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Industrial Heritage in the historical neighbourhood: BIM strategies for urban regeneration

The recent investigations about sustainable transformations of urban areas in the industrial or post-industrial districts of European and Mediterranean countries showed the need to face new possible urban assets within the framework of migration, climate change, global economy changing and adaptation to the new situation with holistically sustainable approaches. Building Information Modelling (BIM) and Building Information Modelling (BIM) and Management is here clearly a strategic tool, supporting all the operational activities and even contributing to manage the revitalization of the building heritage during the entire life cycle. For this reason, industrial heritage can be seen as a special experimentation field of a new balance across the urban tissue, capable to pass from decay to resource or getting lost for ever.

Key words:
sustainable transformation; post-industrial historic neighborhood; re-design and development; urban regeneration; BIM

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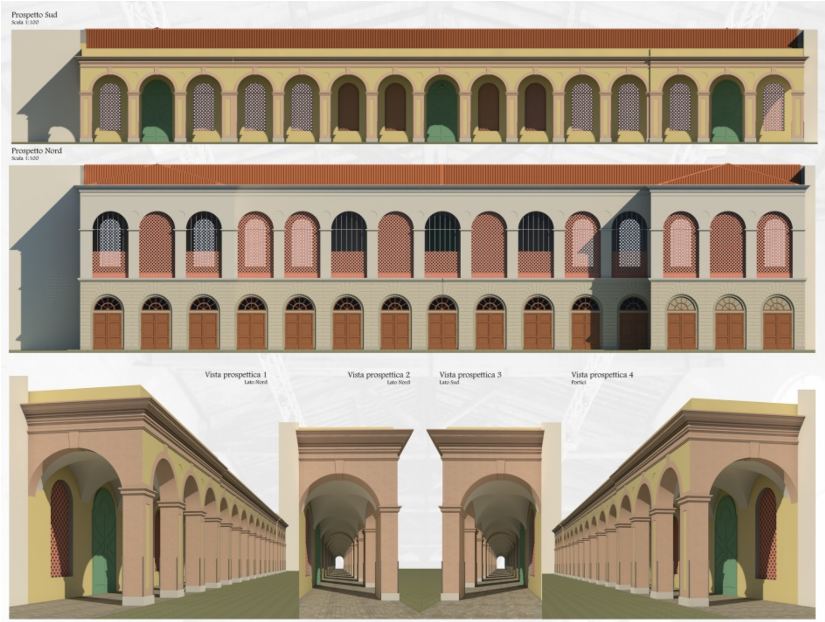
1. INTODUCTION

The industrial heritage is a key element in the regeneration and evolution of the contemporary town all across Europe, thus it stands in balance between falling in final decay and changing into a resource. Its connexion with the historical city centre may happen in a myriad of different ways, but most of the time, it starts when the evolution of the urban tissue reaches the nearbies of the former industrial area, introducing new assets around a partially or totally abandoned facility.
The recovering challenge often meets problems of readings and re-integration, while these districts have to face the limit between being an “invisible place” and backpedal to be a part of the town, sometimes even facing social phenomena of rejections and important issues in the possibility of a recovery. A sustainable transformation based on design/re-design/regeneration processes of industrial urban districts needs innovative design support tools. Socio-cultural sustainability is an input into management strategies by considering changes due to urban culture, and principles regarding design criteria such as spatial perception and the inclusion of interdisciplinary competencies aimed to sustainable development objectives where the role of architecture is central. In these effort of transformation, the use of digital, appropriate, tools seem both a solution and a challenge. It needs at the same time consolidation of procedures and innovative ideas. Target result should be a scenario where the current technology support combines the value of the land and the understanding of space in the framework of an efficient transformation, to lead towards sustainable cities with less consuming needs, with buildings presenting better conversions and reuses, guiding these districts into their following life cycle.

