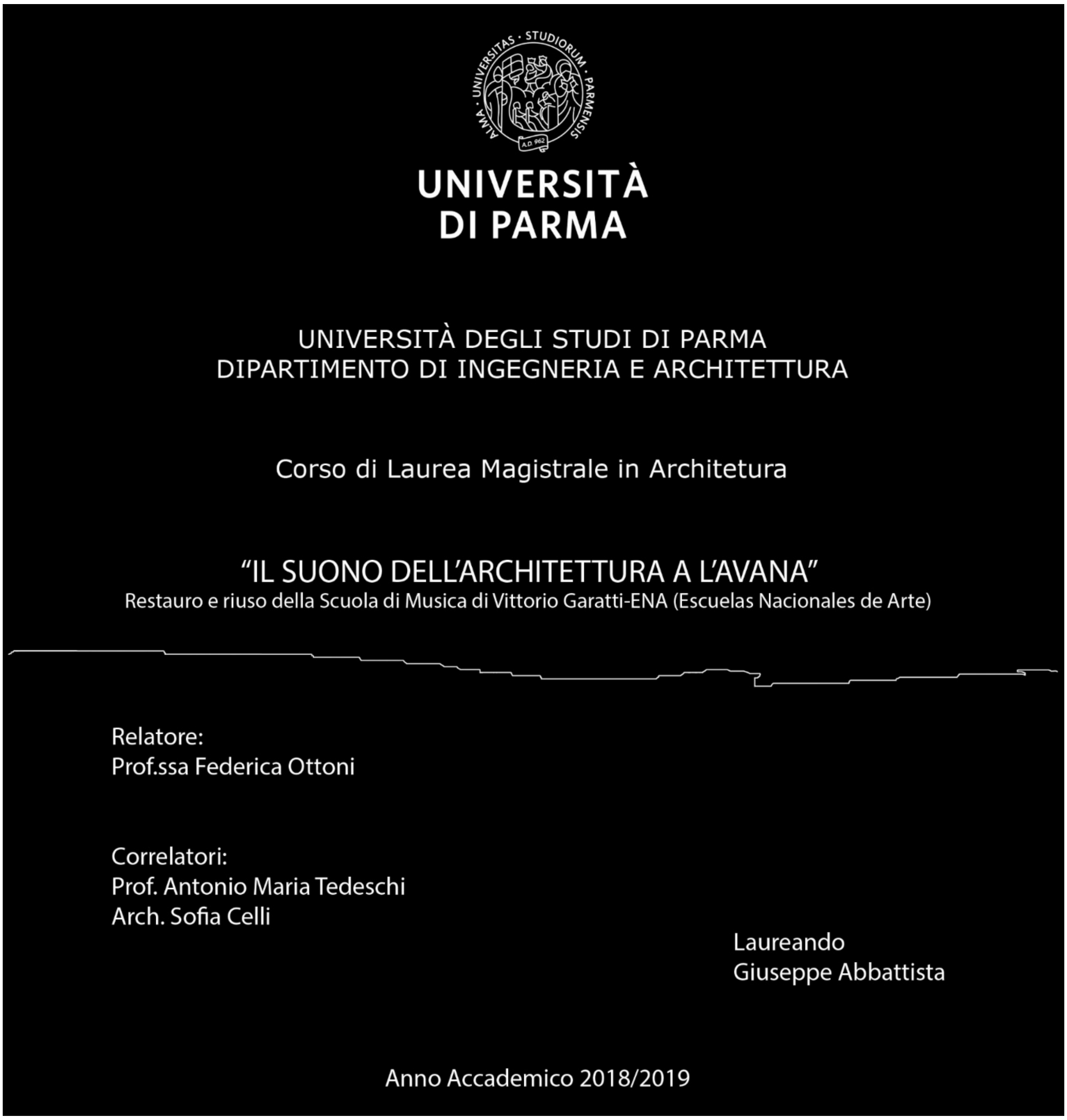


Figure 50 - Panel n. 9: Gusano building. Proposed reconversion with plans, sections, elevations.

Il suono dell'architettura a L'Avana.

Restauro e riuso della Scuola di Musica di Vittorio Garatti-ENA (Escuelas Nacionales de Arte)

By Giuseppe Abbattista, Master Thesis, A.Y. 2018/2019, Università degli Studi di Parma



UNIVERSITÀ
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UNIVERSITÀ DEGLI STUDI DI PARMA
DIPARTIMENTO DI INGEGNERIA E ARCHITETTURA

Corso di Laurea Magistrale in Architetura

"IL SUONO DELL'ARCHITETTURA A L'AVANA"
Restauro e riuso della Scuola di Musica di Vittorio Garatti-ENA (Escuelas Nacionales de Arte)

Relatore:
Prof.ssa Federica Ottoni

Correlatori:
Prof. Antonio Maria Tedeschi
Arch. Sofia Celli

Laureando
Giuseppe Abbattista

Anno Accademico 2018/2019

Figure 51 - Frontispiece of the Thesis.

INDICE DEI CAPITOLI

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Figure 52 - Summary of the Thesis, first page.

VI

Figure 53 - Summary of the Thesis, second page.

VII

Figure 54 - Summary of the Thesis, third page.

Figure 55 - Summary of the Thesis, fourth page.

