Historic Building Information Modeling: from historical database platform to fully suitable and multidisciplinary design instruments

Fabbrica della Conoscenza

XIV Forum Internazionale di Studi

Le Vie dei Mercanti

Carmine Gambardella

WORLD HERITAGE and DEGRADATION

Smart Design, Planning and Technologies

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WORLD HERITAGE and DEGRADATION
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More than 550 authors involved.
212 papers published.

Preface

The theme of the XIV Forum “Le Vie dei Mercanti” is an international discussion on the disciplines of architecture, design and landscape through the presentation of research and operational projects on the conservation and valorisation of World Heritage and “smart” regeneration of degradation, with analyses and proposals ranging from the design at all scales, to architectural assets, the territory, infrastructures and the landscape. Academics, along with professionals who have a role in the governing, managing and controlling of public agencies, institutions and the business world are invited to submit papers related to design objects, architecture and landscapes. This is with the aim of conserving and recovering, valorising and regenerating, managing and designing (or re-designing), for the more general improvement of the quality of life, in an innovative and contemporary relationship between man and the environment, through “beauty”, while respecting the history, traditions, identity and principles of sustainable development, as well as being attentive to the needs of our and future generations. Internet of Everything, smart design, planning and technologies, building information modelling, in this age of globalization, have become operational tools – that alongside the traditional ones of the profession – for the protection and promotion of the World Heritage, are considered as well as shared by the whole of Humanity, and the regeneration of the degradation and the “Minor Heritage”, in all aspects, and as contemplated by the UNESCO Conventions on tangible and intangible assets and the European Landscape Convention. The event aims to create a critical transversal dialogue, open to cultural and “unlimited” influences, in a logic of integration between the skills that extends, and is not limited, to the following disciplines: anthropology, architecture, archaeology, history art, cultural geography, design, ethnology and folklore, economy, history, landscape, museum management, philosophy and political science, urban history and sociology, cultural tourism, planning and integrated management. The location is exceptional. Campania, with six sites included in the World Heritage List, two UNESCO Man and Biospheres, two sites on the List of Intangible Heritage, is one of the richest regions in the world for cultural and landscape heritage.

Carmine Gambardella

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Historic Building Information Modeling: from historical database platform to fully suitable and multidisciplinary design instruments

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Abstract
The aim of the research intends to provide innovative solutions to the more and more hard challenge of organizing in a virtuous manner the information concerning the architecture patrimony: the realization of complex parametric models could guarantee a formal, architectural and relational coherence, inside a shared virtual system. The HBIM (Historical Building Information Modeling) represent virtual models for cultural assets, essential supports to archive, compare, manage and design heterogeneous data that constitute the building: its analysis give the possibility to interpret it in a sort of "as-is" model, made by deductions coming from information derived by archivist, geometrical and topology data contained into the virtual model. The report will focus particularly on the case study of the V Pavillion made by Riccardo Morandi nearby the Torino Esposizioni exhibition building cluster: built using the pre-stressed technology on concrete lowered arcs, it passed very fast from being an iconic building of the excellent Italian engineering school of the post-war period, to a debatable and malfunctioning municipal garage. For this reason the virtual model could be helpful to collect on one side a fully shared information database capable to transfer all the historical path of the building, and on the other the efficient and multidisciplinary instruments supporting future design interventions on the next period.
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Keywords: Cultural Heritage, HBIM, database, V Pavilion, Morandi

1. Introduction: towards virtuous multidisciplinary approaches (MLT- EB)
This paper aims to explore the possibilities offered by a new design method called Building Information Modeling, as a wise relationship between drawing and database. This virtual environment organizes geometrical data, material performances and quantity take off. These data are associated with AEC components to virtually simulate the construction (or restoration) phase of the building. In recent years, the systemic approach to a new way of conceiving the building process is rapidly spreading both in the scientific community and in professional practice, thanks to the recent international guidelines that promote the BIM adoption as the proper methodology to be used, with legal consequences related to the reliability degree of the model.
It is worth mentioning that the adoption of BIM methodologies in many foreign countries (Northern Europe and US among others), together with the tendering reform approved by the European Parliament indicates a growing demand for the use of BIM methodologies in designing operations in the public construction sector [1]. This methodology can be considered virtuous practice but increasingly widespread for new construction, especially for interventions of great importance; surely the practice applied on Cultural Heritage buildings is less explored. No guidelines are now available to define a

workflow useful to preserve the permanence of the information and to wisely relate the entire dataset, starting from the survey up to the new proposals for the construction project: this procedure could be designed using a single virtual environment shared by individual professionals. As often happens, the research seems to be at the forefront of professional practice: in this regard we briefly show some authoritative eminent samples classified as HBIM [2].

2. The status of art (MLT)

The features of a BIM-based approach can be effectively used for the investigation on existing buildings, through a catalog, hierarchical and implementable, that recovers the heterogeneity of the information related to Cultural Heritage, starting with the amount of data that must be organized for a survey: original drawings, historical and recent pictures, inspection and degradation analysis, to name a few. The BIM database is able to recover such information and constitute an indispensable resource for different professionals that could be involved in the protection, intervention or management of the building.