2. INDUSTRIAL HERITAGE AND HISTORICAL NEIGHBOURHOOD: A SCHEMATIC SCENARIO OF INTERVENTION

Industrial residuals have quickly populated our time: the migration of production processes and the rapid industrial renewal with new requirements in favour of healthier environments, led, within about a century, to a substantial change. A moment in a process of trans- formation started when natural or agricultural areas became the lots for industries, later destined to abandonment and decay. The reuse of these spaces rarely took place, it met stagnation, with the complete trans- formation into a “non-place”, with these architectures and districts near to disappear from perception. A process made of two moments: the first at the transformation of that part of territory into an industrial site: industrial spaces, for their own needs, close them- selves from the outside. The second followed the habit to bypass the lot/area, first when active, then when abandoned: the people living in the nearby lose the sense of dimension, of hinge, so that the former industrial lots become perceived as a space just to "jump" beyond, a place that can be only observed from the outside while sliding around its limits [Verdiani, 2015]. Therefore, the redevelopment of dismissed industrial areas is not a areas is not only linked to their loss of functions, but above all to the emptiness of meanings that has been produced in them. Dealing with "industrial archaeology" means to rediscover and give back a value to ancient architectural forms and construction techniques underlying the production processes, once present in the building.
In such an approach, the projects of reclamation and reuse of industrial pre-existences have always had to address a physical context full of history and symbols in a difficult balance between conservation of matter and change in uses, transforming the places of "work memory" into new spaces for the citizens lives.
In recent years, however, with the introduction of the concept of "urban regeneration", the traditional problems of building reclamation have been traced back to a broader framework of social and cultural redefinition of these areas through interventions characterized by an increasing attention to participation processes, quality of life and environmental sustainability.
More recently, the new scenarios opened by IT in the management of urban activities, such as the "connected city" and the "blockchain", cannot fail to have their privileged field of experimentation in the redevelopment of dismissed industrial areas, as it has been demonstrated by the innovative and in some ways “disquieting” intervention of Quayside in Toronto (fig. 1, 2) by Sidewalk Lab [Austen, 2017]. In any case, the identification of suitable knowledge processes of industrial built heritage through the digital representation tools, remains the essential premise for any action of urban regeneration.
In the scenario of interventions on an industrial heritage context the casistic can be simplified in four main ones, considering that it is quite difficult to find an industrial architecture where the original building, even if of some value, has not suffered from alterations and superfetations: 1) intervention where the main parts are preserved and recovered to create a "museum of itself" of the industrial building, in such

Fig. 1, 2 - Quayside in Toronto, the new neighbourhood designed by Sidewalk Lab (*).



