DIGITAL METHODOLOGIES FOR EXISTING BUILDINGS EMERGING EDUCATION AND TRAINING FOR PROFESSIONALS

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ABSTRACT:

Processes such as Building Information Modeling and, more generally, those involving the digitization of the built environment whose BIM is one of the possible expressions, are becoming increasingly pervasive in many different practices, from the design activities to the building site and management. Professional skills and working experience have now to be fostered by specific training on new methodologies concerning virtual replicas of existing domains, to explore the possibilities offered by digital interactions with Smart Heritage artifacts. This paper delves into the outcomes from the BIM Master Program held at the University of Pisa since 2016, presenting the results of the application of novel teaching techniques and topics related to the digitization of the built historic environment for the design preservation of Cultural Heritage monuments or sites.

1. INTRODUCTION

The application of information management processes and related digital tools within the building process, at first gradual and later more pervasive, amplified in re-cent years the potential for visualization, processing and management of data flows, from the conceptual elaboration to the final fruition of the real construction. However, when dealing with existing buildings or monumental ones, the process is still fragmented and not devoid of criticalities. In this way, disciplines such as Building Information Modeling and, more generally, the digitization of the construction whose BIM is one of the possible expressions, find in the art of design and architectural representation those regulatory principles of prefiguration, exchange, sharing and documentation that always characterized the professional legacy of architects and engineers, who need to improve further their skills in order to exploit in the best possible way new technologies and digital procedures. This evolution, in some ways ontological, keeps the professional figures at the centre of a wider discussion rooted in the synthesis of complexity, renewing its central role in the transmission of knowledge in a multidisciplinary context favoured and promised by the advent of digital modelling technologies. New codes and rules, who are starting to spread all over the different countries worldwide, are keeping all the actors in need of a constant improvement in terms of experience, skills and training. This paper investigates the outcomes of many years of specific training in digital methodologies and tools in terms of second level master program at the University of Pisa.

2. METHODOLOGIES AND PROCESSES FOR THE BUILT ENVIRONMENT

Building Information Modeling (BIM) is a consolidated strategy meant to optimize the building design process, avoiding spatial conflicts, time wasting reworks and costs associated with them. Even if it has been developed for new buildings, BIM attitude to gather data about components, which can be properly related by virtue of their self-awareness and semantics, can be successfully applied to existing domains as well. This is a considerable feature since the database of contents hosted in a digital model, structured following BIM criteria, is suitable to document heterogeneous Cultural Heritage sites and common built facilities. To be as faithful as possible, these contexts often need to be digitally surveyed using high definition technologies, des-tined to capture data about morphologies and preservation state of materials and elements. Computer models generated this way are useful in particular for documentation purposes, for periodic checks on structures preservation and they allow studies on technological building systems over architecture history. However, digital surveys are not structured entities per se, since they are usually collected for example in form of point clouds, without topology or semantic discretization. BIM on the contrary requires well defined relations among components, called “smart” by virtue of their own knowledge about their mutual placement. Importing un-structured datasets into BIM software is still a tricky process and very few professional courses are now available to develop skills in this peculiar field. Also, software is still lacking features when dealing with the existing domain; very few commercial applications can be counted as environments dedicated to a correct BIM process: Nemetschek AllPlan, Graphisoft ArchiCAD, Frank Gehry’s Digital Pro-ject, Bentley Microstation or Autodesk Revit are among the best-known authoring ap-plications. However, when they were originally designed, not any serious consideration was given to bring in digital survey data, since they were expressly written to de-sign new buildings, with attention mainly to the building site. More recent releases of these products are considering point clouds collected with laser scanning techniques or digital photogrammetry along the workflow, but the management of a huge number of entities is still tricky and not well tolerated in BIM environments. Automatic recognition of building elements and direct 3D modelling conversion from point clouds are problems still far from resolution, even though some prototype algorithms are promising. In addition, BIM models are not simple geometric shapes: on the contrary, they are made of “smart objects”, components self-aware of their identity and conscious of their interactions with each other. Even if the knowledge-enrichment of elements, including their morphology, se-mantic and topology, has to be mostly performed by hand, these 3D representations are worthy of consideration since they actually