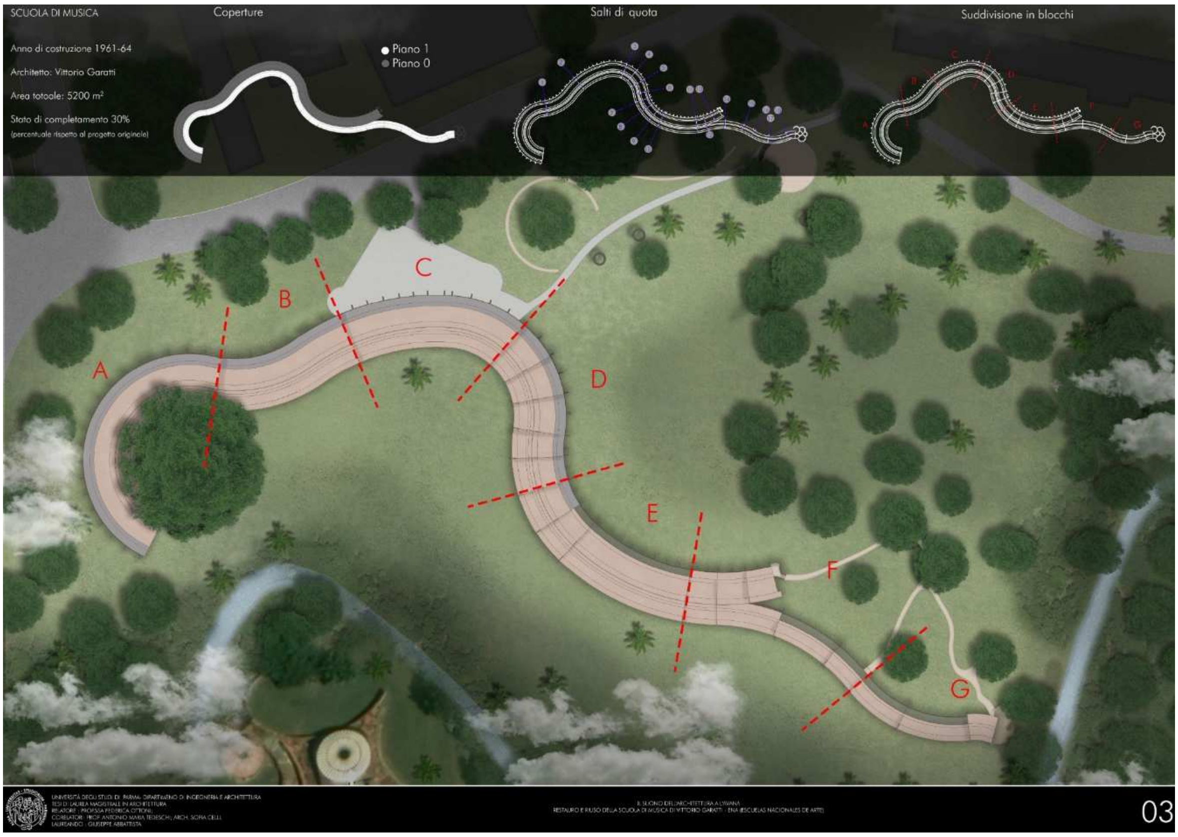

Figure 56 - Panel n. 3: School of Music: roofs plan.