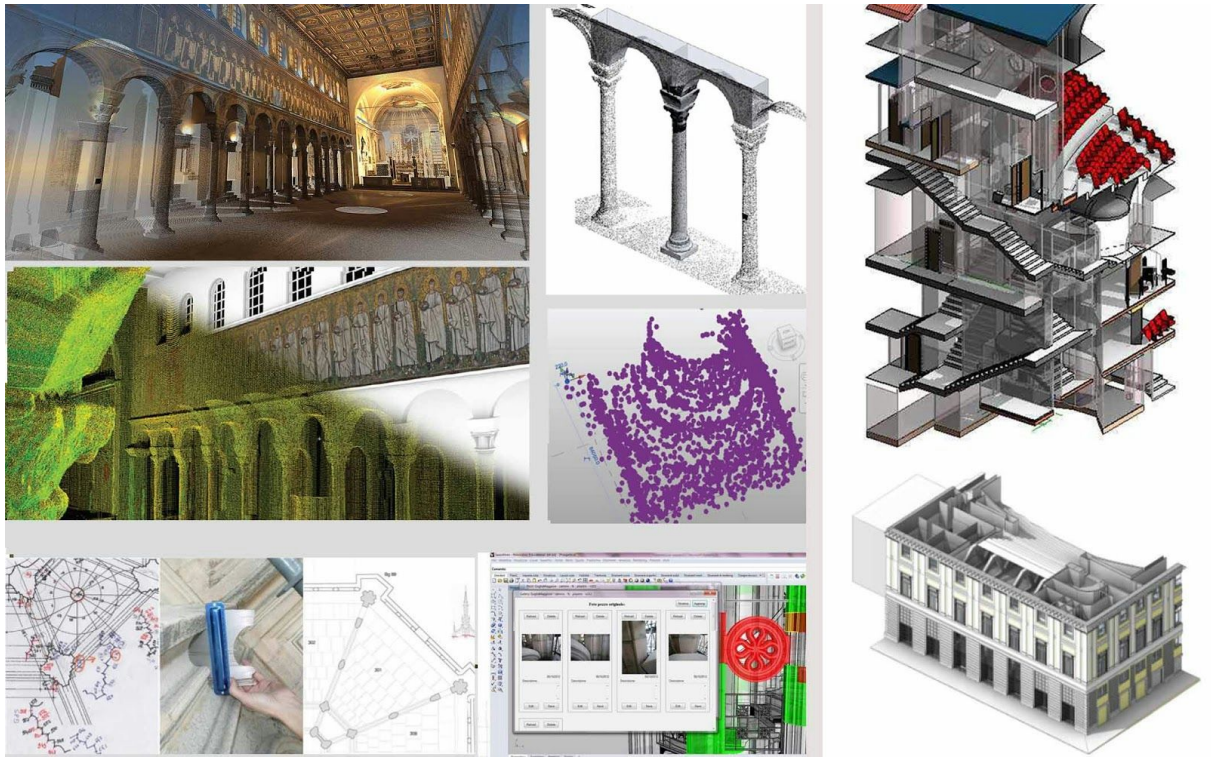

Fig. 1: On the right: BIM model of the Teatro Lirico, in Milan. On the left, above; point clouds and virtual reconstructions of the church of Sant'Apollinare, in Ravenna. On the left, below: survey procedures and database implementation connected with 3D Modeling of the Gran Guglia del Duomo, in Milan.

A virtuous example is the restoration project of the Teatro Lirico in Milan, achieved by combining BIM and laser scanning to establish an important precedent for the government. It is a complex and innovative process, which is essential to check the actual building conditions, even for those environments difficult to be measured that have been modeled in a virtual form using geometric information acquired from the point clouds.

A second example is the intervention on the Veneranda Fabbrica del Duomo, in Milan: the SITECH3D group (Surveying Information Technology for the Environment and Cultural Heritage) has set up a 3D BIM WEB consistent with the contents of a 1:50 scale, through a strong integration between laser scanners, topography, photogrammetry and direct survey. The previous restoration works were made by Ambrogio Nava in 1844 and Carlo Ferrari da Passano between 1962 and 1967); in recent years it is taking place the third intervention at the Guglia Maggiore of the Duomo; but this is the first major restoration that will leave a very detailed documentation for future references. In fact, using the special scaffolding built just for the restoration, it was taken over each part of the Gran Guglia, from the lantern to the Madonnina statue, modeling every single part with Rhinoceros. All virtual models are NURBS surfaces that enable more efficient evaluations and simplify calculations rendering.The image database contains a photo collection of each object, to keep track of the interventions done [3]. Another case study that demonstrates how this approach can be successfully applied on the existing architectural heritage is

the research work on the church of Sant'Apollinare Nuovo in Ravenna: the virtual reconstruction of the Byzantine church was made through the revision of the point cloud imported into the parametric platform, too; but unlike the other case studies a plug-in has been designed to convert portions of point cloud into reference points (recognized by the BIM software as editable objects) more effectively used to make a virtual reconstruction semantically reasoned [4]. A similar experience concerns the conversion of the old heating stuff of the Politecnico di Torino into new classrooms, where we personally investigated the transition from the point clouds and the BIM model [5].
Finally, it is worth considering Maurice Murphy's work [6], perhaps one the first to deal specifically with Historic Building Information Modelling. He Defined his PhD work as a novel prototype library of parametric objects, based on historic architectural data, in addition to a mapping system for plotting the library objects onto laser scan survey data. Briefly, this HBIM sample process begins with remote collection of survey data using a terrestrial laser scanner, then followed by the processing of the laser scan survey data to generate ortho-image and segmented point cloud data for mapping of library objects. The next stage involved the design of new shape and parametric rules for the construction of a library of objects that are based on 18th century architectural pattern books. Finally, HBIM can automatically generate conservation documentation in the form of survey data, orthographic drawings, schedules and 3D CAD models, both for the analysis and for the conservation of historic objects..