are a real graphical database, in which several actors involved in Cultural Heritage preservation, study or research can find specific data pertaining to their fields of interest, including technical drawings, sections, details and schedules so rigorous as a BIM process is required to provide. It is no coincidence that in recent years much of the scientific production has focused on computerized spatial surveying (a digital acquisition of the built environment) and on the subsequent digitization of the cognitive data connected to it, with increasing attention to databases graphic and ordered according to the most disparate principles of representation. However, BIM abstractions must be mostly remodelled by hand, since automatic feature recognition and extraction in available AEC computer programs are still not effective, experimental and still under development by several software houses. A possible solution experimented and documented in scientific literature, involves the Historic Building Information Modeling (HBIM) approach, in which parametric objects are built beginning from historic data and layered in plug-in libraries aimed to map the elements onto point clouds and image survey data. Nevertheless, this methodology assumes buildings to document made of correctly codified components, already present in libraries, with limited capabilities to change them in order to represent possible existing different states, in terms of damages and deformities. The human need to evaluate the distances between objects and measure has certainly been manifested since the dawn of civilization. Instruments, methods and units of measurement have thus alternated and refined over time; since the seventeenth century metrology (the discipline linked to the measurement of physical quantities) met optics, starting a new series of studies that are still being perfected today by increasingly modern instruments. If the seventeenth century "dioptric level" by Geminiano Montanari greatly influenced the topography studies, in 1810 Von Reichenbach and Von Fraunhofer developed a more precise, but empirical, telescope with a graduated staff. which will later be scientifically validated by Ignazio Porro. In the 1930s, however, Balaikov theoretically developed an electromagnetic wave instrument which, a few years later, was produced by his compatriot Lebedev, effectively introducing the first electro-optical distance meter in history. Since then, the technology and production behind modern optical measuring instruments has evolved greatly, favouring the development of active (i.e., capable of emitting energy) and passive devices (capable of receiving it from the surrounding environment). If the latter are in common use, just think of the cameras equipping smartphones which are a widespread example, the former received an important boost in the early 90s of the last centuries, when the technology of Terrestrial Laser Scanning (TLS) began to be pervasively used in the construction sector. Assuming a single reference system for all the TLS survey stations (i.e., the real position where laser scanners are activated from time to time), the output data takes on the appearance of a very large series of geometric points positioned in the digital space: each point represents the distance of the instrument from the surface that reflected the light wave emitted by it. All points, usually millions for each station, represent a digital transposition of reality made possible by the generation of a point cloud. It consists of a series of points in space, defined by unique geometric coordinates, not connected to each other and, in all cases, integrated by information on the colour of the surface that allowed its reflection back towards the measurement instrument. If, on one hand, the point cloud produced in a very short time provides a very comprehensive picture of the state of the surveyed places, it is not feasible to automatically define the characteristics of the building components, limiting itself to documenting only what the laser scanner "sees", for example the external envelope of the investigated buildings. However, the segmentation of a point cloud into portion of it is useful to define parts of the survey destined to be translated into the smart objects proper of BIM systems, following various approaches: from the mostly manual one to automatic surface recognition systems, although the latter are still not particularly effective for complex objects. This methodology often takes the name of ScanToBIM, to indicate all those com-plex workflows that start from the accurate survey of the point cloud to arrive at the assembly of the intelligent components as already mentioned. ScanToBIM is a more accurate process than HBIM, but it is far more expensive in terms of time and knowledge. Each object segmented by the survey must be recognized, remodelled as a semantic component and “made smart” by integrating data from diversified sources.

3. THE EXPERIENCE OF THE PROFESSIONAL MASTER PROGRAM IN PISA

A significant chance to understand in a congruent manner how these BIM-based methods work, is offered by courses for professionals, proposed by some Universities. In Italy these courses are named “Master” even though they are not degree course (as the “Master Degree” are instead) but professional paths, aimed at those who have already graduated. At the University of Pisa, the Master originated from a research group focused on BIM, which brings together experts from various parts of Italy, following a meeting in 2016 with the Institutions of the Government and of the Italian Ministry of Transport (MIT). Because of the European Directive n. 24/2014, in Italy as in other European Union countries, the use of BIM method for all public works became mandatory: therefore, an urgent need to spread BIM knowledge throughout the construction sector raised, also because it is still little known and there is a lack of it in universities courses. Due to these reasons it seemed appropriate to propose some Master courses able to teach the use of BIM to everyone: from experienced professionals to younger colleagues, working in public administrations as well as those looking for a placement, employees of the public and private sectors, professional practices, companies, construction companies, etc… Due to the connection and long standing friendship with the creator of BIM, Prof. Charles Eastman, the research group found it necessary to engage in the teaching process, to bring to everyone all the opportunities that BIM has to offer in terms of high quality results and saving resources, also to the field of Cultural Heritage. Today a Master course in Italian universities is considered successful if it has on average twenty people attending.