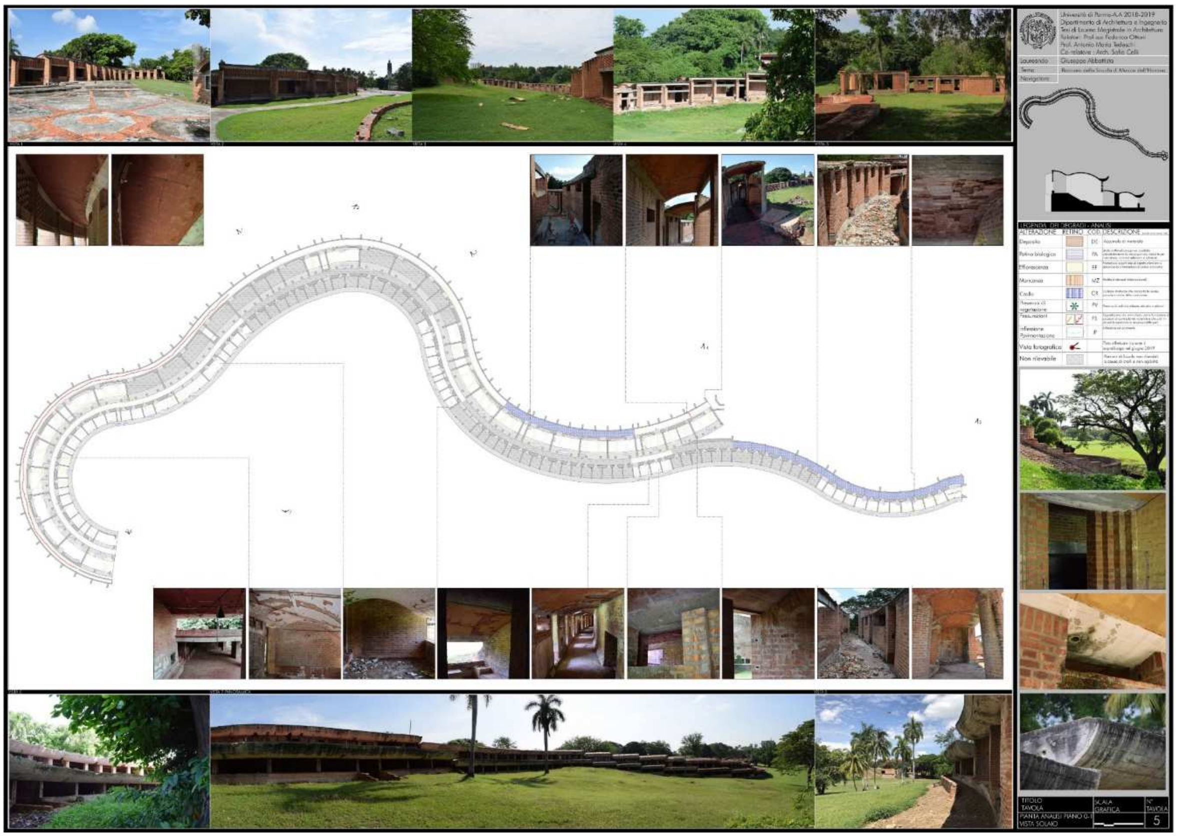

Figure 57 - Panel n. 5: School of Music: survey of decays.

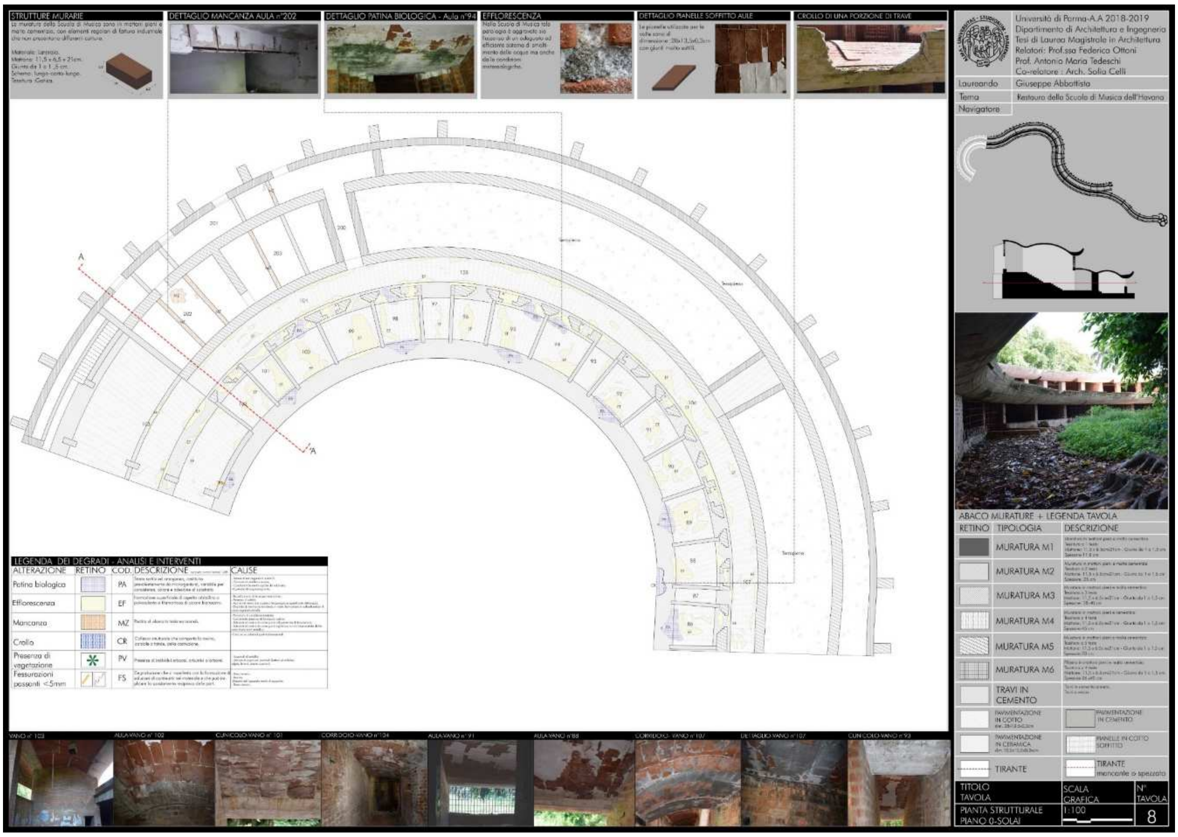

Figure 58 - Panel n. 8: School of Music: wall typologies.

