FIFTH PART

Chapter 8

Results

"Without continual growth and progress,
such words as improvement, achievement, and success
have no meaning".
Benjamin Franklin

8.0 Chapter abstract

This chapter describes the main outputs of this three years research path. First of all more than 250 buildings were catalogued and thanks to 3D BIM modelling procedures and integrated surveys the overall knowledge on some of them was greatly improved. These data should now be used as a base for students and academics(not only in Brazil and India) for further analyses on buildings or more specific research on the modern architecture in Brazil and India even from afar. Great importance in this process of knowledge and toward a real scheduled maintenance programme have had the 3D integrated surveys. The cooperation with the scanners manufacturers in Brazil has shown how it could be possible to use expensive tools even in low budget projects. These tests were also useful in order to evaluate the impact of the research: beside the important outputs extracted from the three-dimensional database that allowed high technology analyses on the buildings, several awareness programme (seminars and conferences) on stakeholders have been based on these surveys. This helped to improve the spreading out of new technologies in heritage field in both the countries and has led to the creation of a laboratory net able to autonomously develop local methodologies for the modern buildings preservation. Last but not least some indication for the preservation of modern buildings by integrated methodology and continuous maintenance have been conceived in order to reduce the need of important restoration works. This has been the challenge of the recent past and it will be the one of the near future: how to use the right tools for the monitoring and the yearly maintenance of these buildings.

8.1 Application of topics on case studies: problems and new inputs

Along the application process, the chosen topics were applied to the most suitable buildings in order to test the proposed methodology. Obviously, difficulties have been faced in some cases. In Data sheet and representation techniques topic (applied on 80 buildings out of more than 250) sources were sometimes scarce. Collecting information on some buildings thus have been awkward even for the most important architectures.

In this framework both primary and secondary sources have been utilized. Among Primary search (i.e. original materials on which research is based) in some cases were included also first-hand testimony or direct evidence concerning the building under consideration. Some information were collected in their original form, neither interpreted nor condensed nor evaluated by others. For instance newspaper articles (reporting events), photographs, interviews (meeting with local experts or buildings managers), autobiographies, personal narratives, memoirs or manuscripts have been consulted. In order to draw effective BIM models also secondary sources offering interpretation or analysis based on primary sources have been part of the research. In some cases they have been used to support a specific thesis or argument or to highlight a certain point of view. This kind of material could be very useful to heritage professionals who do not always have enough scientific data on the nature and behaviour of these architectures to develop the necessary protocols for conservation. Nowadays research studies carried out in 3D representation field on built heritage focus the attention on the possibility to transfer many information into BIM model. Either from traditional or advanced survey the captured data could be insert and structured within the BIM file characteristics. 2D information (i.e. drawings and pictures) are often essential in order to improve the knowledge on a specific building. They are actually simpler to be used than 3D file and can be easyle share by the research community without any limitation. Interoperability in BIM universe is a key point of many research in progress in IT field. The European Union is currently encouraging research studies in this direction: among these it is worth mentioning the INCEPTION project[1], an HORIZON2020[2] fund research. The three main goals of the project are: to create an inclusive understanding of European cultural identity and diversity by stimulating and facilitating collaborations across disciplines, technologies and sectors; to develop cost-effective procedures and enhancements for onsite 3D survey and reconstructions of cultural heritage buildings and sites; to develop an open-standard Semantic Web platform for accessing, processing and sharing interoperable digital models resulting from 3D survey and data capturing.

[1] The INCEPTION project, Grand Agreement no.: 665220 started the last June 2015, is developed by a consortium of fourteen partners from ten European countries led by the Department of Architecture of the University of Ferrara. More information can be found on http:// www.inception-project.eu/.

[2] For more info check: https://ec.europa.eu/programmes/horizon2020/

Keyword such as "Real based model" and "Parametric modelling" are becoming more and more common also in heritage sector due to the improvements of tools and methodologies and the use of BIM for Cultural Heritage is becoming an effective tool to manage 3D representations at different layers and for multiple purposes.

This research, with the main aim of pursuing a common international vision for the preservation of modern architecture, has been showing how technology and innovation in media tools are able to expand understanding and access to this kind of heritage. Future challenges are going to be for instance the management of the complexity of heritage buildings and sites by 3D technologies, filling the gaps between technical limits and heritage characteristics[3]. For doing this it is necessary to foster the international collaboration across disciplines avoiding the segmentation of knowledge and supporting the information sharing among research centres in different countries.

8.2 2D and 3D database on modern buildings

The twentieth century architectural legacy has shown an interesting evolution of the concept of cultural heritage by the development of new ways of protection, preservation and enhancement of modern buildings. The conservation approach toward this kind of heritage, according to the theoretical and methodological approach of preventive restoration (rather deep intervention) should be developed starting from the knowledge of its characteristics.

In order to have effective programmes of maintenance conceived through conservation plans interdisciplinary and organized databases are needed. These source of information, able to target specific built architecture in all its aspects (historical, formal, figurative, symbolic, constructive, functional...) and even in its urban and environmental context (able to select and guide the operational decisions) can help in diagnosing and monitoring processes of the site and to check up constantly the building over time.

This research aimed at providing an innovative contribution in defining the organization and procedural arrangements of integrated database, aimed at the documentation, and the protection, conservation of modern architectural heritage.

This data can be used by both local public bodies and technical professionals. The field of investigation is nowadays attracting students, teachers and professionals in Brazil and India, and it is increasing the awareness on the value of these architectures. As identified by Simon Thurley, (THURLEY 2005), it is possible to define a phenomenon called "the Heritage Cycle", an approach that gives us an idea how we

[3] See the interesting contribution: Hichri, N., Stefani, C., De Luca, L.; Veron, P.; Hamon, G. (2013). *From point cloud to BIM: a survey of existing approaches*. In: International Archives of the Photogrammetry, Remote Sensing andSpatial Information Sciences, vol. XL-5/W2 (2013).

can make the past part of our future [4] and how technologies can really play a key role to foster the value of modern heritage.

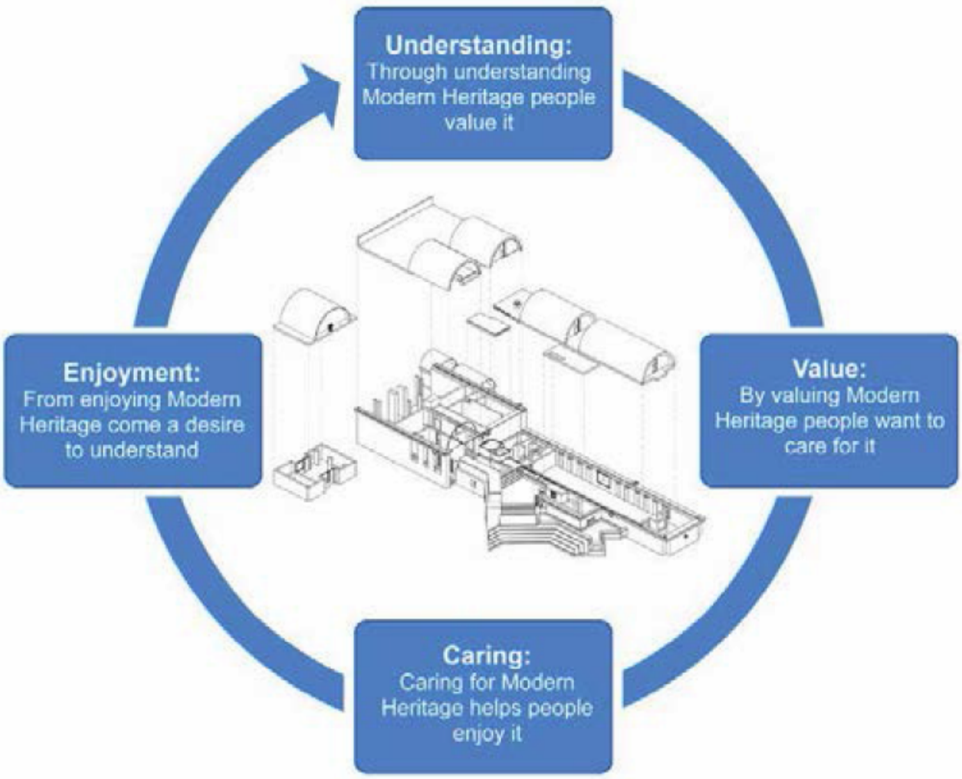

Figure 8.1: The “Heritage Cycle” as defined by Simon Thurley adapted by the author to the Modern Heritage.

8.2.1 2D and BIM database

The case studies identified by the research make up a significant contribution on an issue of permanent validity, since the emergence of preservation of modern heritage has dramatically highlighted the lack of knowledge, organized and finalized information about this kind of architectural heritage in Brazil and India.

Through the analyses of examples of high quality built heritage it is possible to investigate the dynamics of the construction and design processes highlighting technological elements that have

Led to a morphological evolution of case studies and offered an opportunity for a methodological comparison. The adopted "architectural redrawing" process has been based on critical survey of bibliographic sources: thanks to interpretation and dimensional homogenization by sketches, it has come,

[4] See: Thurley, S. (2005) *Into the future. Our stategy for 2005-2010*. In: Conservation Bulletin, London: English Heritage (p. 49)

in some cases, to the definition of a 3D model, where the building is fully represented through computer-generated images (by plans, sections and renderings).

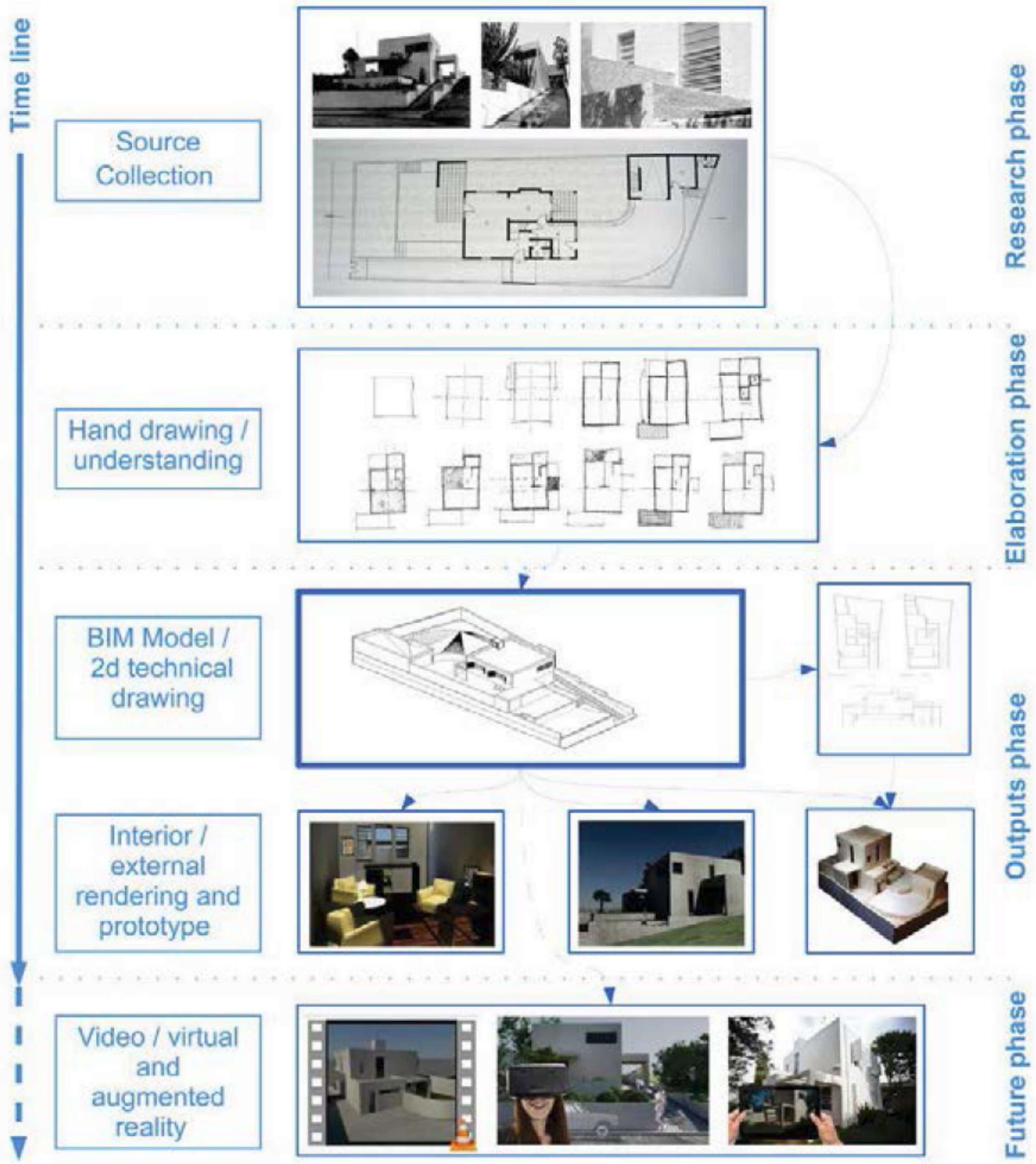

Figure 8.2: the methodology conceived fot the BIM database creation and related outputs.

From this workflow it was generated, until now, a consistent and updated 3D catalogue of residential buildings, an heterogeneous group of typologies, including patio houses, detached houses, single-family residences, residential blocks etc.

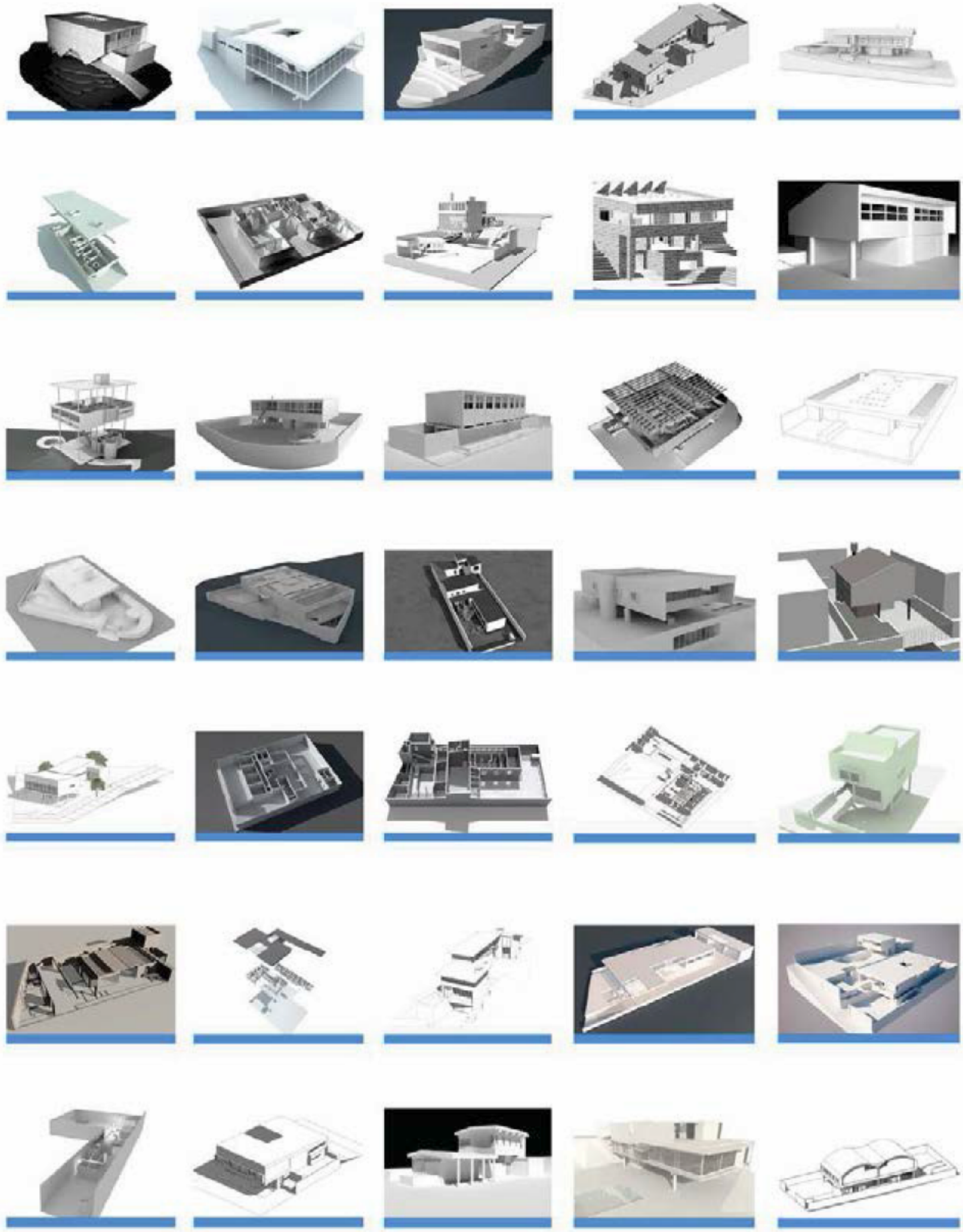

Figure 8.3: some examples from BIM database.

It is a morphological assets related to Housing of great interest that is not only part of a representative system and interpretative languages identified chronologically, by author, site, location,
but it is also, a large collection of solutions conceived by renown modernist architects. They are still very contemporary and can be used to teach to young students how to design access, fix a corner solution, find a relationship inside-out.
The modern heritage through the experience of redrawing with 2D digital media and 3D techniques has been archived and identified in a database structure useful for testing quantitative research methodology by the application of a logic grid documentation.
Furthermore the European Union 2014/24/EU directive states that "For public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modelling tools or similar"[5]. This means that the use of digital tools for heritage management will soon become a standard and a mandatory approach at least for public works. For instance the UK government's construction strategy since 2016 is requiring that all government projects utilise a fully collaborative 3D computer model.
By this means the RIBA (Royal Institute for British Architects) wanted to improve and facilitate the knowledge sharing for information about a building forming a reliable basis for decisions during its life cycle, from earliest conception to demolition.
3D database are nowadays important tools for the study of modern heritage, a standardize heritage which needs new technologies to be analysed and preserved.
The contribution that this research can give to the study field, thanks to the application of some topics, consists in highlighting a possible methodology for heritage condition assessment and prioritization of intervention.
The image 8.4 below shows the framework coming out from filter2 analyses on 25 buildings in Brazil and India and it is a good starting point in order to possibly define some common issues or peculiarity of case studies.
It is possible to see that in some cases the buildings bring similar condition and in other cases they are very far each other. The climate in both the countries can play a key role as potential problem for the conservation of these architectures. So it can be said for the high level of innovation by the which the buildings were conceived and the constructed: nowadays the lifecycle of some materials is shorter than we thought in the past and this modernization can act as hazardous factor for this heritage.
At the same time the divergences show for instance that orography is a tricky issues only in Brazil, where the strong integration of construction and nature led to architectures really linked to the surrounding landscape. In some cases this brought to the choice of problematic site due to intricate orography.