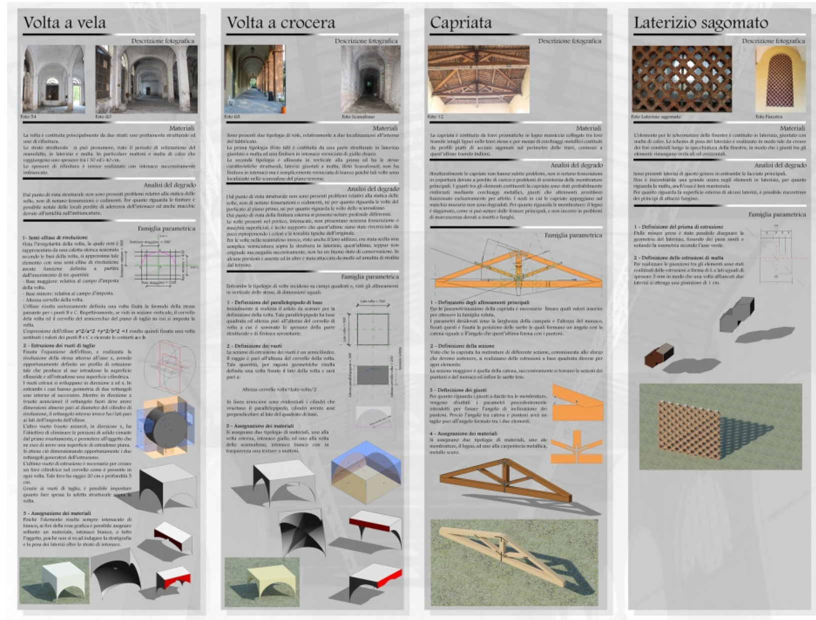


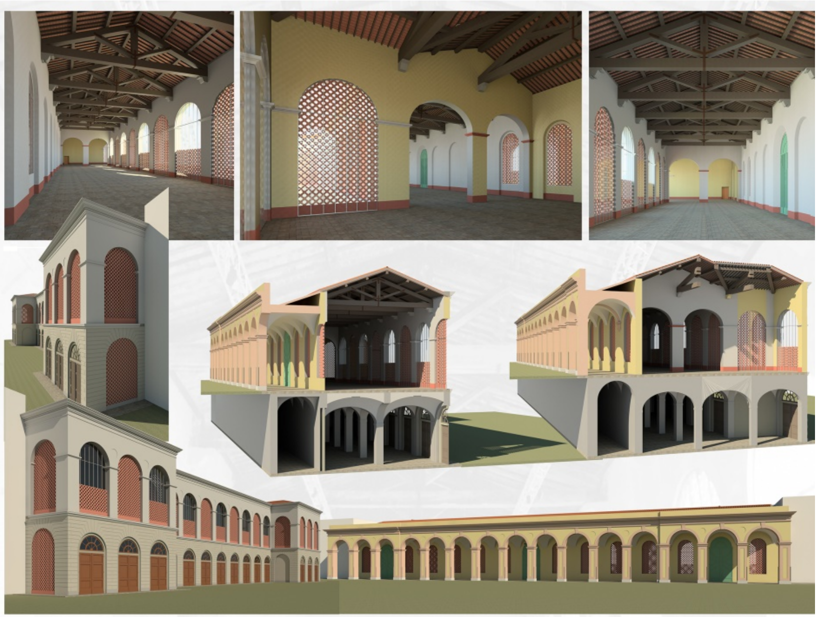
Fig. 3- H-BIM of "Pagliere factory" at Porta Romana district in Florence
Fig. 4 - Implementation of Building Object Models (BOMs) from direct survey

a place, the history and past technologies can be an interesting story to tell and to learn. At the same time the museum may host some additional exhibition spaces, presenting the most various subjects; 2) intervention where the main parts are preserved and trans- formed into completely new use, from housing to social spaces; 3) intervention where only minor parts are preserved, the new intervention take the place of industrial heritage that remains a secondary (most of the time strong) reference to the past. In this case the kind of reuse may be similar to the case one and two; 4) intervention where the industrial area is completely demolished to accomply needs of safety and environment regeneration, the new construction may be inspired or not to the removed heritage, thus, as it is quite common, the toponym of the area will remain [Preite, 2009].

These four main categories may have some gradients and declinations, but any the intervention, the use of a well-planned and articulated BIM strategy will be the base of a positive approach and will give better chances in terms of control and management of all the operations. Even in the case four, the digitalization of what it is going to be removed have to be recognized as a correct practice to avoid the loss of valuable information from the industrial site. While the management of the demolition and waste materials may greatly benefit from the digital approach [Nan, Wang 2017].

3. BIM AND INDUSTRIAL HERITAGE, STATE OF THE ART AND MORE

The intervention on industrial heritage, sometimes indicated also as “Industrial Archaeology” has been a key subject all across the last decades. The approaches to this kind of buildings have been variously explored and defined [Faustini, Guidi, Misti, 2001]. In our time, the potentiality, tendencies, challenges, limits and vantages in the modelling and management of this specific built heritage have reopened the discussion about strategies and multi-disciplinary approach, underlining the need to open the procedures to a wider range of skills and competencies. To investigate the historical