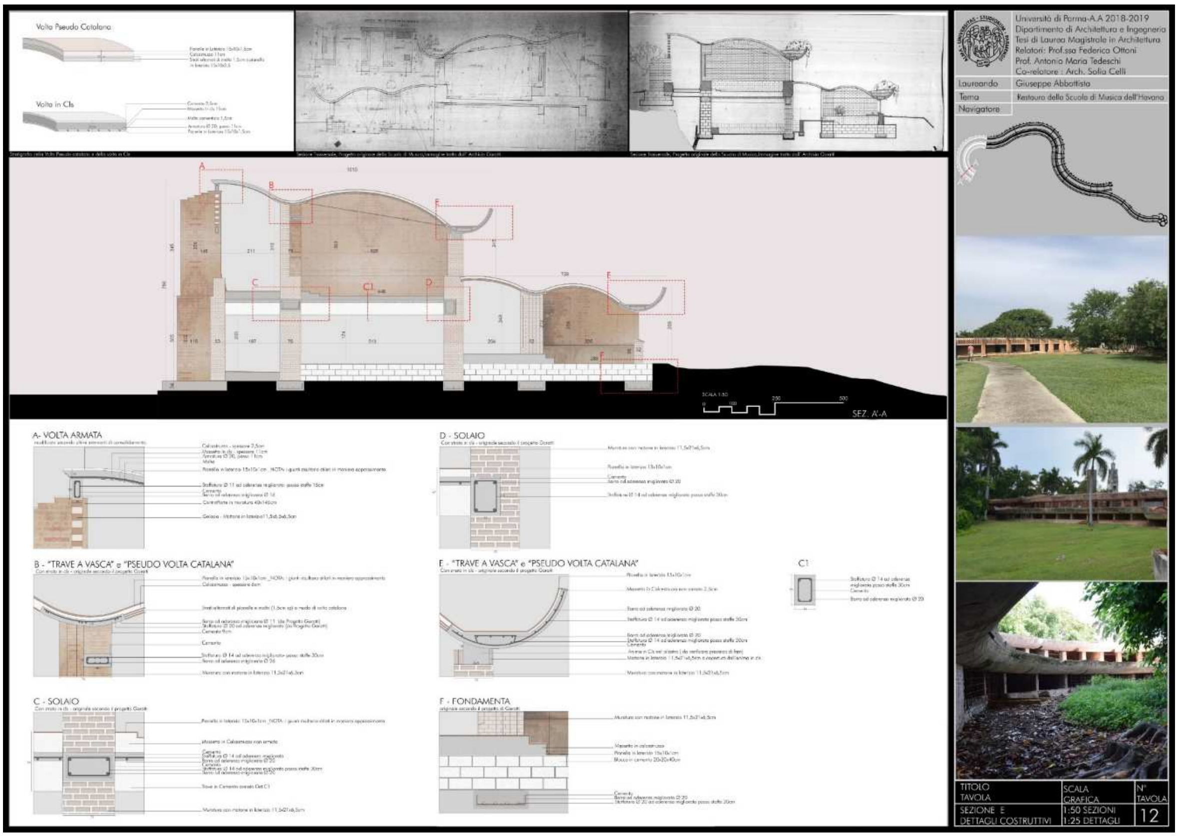

Figure 59 - Panel n. 12: School of Music: cross-section and technical details.

Refinement of Form:

A New Analysis of Cuba's National School of Ballet

By Camille Heubner, Bachelor's Thesis, A.Y. 2019/2020, Princeton University

Refinement of Form:

A New Analysis of Cuba's National School of Ballet

Camille Heubner

April 24, 2020

Submitted in partial fulfillment

of the requirements for the degree of

Bachelor of Science in Engineering

Department of Civil and Environmental Engineering

Princeton University

Figure 60 - Frontispiece of the Thesis.

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Figure 61 - Summary of the Thesis.

3 Initial Analysis

3.1 Site Visit Description

Overall Impressions of Outer Dome

The author visited the site from February 17th to 22nd, 2020, to perform in-depth examinations of the structural degradation of the Choreography Theater and of the Ballet School in general. For the most part, this visit confirmed the data provided by Parma: the most significant structural damage is caused by biological growth, with moss staining the interior of the dome and significant plant growth on the outer dome, especially along the vault that rings the lower crown of the dome, as seen in Figure 8. In many locations on the exterior of the dome, tiles are missing because of water infiltration or plant growth; in the case of the latter, roots grow beneath the tiles and cause them to lift upwards (Figure 9). However, the most significant damage appears to be on the lower crown, with large sections of tile, around 4 tiles by 6 tiles, missing from the structure. The concrete beneath the tile appears to be in very good shape, however, with very little pitting and no reinforcement exposed. This indicates that the tiles have provided effective protection for the concrete throughout the life of the structure. There is also no iron staining visible which would indicate that reinforcement has been exposed to water. Additionally, because this damage is mainly concentrated on the crown, where the concrete layer is 26 cm thick [8], this causes less concern to the observer. The tiles on the upper part of the dome, seen in white (Figure 10) are ceramic glazed tiles rather than the plain terracotta of the rest of the structure; the glazed finish appears to be more effective against water infiltration and biological growth because damage is much less significant in those locations. On the upper dome level, the raised terra cotta tile along the ribs, which is a decorative feature and does not correspond to a thickened concrete shell along the ribs, have proven to be the weak point: this is where plants tend to take root, causing cracks and infiltration along the edge of the ribs. Although it is clear that whatever structural purpose the tiles may have originally served no longer is in effect because of the damage observed, the tile has nonetheless functioned well in its purpose of protecting the concrete of the dome.

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4.2 Rhino Model Construction and Geometry

The dome geometric data was provided by UdP, and included 2D geometric drawings of the Choreography Theater (Figure 7). Using these drawings, along with the field dimensions provided by the same group, a Rhino model was constructed which articulated each component (ribs, rings, shell, pillars) as separate volumes (Figure 17). As noted in Section 3.1, the pillars and mezzanine level were not included in the FEA model of the dome, because they are not considered to be the critical points of the structure, although they were constructed in the Rhino model for visualization purposes.