[5] See Directive 2014/24/EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC

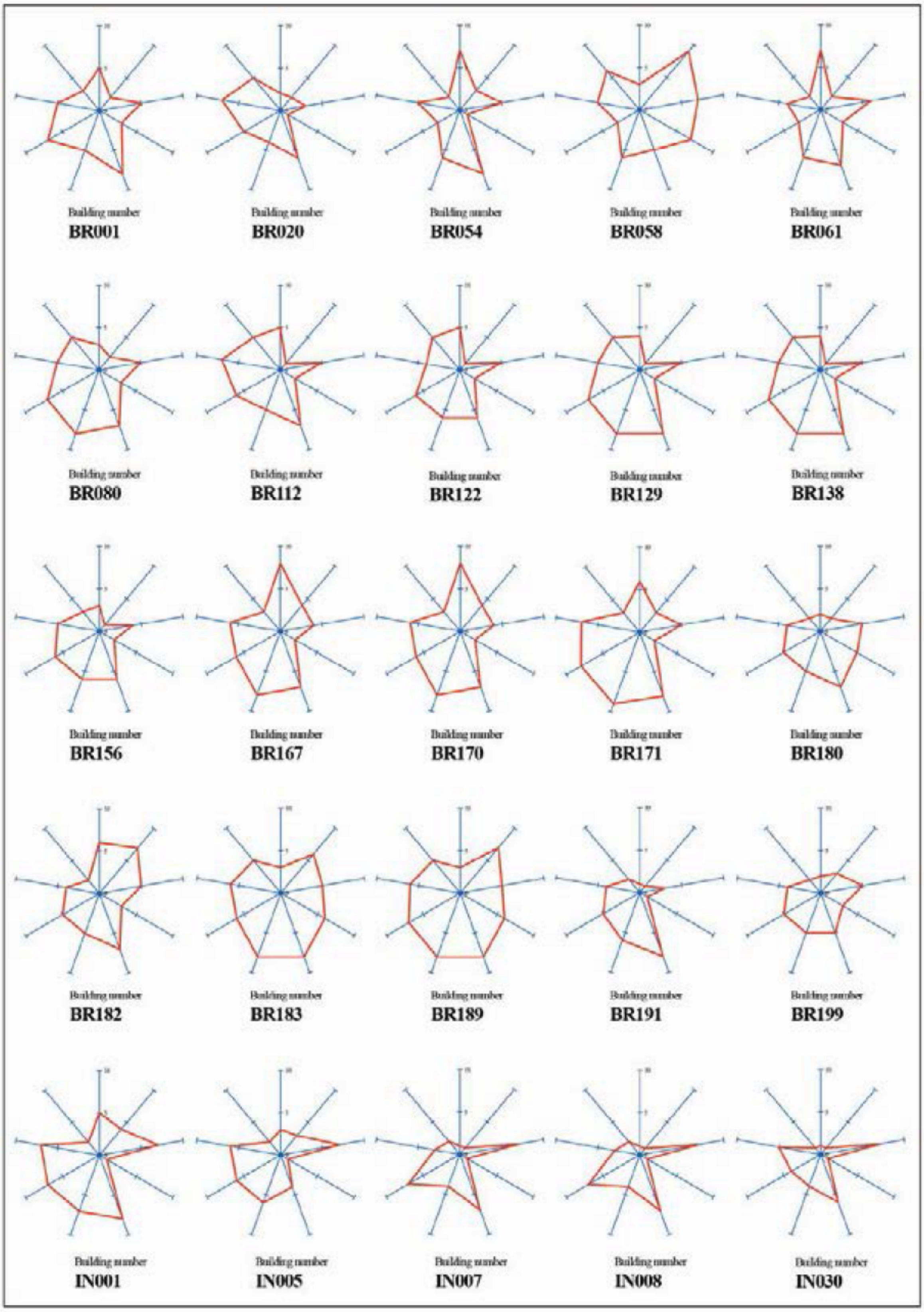

Figure 8.4: framework coming out from filter2 analyses on 25 buildings in Brazil and India.

Data integration and questions to research

The research questions posed on chapter 1.3 can find a possible answer through the data integration.

- Is it possible to apply a methodology also to more recently built buildings?
- Is it possible priority list of buildings intervention?

The answers could came from the relation between the diagram output of filter1 and the one coming out from filter2 of this research path. It results in an three dimensional extrusion for each building.

The data elaborated in filter1 (the three couples of indicators identifying moderate and high danger for the cultural heritage and describing the level of maintenance and restoration works on it) can be summarized in a 3 dimensional solid figure split up into 3 levels, one each couple of indicators. This 3D shape brings the footprint of the area coming out of Kiviat diagram in filter2. In this way it was basically possible to extrude the data captured during filter 2 elaboration making them more clear at first sight.

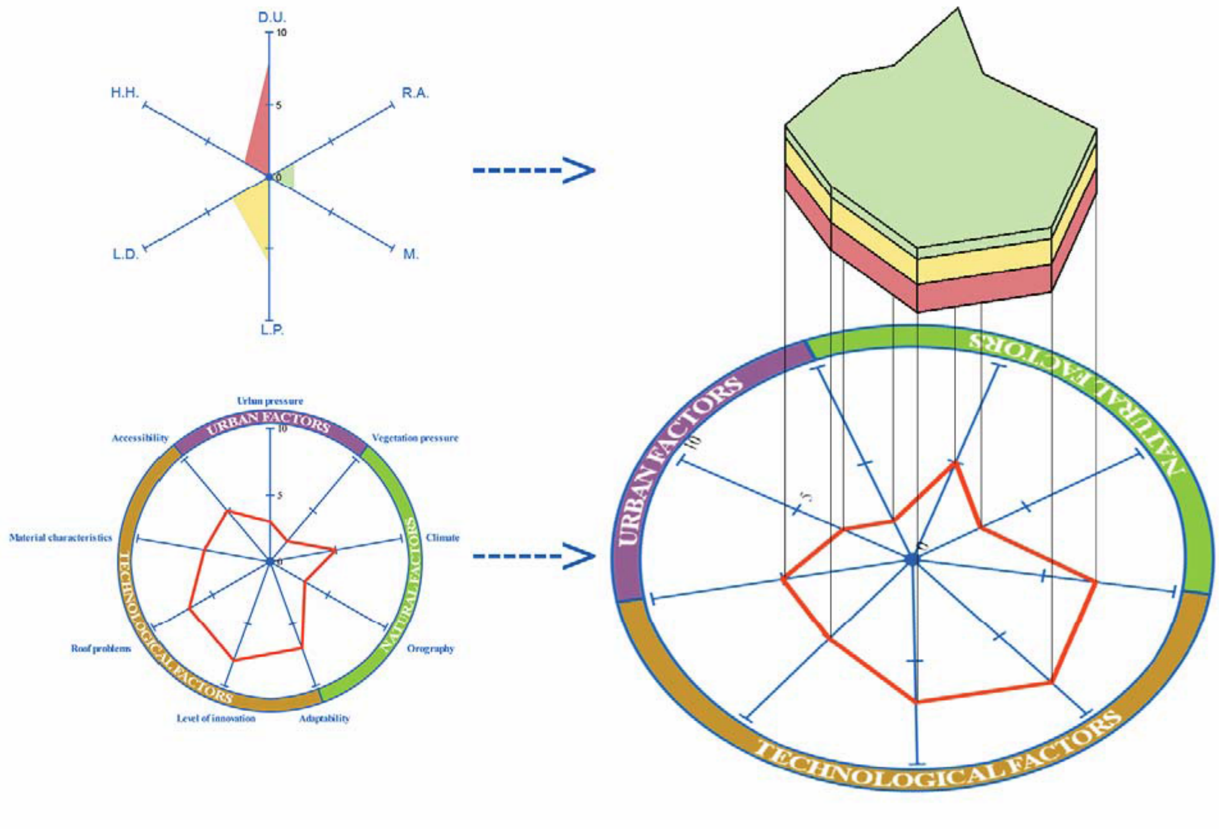

Figure 8.5: three-dimensional integration of filter 1 and filter 2.

The resulting solid can highlights the global condition of a building and can be used in order to prioritize the interventions that can be planned on this heritage.

The examples that follow show some tentative to make this process clearer.

Example 1: Casa de Vidro by Lina Bo Bardi

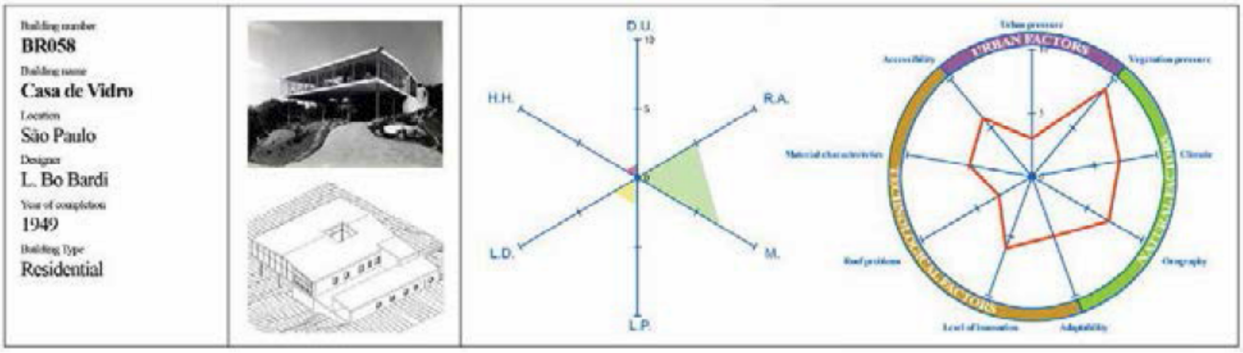

Figure 8.6: analysis of Casa de Vidro by Lina Bo Bardi: framework resulting from filter1 and 2.

The filters application to the Casa de Vidro case study has shown some issues concerning its conservation. Basically the main problems that have been identified are related to the São Paulo humid climate and vegetation pressure. The action of plants surrounding the buildings is double: on one side they highly improve the humidity of local micro-climate and on the other side the roots action is slowly deteriorating the garden concrete walls designed by Lina Bo Bardi which are really part of this heritage.

The diagrams clearly highlights that also the difficult orography could be an obstacle for the preservation of the house that was designed by the architect in strong connection with the landscape of the area. The integration with the site orography has, at the same time, made the access to the house slightly problematical, with the chosen solution of a pretty steep paved road. The property management by "Istituto Lina Bo e P.M. Bardi" will ensure continuity to the protection of the house.

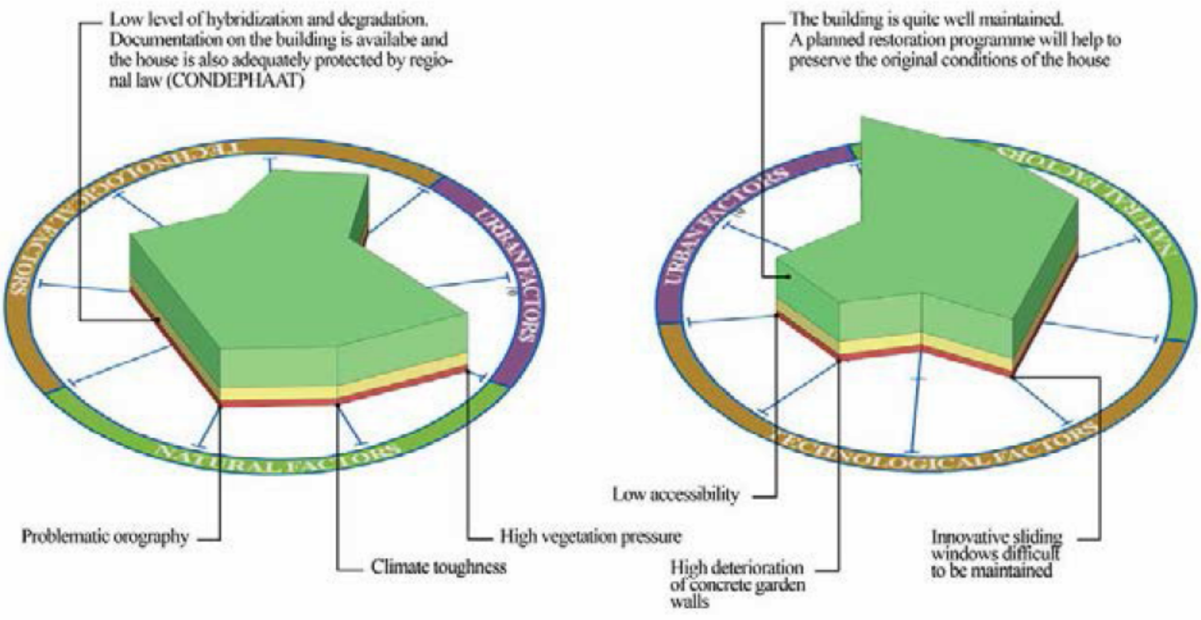

Figure 8.7: joint diagram from filter1 and 2 of Casa de Vidro.

Example 2: Residência Olivo Gomes by Rino Levi

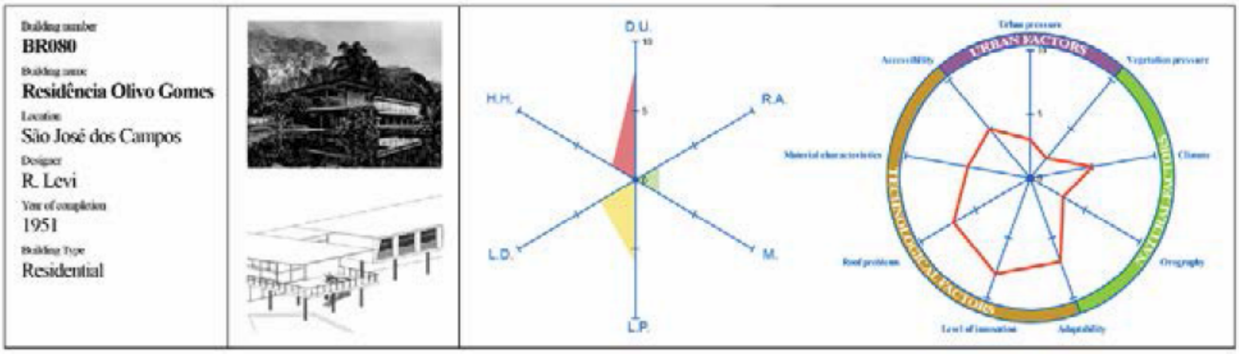

Figure 8.8: Analysis of Residência Olivo Gomes by Rino Levi: framework resulting from filter1 and 2.

The integration of data collected by both the applied filters has highlighted that the Olivo Gomes house, located in São José dos Campos, near São Paulo, is facing an high risk of material and integrity degradation. Even if the building is protected by national low (IPHAN) the global state of conservation is quite poor. Water is leaking from the roof and some rooms are nowadays used as storage places.

A critical issues is related to the shutter systems personally design by the author Rino Levi. The high level of technology innovation will lead to difficult restoration of these peculiar systems that currently are not maintained by any kind of activity.

The future preservation challenges of this house will be strongly connected with the solution that Brazilian professionals will be able to find for windows frames and roof structures.

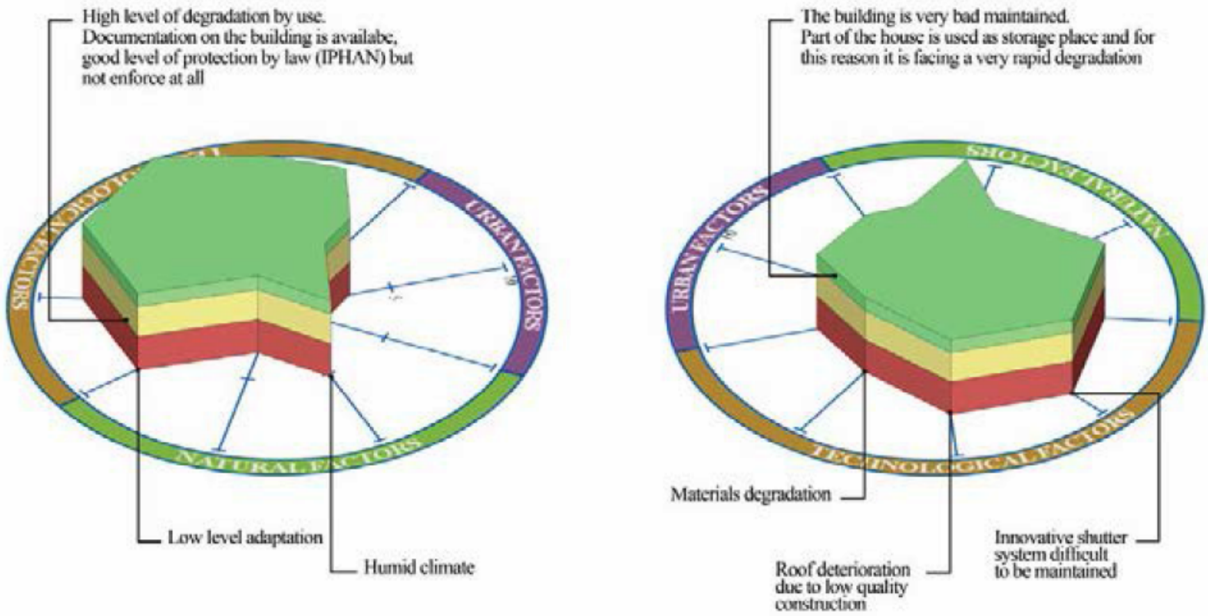

Figure 8.9: joint diagram from filter1 and 2 of Residência Olivo Gomes.