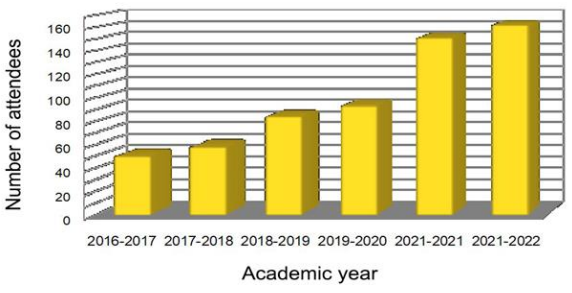

Figure 1. Number of practitioners attending the Master all over the academic years (Figure by P. Fiamma).

The BIM Master at Pisa in the first 2016-2017 edition was attended by forty-eight students; today, in its sixth edition, it has 161 students (Figure 1), showing consistent growth and becoming the first BIM Master in Italy, and one with the most

numerous groups of users amongst all disciplines involved in the construction sector.

4. HOLISTIC TECHNOLOGIES AND PROCESSES FOR THE SAFEGUARDING AND DOCUMENTATION OF CULTURAL HERITAGE

BIM in the Master program has a special session dedicated to technologies and processes for the safeguarding and documentation of Cultural Heritage. The approach we decided to follow, to teach them, differs a bit from the traditional training on BIM applied to the existing buildings (often generally mentioned as HBIM), where often a small portion only is modelled, according to the single intervention to do on it. In our view, the building must be considered as a whole, spreading the usual BIM approach toward a holistic perspective. In the Italian tradition, a monumental asset is distinguished by its history, which layered over the centuries (or millennia) the building events that brought the construction to us for each and every component: a single column in a medieval church, for example, will never be identical to the others in the same building, like none of those in other churches, even if contemporary. The architectural "Opera" changes during the centuries according to the human History. In Italy, the BIM approach is still used in the design phase (and not in the construction phase) and by a private entity (and not by a public in-situation). This trend also affects the HBIM sector, although built heritage is of enormous size and importance.

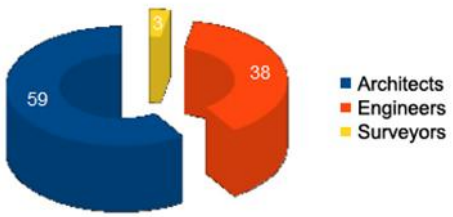

Figure 2. Degree distribution for the Master Attenders: Engineers, Architects and Surveyors percentage visualization (Figure by P. Fiamma).

Consequently, those attending the Master are technicians and not, for example, CEOs of companies, commercial managers, organization employees or legal expert. The participants are Architects, Engineers, Surveyors; we observe that their distribution is characterized by a constant ratio during all the editions of the Master.

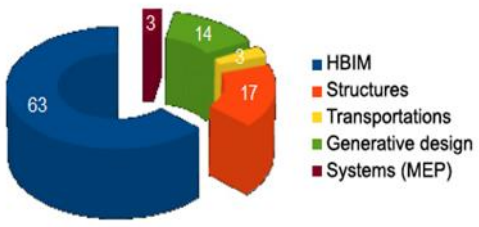

Figure 3. Subscribers to specialized BIM modules: percentage overview (Figure by P. Fiamma).

Data document how BIM is considered a knowledge able to integrate every graduate title in the architectural and construction field (Figure 2). The selection of the specialization modules by the attendants from the different choices offered in the Master program, proves that the HBIM module is the most numerous; in addition, we observe that module attenders are more numerous than the number of all Architects attending the Master which have a big interest about the HBIM (Figure 3). This is because several engineers choose the HBIM module to apply their structural knowledge to the built heritage. The approach to the conservation of Cultural Heritage using BIM is also considered interesting to engineers, especially those who are into structures, who have al-ways considered their action in current non-BIM practices, independent from others and restricted to static calculation. BIM is considered, above all, a cultural innovation process, which allows a more integrated approach for the Heritage sector across the disciplines. BIM is a process that involves many skills and professionals practicing it must be prepared to better coordinate working activities. This is far from traditional ways to approach the design process. Generally speaking, the digital dimension opens ever, worldwide, new links be-tween theory and practice, research and Industries, leading to a holistic view in which many disciplines may converge in order to better express design choices and opportunities. It is the expression and documentation of the awareness that extends from the horizontal joint action between the various disciplines, to a vertical one among all the temporal phases of the process. The innovation of the BIM methodology for the Heritage reduces the space be-tween documentation and management of the work, which in Italy too often makes the interventions to safeguard the Cultural Heritage ineffective, with the risk to flatten actions on one of the levels of interpretation only: static, historical, chemical, etc ... with-out an effective consideration for all the elements involved in the management of the built domain. Luckily, BIM is increasingly considered a new method for obtaining an ancient result: transmitting Cultural Heritage. As a 360-degree process-product method, it is considered capable of encompassing all different specializations, including those for engineers. In addition, it is documented that even non-technical professionals, for ex-ample administrative ones, consider BIM for Heritage an important opportunity to acquire a methodology capable of enhancing their knowledge. BIM for the existing domain is also a remarkably interesting new knowledge environment to structural engineering research and applications. The recovery of the historicized work often includes a static restructuring, which is an expansion opportunity for facilities companies looking for BIM implementations.