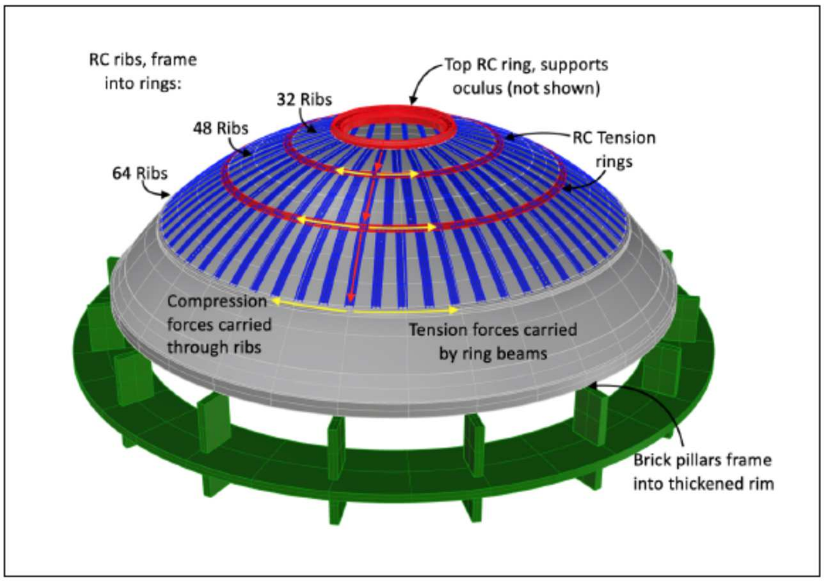

Figure 17: Dome structure in Rhino, with pillars and mezzanine depicted in green, dome shell in grey, ribs in blue, and tension rings in red. For ABAQUS analysis, pillars will not be included.

In order to create the final model for importation into ABAQUS, the ribs were joined together with the lower crown and ring beams to create a unified-volume model (Figure 18). The unified-volume model was determined to be appropriate to model the concrete rib and crown system because it accurately mimics how the dome was constructed, with one continuous concrete pour for the crown, ribs, and ring and interlocking reinforcement between the components. This structure will be referred to as the concrete rib system.

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reinforcement, and the dome shell. These structures were exported from Rhino as .sat files and imported into the FEA software.

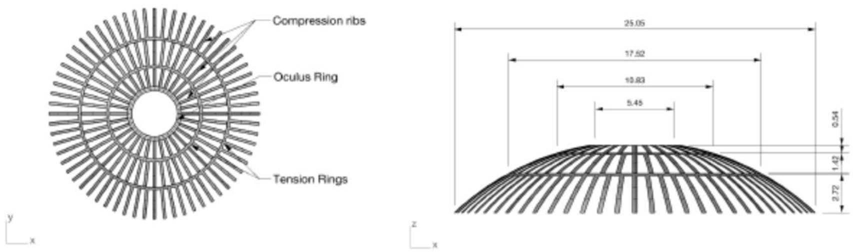

Figure 20: Rib reinforcement shell with dimensions, modeled as a surface with no thickness in Rhino

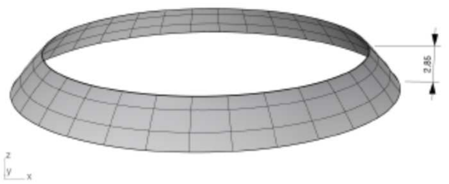

Figure 21: Crown reinforcement shell with dimensions, modeled as a surface with no thickness in Rhino.

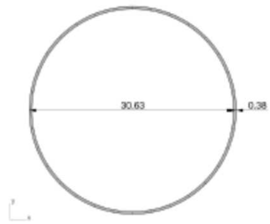

Figure 22: Lower beam reinforcement shell with dimensions, modeled as a surface with no thickness in Rhino

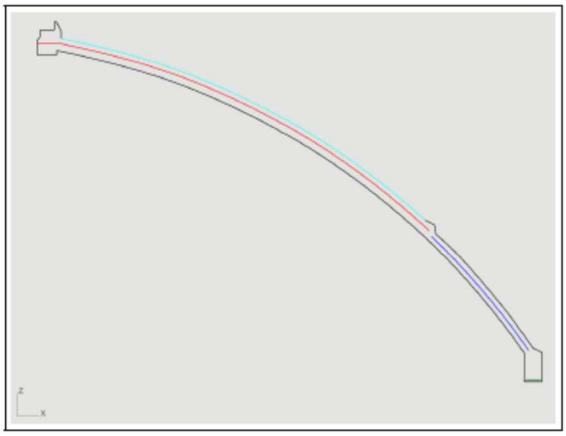

Figure 23: Locations of the reinforcement within the rib system body; dome shell is depicted in light blue, rib reinforcement is in red, crown reinforcement is in dark blue, and lower beam reinforcement is in dark green.

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Wind Loading

For the hurricane loading, the calculated wind pressure applied was ±1821 Pascals across the surface of the dome, with downwards pressure acting on the windward side of the dome and uplift acting on the leeward side. Wind load combined with dead load should mimic the most extreme possible natural loading of the structure. The wind pressures act normal to the shell or dome surface, as outlined by ASCE 7-10 directional procedure [15].