Example 3: Ramkrishna House by Charles Correa

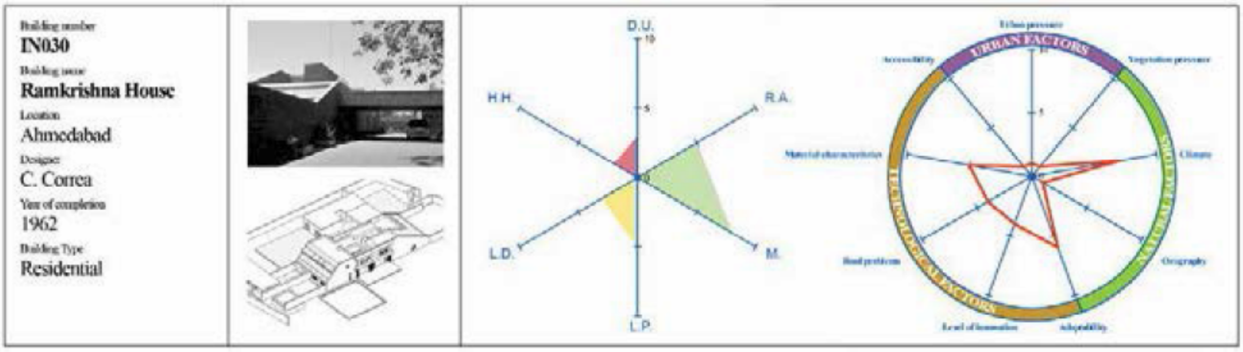

Figure 8.10: Analysis of Ramkrishna House by Charles Correa: framework resulting from filter1 and 2.

The joint diagram based on data elaboration of Ramkrishna house by Charles Correa in Ahmedabad, shows that some factors could be really critical for the preservation of this architecture.

First of all the local climate in Ahmedabad, with temperature ranging from 20°C to 45°C and heavy rains period could bring to deterioration the concrete structures of the house. Furthermore some bricks and concrete surfaces if not adequately maintained (roof protection) can face a quick decline also because of the low quality of the materials. Even if the building is well kept a continuous maintenance is needed due to level of innovation of the project.

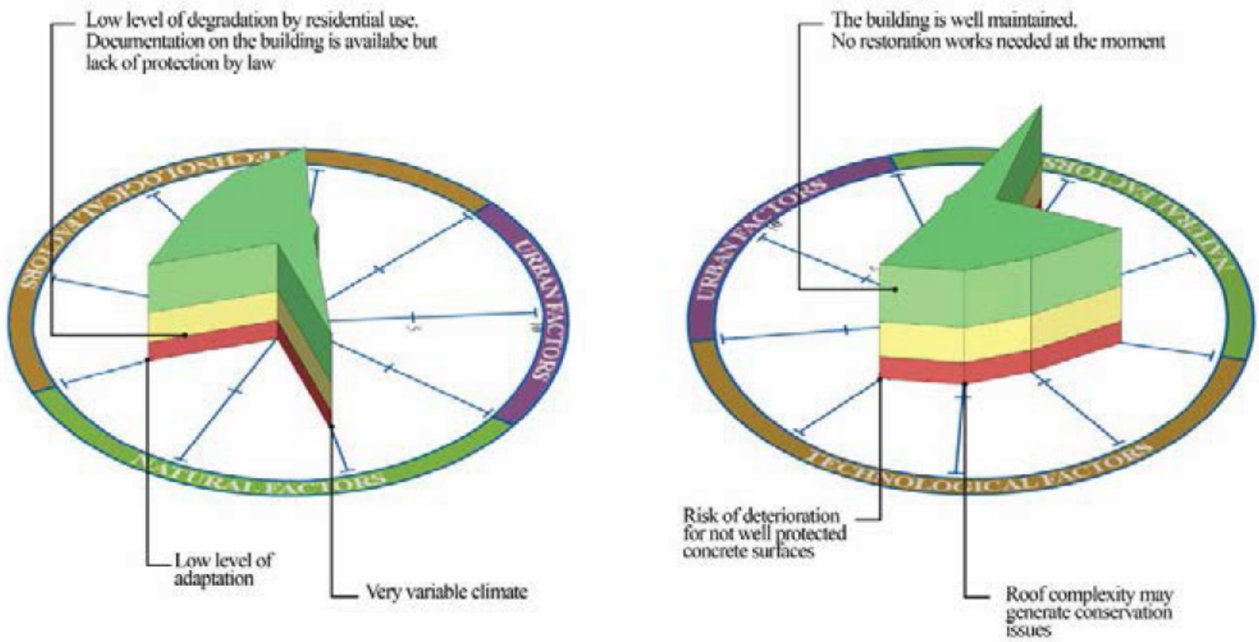

Figure 8.11: joint diagram from filter1 and 2 of Ramkrishna House.

8.2.2 3D integrated survey database

FAU USP Building, by João Batista Vilanova Artigas, Sao Paulo, Brazil (1960)

The FAU USP building is a very good example of the importance of effective maintenance programme on modern buildings. The complex designed by Vilanova Artigas was partially restored in its external concrete walls and roof' shells, during the intervention campaign that (due to difficulties in obtaining funds) effectively began in 2012, and it was recently finished in February, 2015. The building during its life had to face basically the lack of a maintenance culture, especially regarding reinforced concrete buildings. In fact, supporting the adoption of this material by Brazilian modernists was the belief that it was indestructible. The modern architects believed that reinforced concrete was capable of facing time and climate with little alteration, thus underestimated little problems that could be handled by daily maintenance developed into major damages to the building.

Figure 8.12: FAU USP building, one of the façades before restoration in 2014.

This has been especially damaging to buildings which are innovative both in its construction technique and its form, such as Vilanova Artigas Building. This attitude towards the building's maintenance has contributed to the deterioration of the concrete surfaces, a phenomenon that is known today and is accelerated by the worsening of the environmental conditions. The constant treatment and protection of the exposed reinforced concrete structure, especially its vast and intricate roof and the façades, thus is essential. The last intervention in 2015 left many doubts concerning the quality of the choices that have been taken: particularly the filling material that was injected to repair the crack of the concrete façades seems to be non-consistent with the old material. This recent large scale intervention has great implications to the conservation plan that will be developed, hopefully, with the funds of this grant initiative. these interventions have, so far, been approached with little consideration to the building's historic fabric..

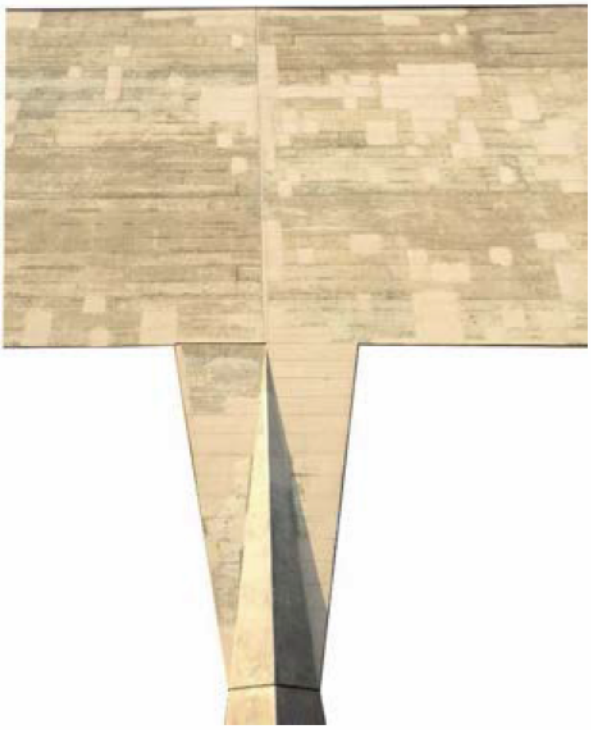

Figure 8.13: FAU USP building, one of the external pillar before (left) and after the heavy treatment in 2015.

As a result, past interventions, although respectful to the original design intent, have not followed a historic conservation methodology, often causing sacrifice of original fabric and application of treatments that are not compatible with conservation of historic significance, as is the case of the most recent façade concrete patching campaign

The building is currently in a good conservation state and adequate to its use. It is important to remind that even with the aforementioned problems faced during its 46 years of existence Vilanova Artigas Building has never stopped being fully used, even if without ideal conditions[6].

The research carried out by the DIAPReM centre at Ferrara University Architecture Department has deep roots into the submission of the proposal for grant request concerning the building detailed by the FUSP

[6] Source: FUSP Getty Foundation "Keeping it Modern Planning Grant Award"

foundation (*Fundação de Apoio à Universidade de São Paulo*) to Getty Foundation initiative *Keeping it modern* in 2016.

The Getty Foundation developed this international grant initiative in order to continues its deep commitment to architectural conservation with a focus on important buildings of the twentieth century. Keeping It Modern since 2014 is supporting grant projects of outstanding architectural significance that promise to advance conservation practices. Grants focus on the creation of conservation management plans that guide long-term maintenance and conservation policies, the thorough investigation of building conditions, and the testing and analysis of modern materials.

The submission was really appreciated and a grant of 200.000 USD was awarded to the Brazilian foundation in order to start the management and conservation plan of the building with the following comment: "In the early 1960s the School of Architecture and Urbanism at the University of São Paulo turned to one of Brazil's most important modernist architects, João Batista Vilanova Artigas, to design a new faculty building in collaboration with Carlos Cascaldi. Taking their cues from the Brutalism of the late Le Corbusier, Artigas and Cascaldi created a monumental structure that emphasizes the elegance of modern materials such as concrete and glass with minimal decoration. One of the building's most prominent features is its dramatic roof, a large grid of skylights set into reinforced concrete that fills the courtyard below with natural light. While past repairs have been undertaken on a case by case basis, now faculty are embracing the development of a conservation management plan with Getty support to produce a holistic approach to the maintenance of the building's key features. This methodology will be integrated into the teaching curriculum as a tool to educate the next generation of Brazilian architects on the value of strategic planning for the conservation of historic sites"[7].

Following the needs identified by the FUSP Foundation the DIAPReM centre has been identifying the proper methodology for the metric and diagnostics analysis of the building[8].

First, in order to keep the total cost lower it has been decide to limit the 2D survey to the 4 elevations that define the perimeter of the building of the Faculty of Architecture of the University of São Paulo (FAU USP). The façades have been then evaluated in their conformation by scanning the outer surfaces and concrete structural elements that define the perimeter of the building.

The identification of the areas of survey has been closely connected to the possibility of access (with or without time restrictions), to the anthropic context and compatible with permission of private or public property and in safe condition.

[7] Source: http://www.getty.edu/foundation/initiatives/current/keeping_it_modern/grants_awarded_2015.html

[8] Project credits: DIAPReM Center, Department of Architecture, University of Ferrara - Scientific Responsible: Marcello Balzani; Project Coordinator: Luca Rossato; 3D and topographic survey: Guido Galvani, Daniele Felice Sasso; Diagnostic survey: Federica Maietti. In cooperation with: Consorzio Futuro in Ricerca (Director: Stefania Corsi), FUSP Foundation (Supervisor: Beatriz Mugayar Khul. Technical support: Leica Geosystems, Sao Paulo.

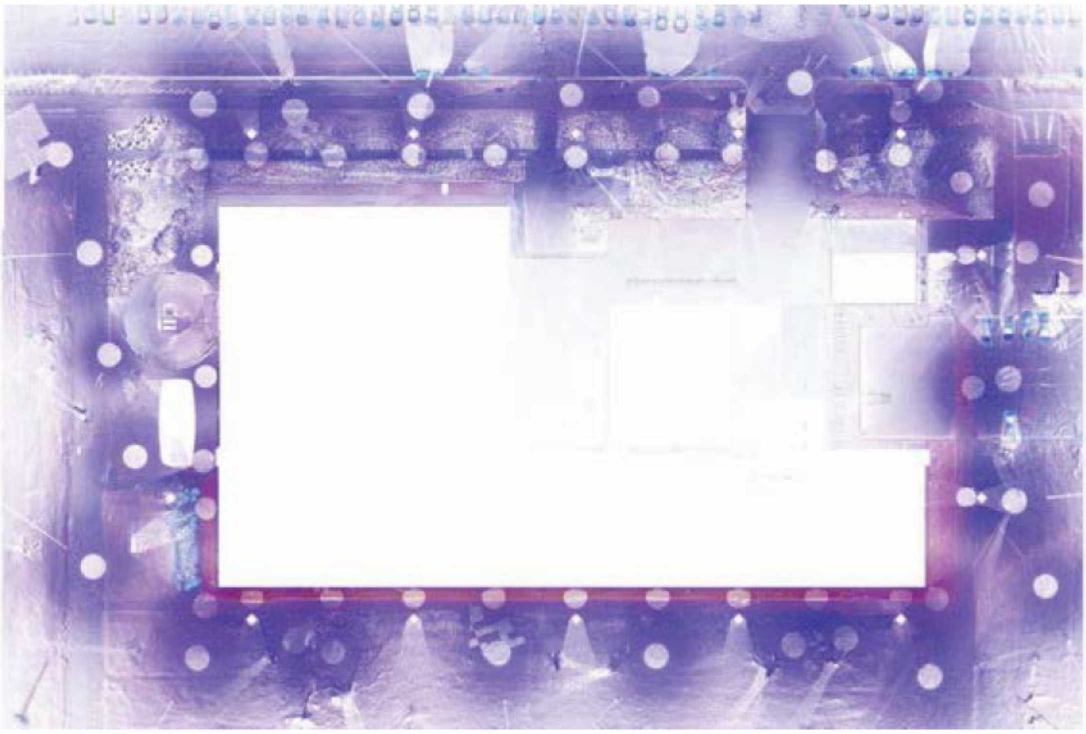

Figure 8.14: FAU USP building, position of external scan stations of the 3D survey.

During on-site activities the survey vegetation and other natural or man-made non-removable obstacles were integral part of the survey in some case allowing only a partial assessment of the hidden surfaces. The survey was an integration of technologies and skills: a topographic survey by total station (by Leica TPS instrument type 1202) has been initially carried out in order to capture coordinates of target, and the generation of a local system reference. After that a 3D Laser Scanner survey by time-of-flight equipment (by Leica type C10) has allowed the survey of the geometric detail of the surfaces and DEM (Digital Elevation Model).

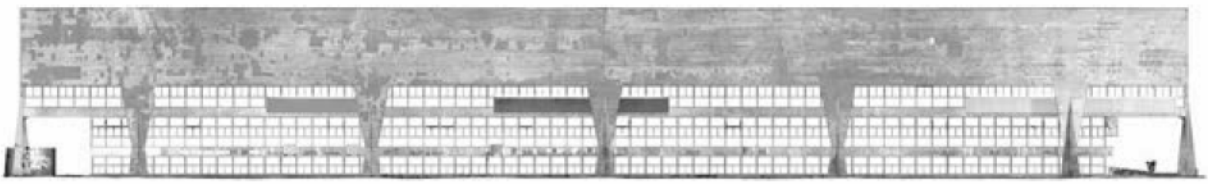

Figure 8.15: FAU USP building, image DEM in black and white of the south-east façade from 3D database.

In the meantime a photographic documentation (by Canon 650D) on the building has been implemented to describe the most important survey operations and areas that are most representative of the general state of conservation. These data have then been used for the analysis of macroscopic morphologies of degradation affecting the surfaces. This diagnostic analyses was crucial to support the comprehensive picture of the state of conservation given the amount of material instability identified during the first days

on site. The integrated methodology led to a geometric model of spatial coordinates hierarchically-defined and with a single reference system.
After the on field activities, back in laboratory, the DEMs were created and used as basis for editing CAD drawing of the façades.

Outputs of the survey

After the data processing steps of the geometrical survey the deliverable outputs have been developed by the DIAPReM centre and sent to the Brazilian colleagues for a first evaluation. Only after this step all the elaboration, drawings, database have been finalized in order to best fit it to the local's needs.
The outputs has been:
- Optimized and organized point cloud model;
- 1 CAD files on the general plan of the exterior space with indication of section at an altitude of about 1:20 mt from the floor and projected raster point cloud with altimetry elevation;
- 4 CAD files related to façades, with indication of section and scaling of DEM (raster point cloud) for the façades drawing at a scale of 1:50;
- detailed report on the survey methodology, surface degradation and the overall state of conservation;
- morphologies abacus of main degradation affecting the concrete façades, drawn up on the basis of the document UNI Normal 1/88 containing the definition and description of the morphologies of deterioration (nomenclature);
- 1 CAD file of a portion of surface, particularly representative, in order to illustrate the methodological procedure for the identification and localization of the morphologies of degradation via graphics solutions (hatches or false colour).

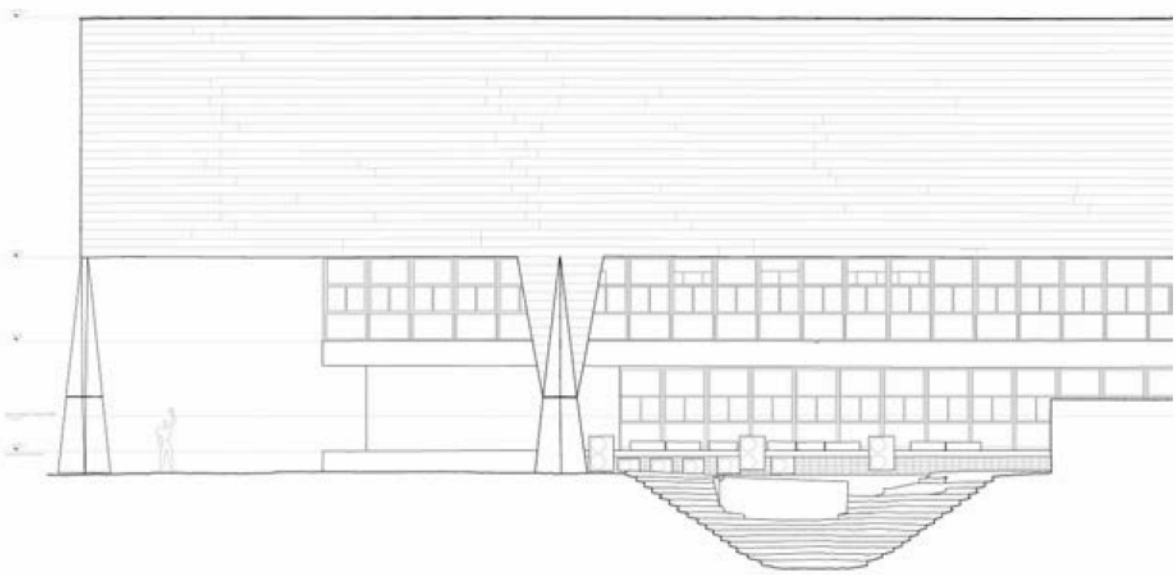

Figure 8.16: FAU USP building, CAD drawing of west façade.