3. The historical strata of the V Pavillion of "Torino Esposizioni" as multidisciplinary case study (EB)

The V Pavillion of Torino Esposizioni is an underground exposition building, designed between 1958 and 1959 by the famous prestressed Italian Engineer Riccardo Morandi [7] (better known for his realization of the iconic bridge of Maracaibo bay in 1957) and the Director of that time of the Office "Servizi Costruzioni e Impianti Fiat" Vittorio Bonadè Bottino. The project was carried on by the Society "Torino Esposizioni" owner of the near and huge spaces already drawn between 1949-1950 by the other great protagonist of the Italian experience in concrete structures, Pier Luigi Nervi [8] and Ettore Sottsass. "Torino Esposizioni" Society was searching since the middle Fifties new spaces for its annual car exposition, attracting every year many people all over the world in Turin, presenting itself as key economic player in car industry.
The difficulties in founding big open areas around Nervi's project, prompted the Torino Esposizioni Society looking at the near void areas of the "Valentino" Park, where the license gave in 1934 to the "Società Ippica Torinese" for its horse riding activities was expiring in 1958, proposing to the Mayor of the City Amedeo Peyron a new economically profitable utilization of the areas, creating an exposition cluster of different pavilions.
The utilization of these areas addresses the question of the stratification of the historical purposes of a transforming industrial city like Turin that, since the Nineteenth Century, trying to expresses itself as the main industrial player of the country, has obviously changed many times its urban image. This process has occurred by continuous demolitions and new projects submissions, intending the peripheral area of the "Valentino" Park as spaces for consumption more than the nowadays theoretical framework of patrimonialization, forgetting the historical layers delivered to us.
For this reason is necessary to understand the background of the "Valentino" Park that has hosted between Nineteenth and Twentieth century, exactly in the area of the V Pavillion, many international exhibition (in 1884, 1898, 1902, 1911 and 1928), showing itself more as an creative hub than as a natural resource for the city.
For example in the specific area now occupied by the V Pavillion since 1872 to 1933 persisted an artificial lake made up for winter skating and rowing leisure during the hot seasons [9]. This utilisation had many interruption due to the International Exhibitions, transformed and covered due to miscellaneous purposes. The nearby university of the Polytechnic of Turin, using its water for hydraulic experiments, compromised its function and in 1933 was substituted by the above mentioned "Società Ippica Torinese" that was formed in 1932.
The history beyond the site of the V Pavillion suggests a research that, despite compressed in less the one hundred years, recalls an archaeologist approach. In the practical operation of reviving all the different utilizations, it's possible to reconstruct also the reasons why the city has always sees this area intending leisure in a consuming way.
In this way, at the beginning of the 1958, emerged a contraposition showing on one side the "Torino Esposizioni" Society, Fiat Company and the city local government supporting the new initiative for a new exposition building, and on the other the Agency for the Historical preservation that officially neglected the permission for a new construction. "Torino Esposizioni" Society was searching for a concession from the local government that, at that time, was giving its political support. The opposition was carried on by

the former Director of the Agency Arch. Umberto Chierici, that expressed a negative judgement based on the necessity to preserve the natural landscape of the Park that could have been completely destroyed its identity by reducing the available green areas. The political and institutional battle around the construction assumed hard tones and, in front of the difficulties on carrying on the project, the Director of the Society “Torino Esposizioni” even faced the possibility to move to other cities the annual car exposition with a certain economical effects for the city image. But an important effect that emerged by this contraposition is the effort made by the Società Costruzioni Impianti Fiat, in overcoming the position of the preservation agency in proposing different solutions for the new building, finding consensus through different architectonic image. In this way there were proposed five solutions that, starting from a building over the ground, gradually moved to a completely underground space, defending the green spaces. Thanks to these attempts in 1958 the “Torino Esposizioni” Society found a positive counsel from the Ministry of Education (responsible at that time for landscape and heritage matters), despite at local level persisted an hard opposition. The final response, achieved with a long political discourse at national level, combined all the contradictions over the underground project, acceptable for maintain the image of the landscape, but risky in its long term economic vision [10].

Obtained the approval the engineering machine, that combined both the twenty years of experience of Riccardo Morandi in prestressed construction and “Servizio Costruzioni e Impianti Fiat” sitework organization and methodology, the project was built in the record time of six months, employing 250 people per day, and just in time for the opening ceremony of the 41th Turin car exhibition. The pavilion is the top expression of Riccardo Morandi in managing the structural grid of the balanced beam where, after twenty years of applications in many infrastructural projects, it’s applied into a building open to the public [11].

But despite the considerable elements in history of engineering and concrete construction [12], some causes generated a slow decline in the utilization of the V pavilion, emptying it of its core businesses in the following decades. Above all the inauguration of the Italy ’61 area for the celebrations of the first 100 years of the Italian reunion shifted the exhibition zone outside the Valentino Park towards a new peripheral area. Another reason has to be searched in the economical decrease of the whole industrial compound of the city, passing from the enthusiastic tones of the Fifties and the Sixties to the necessity of figuring out a post-industrial rehabilitation, where huge containers like the V Pavillion have difficulties to be maintained. In addition has to be considered the underground disposition of the building that, excluded from an integration into the urban landscape, appeared secondary to the nearby building of Torino Esposizioni facing the main streets: its dark and not so tall interior aspect resembles it more like a garage [H] than a wide trade fair centre, excluding it from many possible activities.