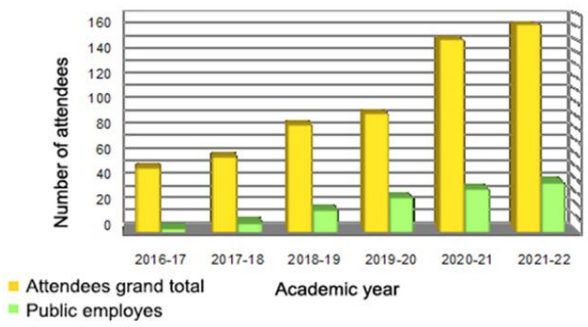

Figure 4. Public workers total percentage attending the Master (Figure by P. Fiamma).

With regards to the workplaces of the members and the applications to the internships of the Master, the public sector is constantly growing with an increase in the number of members themselves (Figure 4). In Italy, the Public Administrations usually are the ancient monuments owners: it is important to

have their workers attending the Master course, because this is the way to a conscious BIM application in Cultural Heritage.

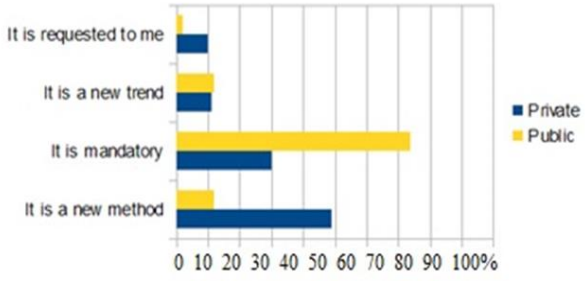

Figure 5. Reasons, indicated in percentages, for use BIM in public and private works (Figure by P. Fiamma).

The reasons for the cited increase are, mainly, of four types, showed in the following table (Figure 5) and divided by public and private sector. The use of BIM is considered differently according to the subjects. For the public sector it is required by law; for the private sector it is considered an innovative method. The private sector can learn the use of BIM in a more direct way, than the public, since it is more directly connected to competitiveness needs and therefore to the possibility of beneficial repercussions in economic terms. In the public, BIM is considered necessary because it is required by law and therefore felt as a weight in practical implementation also due to the lack of resources and time to acquire the necessary tools and skills. This data can be disaggregated and al-lows to obtain incredibly significant results. The public sector represented at the Master is made up of several areas in which categorisation of BIM as a "necessity" or "opportunity" are remarkably diverse (Figure 6) depending by the project object.

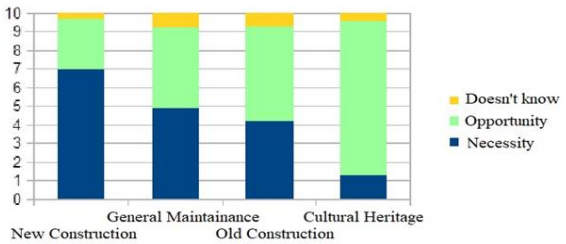

Figure 6. Consideration of BIM in some application areas by public works operators (Figure by P. Fiamma).