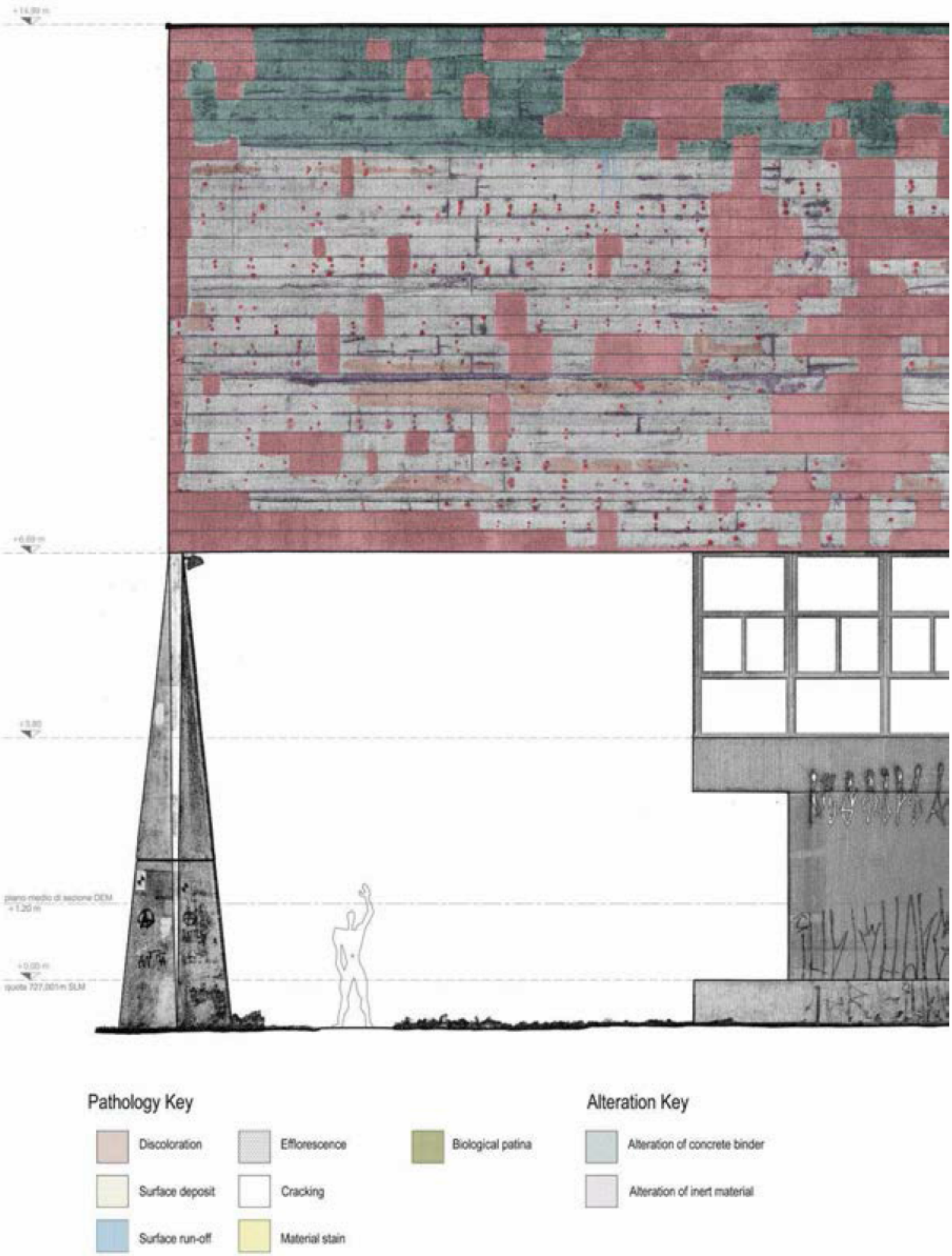

Figure 8.17: FAU USP building, surface analyses identifying main pathologies and materials alteration.

The physical phenomenon which is the basis of the measurement makes it easy to understand that the reflection light captured brings not only information of a geometric type but also of a given spectral type:

each detected point is defined by the 3 coordinates x, y, z, from the given reflectance, spectral response which is emitted from the contact material with the laser light frequency, in a band of the green.

The knowledge of this data, though limited to a particular value, allows the collection of information for homogeneous areas of surface material; the variation of intensity from point to point of the reflected ray of green light can serve to draw information on the materials and on the degradation of the surface investigated. The reflected laser beam will always have a lower intensity than the incident laser beam, in particular in dependence of the reflection geometry on the facade and of the characteristics of the impact point (nature of the material, its surface treatment, state of deterioration). With the right methodology the reading of the reflectance data variation may allow a completely non-invasive monitoring of surfaces.

This methodology should calibrated by a comparison with specific investigations and any conversion parameters of reflectance data, especially comparing with other data acquired on the same categories of materials / components.

On the basis of the metric-morphological survey it can be obtained in similar views of the photo in which the reflectance data are identified in false colours (the dedicated to the instrument software associates a color with reflectance values detected) or grayscale, and on which add any other layer (photographic images, high-resolution infrared photo, thermographic information, ultraviolet, etc.) to build on the metric three-dimensional model also references a multi-spectral database. On the basis of these calculations it is possible to extract thematic tables (in either 3D or 2D vector format depending on the purpose of the project) in which the display surface areas that have different responses in the reflection of the laser beam. These areas can be selected in various ways, for instance by using maps in false colours and varying the number of levels of intensity of reflectance that is to be analysed.

After getting the display of reflectance data, should be careful comparison with the photographic analysis in real colours (and with other surveys that may be available) for a first assessment on the material characteristics, the assessment of the conservation status and macroscopic forms of degradation. The reflectance interval can be divided into different levels in order to discriminate the various zones of the wall face.

The processing of the reflectance data acquired can then highlight uneven areas on which further investigation could be carried out. In order to achieve an effective technology and methodology transfer on activities of diagnosis of the facades deterioration (towards a future complete analysis of all the surfaces of the four façades), a 30 hours seminar has took place at the FAU USP building at São Paulo University during which the staff of the DIAPReM research centre has been teaching the methodology that helped later the staff to complete the diagnostic procedures independently.

The topics of the seminar has been discussed and chosen in cooperation with FUSP staff and they were related on one hand to the representation by database inquiring of façades and plans of the whole building and on the other hand to macroscopic analysis of the degradation of the surfaces and their classification and nomenclature. The achieved objective of this seminar has been to train the University of São Paulo staff to continue and complete the characterization of the state of conservation on the whole building: young generations of researcher are now ready to work at the conservation plan of the building keeping in mind the knowledge transferred during this experience.

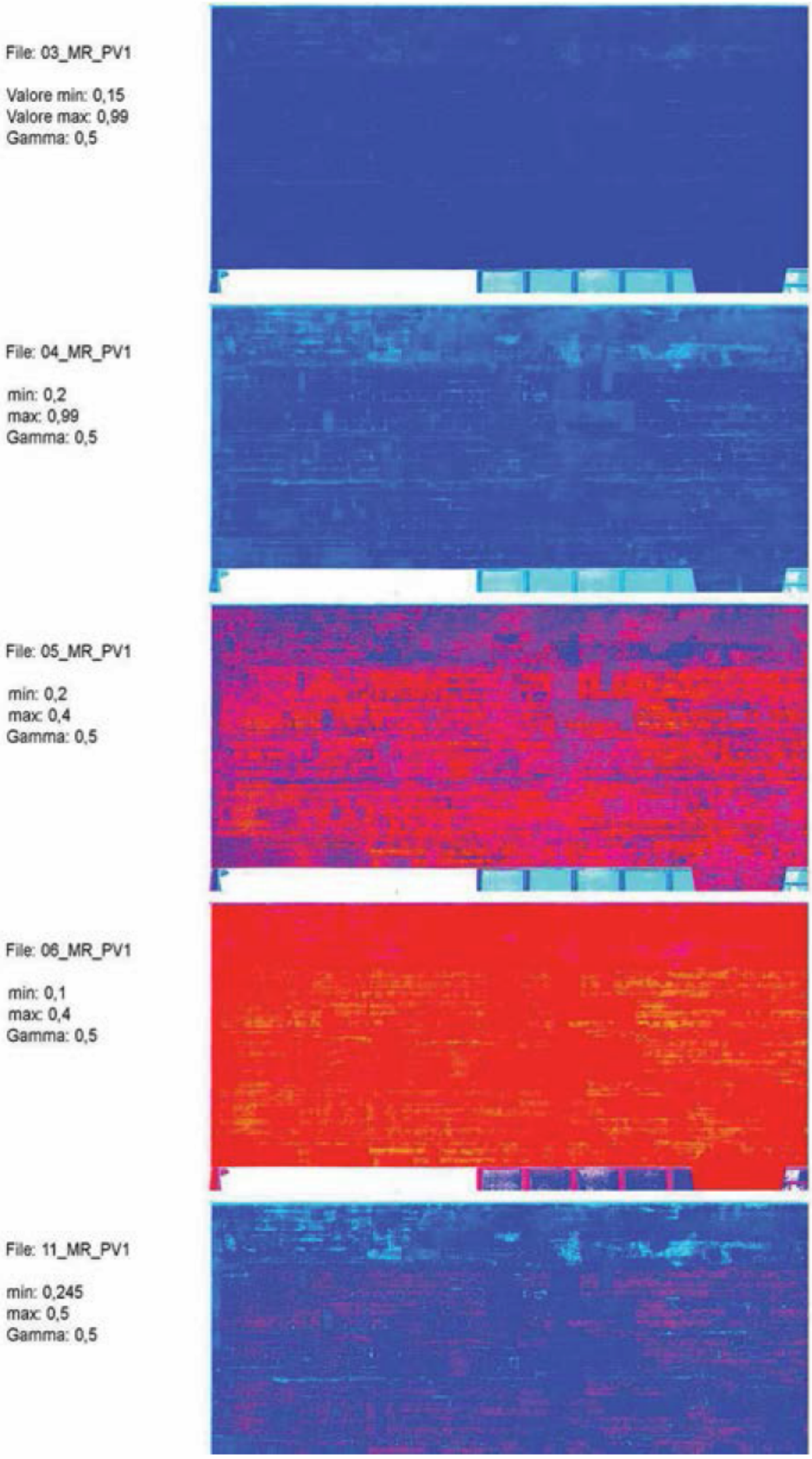

Figure 8.18: FAU USP building, surface analyses by reflectance data modification.

Day1 – 6 hours	**Morning** Integrated Architectural Survey; 3D Laser scanner technology. **Afternoon** Case studies and technology possible applications.
Day2 – 6 hours	**Morning** Basic concepts of point cloud; Coordinates of the point and fundamental coordinates; Secondary coordinates and concept of "normal of a point". **Afternoon** Rendering without geometric modification of the point cloud; Rendering with calculation agent on the pixel; Rendering with calculation agent on the reflectance; Rendering with calculation agent on the geometric shape.
Day3 – 6 hours	**Morning** Generating plants elevations and sections; Digital Elevation model; Export digital elevation model. **Afternoon** Import of plants in CAD; Import elevation in CAD; Import of sections in CAD.
Day4 – 6 hours	**Morning** Management in CAD of DEM (digital elevation model). **Afternoon** Editing cad with DEM.
Day5 – 6 hours	**Morning** Integrated diagnostic survey in the framework of conservative strategies; Analysis of macroscopic morphologies of degradations ; Diagnostic survey: visual analysis, photographic documentation, instrumental survey, documentation in site. **Afternoon** Diagnostic procedures based on instrumental devices; Use of the reflectivity index as an integrated tool for diagnostic; Data extraction and representation.

Chart 8.1: Topics of the capacity building programme developed in cooperation with FUSP and conceived to improve the skills of local staff in 3D data managing, 2D drawing from DEM elaborations and diagnostic analysis.

Casa das Canoas, by Oscar Niemeyer, Rio de Janeiro, Brazil (1951)

The integrated survey at Casa das Canoas in Rio de Janeiro, has been part of this research path since 2014, when, in late November the DIAPReM Centre of the Department of Architecture of the University of Ferrara carried out the on field activities in Brazil with the aim of documentation, knowledge and preservation of one of the most important architecture by the Brazilian architect, Oscar Niemeyer[9]. The research project has been developing under the patronage of Foundation Oscar Niemeyer the which is currently trying to identify a proper methodology for documentation and conservation of the architectures designed by the Brazilian master architect, after his death in 2012.

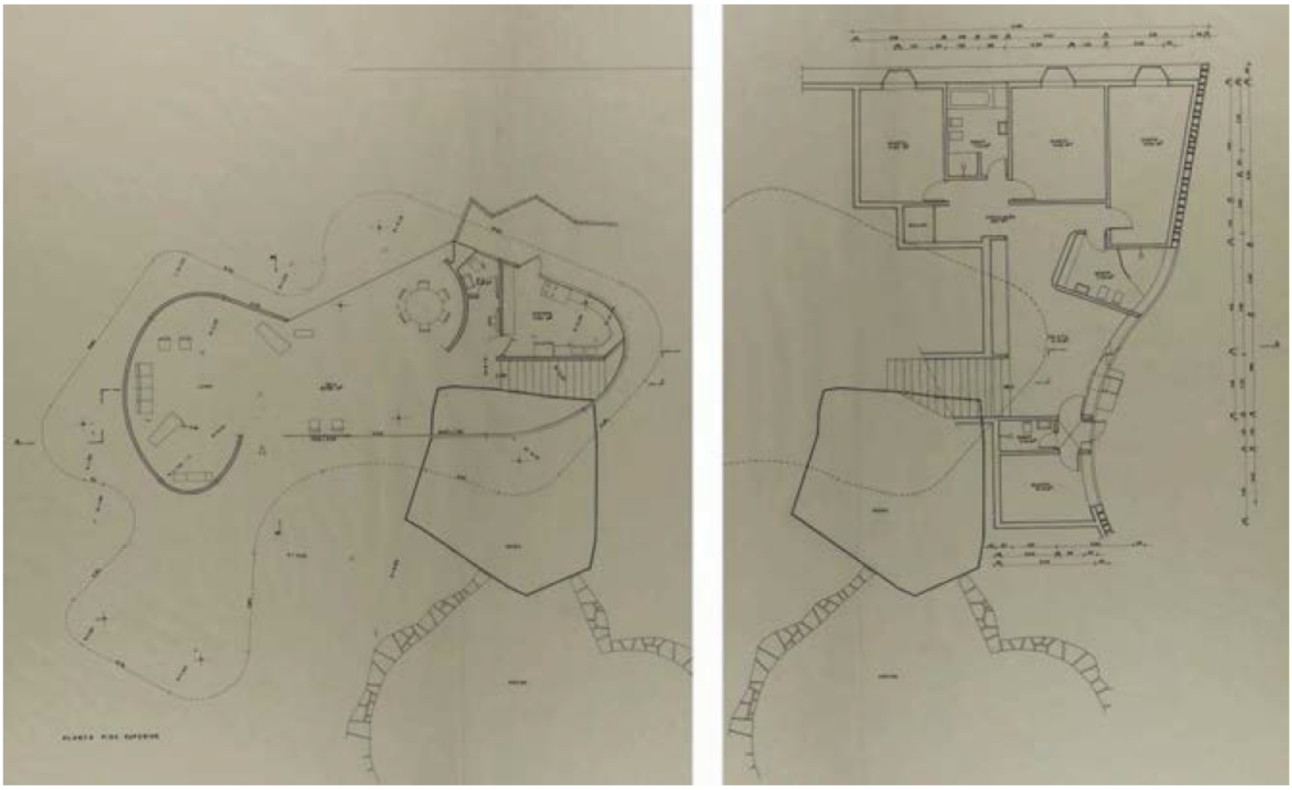

Figure 8.19: Niemeyer's original drawings for "Casa das Canoas" (1950) digitalized by Oscar Niemeyer Foundation, on the left ground floor and on the right the basement plan (same scale).

[9] Project credits: DIAPReM Center, Department of Architecture, University of Ferrara - Scientific Responsible: Marcello Balzani; 3D and topographic survey: Guido Galvani; diagnostic survey: Federica Maietti; international coordination for heritage and conservation: Luca Rossato, Denise Araujo Azevedo. In cooperation with: Consorzio Futuro in Ricerca (Director: Stefania Corsi), Oscar Niemeyer Foundation, Rio De Janeiro (Supervisor: Ricardo Niemeyer) Escola da Cidade, São Paulo (coordination: Ciro Pirondi). Technical support: Leica Geosystems, Rio De Janeiro.

The project has been performed also with the support of the Escola de Cidade, an institution of São Paolo partner of Ferrara University since 2012. Furthermore the work has been selected to be part of the "CyArk 500 Challenge" an ambitious initiative which aim at digitally preserving 500 cultural heritage sites within the next five years[10].

The main purpose of the work was to develop a detailed architectural analysis, in order to have an accurate database useful for site restoration work or management plan.

In terms of architectural design on one hand the house possesses qualities such as flat, thin roof and full height glass, typical for some famous modernist houses such as Mies van der Rohe's Farnsworth House and Philip Johnson's Glass House but on the other its plastic curves and strong connection with the site, make it a peculiar phenomenon in the history of Modernism.

Figure 8.20: from left, "Glass House" by Philip Johnson (1949), "Farnsworth House" by Mies van der Rohe (1951), "Casa das Canoas" by Oscar Niemeyer (1953).

The existing differences between the upper floor and the lower make clear the design intentions: while the glass gives a feeling of lightness and openness the occupants would feel exposed at night, so the private part of the house that accommodated the bedrooms, was positioned into the slope of the terrain, where the space feels enclosed, private and secured by the surrounding mass of soil. Thus first floor was liberated and flowing, while the second was cellular and ordered.

Niemeyer during the design process decided to locate the house into the landscape simply cutting three plateaus: one for the small upper car park and two for the floors of the house. The continuous floor of the foreground accentuates the flow of the succeeding spaces: the living rooms, dining room, a small toilet, the kitchen and the pool area. At the same level, behind, is a large open terrace and the service area, enclosed by a curved masonry partition - originally a wall of alternating brick, but in the 1995 restoration, led by the architect himself, became entirely full. This external area is a platform housed in the upper slab of the lower floor, where the intimate part is located.