Remembering important fairs like FLOR ‘61 in 1961 or fixed annual event of the Mountain Exhibition since 1970, the building decline stopped in 1989 when the Society “Torino Esposizioni” didn't renovate its concession and passed the property to the City of Turin. The first decision of its transformation into public parking lot, despite its marble pavement, deeply necessitated to reconverts its spaces. The project, operated by the local transportation company ATM (now well known as GTT) in 1998, completely distorted the original image of the building, inserting new walls and covering the concrete surfaces according to fire protection laws, and closing 11 skylights on the rooftop that reduced the natural illumination of the whole building. Another important implementation came out in 2003 when it was intended to transform the covering surface of the pavilion in order to be used with public amenities. Despite some conceptual solutions thought for sports and kids gardens the final result, in order to be finalized for the Winter Olympic games in 2006, showed only the presence of a plastic green surface on the rooftop, completely not integrated with the surrounding green areas and distorting the original idea of an underground building in order of maintain untouched the surrounding park landscape [13].

The parking lot imagined during the Nineties, despite could have resolved many traffic congestion of the district, was not used enough forcing at the end GTT Company to close it to the public. This stagnation opened the debate inside the city government to find a comprehensive new utilization. The occasion resulted in 2013 when “Politecnico di Torino” and the City signed an agreement for a preliminary investigation around the topic of creating a creative cluster for a public library and the Campus for the school of Architecture in the former spaces of “Torino Esposizioni”. The intentions have to be seen in the volunteer to create along the Po river an urban axis working as collector for cultural and natural activities, an urban regeneration supported by the presence of iconic buildings searching for a post-industrial sustainable utilization. Taking into consideration the UNESCO site of the “Valentino” Castle, the former “Torino Esposizioni” building designed by Sottsass and Nervi, the V Pavillion drawn by Morandi and the many others infrastructures inside the park, they constitute a net of functions that could be reconvert in order to become strategical in enhancing the image of Turin as a cultural capital city. Politecnico di Torino, called to present a specific study for the project, inserted it in its “2014-2018 University

Strategical Plan", while a public competition promoted by the City has terminated in mid February 2016 in order to assign its development to the best architectural firm.
The recent events, following the overlapping transformation occurred on the site since the building decline, suggests the researches to focus on the creation of a strong knowledge base occurring before any modification. Only a deep consciousness on the many aspects of the different historical layers could give mean to the maintenance of identity shared with the (pursue?) of new profitable functions. Crossing fieldworks professional surveys and archive research on the processes beyond an iconic building like the V pavilion not only could scientifically preserve the modern heritage, but also gave to the future decision-maker a fully comprehensive instrument, immune from rhetorical abuses and capable of representing the intervention limits.

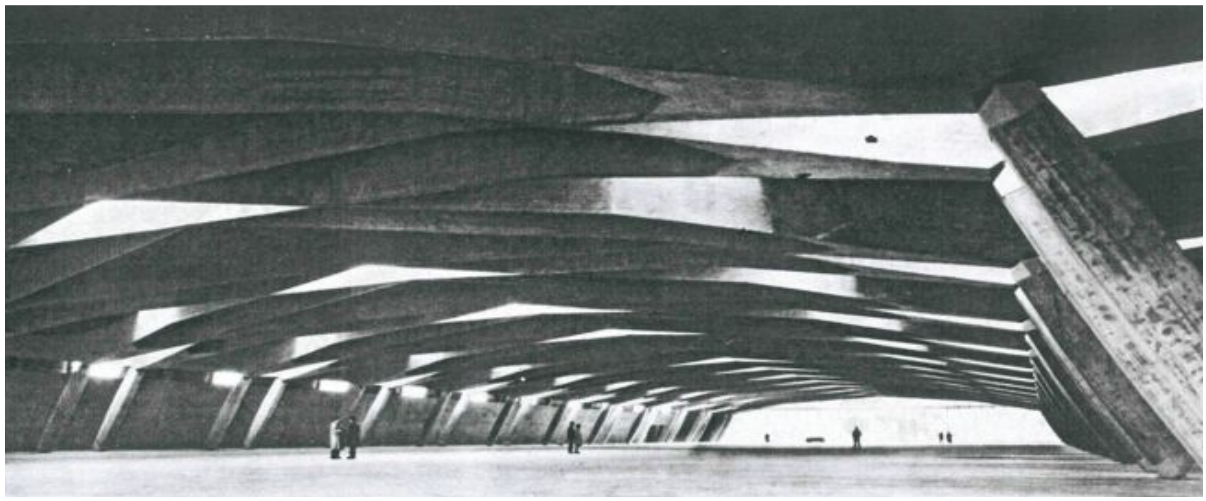

Fig. 2: Internal view of the V Pavillion in its original composition just after having finished the sitework in 1959.

4. The knowledge approach for Cultural Heritage in the Digital Age (MLT)

The process aims to critically evaluate whether the BIM approach of geometric/relational nature can contribute to the knowledge and the enhancement of Cultural Heritage, often overlooked and today involved in a dynamic upgrading work. The work consists of two parts: the first one deals with analyzing the various project proposals for V Pavilion, to define an expertise useful to better understand the design choices made by Morandi. The second part relates to the virtual reconstruction of the building following a critical path, implementable and easy to be consulted [14].