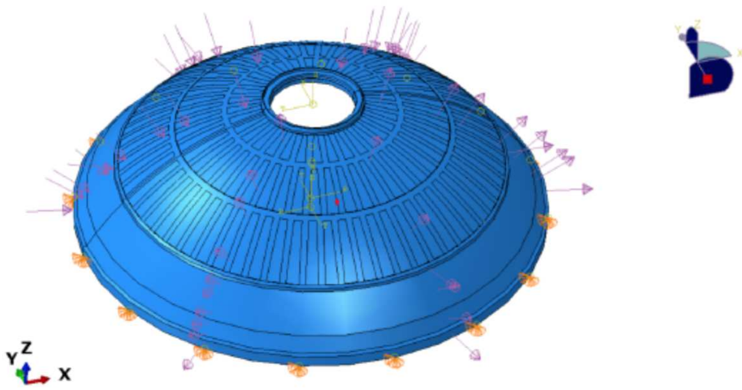

Figure 25: Wind loading on the Choreography Theater as visualized in ABAQUS, with purple arrows signifying the wind pressure into and out of the dome.

Settlement

Due to the common flooding of the Rio Quibu and full saturation of the soil at these times, settlement is a severe risk to the structure [8]. Additionally, some of the masonry pillars have superficial concrete damage and may need repair during the renovation of the Ballet Dome, so the maximum possible span length of the lower ring is useful to determine. For this analysis, one boundary condition is removed at a time, widening the space between pillars. The first iteration, with one boundary condition removed, can be found in Figure 26. No wind loading is added to the structure due to low probability of incidence, i.e., settlement is combined with gravity loads only. Future work will address very extreme loading where wind, deadload, and settlements are combined.

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Teaching the Arts beyond Modern Architecture.

Adaptive reuse of Havana's former Clubhouse as a contemporary School of Music

By Federico Taravella, Master Thesis, A.Y. 2019/2020, Politecnico di Milano

POLITECNICO DI MILANO
School of Architecture Urban Planning Construction Engineering
Master of Science in Architecture and Urban Design

POLITECNICO
MILANO 1863

TEACHING THE ARTS BEYOND MODERN ARCHITECTURE

ADAPTIVE REUSE OF HAVANA'S FORMER CLUBHOUSE AS A CONTEMPORARY SCHOOL OF MUSIC

Supervisor
Prof. Davide Del Curto

Co-supervisor
Arch. Andrea Garzulino

Candidate
Federico Taravella, matr. 914167

ACADEMIC YEAR 2019/20

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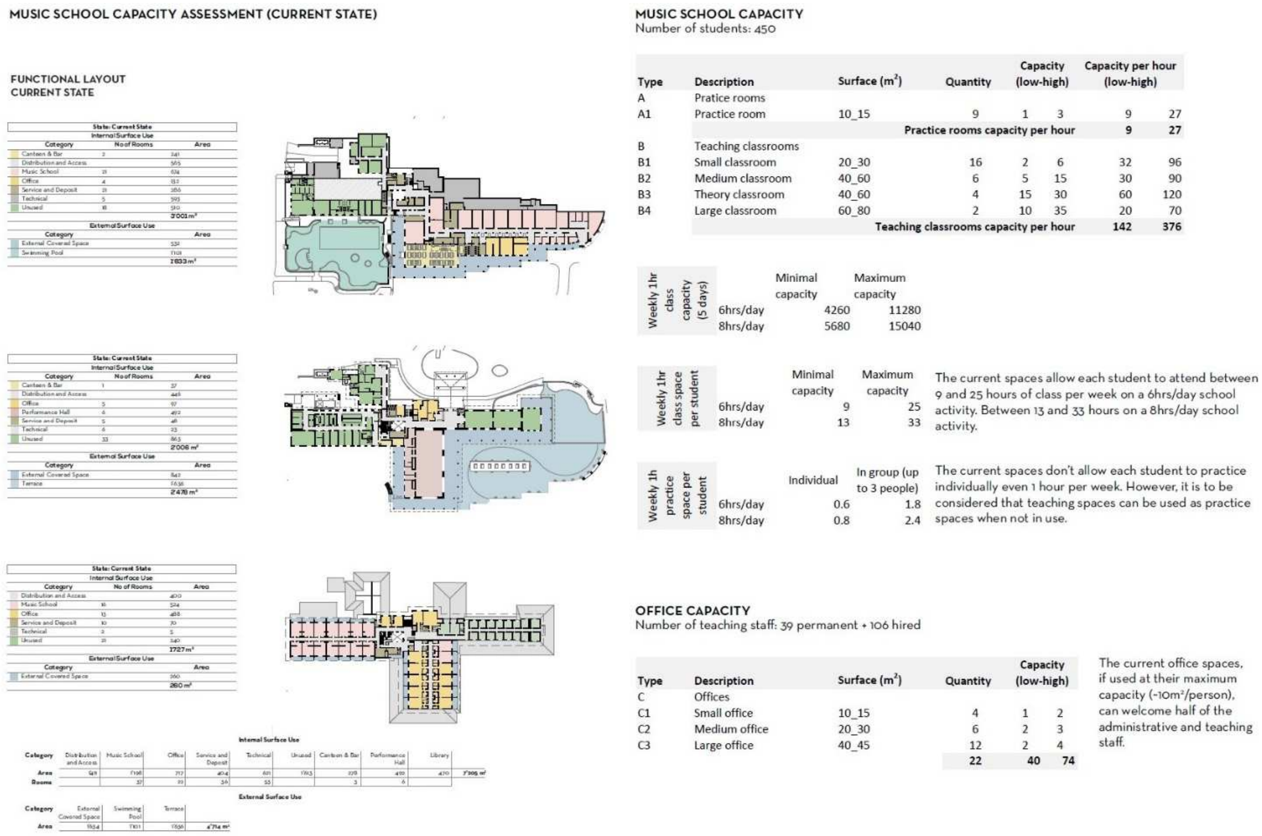


Figure 70 - Panel: Music school capacity assessment (current state).