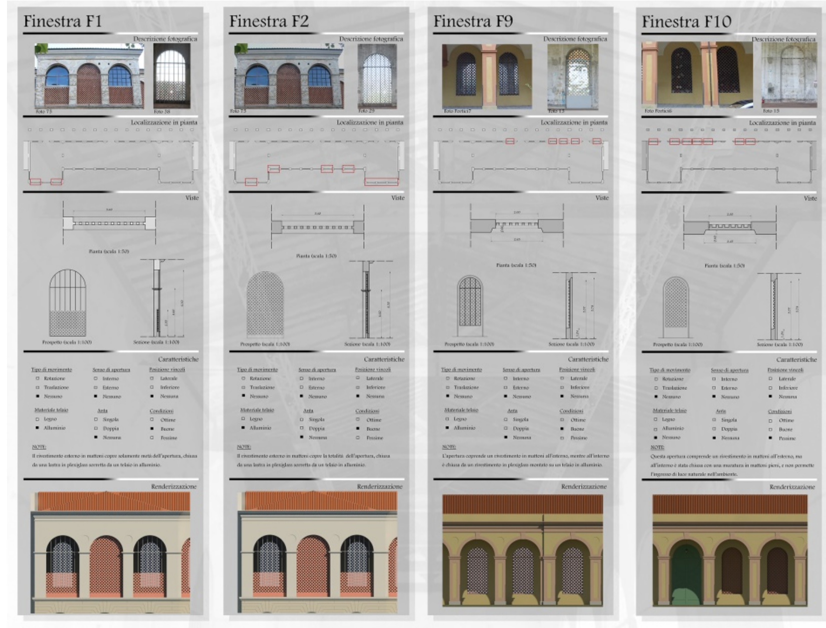


Fig. 5 - H-BIM of "Pagliere factory" at Porta Romana district in Florence
Fig. 6- Implementation of Building Object Models (BOMs) from direct survey

background and identify the critical role taken by architecture and urban design, the use of innovative design support tools oriented to the development of BIM is nowadays a strategic, fundamental element. From the building to the urban scale, it is clear that the search for an innovative method is still ongoing, something capable to coordinate different scale interventions to the scope of larger scale sustainability, urban development, management and governance. Any change should start from the base of the operators, architects, engineers, urbanists, but it is believed that a possible starting should move from an aware owner (public or private client), who knows how to recognize not only the potential of BIM, but to elaborate its objectives for the implementation of information models, whose semantic enrichment cannot be separated from their expected use.
In recent years many difficulties encountered in consolidating procedures for BIM models' creation of historical heritage (HBIM), are caused often by unclear definition of modeling purposes, which rarely can be identified with the geometrical "*digital twin*" of the building [Wired Brand Lab, 2017].
A BIM use is in fact defined as *"method of applying Building Information Modeling during facility's lifecycle to achieve one or more specific objectives"* [Kreider, Messner, 2013]. However, the BIM modeling pursuing objectives, leads to focus the implementation process on the information contents of parametric objects, which can be extracted in the following stages. In this context the over-modelling of BIM objects, namely the insertion of redundant data without respect to uses and objectives are considered incorrect practices. The same protocol for implementing BIM models proposed by Messner in the BIM Project Execution Planning Guide [CICRP, 2011], as regards both the definition of the specific BIM use, "Existing Condition Modeling" (referring in a broad sense to the creation of digital models of existing buildings), and the second-level mapping of the relative modeling process does not seem able to fully grasp the complexity of the historical nature of the architectural heritage, whose analysis cannot be liquidated with a generic *"ability to sift through mass quantities of data that is generated by 3D laser scan to determine what level of detail will be required to add "value" to the project "* [ibid].
On the other hand, the current implementation of BIM models for the analysis and management of Cultural Heritage [Chiabrando et al., 2018] is still affected by the prevalence of methodologies developed for applications to new projects, as well as scan-to-BIM, is still strongly limited to simple the automation of processes semantic recognition, geometric elements. Therefore, the production of parametric models consistent with the information density derived from massive data acquisition