4.1 From the simulation of different solutions ....

The historical analysis began with the modeling of five solutions (with associated sub-options) proposed by the Servizio Costruzioni e Impianti Fiat in 1958, before the Morandi's solution that outlined the present structure of the room. This was done to understand which was the process that led to the genesis of the final version: through the analysis applied by a BIM model, it is easier to understand the inspiring reasons of that structure. The modeling of different solutions has been carried out on the basis of design drawings kept in the Maire Tecnimont archives. These are five solutions for a total of eight different design options, shown through a comparison between axonometric and internal perspective views. The first and the second solutions have three and two choices respectively. The first solution provided for the creation of a single level glass prism overground with three variations of the external windows.
From the second solution on we attend to a progressive mimesis of the pavilion with the Valentino park. The mimesis can be considered complete with the proposal of a completely underground hall (third solution). It was used the Light Analysis for Revit plug-in to quantify the internal natural lighting, defining the geographic location of virtual models and material consistency of the building elements.It was set the simulation of different lighting conditions, using a specific parameter taken from the LEED system by identifying the percentage of gross floor area subject enlightened, between 300 and 3000 lux at 9 am and 3 pm, during the equinoxes. The analysis was integrated with lighting conditions at the solstices, simulated by a setting range between 100 and 750 lux for the illumination of workplaces (two values derived from the Italian norm UNI EN 12464-1) to evaluate the average levels to ensure. The obtained results shows the overexposure of the first solution and the gradual reduction of the percentage of the other ones, however, contained into acceptable ranges.

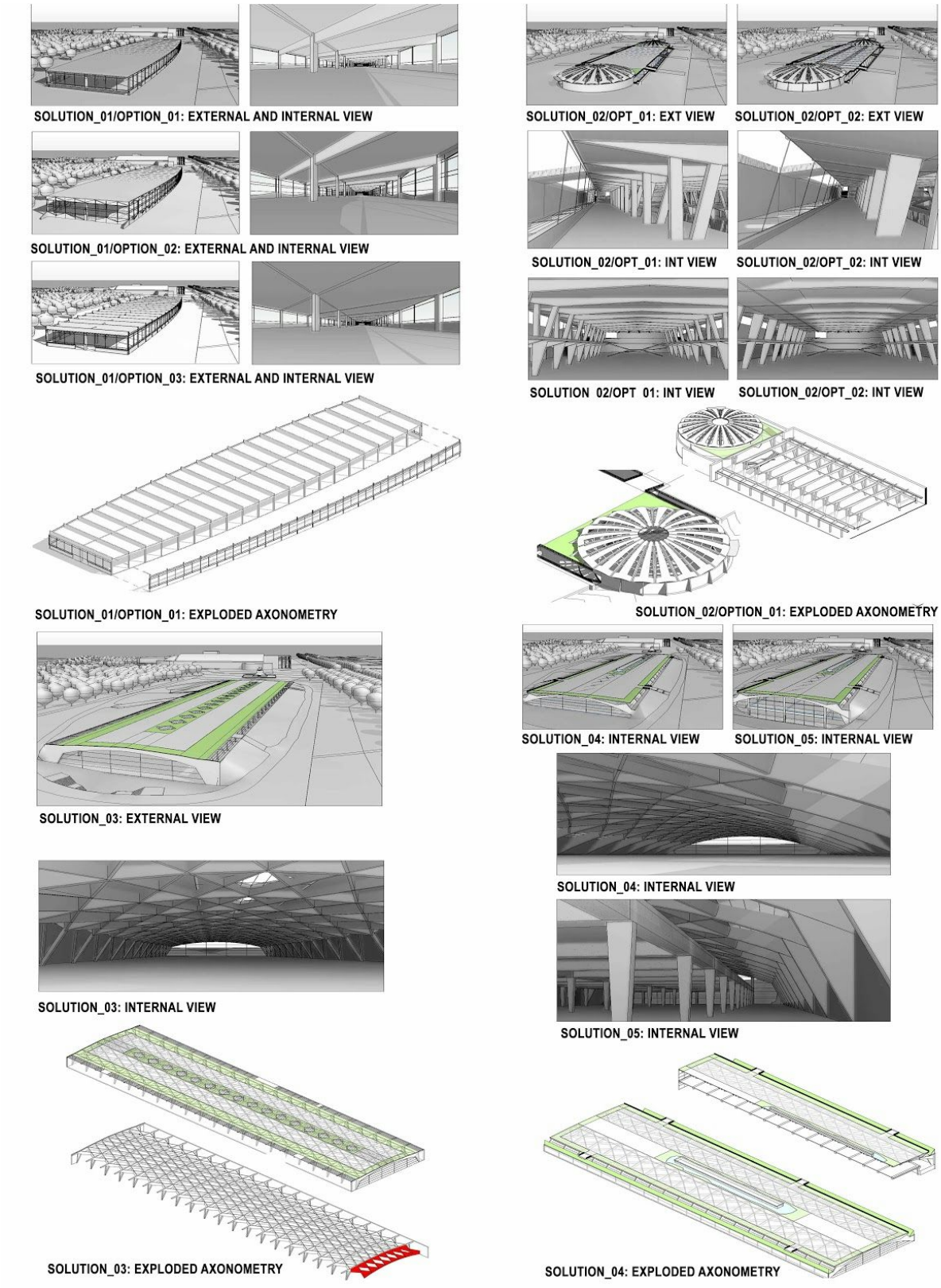

Fig. 3: The different solutions (and options) compared together using bird's eye views, internal perspectives and isometric views derived from a single BIM model able to collect such data.