The integrated survey project took 10 days of field working. The total computed area for the 3D survey campaign included the external area of the house and the garden. This is because the landscape project

[10] For more info about "CyArk 500 challenge": http://www.cyark.org/about/the500/

was an essential part of the overall design process by Oscar Niemeyer and in order to study the effects of vegetation on the state of conservation of the building. The 3D survey has been performed with Leica C10 Laser Scanner (Lidar technology) with a medium resolution of 1 cm using green and blue reflective targets for the scans registration.

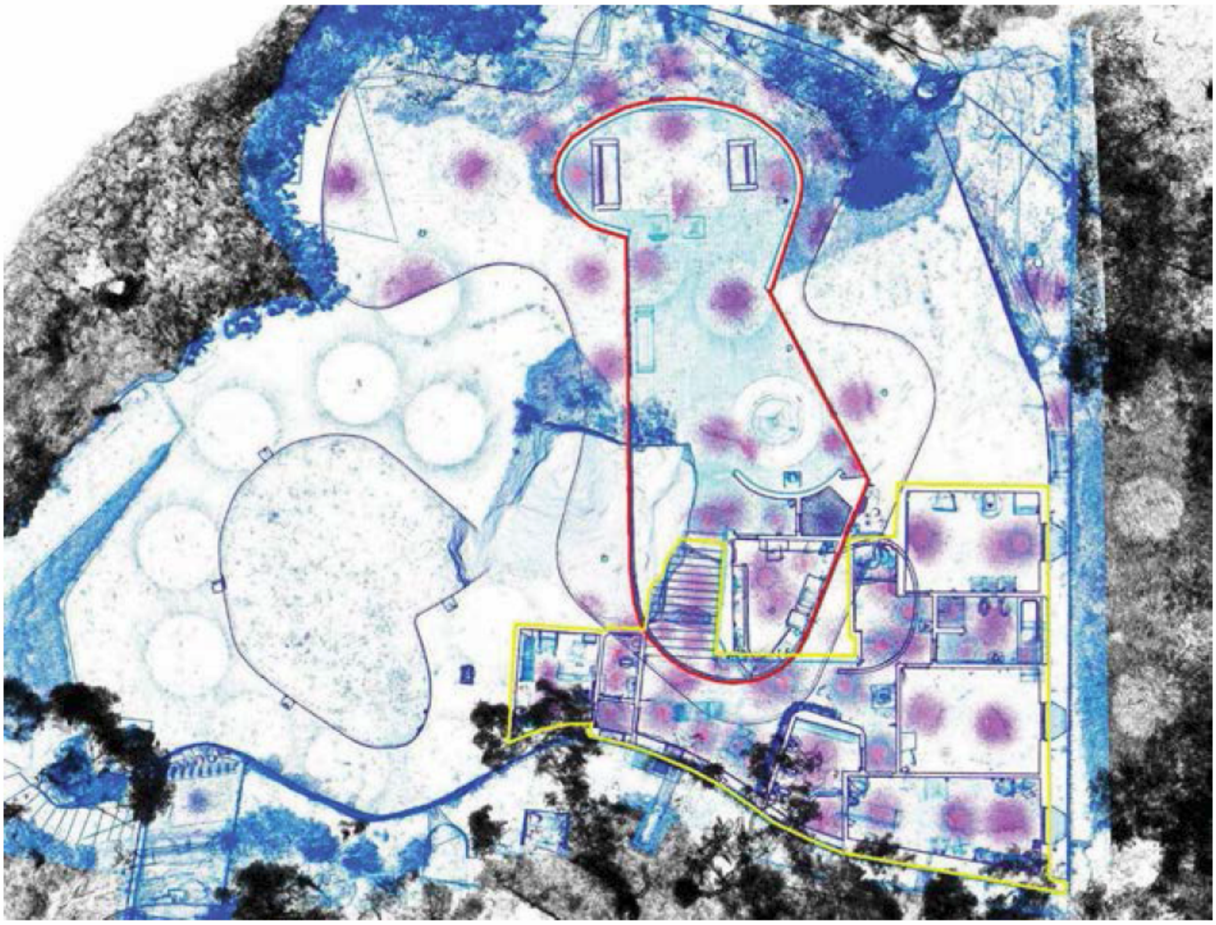

Figure 8.21: in red the ground floor boundary, in yellow the basement one.

The topographic survey will be performed with Leica Total Station TS06 plus 2". Topographical main connection to the network and framework, consisting of a polygonal closed or opened to bench marks at the ends and with polygonal rods with no longer than 80m. A detailed topographic survey (based on targets acquisition) composed of open polygonal with control points for the targets has been completed. The survey campaign has been documented by a detailed photographic survey.

Thanks to the 3D database it has been possible for the first time exactly locate the two levels of the house, the which are not overlapped. The figure 8.13 shows the accurate position of the two independent floors of the house in these data could be very useful in case of future restoration plan or required work on the systems of the house. From the elaboration appears pretty much clearly that Niemeyer was attracted from the solution that doesn't overlap at all the two levels.

Figure 8.22: image overlapping the original drawing of Ground Floor by Oscar Niemeyer and 3D survey output, in red colour the original walls designed by the architect.

The elaboration of the database end the following outputs, such as building plans have been then analysed in order to understand whether during the construction phases the original project of the master Niemeyer was carefully accomplished or not. For doing that, after the survey the database was registered software and enquired with the purpose of extracting the buildings floors plan. On the ground floor plan was then overlapped the original drawing by Niemeyer scanned at high resolution by the Oscar Niemeyer Foundation during the process of digitalization of the whole archive. The result has been a difference up to 36 centimetres in walls locations and curve radius. Building the house without right angles must has been very difficult for local contractor. Particularly the built stairs position is quite different from the designed one, probably due to technical difficulties working around the big rock which is completely integrated with the pool.

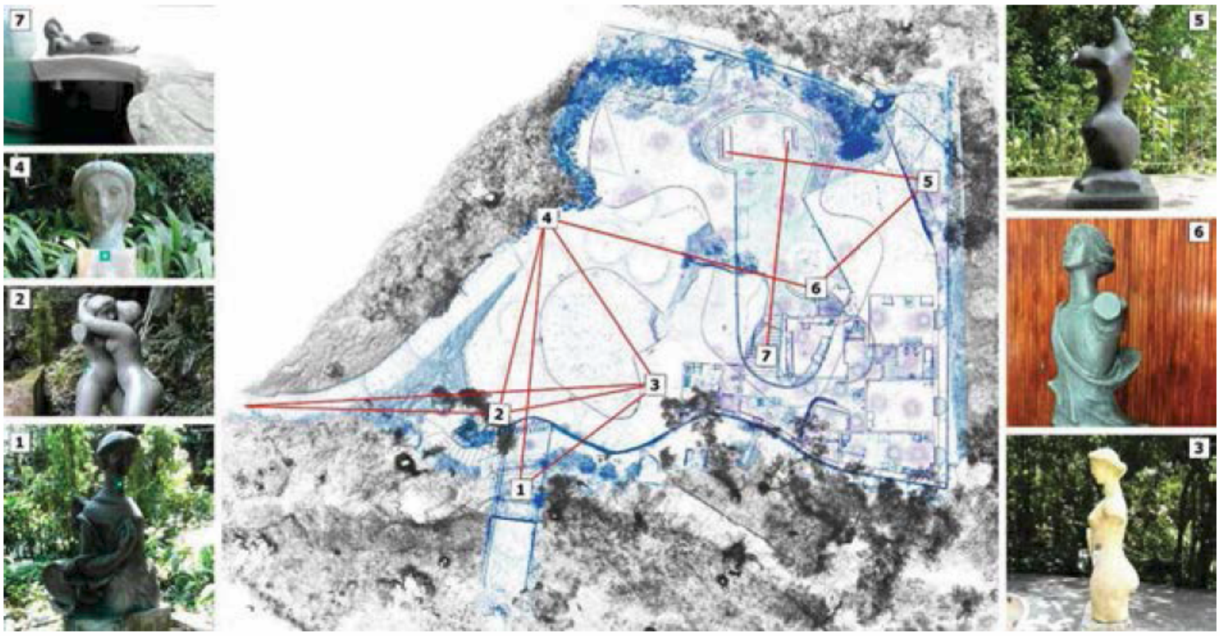

Figure 8.23: study of locations and relationship between the sculptures located in Das Canoas House garden.

A second issue that has been studied is the relationship between architecture and sculptures. The integration between architecture and art was actually a crucial point in the Niemeyer's mind. Thus along the year Niemeyer spent at the house even works of art were brought in at the right stage. The reason behind this was to promote Brazilian creativity and culture. Niemeyer adopted this idea and throughout his career insisting for the right sculptures and paintings to go with architectures. In the case of his house the architect had sculptures by his friend Alfredo Ceschiatti.

The artist reflected the liberated and plastic curves of Niemeyer's architecture into the sensual curves of the female bodies, which were placed around the pool. Figures, busts and heads, for a total of seven sculptural bodies have been placed outside and inside the house. They represent angelic female figures or sinuous bodies, which seem to guard the entrance and can be admired in the area outside the house; their positioning is also based on internal observation points.

For the first time a 3D survey with high level of detail (2 mm grid) allows to identify the features of each sculpture leading to interpretation the exhibition design that was at the base of Niemeyer's displacement of pieces of art. Thanks to the detailed data capturing it will be possible to identify the axes of relationship that develop from the placement and orientation of the female bodies to encourage to share the environmental and architectural experience. The morphological survey of the 7 statues in the garden through laser scanning technology at high level of accuracy could be an important contribution to historical-artistic studies of these masterpiece. Furthermore the details captured will allow to check the state of conservation, and in case of restoration work or temporary displacement of the statues it will allow the reproduction of copies both hard and soft. For instance the use of the database by means of Virtual Reality systems could improve the dissemination of this art pieces for the specialist or general public with the possibility of integrate, the precise and objective referencing, even the information coming from the studies and other elaboration.

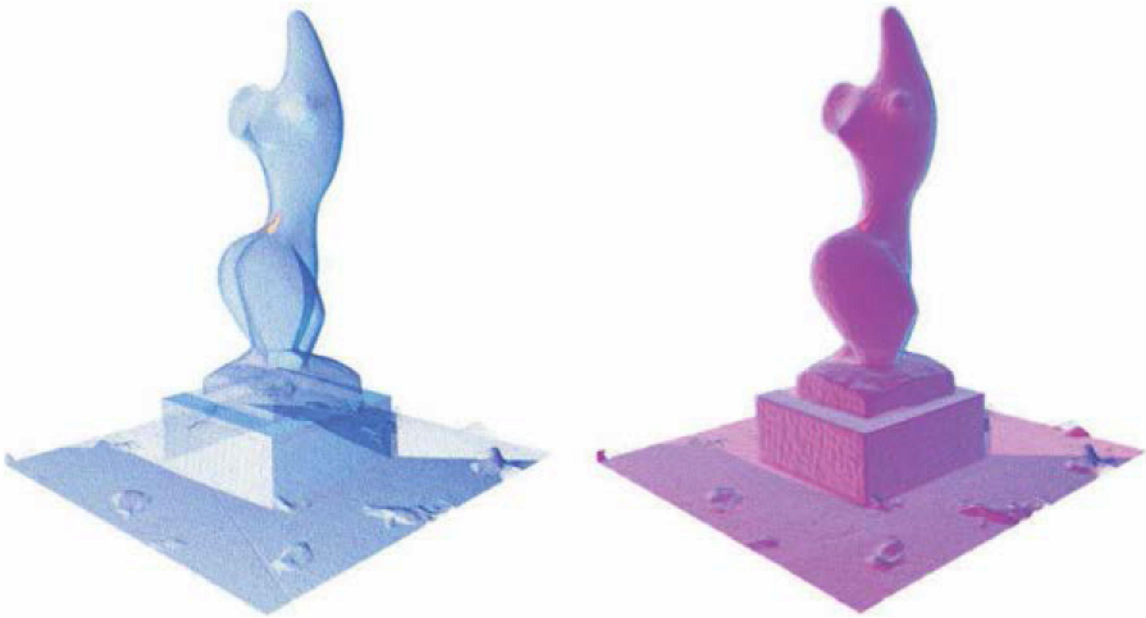

Figure 8.24: Detailed survey of one of the sculptures placed around the house; on the left, point cloud model and, on the right, the meshed model.

A third topic that was evaluated has been the relationship of architecture with the surrounded green landscape. As the majority of the project coming from the Carioca School the design process of Das Canoas House brings a very strong unity between outside and inside environment, the natural and the artificial is expressed through the integration between the building and the surroundings, one of the driving forces of the design. It was not just about creating a beautiful setting around the dwelling, the architect wanted to make the house a part of the landscape. Thus the house is surrounded by greenery from all sides. The winding paths in the gardens provide numerous routes for a walk and relax. The house itself had such a flowing shape that it was hard to distinguish it from the surroundings. The project is designed to fit the topography of the site by exploiting the full potential in terms of peace and relaxation and contemplation of nature and, at the same time, let the vegetation enters and appropriates architecture, integrating with it.

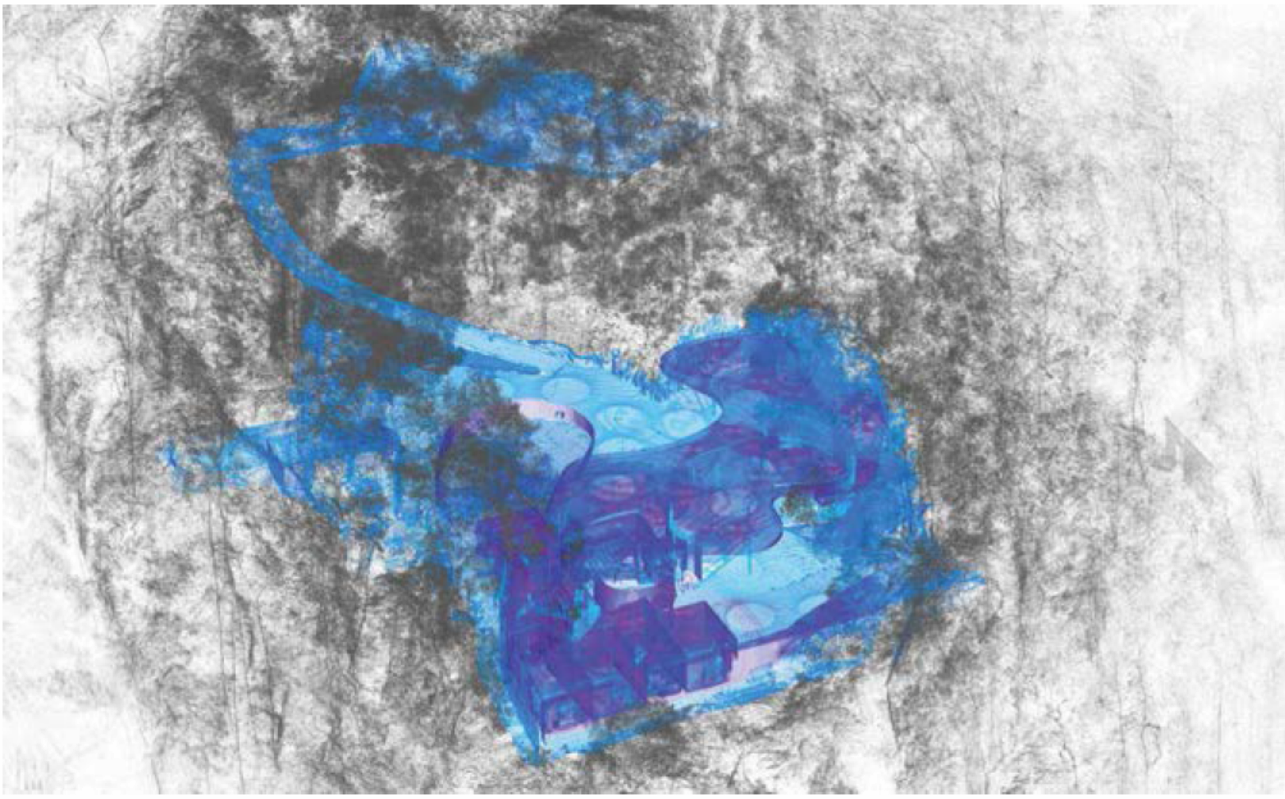

Figure 8.25: 3D database elaboration which shows the possibility to highlight the architectural features despite the luxuriant vegetation all around the building.

The documentation of the house has also been intended to analyse the current condition and the state of conservation of the building, which currently suffers from a lack of maintenance. The digital survey campaign, including the external areas and the garden, has been integrated by a diagnostic survey in order to map the state of conservation and the main degradation issues.

After a first general inspection of the overall building, a macroscopic analysis of deteriorations have been implemented on the basis of the nomenclature of the UNI Normal 1/88 recommendation. The result of the visual analysis will be related to the surface specifications surveyed by means of the 3D laser scanner and particularly through reflectance data[11].

The vegetation, deliberately integral part of the architecture, determines minor consequences, while the presence of humidity damages the state of conservation of the building, especially in the lower floor.

[11] For more info about this methodology: MAIETTI, Federica, BALZANI, Marcello. *Development of integrated procedures for diagnosis of architectonical surfaces. Dimensional data and surface aspects,* in Proceedings of the International Workshop SMW08 *In situ monitoring of monumental surfaces*, 27-29 October 2008, Florence, Edited by Tiano P. and Pardini C. (ICVBC-CNR, Florence, Italy), Edifir Edizioni, Firenze, pp. 131-140.

The presence of water was found primarily by infiltration (involving especially the conditions of the rooms of the lower area, on the back side).

Besides vegetation, the main degradations identified on external surfaces are:

- biological patina and biological crust;
- chromatic alteration;
- surface deposit;
- incongruous interventions and extraneous materials.
- lacuna;
- deformation and detachment.

Figure 8.26: the main deterioration issues identified during the diagnostic survey.

The main deteriorations on interior surfaces concern:

- ceiling cracks and infiltrations;
- lacuna and deformation of the plaster;
- stains for humidity and biological crusts.

Knowledge of the main deterioration causes as additional "level" of integrated survey will allow a precise mapping of the detected damages and will contribute to conservation actions.