In the new construction sector, BIM is considered, above all, a necessity that must be adopted for reasons of competitiveness. For maintenance in general and interventions on existing buildings, the two options are equivalent; it is precisely on the Cultural Heritage that BIM is seen as a great opportunity in terms of its cogency. The need to use resource-optimization methods emerges as a priority together with another consideration: BIM is considered as an "ordering" approach. The maintenance of a monumental asset, or part of it, has always been considered a set of technical interventions, which have followed one another over time (often without any precise documentation being left). In the BIM method, the concept of maintenance also extends to the maintenance of knowledge of that asset: tracing, organizing and making available all the data connected to the model (including data relating to the maintenance interventions). If we also consider the internship experiences that took place in recent years in the Public Work Administrations affiliated to the Master, different characteristics and objectives can be documented depending on whether the object of the interventions is either a historical and monumental asset or not, such as, for example, the maintenance of modern buildings or new constructions.

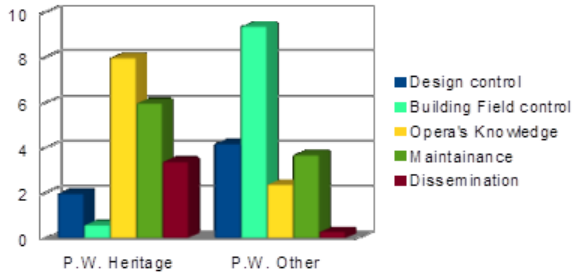

Figure 7. Impact of BIM in public works: Heritage - Other (Figure by P. Fiamma).

For an intervention on a cultural or historical asset, the use of BIM for the Cultural Heritage is oriented to the possibility to get a better knowledge of the work and this for its continuous and necessary maintenance. Nowadays, the historical opera maintenance can be conceived as an integrated result of a BIM planned program and an interactive data coming from IoT automation devices that can be applied in the constructed Heritage preservation and known as Smart Heritage. The possibility to have greater control of the BIM project by the Public Work Administrations, would seem to be considered of lesser importance. It can be deduced how the intervention project on a cultural asset, due to its specificity and uniqueness, remains – up to date– - based on the confidence in the competence of the individual appointed professional. This becomes more evident in the low value that is normally assigned to control the BIM construction site: the specialization of companies and construction firms called upon to intervene remains the best guarantee of correspondence to the project. The responsibility of the Public Works Administrations to disseminate knowledge of the asset considers BIM as an innovative and effective tool. The oriented object model is considered as the hub of the intersection and storage of all the elements of knowledge, data and historical events relating to the monumental asset. This need unites many Public Works Administrations operating in this sector. BIM can be, for example, combined with immersive virtual approaches in order to make the opera an open-air museum. There are always no archiving systems that contain a continuity of the interventions that have followed one another on the work over the centuries. Thousands of information are dispersed in different places, in a fragmented way, pertaining to control bodies or subjects who cannot dedicate adequate spaces and time for managing the knowledge they represent to that work. The object-oriented BIM model connected biunivocal to the information contained represents an opportunity to recompose a crossroads of knowledge, an environment of interaction which in turn is the node of an international network of culture and technology. It is necessary to think in perspective and have a vision of relational dynamics between people's knowledge and characteristics of the work: an open system where info is continuously added. The priorities and interests of Public Works Administrations in interventions that do not have historical and Cultural Heritage as their object show great attention to the new opportunities for controlling the design and especially the construction that the BIM method allows. The correspondence of the built work to the one designed and its correct execution are the main expectations of innovation. The public system has one of its

major critical points precisely in the scarce possibilities that traditional (non-BIM) practice offers to Public Works Administrations for controlling the construction site of the work. The responsibility of the construction site professionals within the Administration is relevant and they usually have very modest resources available. Following the progress of the construction site, checking the correspondence of quantity and quality of the materials, ensuring the correctness of the implementation and the many other management needs push the professionals to seek effective answers to these needs in the BIM method. Due to these reasons, primarily related to the building process of new constructions and their economic efforts, the ap-plication of BIM-driven approaches to the Cultural Heritage is still limited when compared to its use on new projects that can be optimized following BIM processes. Not all Public Works Administrations can afford an internal design office and this affects the way in which the project is very often assigned externally. Of great interest even if still not widespread is BIM based maintenance, which is affected by the absence of object-oriented models on the existing infrastructure. Often there is not even sufficient documentation for the construction characteristics of a building; for example, it would be usually of great interest to know the location of the mechanical, electrical, or plumbing systems (MEP). All requests received by the Master always contain requests for the use of the BIM method also for the re-aggregation of a dispersed archive and the theme of BIM as a conjugated tangible and intangible heritage becomes increasingly full of technical and cultural contents for the use of BIM in the maintenance of monuments. BIM for the existing domain (following both HBIM and ScanToBIM approaches) is taught in the Master and proposed to the construction sector as a concrete method to safeguard and spread the Cultural Heritage, to effectively combine cultural knowledge and not just technical one with process-product innovation.