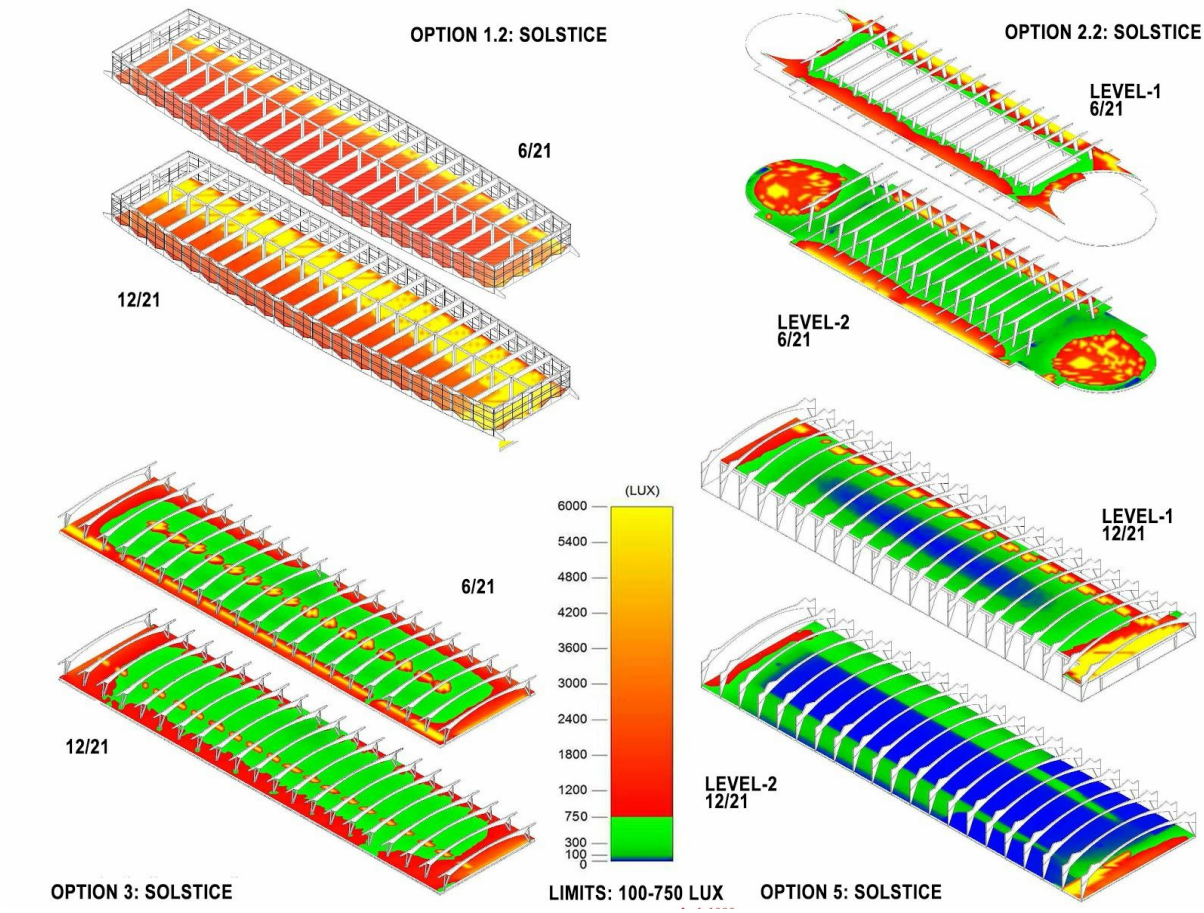

Fig. 4: Lighting analysis of the interior of some proposed design solutions.

4.2. .... up to the modeling of the status of art

The survey of a typical structural span has been conducted to model the actual state of the pavilion, relying on symmetry and the modularity of the building, through digital photogrammetric techniques [15]. They were taken 175 photos, divided into four series (at increasing distances and variable angles) related to the selected span. The frames were then processed with Agisoft PhotoScan software that interpolates set of three frames to extract the common points. Each point is characterized by three spatial coordinates and the RGB code. The software showed a 0.56% error: this percentage is contained within the graphic error; so, it can be considered acceptable for the level of detail used in the representation scale 1: 200 [16].

The obtained point cloud represents the spatial reference for modeling: for the inclined connecting rods it was made a comparison with the measures of the original drawings. The references have been imported into Autodesk Revit: using several elevations above the floor level, the silhouettes have been identified, allowing to create the volume of the connecting rods. The measures confirm that the slope of the connecting rods is identical to which indicated in the original drawings, while it was registered a difference of 4 cm in the distance between the support surface of the pillar and the one at the hinge. This error (equal to 0.9% of the entire length) can be considered an acceptable value because of the adopted representation scale. Regarding to the measurement of the width of the hexagonal generating silhouettes of the connecting rod, it also highlights a variable deviation between 1 and 3 cm: this value is comparable to the thickness of fire-retardant foam with which the GTT (Gruppo Torinese Trasporti) in '96 has plastered the pavilion structures to make them fire resistant. A similar process involved the modeling of the roof beams: the point cloud was overlaid on digitized original drawings: referring to the indicated sections were defined 19 different sections, and for each section it was analyzed the correspondence between the original drawings and the spatial coordinates of the point cloud to define the elevation of the soffit of the beams. Particular attention has been paid in the modeling of the hedge element, subjected to multiple interventions over time. The BIM model allows to relate the digital model with three time phases, corresponding to the most significant interventions that involved the pavilion: the project of 1959, the transformation and the related functional adaptation in the car park and the municipal reorganization in 2006. In each view (graphic or alphanumeric) the number and type of the elements provided for a given operation can be displayed, highlighted and counted: for example the closure of low skylights only

appear in schedules of 1996; the same for the iron grills that allow natural ventilation created by the GTT and for the transformation of the skylights: the original drawings were used to understand the technological details of the low skylights closed in '96 and those defined as "high", for each stage of processing; as known, the BIM platform allows to assign a creation and a demolition phase to each modeled component. The study of the levels of internal lighting of each transformation of the V pavilion followed the same criteria described for the analysis of previous solutions; in fact, this drew attention to a substantial decrease of lighting levels after GTT's adjustment works: the closure of more than half of the skylights has significantly decreased the internal visual comfort.