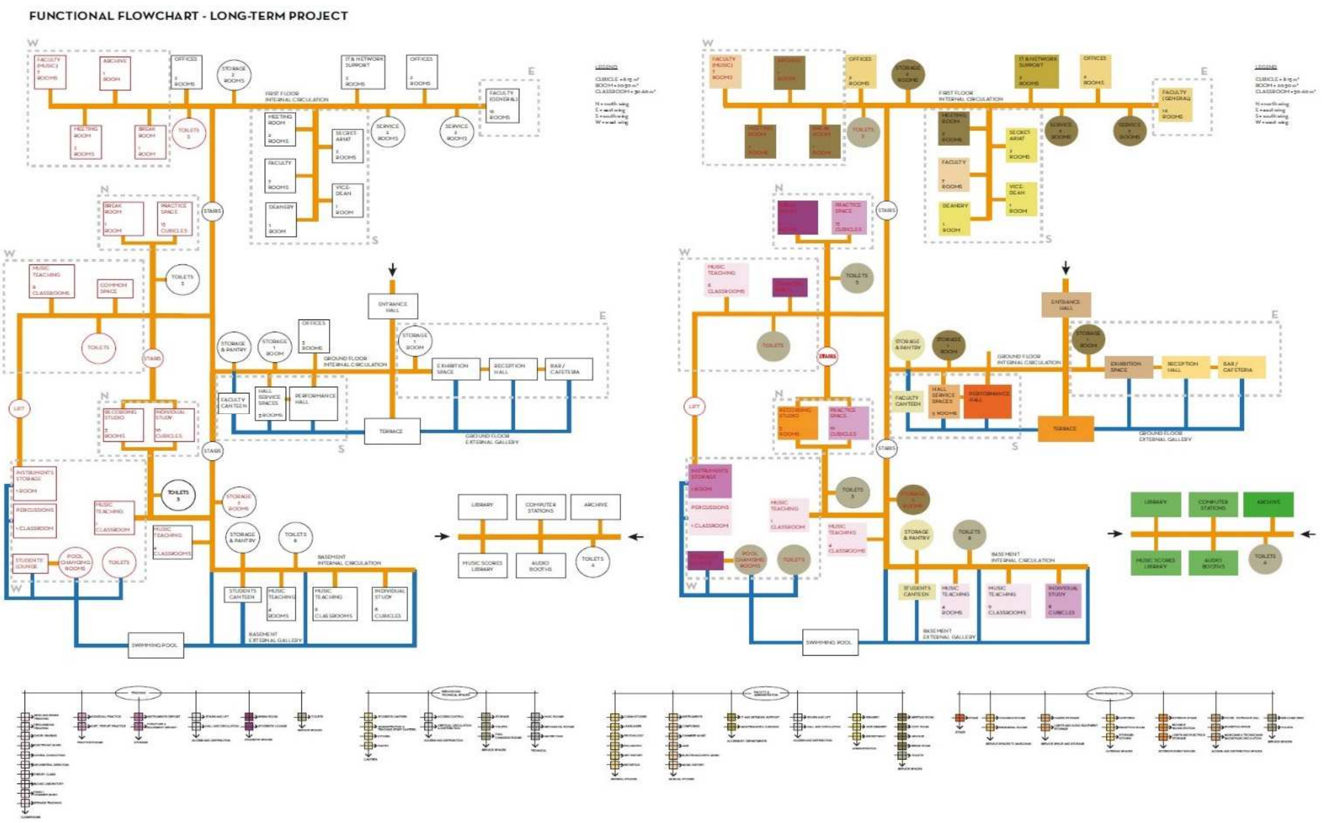
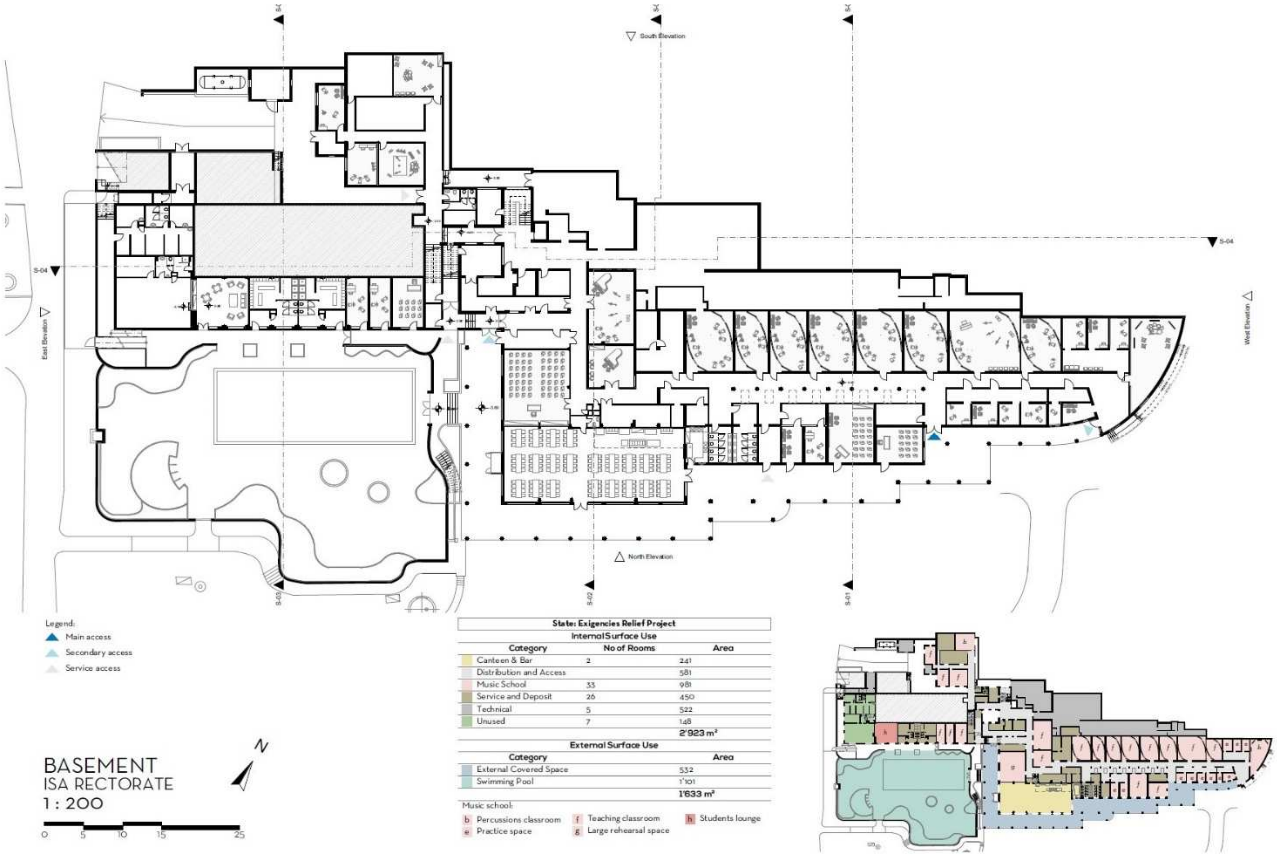