5. METHOD, CONTENTS, NOVELTY

In these years, only around 20% of the Master's attendees are people recently graduated (from 1 to 4 years); all the other attendees are professionals. The perception of what BIM is by the attendees is not the same for all, especially when they are at the beginning of the Master classes. There are several aspects involved in teaching BIM and our proposal must consider the needs of both type of attendees.

- BIM is a method, it is not a software or a standard (in Italy, unfortunately, there is a business driven by the software market and the certifications of private skills given by subjects, self-referenced through courses of a few tens of teaching hours).
- The BIM method cannot be improvised: for a conscious use, it takes years and a lot of practice (it is wrong to think that it is enough to learn the basics of a software)
- BIM does not replace the knowledge and experience, that a professional of the construction sector must have it is, rather, a method that enhances it optimizes and extends them instead.

The theoretical aspects, the use of software resources and the internship/stages in the Master's Partners (Companies, Industries, Practices, Institutions) are conceived and proposed in the Master as an integrated whole. The Master is a path of BIM knowledge at 360 degrees. We teach the method and the content of the object-oriented modelling: this is a part of knowledge we call "horizontal" (architecture, structural engineering, MEP engineering). Then, there are other modules, connected and integrated, this is a part of knowledge we call "vertical": we teach techniques of clash detection, coordination of models and data extraction. Then, the Master's Pro-gram continues with an accounting and project management module. And then, a module for managing the development of work on the building site. In addition, GIS techniques and use of tools for 3D laser scan detection are taught. All the modules mentioned are part of a path, common to all members: engineers, architects, surveyors. The lessons on software are always interspersed with theoretical lessons: Italian (and also European) laws and regulations are commented; the management of the BIM process is introduced in detail. Meetings with BIM professionals, working in public and private sectors, are also offered with continuity: Design Studios, Construction Companies, Supervisory Authorities, Public Institutions. In addition, the Master presents an absolute novelty in Italy: it is the only one able to offer BIM specializations, planned for specific professional fields. The contents of the common modules allow to follow the subsequent specialization modules: each attendee can choose one module. The specialization modules, which are also designed to teach dedicated software, are dedicated to Structures, Generative Design, MEP systems, Road Infrastructure and HBIM (to indicate the adoption of BIM principles to the existing domain). It is important to note that more than 50% of all the Master's attendees, choose the HBIM module: this is a proof of the importance of that module (and not only in Italy, given that the Master has about 10/14% of foreigner attendees). The specificity of the built environment leading to a wider perspective in Cultural Heritage preservation is known by professionals attending the Master. The common modules teach BIM topics for design, construction and management, common to existing and newly designed buildings. The HBIM module teaches specific contents of the BIM method for Cultural and Smart Heritage, which professionals do not know. For example, how solve the issue of the absence of oriented object libraries, a condition that distinguishes HBIM from BIM for new interventions. A historical Opera, in fact, is unique and marked by time: therefore, it requires, always, a survey of its condition before any Project for it. The HBIM module uses the knowledge given by the laser survey module (for example, the raw data in the point clouds) to teach how to produce meshes and how get, from them, the HBIM object-oriented models. Due to the widespread interest in HBIM among attendees, it is possible to compose interdisciplinary groups to train them on real buildings (involving structural engineers, architects, employees of Public Institutions), in order to simulate a real BIM workflow. This is an important original factor: the teaching method on real cases, combined with modelling and data collection practices on Cultural Heritage make the HBIM module an innovative and multidisciplinary learning path. In these years (right now the sixth Edition of the Master is running) hundreds of people got a job thanks to this Master; in addition, its popularity has always been growing. This is not a formal assessment; it is a substantial documentation of its effectiveness. The approach developed during Master lectures and classes proved to be successful also due to the offer of many teaching modules, some of them simultaneously held for students divided into different working groups and focused on specific topics and activities as already mentioned.