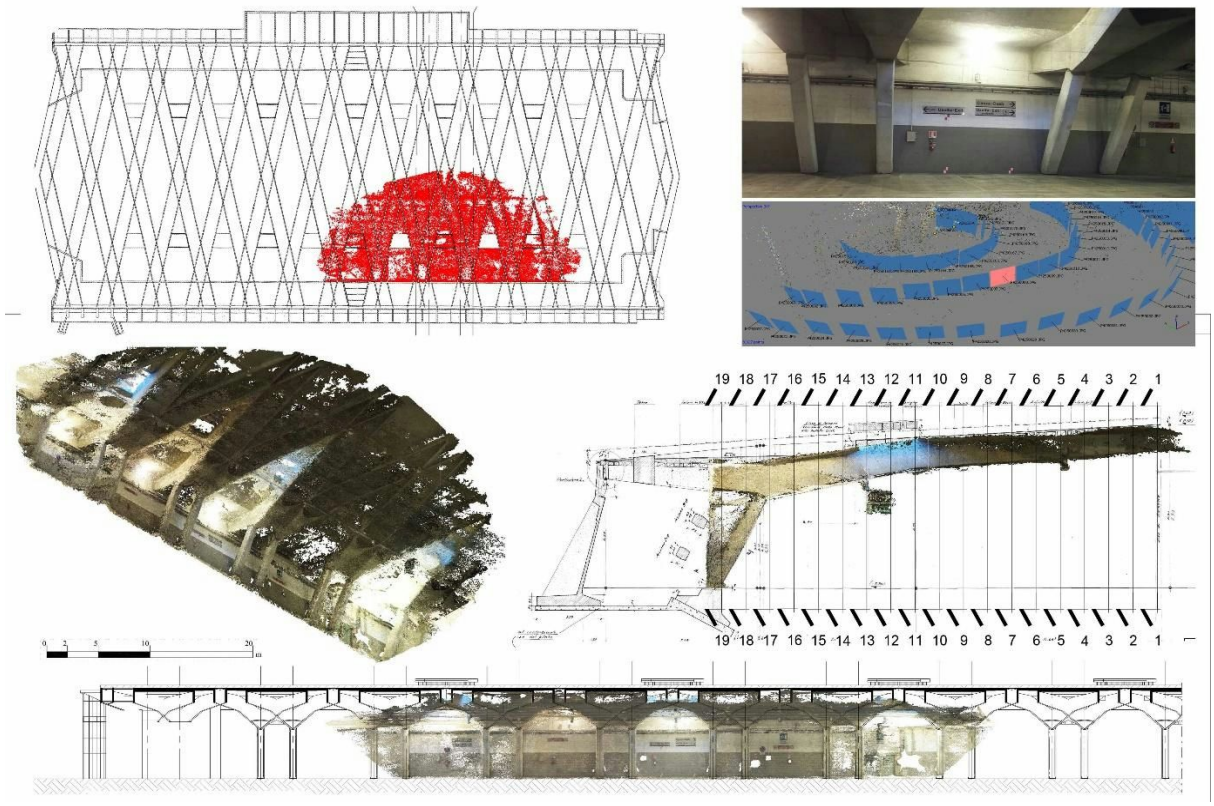

Fig. 5: A summary of the selection and measurement of spatial coordinates with reference to the inclined connecting rods of V Pavilion.

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5. The new central role of Drawing: ideas for future research (MLT - EB)

At the end of the modeling process we have worked on the database to organize the different information gathered. All documents used for modeling, in fact, have been linked to their virtualized components, associating an image parameter to the different elements categories. This implementation allows to link together in a unique virtual environment the various original sources, often kept in institutions or funds not always available. The virtual reconstruction permits multiple queries and the production of thematic drawings (such as the identification of the different measurement instruments, the evaluation of the types of degradation, the fourth dimension control, etc...). The ideal development of the research work will help to create a sort of maintenance booklet, useful throughout the building lifecycle; in addition, the next transformation of the Pavilion will be certainly more aware and compliant if compared to the previous interventions.

From the operational point of view it is easy to foresee a significant improvement on data management, through procedures able to make effective the collection of several information, from earlier stages of design and construction (vertical integration) up to processes that belong to different areas of Facility Management (horizontal integration services). The aim is to make even closer the relationship between the maintenance schedule and the set of design and construction documents tools for the definition of new government rules of the building process [17]. At this regard it seems feasible to figure out some future integration between the documents produced by the examined digital techniques and the current methods of cataloging and management of cultural heritage, with a particular reference to the guidelines defined by the Istituto Centrale per il Catalogo e la Documentazione.sponsored by the Ministero dei Beni e delle Attività Culturali e del Turismo, that is the responsible for the definition of standard protocols for this specific topic.