Figure 71 - Panel: Functional flowchart. Long-term project.



State: Exigencies Relief Project		
Internal Surface Use		
Category	**No of Rooms**	**Area**
Canteen & Bar	2	241
Distribution and Access		581
Music School	33	981
Service and Deposit	26	450
Technical	5	522
Unused	7	148
		2'923 m²
External Surface Use		
Category		**Area**
External Covered Space		532
Swimming Pool		1'101
		1'633 m²

Figure 72 - Panel: Rectorate building, basement. Exigencies relief Project.

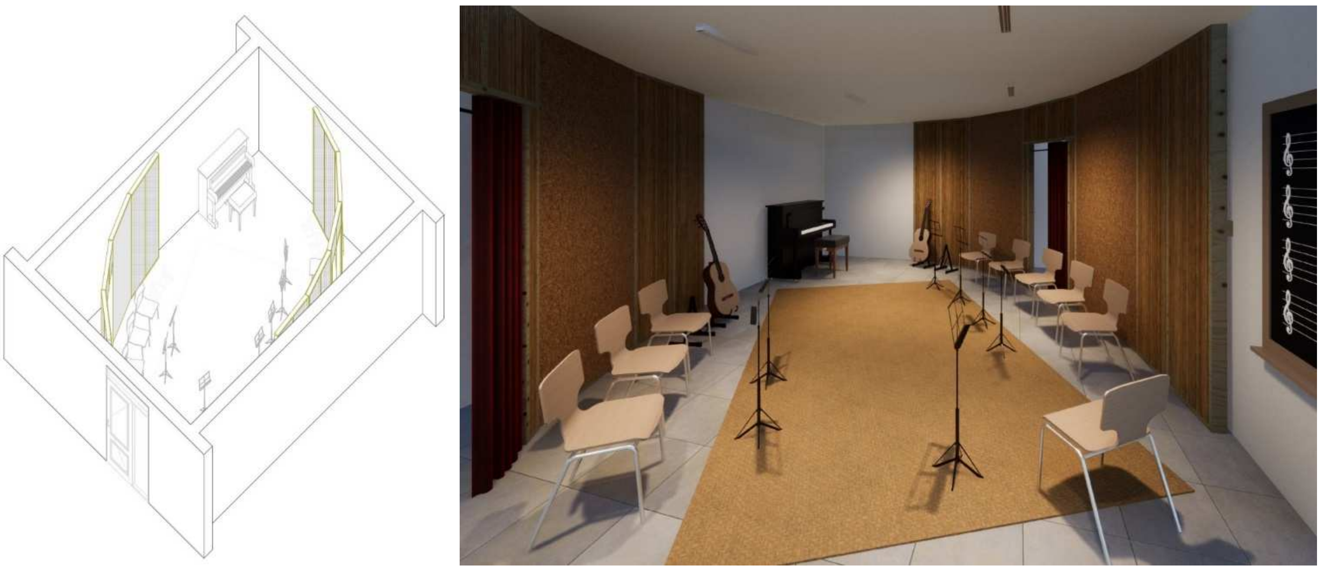


Figure 73 - Panel: Modular acoustic panel system. Basement classroom application.