5.1 Theoretical lectures

The module dedicated to the Cultural Heritage (generally and somehow erroneously identified by attendees as the HBIM module) was refined and optimized over the years for digital documentation and archival purposes. Since the BIM modelling of monumental buildings or existing architectures is still difficult in terms of data collection, shape definition of historical components and usage of data formats able to guarantee a proper software interoperability, classes of the

Master module were organized following these criteria. After a general introduction of the theoretical background, presenting the most common regulations and codes actually adopted in Italy for restoration and documentation for the built heritage, detailed studies were dedicated to 3D parametric BIM software, in order to establish ontological connections among data, organized in an as much as possible interoperable way, and three-dimensional virtual replicas of the buildings, as documented in many scientific works.
The theoretical syllabus proposed to the attendees was prepared following this orienting scheme:
- Definition of the proper context in which BIM applied to the Cultural Heritage can be adopted;
- General overview of mandatory regulations in Europe and in Italy, which are considering the existing domain as well as the new constructions;
- General overview of the guidelines which can be voluntarily adopted by professionals in a BIM process, with regards to the Cultural Heritage (ISO codes, UNI EN best practices, etc.)
- A presentation of some of the most important scientific works on the topic;
- Definitions and concepts: from BIM to HBIM, to ScanToBIM;
- Introduction to the digital survey of existing buildings: elements of terrestrial La-ser Scanning and Digital Photogrammetry;
- General methodologies and workflow to get semantic models from point clouds;
- Possible BIM uses for authored 3D model, with particular interest in interoperability and Smart Heritage models generation (possible IoT interactions, multiple ways to interact with the data repository, etc.).
Some historic contexts were chosen over the different editions as case studies, to face many of the possible scenario in BIM documentation of existing domains, both in terms of digital 3D modelling and in data attributes hierarchical management. The most significative ones were the main apses in the Duomo in Pisa, the San Francesco church which dates to 1233 and Santa Maria del Carmine (1324) together with application studies developed individually by attendees, just like the belfry by Giotto in Figure 10. Many technical approaches were presented, spanning from the classical HBIM procedure made of general geometry abstractions, to ScanToBIM methodologies, in which some detailed lectures on Terrestrial Laser Scanning techniques and Digital Photogrammetry were proposed, with hands on typical scanning devices and photographic equipment, physically tested by all the professional attending the Master program module.

5.2 Pragmatic workshops

Mark footnotes in the text with a number (1); use consecutive numbers for following footnotes. Place footnotes at the bottom of the page, separated from the text above it by a horizontal line. Many real buildings were investigated during classes, spanning from the archaeological field to more contemporary constructions. Some of the most effective 3D modelling techniques were introduced to train the attendees in developing correct BIM models for many scenarios, following the precepts of consolidated BIM approaches. In field workshops at specific monumental sites, in which survey devices just like terrestrial laser scanners (with Time-of-Flight and Phase shift technologies) were accurately introduced, were then proposed to attendees, letting them author detailed surveys to be later used as a general reference for 3D models related to single components or whole buildings (Figure 8). Some extensive tests were also conducted with Faro Cam2 Focus 3D, Leica C10 and BLK360 scanner devices. BIM modelling was introduced in form of one-to-many lectures, authoring step by step the most relevant components, isolated form point clouds collected during field tests. The average feedback by professional attendees, who generally chose voluntarily to attend the Built Heritage module as it was not mandatory in the Master Program, resulted in appreciation of methodologies learned, with many confirmations on how they could be useful in the everyday duties in professional firms, cultural institutions or superintendencies.

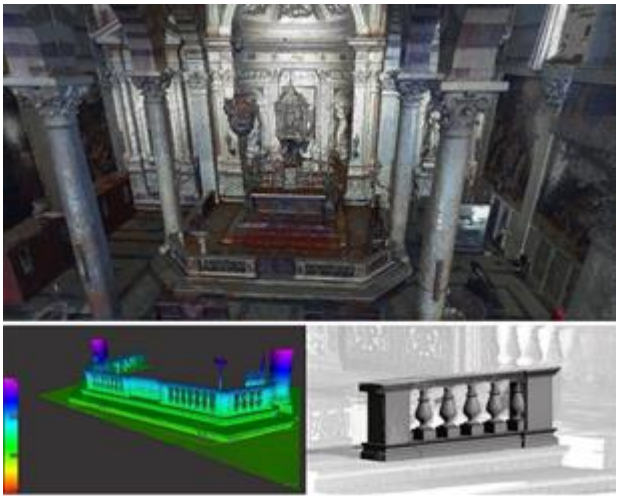

Figure 8. Some details of a ScanToBIM process as presented in the Master class: a marble balustrade from the Duomo di Santa Maria del Carmine in Pisa as inferred by a TLS point cloud for one of the main apses (Picture + BIM components by authors).