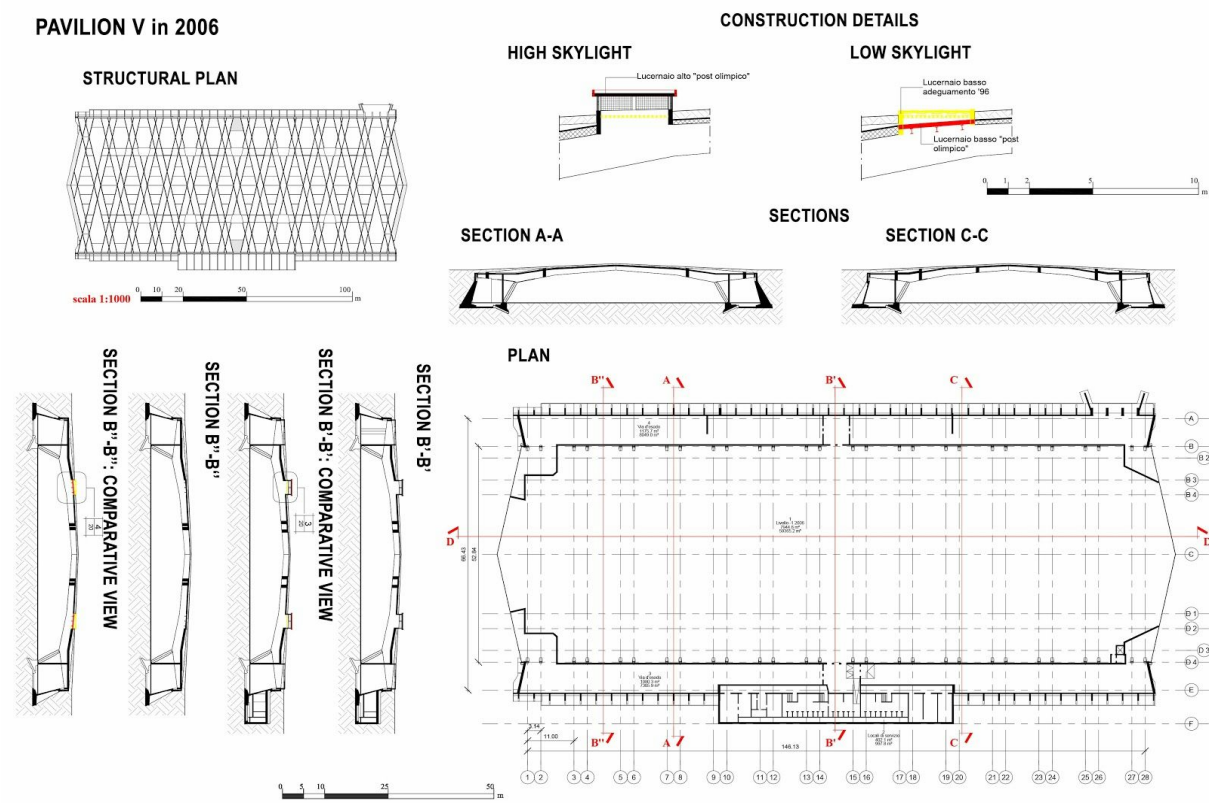

Fig. 7: Digital reconstruction of V Pavilion in 2006: plans, sections and construction detail filtered by thematic views (red: new constructions, yellow: demolitions) obtained by the BIM model.

The cataloging system currently used is based on the use of schedules that contain documentary, geographical or technical informations, linked in a dynamic way to other more specific ones, together with more digital and archival contents. A parametric model is able to contain multimedia and documentary information, allowing to relate them to three-dimensional objects that can be compared with the actual building: an update of the architectural heritage schedules could make use of a link useful both to a virtual exploration of the building and to relate together graphical and tabular documentation obtained from the 3D model. Data accessibility and communication may finally be rationalized according to different profiles, from purely educational purposes to the most specialized procedural uses. According to this, it is crucial to make a general thought on the methodological accuracy: at this regard, the London Charter [18], defines the principles to be followed for the three-dimensional representation of the Cultural Heritage, in line with the values of transparency, communicability and repeatability of the methods and results of this modeling process. We agrees to state that "*knowledge is the first stage of conservation*" [19] and the conducted research corroborates this assumption. The opportunity to set up database in situ, even by less experienced users, significantly reduces the costs (of survey, drawing, design, construction and maintenance) because the data is not duplicated on the various applications and the information is no redundant, since it is a simple query of a shared virtual space. So, this guarantees a repeatability of the scientific process where the variable element is the data, the fixed one is the process [20]. From a more scientific point of view, the application of these principles will allow to address and define a methodology for the knowledge (and the representation) of the Cultural Heritage that makes the virtual reconstruction, the processing and communication of data more transparent. It is therefore proposed a reflection on the infographic drawing, leading to a new form of design, and expanding the frontiers of our discipline. The concept of cultural dimension is thus a greater formal qualification in a permanent relationship between architectural space and information space.

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[18] Point 8.3 of the London Charter (italian version) states: "*It must be recognized that the three-dimensional representation allows types and access degrees not otherwise possible, including the study of change over time, the extension, modification and manipulation of the virtual object and integrated database multi-level and its global instant deployment, with all the consequent and expanded curatorial opportunities.* "Cf. DENARD, Hugh. *La Carta di Londra*. (Translated by NICCOLUCCI, Franco, HERMON, Sorin). Translation of the original The London Charter for the Computer- Based Visualisation of Cultural Heritage, 2009.

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