In conclusion, as stated by BALZANI, MAIETTI in their exhaustive paper about the survey, "the documentation and survey one of the most significant architectures by Oscar Niemeyer has shown how the integrated methodology is able to reveal new aspects of the building and to analyse spaces and surfaces by means of innovative methods that have allowed to track intellectual avenues completely unexplored and unpublished. The three-dimensional survey has proved to be essential to represent areas that would be otherwise impossible to analyse, for example elevations immersed in the trees, especially because of the surrounding landscape, and to find plan matches essential to understand the architectural "philosophy" on which Niemeyer has based the realization of the Casa das Canoas. In the representative phase there is a motivational value, which makes the survey-representation a real project itself, with significant critical implications aimed at the determination not only of geometric precision but, especially in architecture, of visualization and conceptual representation of reality"[12].

The case study thus confirmed for the first time the adaptability of a 3D integrated methodology to the Brazilian context, in which factors such as climate and natural environment are really dissimilar from those in Europe. Despite this the effective data capture activities led the research team to a very deep knowledge of the architectural features of the House and its state of conservation. Hopefully the Oscar Niemeyer Foundation will have a good tools to plan the conservation project of the house using the 3D survey as a strong base also for maintenance, preserving the memory of this extraordinary house. Last but not least 3D survey is also consistent with the digitalization of the Oscar Niemeyer Foundation Archive, one of the Foundation' priority in order to create a Niemeyer's drawings archive for researchers and academics.

[12] See: MAIETTI, Federica, BALZANI, Marcello. *Integrated methodologies for documentation and restoration of Modern architecture: survey and representation of the "Casa das Canoas" by Niemeyer,* in Proceedings of the XIII International Forum *Le vie dei Mercanti*, 11-13 June 2015, Aversa, Capri, Edited by La Scuola di Pitagora Editrice, Napoli, pp. 878-887.

CEPT University complex, by Balkrishna V. Doshi, Ahmedabad, India (1972)

The collaboration project with CEPT University started in 2014. The choice of the involvement of the Indian Institute as a foreign partner is due to the desire to cooperate in the Heritage Conservation Technologies sector, with one of the leading Indian centres of excellence in architecture.

Furthermore, the development of contacts with the Indian colleagues could be a huge opportunity for investment in projects aiming at the protection and enhancement of the Indian cultural heritage, partly still not evaluated in its great potential.

In this way the "CEPT 3D survey pilot project" firstly wanted to evaluate the possibility of mutual technical and methodological exchange in an application environment in exponential growth, driven by an increasing cultural tourist demand. The pilot project has been divided into 2 phases.

Along the 1st phase the collaboration aimed at the development of the project evaluating the feasibility related to the vulnerability of Indian cultural heritage and Indian architecture. The aim of this first step has been to develop research segments sharing the methodologies already developed individually by each university, in terms of case studies addressed, methodology, analysis and monitoring procedures and communication and dissemination strategies.

The project activities were focus on the definition of methodologies and process for conservation of Indian Cultural Heritage by meetings, workshops, case studies. The researchers had the chance to develop activities related to the 3D survey by laser scanning technology and processing of digital material. These activities were also helpful for fostering the purposes of conservation and enhancement of the existing heritage.

The project objectives have been divided into two different types:

• Evaluation of monitoring and intervention strategies by 3D survey technologies aimed at a specific application use for conservation procedures implemented historically and in recent times, for cultural materials and traditions related to the built heritage.

• Establishment of a preliminary collaboration between the two institutions, based on exchange of information in fields of common interest, on the monitoring of modern buildings with advanced laser technologies, consolidated in joint research activities.

During the 2nd phase the proposed collaboration with the Indian Institute it has been discussed a creation of a local research group capable of operating in autonomy in case studies application in India. Funding for the continuation of the research may be provided by institutions also from other Indian states like Mehrangarh Museum Trust in Jodhpur in the state of Rajasthan and Ahmedabad Municipal Corporation, Ahmedabad, in Gujarat state, which have already proved interested in collaborating with the University of Ferrara on such issues.

The result of such coordination activities was first of all the carrying out of a 3D survey pilot projects in December 2014 during the which a low cost equipment has been tested.

Figure 8.27: Survey operations at CEPT main building in December 2014.

The survey campaign was carried out in collaboration with CEPT staff in order to have a interdisciplinary team of researchers and students which allowed the exchange of specific knowledge to guarantee the added value of the activity. After the data capture activity, the information were then processed in a preliminary phase, compatibly to the machines processing power available in the field to verify its validity.

The three-dimensional survey for the implementation of a point cloud database at high-information-density consists of 60 stations, all of them registered with the ICP method, with an average of 3,8cm error, for a total of 200 million points.

The survey was executed by 3D laser scanner Stonex X300 and the data were processed with Geomax MPS, Gexcel Recontructor (Stonex edition - demo version) and CloudCompare.

Figure 8.28: point cloud elaboration of CEPT main building.

The survey was focused on the main façade made up of concrete with exposed bricks, giving special importance to the slabs and beams left open by Doshi to create a natural texture.
The 3D point cloud highlights that the studios receive plenty of light and ventilation from the double storeyed even masses that have an opening from both the sides. In addition to this, the roof has inclined skylight on top of the studios, which continuously lets the natural light into the building.
Special attention was paid to the semi-external space of the basement area, one of the most important feature of the building as it is not confined just to the interior space of its blocks, but rather creates external space and platforms, which act as an extension towards the already open nature of the building.
As described before the main scope of this pilot projects has been the testing activity on the low cost scanner.
The Stonex scanner X300 has shown a good battery life with more than 4 hours on a single battery (wifi enabled for remote control) and good recharge time of about 2 hours.

Figure 8.29: point cloud elaboration (elevation) of CEPT main building.

The image acquisition was pretty fast (3 minutes maximum), but conspicuously missing the green channel, the images acquired by the texture of the model are not really usable. Regrettably the minimum distance acquisition 1.6m (3.2m diameter) makes it very difficult (if not unusable) using the scanner in interior spaces. Furthermore the acquisition window of 90 ° vertical is quite limited for an architectural survey. At the same time the size and weight of the tool are good and they allow the equipment to be also used by female users.
For what concerns the control software is easy to use, stable and has never given problems connecting or reconnecting even when you go out of range from WIFI interior of the instrument.
At the end of the campaign the reflectance data appeared to be quite corrupted due to poor quality information and only with Cloud Compare or Reconstructor it is possible to notice that the data is correct and good.

In conclusion this type of equipment has shown still problems for architectural survey purposes and it need to be improved. Beside the difficulties faced it is anyway possible to use the data for dissemination activities related to the modern architecture enhancement.

8.3 International Laboratory net for the conservation of Modern Architecture

International laboratories nets allow researchers to perform research programme or joint activities through web sources from any geographical location with internet access. Recently, the fast technological development have led many universities toward the creation of research centres able to offer opportunity to check methodology developed far away. Furthermore studies on the overall effectiveness of an inquiry-based approach to teaching in universities with regards to raised interest and motivation for cultural heritage subjects have demonstrated how technology can improve skills and also inclusion of disadvantaged students. The EU I nowadays trying to improve quality in high science education by promoting collaboration between universities and research institutes in the provision of remote access to science laboratories through the development of online toolkit and the deployment of the inquiry-based teaching methodology also in cultural heritage sector. A new approach to build a collaboration model for remote labs between universities is needed in order to offer direct manipulation of laboratory equipment, by means of an internet browser and a user interface which allows controlling the actual laboratory equipment from the distance. Both types of laboratories provide tools for data acquisition and data display. This research has had strong connections with local universities and even if remote labs have initially been developed in the area of engineering education, architecture department tare now reconsidering the opportunity to take advantage of technologies for heritage preservation both in India and Brazil.

Figure 8.30: technology transfer by DIAPReM centre staff at University of São Paulo (USP).

In Italy this kind of experiences were not only restricted to a single educational topic but thanks to a growing number of laboratories specific research topics has been addressed and developed. Obviously this kind of structures come with computer limitations. The benefits for universities to enter a cooperation with other higher education institutions are more or less straightforward, as very often technology labs can also offer services that can be sold on the e-market and share these services among providers to increase their own economic possibilities. Partnerships between universities laboratories and private enterprises of IT sector or cultural Heritage Sector, however, are different and – especially in a large scale model many challenges given the cultural boundaries between universities and private sector with their diverse interests, resources and power distribution.

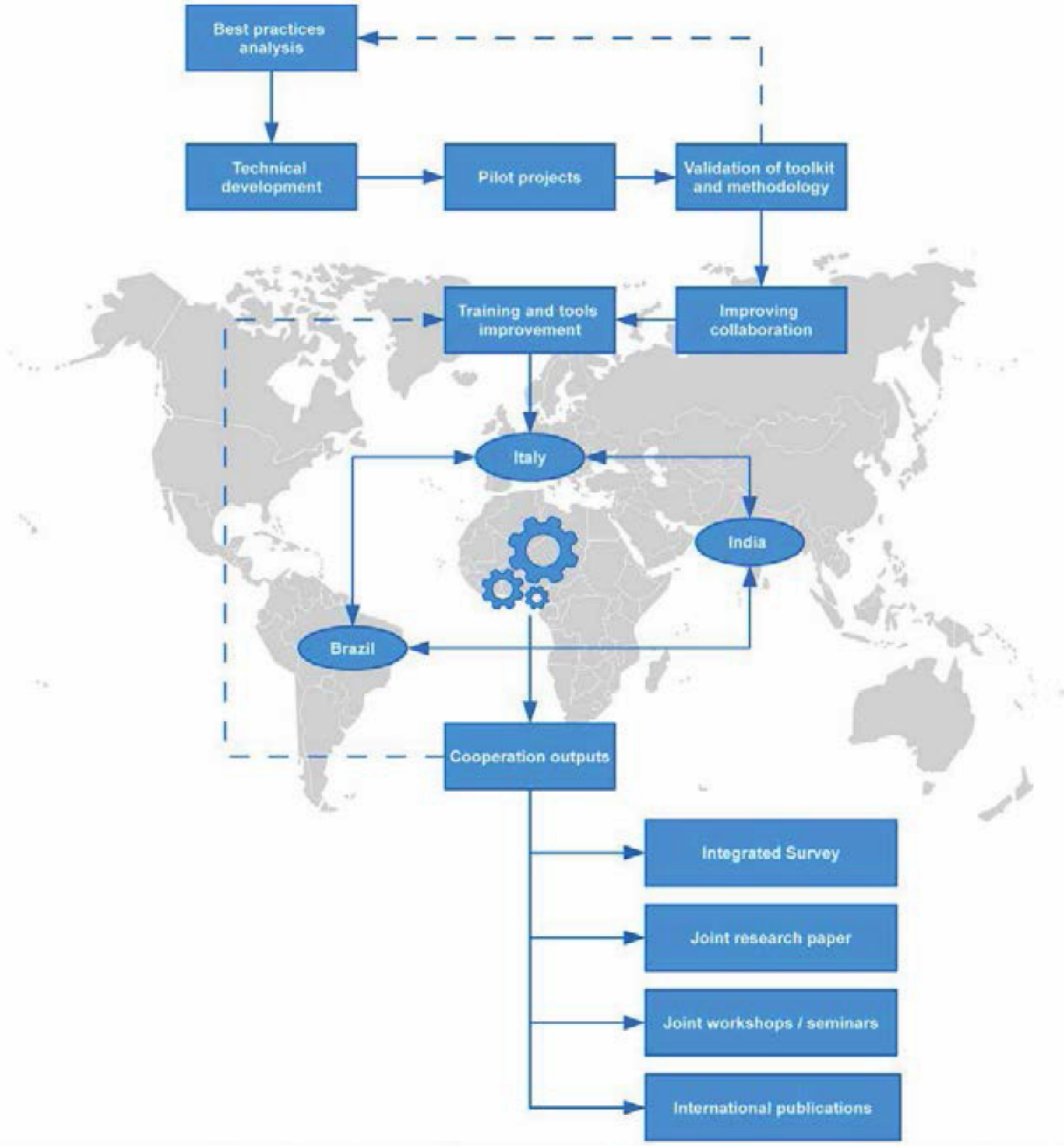

Figure 8.31: international laboratory net and related workflow framework.

On the other hand, policy-makers have understood that university and privates partnerships are a key point in order to increase fund raising programme and sponsorship of cultural project or research grants.

Along this research a successful initiatives was the series of conferences and symposium held in Brazil and India; during these experiences the DIAPReM centre' surveys of cultural heritage were share with both Brazilians and Indians colleagues. This allowed to bring academics and practitioners into closer relationships in order to improve the sharing of knowledge in heritage preservation and enhancement.

Particularly the collaboration between the University of Ferrara and foreign universities such as USP and Mackenzie in São Paulo (Brazil) and CEPT in Ahmedabad (India) has been proven to raise curiosity in cultural heritage preservation, interest, motivation and self-esteem among young researcher and students willing to explore the possibility behind the preservation and valorisation of Modern Architecture.

In USP for instance a research centre for the preservation of Modern Heritage coordinated by Prof. Beatriz Mugayar Kuhl has been set up in order to take care of the conservation of the Faculty of Architecture designed by Vilanova Artigas. This centre in deep collaboration with DIAPReM centre is adapting the Italian integrated methodology for surveying to their building and this will bring a more aware knowledge on maintenance strategy and a more detailed masterplan for the complex conservation.

In India, at CEPT University, local colleagues are trying to identify possible professional courses in order to start capacity building programme on both teacher and professional. The cooperation between these centres in Brazil and India and the skilled Italian universities on cultural heritage field (an, why not, in the near future directly between them) could really led to a more effective conservation of modern heritage thanks to experience sharing on materials diagnosis, repairs and conservation techniques.

8.4 Awareness programme towards the preservation of modern buildings

The approach aiming at the integration of traditional management tools and digital tools for enhancement take into deep consideration also the intangible aspects of this heritage: local traditions, cultural behaviours, and design processes very often related to local culture and need (especially in India and Brazil).

As stated by Yehuda Kalay, Thomas Kvan, Janice Affleck in New Heritage: New Media and Cultural Heritage (Routledge 2008) "The complement of traditional methods to cultural heritage management has been augmented with the introduction of digital or new media. […] Digital media can be utilized for much more than re-creation or re-presentation of physical entities. It has the capacity to become a tool to capture both the tangible and intangible essence of cultural heritage and the society that created or used the sites".

As identified by J.T. Dallen (DALLEN, 2009) one of the most frequent threat to cultural heritage sites (in global south countries) inscribed into the UNESCO World Heritage List is the lack of management. And this framework participatory processes and audits with involvement of students and researchers can improve the knowledge of problems related lack of planning and maintenance.

In order to develop conservation practices for Modern buildings tools such as conferences and colloquium activities have been held all along the time of this research. Training of local staff and related officials in the maintenance procedures has been a key point for the activation of both sensibility and awareness toward preservation.

In some cases a combination of classroom exercises and on-site demonstrations helped to

familiarize staff with the conservation of modern heritage. In Brazil for instance, audience of these workshops has been expanded to include students, professionals, teachers, private companies involved in conservation field.

In India, after several workshop in this issue a colloquium will take in Ahmedabad in late 2017 in order to engage local professionals and train them in appropriate responses to maintenance of the building. The event will be focused on issues concerning the grid-shell structures, bamboo techniques and conservation of Modern Architecture in India. This event is aimed at professionals with the purpose of communicating both practical advice as well as contextual analysis. Consultants and researchers involved on the project will be invited to present their analytical methodology, results and conclusions and to frame their research so that professionals can place this work within a broader field of study.

As part of this process of public awareness further promotion and dissemination may also be achieved by publishing articles in specialized journals and presenting papers at conferences.

This, in country such as India, will be a significant opportunity to engage academics and professionals who may be interested in researching the conservation of Modern Architectural heritage more generally, also abroad. In this framework teacher plays a vital part. To make the teachers well versed with the Modern Cultural Heritage there should be more lectures on this topic as well as other activities provided for better understanding this kind of heritage.

A future step in this field will be involved local municipalities such as Ahmedabad city toward the organization of programmes planned on short term basis and long term basis for professionals at every stage or level of education.

This orientation training programme and workshops as well as seminars& conferences might be organized and all these programme must be mandatory for all the professionals that are dealing with modern heritage as the peculiarity if these buildings are not so few (in terms of shapes, innovative materials, etc.).

Figure 8.32: seminar on 3D technologies for cultural heritage maintenance for young researchers and student in São Paulo.

Through this study it was possible to create awareness about the fundamental principles underlying the maintenance by the use of technologies of modern heritage both in Brazil and India providing an opportunity to formulate methodologies that were part of the process of learning by doing on site.

Dissemination and awareness processes through digital tools could be very effective in heritage enhancement field and bring new affordances to the conservation and valorisation practices. Furthermore, very often, the professionals involved in modern building management know very well the object of their study but at the same time they are less aware of the implicit value of the construction.

Very often existing programmes are not adequate and are to be conducted rigorously rather an on a piece meal approach, It needs to be given more professional touch to bring more systematic awareness involving various professionals, agencies and stakeholders in the field.

FIFTH PART

Chapter 9

Conclusions and further opportunities

“Failure is simply the opportunity to begin again,
this time more intelligently”.
Henry Ford

9.0 Chapter abstract

The undertaken research path has shown that the application of technologies used through appropriate integrated methodologies can be a good approach for the maintenance, preservation and enhancement of 20th Century cultural heritage. The survey of the project, the BIM modelling and advanced architectural survey techniques, can not only increase the knowledge about this heritage but also be valuable tools for its transmission to future generations. The continuous dialogue with foundations also made it possible to understand the extreme importance of preserving not only the buildings but also the projects from the which they were born, a legacy that in many cases is nowadays in danger. For the future of the Brazilian and Indian modernist architectural heritage it will be very important the collaboration between research institutes and universities.

The creation of a network of researchers that could act as a solid foundation for future research in the area and for the application of proven methodologies will be a key point for future international strategies in this sector. This research has shown that project such as the collaboration with the São Paulo University related to FAU USP building and the project in collaboration with the Nirmala Bakubhai Foundation in Ahmedabad can be very useful in order to share skills and experiences that could lead to the use of this methodologies by experts and local researchers in an independent way.