6. TRAINING PROCEDURES AND CASE STUDIES

In the last twenty years, in the fields of academic research related to architectural representation and design, multiple methods and various classification criteria have been proposed and developed for existing buildings, without however setting them-selves free from surveys as the maximum expression of knowledge and from databases as information aggregation environments. If this trend allowed digital models to reach higher complexity and detail in the geometric description, it led at the same time to an impressive number of inhomogeneous approaches, almost never oriented towards a common standardization: the lack of standard, together with the fragmentation of the approaches prevented from the adoption of univocal and shared criteria, almost limiting the research experiences. However, there are many points for discussion that emerge from what has been introduced by the scientific literature. The advantages of a BIM management also for built heritage have already been understood, leading to methodological verticalizations such as Historic Building Information Modeling, ScanToBIM or semantic modelling for the existing. The study of the existing domain for restoration, renovation or adaptation purposes, finds in the digital representation a centrality; digital technologies and processes such as BIM need to understand the precepts of the construction tradition proper of many classical cultures, in which the professionals in-volved in the construction process and in the enhancement of the built environment must overcome the boundaries of independent specialties, sharing knowledge and skills through a conscious framework made of technical preparation. This was one of the paramount elements that were discussed and taught to the Master's attendees, who experimented on monumental historical buildings (Figure 9).

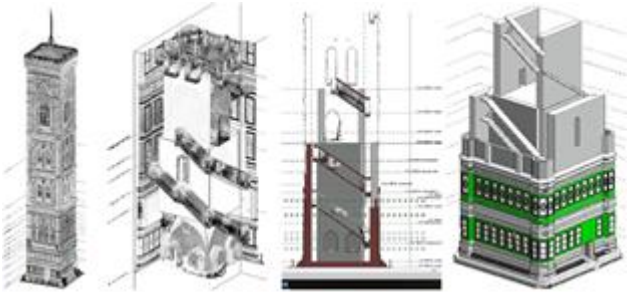

Figure 9. An example of BIM model as authored during the training at the Master in Pisa: portion of the belfry by Giotto in Florence (model authored from a point cloud through ScanToBim techniques by Roberto Di Rienzo, who attended the Master course in 2017).

However, some other themes may be brought into the discussion since the Cultural Heritage still needs a shared international vision in terms of data collection and preservation in form of digital models. This Master program aimed at a general dis-semination of principles and best practices whose peculiarity is versatility. The under-standing of how an historical building works, for example, or the identification of technical features expressed by time consolidated components in a monumental construction, can be only inferred by an accurate analysis of the whole construction, from many perspectives. The digital BIM process is the ideal collector for all these experiences in terms of logbook for a building, while the professional process conducted by professional operators, in the public or private sector, would be tremendously im-proved by centralized and validated data sets. But those databases are prone to schemes and data formats, which most of the times reduce the documentation of Cultural Heritage to a mere list of attributes. In the Master in Pisa, techniques, tools and processes were coordinated to reach the knowledge on the historic context first of any other approach, leaving to the data format a necessary room but considering it as something that could eventually change in the future. Versatility is the word that could better define the novelty of the teaching approach proposed in Pisa.

7. DISCUSSION

Computer models embedding coordinated, consistent and always up to date graphical datasets are rooted into the BIM culture to reach higher quality, reliability, optimized scheduling, errors and costs reduction together with avoidance of any possible misinterpretation by actors involved in the building process. When a computer-er-generated model collects precise geometry and relevant data needed to support the construction, fabrication, and procurement activities it is supposed to be a BIM model and the interaction with it by different figures determines a BIM process. Data modelling and 3D modelling, dealing with an object, a building or a townscape in a digital form, force to more direct engagement than traditional representation; the investigation to acquire shape, proportion and working mechanisms requires greater efforts and more skilled observation. This sequence of actions needs a proper education and training, not always covered by academic programs. The experience in Pisa, considering all the complexities involved, proved to be a valid test field in exploring the average preparation of professionals coming from different specializations and different ages, improving the teaching methodologies ap-plied to them regarding the introduction of novel technologies and processes for the interventions, the management and the restoration of the built heritage. As a final discussion, we believe that the teaching activities developed at the Master in Pisa are a further step into the proper consciousness of what digital information models can bring to the dissemination, coordination and management of the built environment: operators and practitioners, employed in private or public sectors, need to be prepared and trained to future uses of the digital transformation in the construction sector. Dealing with Cultural Heritage in particular means to understand possibilities and techniques to make history understandable and able to be preserved in the future leading to a whole new field of research, the Smart Cultural Heritage, which will be increasingly important for the generation of professionals to come.

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