The future of 20th century architecture both in Brazil and India will be in the hands of local policy makers, researchers and professionals; the western approach to preservation should be only an input able to bring the past experiences as effective examples, this approach needs then to be hybridized with local constrains as the modernism principles were adapted to the fertile grounds in these gorgeous countries

9.1 Impact of the research

The research carried out along this years has made an noticeable impact on the conservation and mainteinance of Modern Architecture both in Brazil and India. These range from impact on culture, scientific production and business. Some impacts of the research are already clear, whereas in other cases it can take years, before the real value becomes apparent. It is no simple to predict the potential benefit or future outcomes, for sure there was an increase of fundamental understanding of the world of modern heritage mainteinance through the use of adavcned technologies.

For the first time laser scanning techniques have been applied to modern heritage in Brazil and India, increasing the curiosity toward this technology and also the involvemtne of local young researcher in this field of application.

The cooperation on activites such as the BIM development on Modern Architetcure has been crucial in Brazil at the Mackenzie University in order to start a common path of research that could possibly led to joint PhD programme topics and professionals course organization.

Several scientific papers have already been sent to internation conferences in cooperation both with Brazilians and Indians colleagues.

The continuos effort of activities such as conferences or simple lectures in both the countries has stressed the importance of the preservation of modern heritage and its valorization. The database collected were used by local institutions in order to understand the potentials of each technology and possible utilization for mainteinace puorpuses.

Brazil was actually a more fertile ground, probably due to the recent development of restoration practices, it has been a good benchmark in order to test a western metyhodology also in South America. In this picture the great support given to restoration activities by advanced tehcnologies has been in some cases really crucial. For instance the diagnostic activities carried out on the FAU USP building façade provided an effective and accurate analysis tool for evaluation of past mainteinance works and future preservation actions.

In terms of business, local interprises have better understood that modern heritage could be very soon a possible source of income: laser scanner producer have greatly helped and supported several activities o this research, and new clients have been attracted thanks to this dissemination. Probably the most important impact was indeed the capacity of new technologies to attract young students and research: they will be the future professionals in charge of the conservation of this huge legarcy.

9.2 Adaptability of the research to other contexts

Having tested the integrated methodology in these two countries have been an amazing source of leanning by doing. Difficulties due to local context constrais were so many that flexibility was needed in order to solve problems and avoid mistakes. This has shown how the methodology could be probably applied also to other context, both in Asia or South America.

It is important to highlight that the aim of thisnresearch was to develop a methodology for mainteinance and enhancement of modern heritage, so the pourpouse was not the implementation of new services provided by the University of Ferrara DIAPReM research centre in these countries.

The real philosophy behind the activities carried out is the identification of local stakeholders able to learn and apply contemporary technique in this field. An high number of restoration projects could be carried out by foreign professionals in these countries. This wouldn't be very useful for the conservation of modern heritage: there is a strong need of multinational projects able to improve the capacity of local professionals in heritage preservation and management field. Learning-by-doing programmes able to take advantage of the crucial mix of western conservation methodologies and local institutions knowledge. These two factors at the same tiem could play a key role in modern heritage preservation in many countries.

9.3 Future developments

This PhD research and its methodology was part of the proposal for grant request concerning a "Vocational Training Workshop building" submitted by the Nirmala Bakubhai Foundation in Ahmedabad to Getty Foundation initiative *Keeping it modern* in 2016.

Due to the very good level of the submission documentation and outstanding features of proposed building the Keeping it Modern' scientific board has decided to award the Indian Foundation with 90.000 US dollars to be used for conservation plan implementation.

The grant statement by the committee clearly describes the importance of the building:

"Designed by Gautam Sarabhai (1917–1995) and constructed as a vocational training center affiliated with the B.M. Institute for Mental Health in Ahmedabad, the workshop building (1976–1977) is a significant example of India's modern architectural heritage. Resulting from local applications of modern engineering and design, the building was inspired by the early work of Frei Otto and embodies Sarabhai's belief that elegant forms emerge from pushing engineering to its limits. The resulting structure is made of a light-weight steel grid frame that is covered by a thin-shell Ferro cement roof, achieving a large column-free space with an unsupported span of 134 feet. Two smaller adjoining administrative additions were constructed using bamboo instead of steel, which was unprecedented in the fabrication of thin-shelled concrete structures. Sarabhai purposely sought to create a structure that could be built without expensive formwork or specialist contractors, but that would nonetheless advance modernist ideals in its concept and construction. Working with a highly skilled local mason, he succeeded brilliantly. Due to its lightweight structure and inherent ability to flex, the building withstood the 7.7 magnitude earthquake that devastated the region in 2001, without sustaining significant damage"[1].

[1] Source: http://www.getty.edu/foundation/initiatives/current/keeping_it_modern/grants_awarded_2016.html

To ensure that the structure will continue to perform as it has over the past forty years, the Nirmala Bakubhai Foundation is dedicated to researching the building's performance in order to prepare a comprehensive conservation plan.

The B.M. Institute proposal, beside the contribution of the methodology presented into this dissertation has assembled an international team of experts for the project that possess as much cutting-edge knowledge as the original designers and builders did. The project team includes architects, structural engineers, planners and conservation experts from India and Europe, an international team of experts including a number of individuals and institutions that were part of the original team: Professor Eda Schaur, who is Emeritus Professor Dr. Ing, of the Institute of Structure and Design (Koge) at the University of Innsbruck and advisor on the original design.

Engineering analysis will be carried out by Dr. K. Ramanjaneyulu and a team from the Structural Engineering Research Centre, Chennai (CISR).

Documentation, analysis and testing of the existing structure and preparation of technical drawings will be carried out using advanced technologies by the DIAPReM Centre at the University of Ferrara. Conservation planning advice will be given Dr. Shikha Jain, Director of DRONAH (Development and Research Organisation for Nature, Arts and Heritage).

Bobby Desai, Director of Design at HCP, has extensive experience working on Institutional building projects in India. He is managing the renovation of the overall BM Institute campus and will be project architect.

The team will collaborate on analysing the data to develop a comprehensive conservation plan. The success of this project will be used to demonstrate the benefits of applying a proper technologies and methodologies scheme in the conservation of important living buildings[2].

The grant award will be used (from April 2017 with final outputs delivery due to November 2017) to research and documentation of the building unique structure, to develop of a conservation Plan and to disseminate the project work through a report, colloquium and edited collection

9.3.1 Gautam Sarabhai

Born in 1917 Gautam was one of eight children born to Ambalal Sarabhai, a leading industrialist who played an important role in India’s freedom movement1. Educated in India and in England at Cambridge University where he studied Mathematics, Gautam was a significant proponent of Modernism in India. Described as one of the ‘early visionaries of Indian design education’ he was committed to bring the avante garde of design and art to India in order to expose the new generation of Indian designers to the best thinkers from around the world. Together with Pupul Jayakar and Charles and Ray Eames, Gautam

[2] Source: Nirmala Bakubhai Foundation Getty Foundation “Keeping it Modern Planning Grant Award”

and his sister Gira were instrumental in establishing the National Institute of Design (NID) in Ahmedabad, the buildings of which he also designed.
It was also through this influence that Louis Kahn, Frei Otto, Alexander Calder, Isamu Noguchi, George Nakashima, John Cage, Robert Raushenburg and others came to visit and work in Ahmedabad. Gautam had no formal architectural education.

Image 9.1: Architect Gautam Sarabhai in his office.

He was a firm believer in the Bauhaus approach of `learning by doing' and his architecture is unique for its fusing of Modern ideas about construction, informed by techniques of mass production, with traditional motifs and local craftsmanship. In addition to the NID campus, innovative for its large span unsupported brick arches, Gautam Sarabhai also co-founded, designed and curated the Calico Museum of Textiles, which has a world famous textile collection; the Calico Dome structure; Darshan Apartments in Mumbai, which was the first high-rise apartment building in Mumbai built in the 1960s, and a number of private houses, as well as the B.M. Institute campus.

9.3.2 The B.M. Institute for mental health, by Gautam Sarabhai, Ahmedabad, India

Designed by Gautam Sarabhai, the B.M. Institute of Mental Health campus is spread across two sites, each measuring approximately 10,000 sq.mtrs. that straddle Ashram Road, a principal thoroughfare in the centre of Ahmedabad. The Eastern campus site fronts on to the Sabarmati river and houses the principal institution building (classrooms, library and offices), Shardar school, Balghar school, with common playground facilities and a guest house; while the Western campus site has a residential building, vegetable gardens, multicategory workshop and a larger playing field. Both the buildings have a unique architectural ambience attached to them. The design is spacious, disabled-friendly and accommodates green space with natural light and cooling effects.

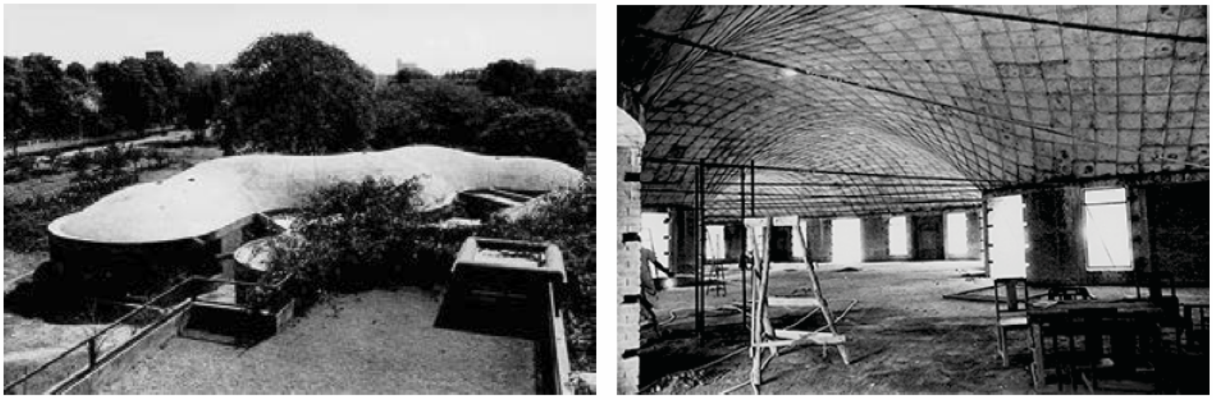

Image 9.2: B.M. Institute for mental health building by Gautam Sarabhai during construction.

The dome building was very innovative for its time and was at one time the largest dome structure in Asia. The dome was used as a multi category workshop and was connected to the National Institute of Design to train people with disabilities in crafts including furniture making. The structural form of the roof was found using the hanging chain method also used by Frei Otto, who visited and assisted in the design of this building. This method of form finding involves hanging a flexible chain net from a ring beam that forms the peripheral boundary of the building on a scale model. This was then fixed and flipped, and the lattice form shape thus derived was ferro-cemented. The structure was built economically in the desired shape without the need for elaborate shuttering.
Originally it was built to stand for only for one year but it is now in use for more then 40 years and it is still the largest free-span wooden shell in the world. A program of conservation planning is presently underway to ensure the life of the building for the next 50 years. This example illustrates the architectural attraction of such spaces formed by shells as well as the structural qualities of grid shells.

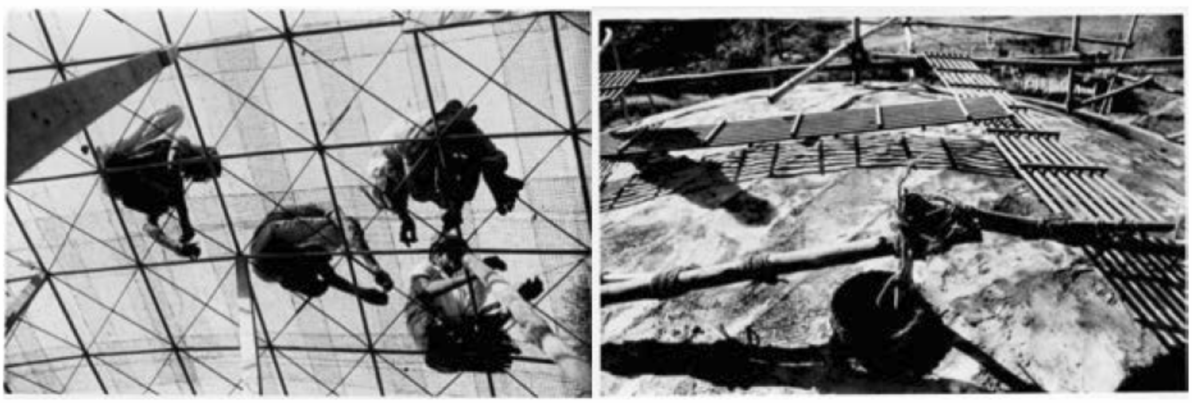

Figure 9.3: Two construction phases of the dome.

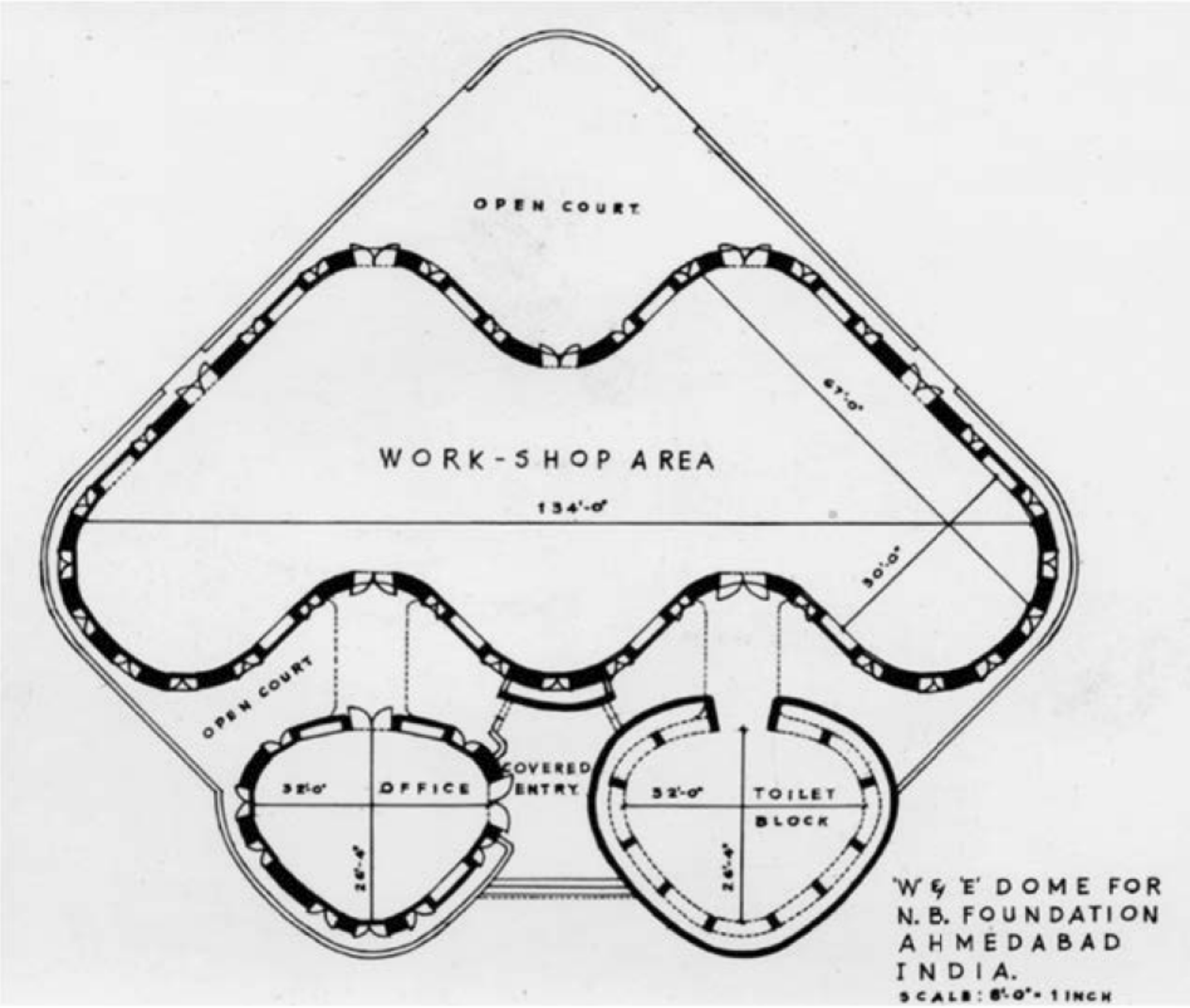

Figure 9.4: Original plan of Vocational Training Workshop.

The architect experimented with bamboo to form the structural lattice rather than steel. One of the smaller structures of the cluster of buildings is formed in this way and the remaining structures use steel pipe sections. The woven steel pipe grid is made up of ¾ inch steel pipes and uses four layers of chicken wire mesh that is filled with cement mortar. A channel at the concrete edge rim was planted with climbing plants to facilitate climate control.

The buildings are well-structured in terms of the placing of classrooms and office rooms.

The ease of movement that the structure offers makes it really easy for the staff to work and coordinate within the Institute. The brick structure of the corridors and the wooden ceiling reduces the anxiety which is usually felt by children and adults in new environments.

One of the best known grid shells may be "Multihalle Mannheim" (Atelier Warmbron, Frei Otto/ Mutschler & Partners/ Ove Arup & Partners) which was built for a garden exhibition in Germany in 1975. Although a much larger structure (9,500 sq.m. roof surface/ 60m free span/ mesh width 50cm), this shell has features in common with the Vocational Training Workshop: also a pioneer building, it is constructed with a timber grid and is covered by a PVC coated membrane.

9.3.3 The project: towards an advanced conservation plan

The Vocational Training Workshop grid-shell is made of a grid of interwoven steel pipes (¾" diameter with mesh width of 50 cm), which is covered by a light ferrocement shell. These two elements in combination are of special interest as they are mutually supporting each other and are forming a structural unit. Thereby the grid shell contributes the advantages of form and
erection as described above.

Figure 9.5: The building in April 2016.

The ferrocement, primarily introduced just as roofing of the grid shell, also has a remarkable structural impact. It increases the dead-weight of the overall shell, which has the advantage of ensuring the compression stresses in the shell surface, and takes a great portion of load bearing capacity. Furthermore, ferrocement is easy to apply on a spacecurved surface and requires little skills. Such techniques are critical in India where the building industry is flooded with un-skilled or low-skilled labour. In this way the BM shell represents a structural system, which combines all described qualities of the two components and is acting as a coherent architectural and structural unit.

The building, built in 1976, is now almost 40 years old and it is still in use. At first sight it doesn't show important deterioration or damages as it also survived the Gujarat earthquake in

2001, which measured 7.7Mw. However, from a deeper analysis it is possible to understand how time has passed since its construction leaving some signs of material instability and cracks. The examination of the present conditions of the shell and development of adequate methods for its
conservation will have not only an individual but also general scientific relevance.
This study will increase our knowledge about such shell structures and their characteristics and may eventually lead to improvement of some structural details as well as to the development of guidelines for future maintenance.

Figure 9.6: Internal view of vaulted ceiling in April 2016.

Careful investigation of all present defects and deficiencies in the shell surface as well as in the edge areas, individually mapping the locations of these defects and studying their possible interdependencies can essentially contribute to a better understanding of this kind of structural system in general as well as in the specific conditions of the Indian climate [3].
As already stated in this dissertation, the experimental atmosphere of modernism period brought also to India the willing to test new materials and shapes.
This, after 40 years has led to the need of a well-structured conservation plan able to maintain the building in good condition and pass it to future generation as an example of what Sarabhai did. For what

[3] Source: Nirmala Bakubhai Foundation Getty Foundation "Keeping it Modern Planning Grant Award"

concerns the steps able to provide the right information for an advanced conservation plan aiming at the effective repairing of this significant building the project has been divided into two phases. The first one aims at improving the knowledge on the building while the second one is completely addressed towards dissemination and awareness increasing programme.

Figure 9.7: Current photograph showing building's cracking and deterioration.

In both the phases international experts and local professionals will work together sharing their skills and capacities. The complex structure needs a comprehensive research and analysis to first understand what it is before deciding how it can best be repaired also to avoid bad intervention as the ones carried out during the last years on the roof' surface. In this framework the contribution of this methodology during the 8 months of project will be split in 6 phases:

Phase a) Researching and collating existing historical data in the form of drawings,
written documents and historical photographs.

Phase b) Topographic survey by total station (Leica TPS instrument type 1202 or equivalent). The use of this equipment will allow the formulation of the geometric structure by acquisition of coordinates of target, and the generation of a local system reference;

Phase c) 3D Laser Scanner survey by time-of-flight equipment (Leica type P40 or equivalent) with a scan speed of 500,000 points per second and 3 mm accuracy on the point. The use of this equipment will allow the survey of the geometric detail of the surfaces and DEM (Digital
Elevation Model);

Phase d) Photographic documentation (Canon 650D type or equivalent) on the building also used in order to describe the most important survey operations and areas that are most representative of the general state of conservation;

Phase e) Analysis of macroscopic morphologies of degradation affecting the dome surfaces; the survey will be carried out through high definition photographic survey, which will be an essential support to draw up a comprehensive picture of the state of conservation given the amount of hard to reach areas;

Phase f) Development of Virtual tour of the building taking advantage of 360 degree high resolution pictures taken;

Phase g) Development of geometrical single-disciplinary Building Information Model (BIM) of the object and garden area. The model will give basic shared knowledge of the data harvested from the analysis and will help to manage all information about the building; Any additional data on the condition of the building derived from detailed analysis and testing of the structural elements that may be deemed necessary in the course of this investigation will be incorporated into the digital model and reproduced in a separate set of line drawings to those described above.

The data gathered during the on-site survey will be organized in order to produce detailed drawings and graphic elaborations related to the different issues highlighted during the survey itself. This elaborations will include architectural drawings (such as plan and sections at different scale), diagnostic elaboration with characterization of individual defects or instances of deterioration (with photographs and physical description) and a BIM model.

Starting from the analyses of survey outputs the experts will be able to carry out their specific tasks. These will range from prescribing method of treatment including, developing methodology of repair (techniques and products to be used detailing specific product names, suppliers and costs if possible) and estimating quantities and repair costs with itemized material and labour quantities. Great attention will then paid to the grid-shell of the building, as at the moment it seems to be the most deteriorated part of the 40-years complex.

Condition mapping of the grid-shell and structure as a whole will be carried out to identify areas of potential damage, water-pooling and structural deformation.

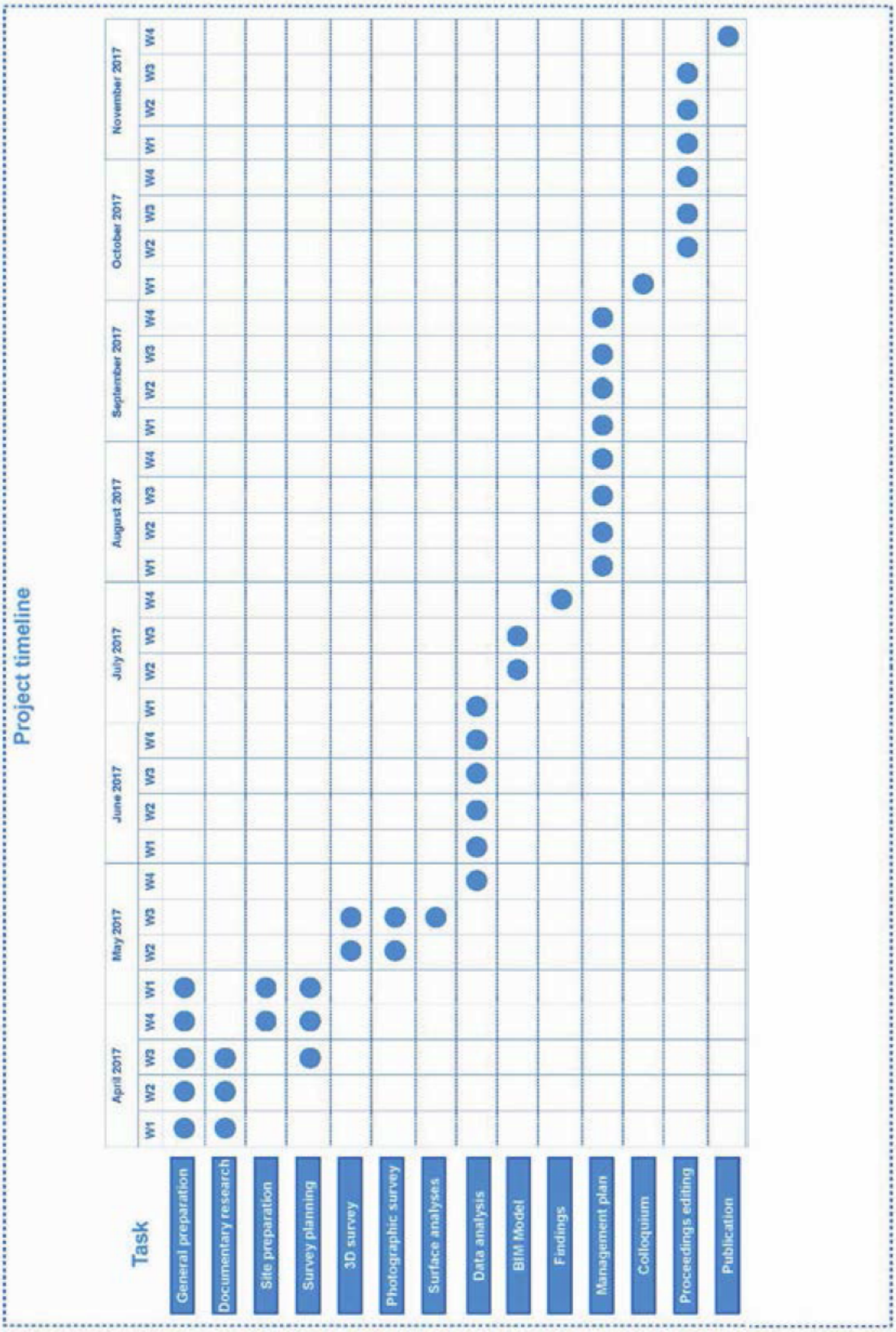

Figure 9.8: project timeline.

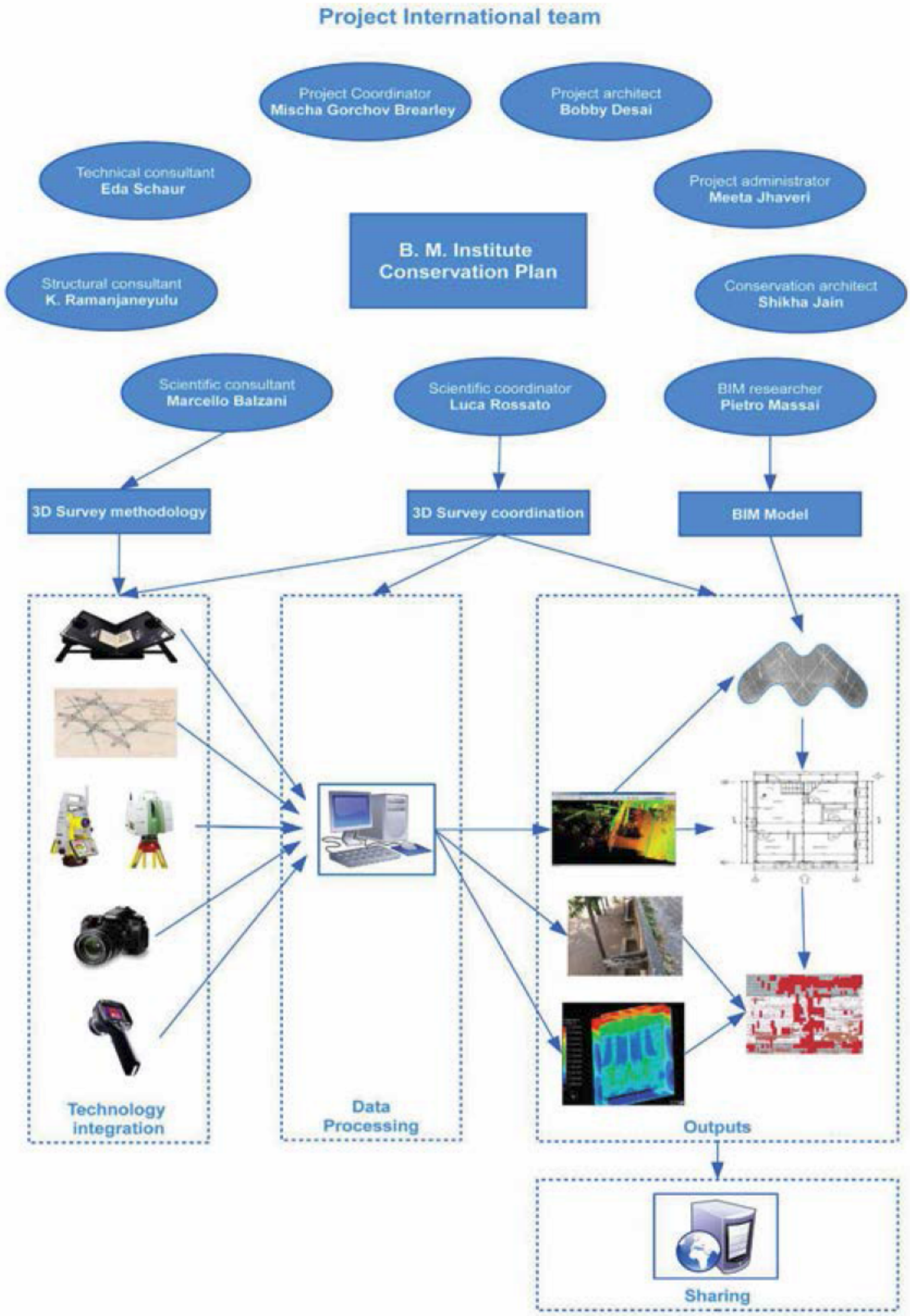

Figure 9.9: project international team and DIAPReM centre survey and representation tasks.

This analysis will require prediction of the original form and position of the grid-shell, which will be estimated through computer simulation using an appropriate form finding algorithm and verified using historical data and photographic information. The estimated original position will be compared to the existing form and position using the point cloud data acquired through laser scanning survey and photogrammetric analysis. This analysis will be prepared by members of the Structural Engineering and Scientific research teams. The results of this comparative study will be presented on the BIM model and as a set of drawings”[4].

[4] Source: N.B. Foundation ‘Keeping it Modern’ Grant Award Project Planning Document

Libraries and research centres consulted during the research

In order to have a more clear picture about the modern architecture scenario, research steps have been carried out in different countries taking into account the most important centres for the preservation of the modern heritage.

ALBANIA

Polis University Library
Rr. Bylis 12, Autostrada Tiranë-Durrës, Km 5, Kashar
Kodi Postar 1051
Tirana

BRAZIL

Pontificia Universidade Catolica do Paranà (PUCPR) Central Library
Campus Curitiba
Rua Imaculada Conceição 1155
Bairro Prado Velho
Curitiba, 80215-901
PR

Facultade de arquitetura e urbanismo Universidade de São Paulo Library
FAU Cidade Universitária
Rua do Lago 876
São Paulo, 04280-000
SP

Mackenzie University Architecture Library
Rua da Consolação, 930
Bairro Consolação
São Paulo, 01302-090
SP

FRANCE

Burgundy School of Business Library
29 rue Sambin
Dijon, BP 50608 - 21006

INDIA

CEPT University Library
Kasturbhai Lalbhai Campus,
University Road, Navrangpura,
Ahmedabad, 380 009
Gujarat

IES College of Architecture Library
Reclamation, Bandra West,
Mumbai, 400050
Maharashtra

David Sassoon Library and Reading Room
152, Mahatma Gandhi Road, Fort
Mumbai, 400001
Maharashtra

University of Mumbai Library
M.G. Road, Fort
Mumbai, 400 032
Maharashtra

ITALY

Giovanni Astengo Library
IUAV University of Venice
Department of Design and Planning in Complex Environments
Venice, Santa Croce 1957

Mario Zaffagnini Library
University of Ferrara
Department of Architecture
Ferrara, Via Quartieri 8, 44121

USA

Getty Research Institute Library
The Getty center
1200 Getty Center Drive
Los Angeles, CA 90049-1679
California

Berkeley University of California Environmental Design Library
University of California
210 Wurster Hall
University of California
Berkeley, CA 94720-6000
California

Images credits

Chapter_1

Figure 0: Scheme by the Author

Figure 1.1: Scheme by the Author

Figure 1.2: Collage by the Author / Source Web

Figure 1.3: Graphic elaboration by the Author

Figure 1.4: Drawings by A. Sousa, I. Bulgaru, M. Abdelhaj

Figure 1.5: BIM model by E. Ranuzzini, O. Ballardini, D. Felloni.

Figure 1.6: Rendering by E. Ranuzzini, O. Ballardini, D. Felloni.

Figure 1.7: Photo by the Author, 3D elaboration by DIAPReM centre

Chapter_2

Figure 2.1: Graphic elaboration by the Author

Figure 2.2: Collage by the Author / Source Web

Figure 2.3: Collage by the Author / Source Web

Figure 2.4: Source Web

Figure 2.5: Source Web

Figure 2.6:

Source left image Cavalcanti, L., 2003. When Brazil was modern: guide to architectture, 1928-1960, New York: Princeton Architectural Press.

Source right image Lang, J.T., Desai, M. & Desai, M., 1997. Architecture and independence: the search for identity: India 1880 to 1980, Oxford: Oxford University Press.

Figure 2.7:

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Chapetr_3

Figure 3.1:

Source left image Web

Source right image Cavalcanti, L., 2003. When Brazil was modern: guide to architectture, 1928-1960, New York: Princeton Architectural Press.

Figure 3.2: Source Segre, R., 2013. Ministério da Educação e Saúde, São Paulo: Romano Guerra Editora.

Figure 3.3: Source Portinho, C., 2000. Affonso Eduardo Reidy, Cascais: Editorial Blau.

Figure 3.4: Source Artigas Camargo, R., 2015. Vilanova Artigas, São Paulo: Terceiro Nome.

Chapter_4

Figure 4.1: Source Web

Figure 4.2: Source Dilwali, A., Ganguli, R. & Vir. Mueller Architects, 2010. Golconde: the introduction of modernism in India, New Delhi: Urban Crayon Press.

Figure 4.3: Image by the Author

Chapter_5

Figure 5.1: Scheme by the Author

Chapter_6

Figure 6.1: Scheme by the Author

Chapter_7

Figure 7.1: Image by the Author

Figure 7.2: Scheme by the Author

Figure 7.3: Chart by the Author

Figure 7.4: Image by the Author

Figure 7.5: Image by the Author

Figure 7.6: Image by the Author

Figure 7.7: Image by the Author

Figure 7.8:

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Figure 7.9: Graphic elaboration by the Author

Figure 7.10: Images by the Author

Figure 7.11: Images by the Author

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Figure 7.14: Source image the Web

Figure 7.15: Images by the Author

Figure 7.16: Source image the Web

Chapter_8

Figure 8.1: Graphic elaboration by the Author / Source Web

Figure 8.2: Graphic elaboration by the Author

Figure 8.3: Graphic elaboration by DIAPReM centre

Figure 8.4: Graphic elaboration by the Author

Figure 8.5: Graphic elaboration by the Author

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Figure 8.13: Graphic elaboration by the Author

Figure 8.14: Graphic elaboration by DIAPReM centre

Figure 8.15: Graphic elaboration by DIAPReM centre

Figure 8.16: Graphic elaboration by DIAPReM centre

Figure 8.17: Graphic elaboration by DIAPReM centre

Figure 8.18: Graphic elaboration by DIAPReM centre

Figure 8.19: Source Fundaçao Oscar Niemeyer

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Figure 8.21: Graphic elaboration by the Author

Figure 8.22: Graphic elaboration by the Author

Figure 8.23 Graphic elaboration by DIAPReM centre

Figure 8.24: Graphic elaboration by DIAPReM centre

Figure 8.25: Graphic elaboration by DIAPReM centre

Figure 8.26: Graphic elaboration by DIAPReM centre

Figure 8.27: Images by the Author

Figure 8.28: Graphic elaboration by DIAPReM centre

Figure 8.29: Graphic elaboration by DIAPReM centre

Figure 8.30: Image by the Author

Figure 8.31: Scheme by the Author

Figure 8.32: Image by the Author

Chapter_9

Figure 9.1: Source Sarabhai Foundation

Figure 9.2: Source Sarabhai Foundation

Figure 9.3: Source Sarabhai Foundation

Figure 9.4: Source Sarabhai Foundation

Figure 9.5: Image by the Author

Figure 9.6: Image by the Author

Figure 9.7: Source images Pietro Massai

Figure 9.8: Image by the Author

Figure 9.9: Image by the Author

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