techniques is still a territory of research and experimentation.
In the BIM-based digitization experience of public buildings in the city of Turin [Osello, Ugliotti, 2015] carried out as part of a research program aimed at optimizing and making the concepts at the base of the Smart City more efficient, the informative (alphanumeric) nature of the modeled data is widely recognized, and it has the task of qualifying the same geometric referent.
The density of the geometric data must therefore be functional to the prefixed objectives, which must be identified for existing buildings in the operational and maintenance activities or reclamation and conservation interventions. Therefore, a parametric model can be simplified from a geometric point of view, with respect, for example, to massive 3D data capturing, but it contains anyhow all the necessary information for its complete description. Special attention must be paid to the creation of parametric objects (BOMs) for BIM models of historic buildings [Biagini, Donato, 2014]. It is a modelling activity of building elements that can hide multiple pitfalls in the segmentation phase of the parametric object for the semantic enrichment of its components. In many historical buildings, in fact, the language of the architectural order, even if often just evoked by some building elements, overlaps with its own syntax to that dictated by the topological relationships connected with the parametric structure of the corresponding modelled component. Both conformative rules must therefore be known for a correct BOM modelling.
As part of a broader reasoning on the development of methodology for historical visualization, Giordano and Olson [Giordano, Olson, 2017] reflect on the important role that digital technologies play in generating data and new knowledge, but at the same time on the limits that may derive from their application. The visualization processes of the city of Venice are divided into three phases: data acquisition, data processing and data communication.
H-BIM models are implemented with information relating to the buildings transformation over time, thus creating a database of information that can be consulted by multiple users' categories together with the archiving of primary and secondary documentation.
In urban regeneration projects of dismissed industrial areas, however, the processes related to the implementation of BIM models of existing buildings through reality capture technologies, are only the start of a first level BIM based management plan, which involves multiple BIM uses based on the different objectives set.
In fact, issues concerning programs for the energy efficiency of buildings [Patti et al., 2015], management of facilities and smart utilities associated with sensor systems and Internet of Things (IoT) [Teizer et al., 2017], plans for decontamination and environmental sustainability of interventions, also considering a selective substitution of heritage pre-existing building (like the interventions for seismic risk reduction, quite common in the Mediterranean area) require the definition of overall BIM-based modelling strategies for information management throughout the life cycle of the building set in the wider urban context.
For example, the studies of energy simulation on the dismissed industrial heritage are usually motivated by the need to validate hypotheses of transformation towards new uses in alternative design solutions saving managing costs for HVAC systems [Ceccherini, Gallo, 2018]. In these cases, the BIM model implementation is focused on the treatment of the big building volumes and the overall gross floor area with respect to exposure, orientation and geographic location of the building; the problem of the geometrical data accuracy then goes in background compared to the need for completeness of information on the technical characteristics of the shell elements.
A common aspect of the various examples that characterize the state of the art of the different applications of BIM-based methods for urban regeneration of dismissed industrial areas, is the awareness that the informative modeling of the built environment represents today only a phase of transition towards a reconfiguration of the building heritage, which will lead to new forms of urban use and to a new services market of added value to the person.

4. BIM USES AND STRATEGIES: A METHODOLOGY

The definition of strategies for the organization of BIM-based processes in the various phases of the life cycle of a work, from concept to engineering, from construction to operation management, proceeds through the development of a BIM execution plan. Differently to projects of new buildings, urban regeneration projects process must start from the analysis of the built heritage, which means that the project team can have available an Asset Information Model (AIM), a BIM model including not only the existing buildings but also the wider environmental context in which they are arranged. This problem of starting a BIM-based process can be particularly relevant in the case of reclamation of dismissed industrial areas, where situations of decay have been highlighted due to the presence of polluting substances and materials both in the building structures and in the terrain.
Therefore, the BIM modelling for historical industrial architecture must be carry out not only in the context of the H-BIM (countless are buildings of this typology, which are submitted to protection forms because recognized as historical and cultural heritage), but also in implementations oriented to materials technology, geotechnics, etc., and moreover towards total BIM infrastructural approaches.
The BIM project Execution Plan (BEP) is a document aimed at managing the information flow in a BIM modelling process [Eadie et al. 2013], which describes the ways a project team implements, monitors and verifies the reliability of information models during their development. In a fundamental research at Penn State University [CICRP, 2011], the BEP is articulate into four sections each dedicated to the regulation of a specific aspect of the process. In a nutshell, the following aspects are addressed:
1) identification of the objectives and the BIM uses, which add value to the quality of the design and construction process, and possibly also in the operational and facility management stages in the building life cycle;
2) definition of a flow chart of the BIM model implementation processes through their first and

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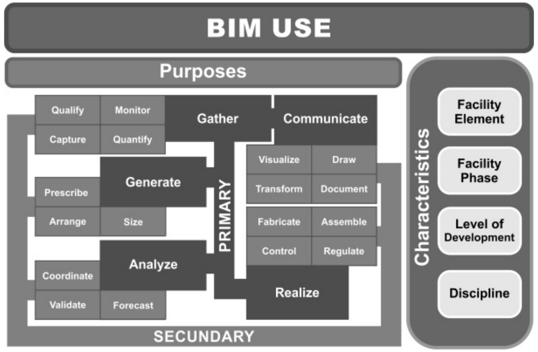

Fig. 7 - BIM Use: Purposes and Characteristics [Kreider, Messner, 2013]

BIM Use Purpose				BIM Use Objective	Synonyms
01	Gather			**to collect or organize facility information**	administer, collect, manage, acquire
		01	Capture	to represent or preserve the current status of the facility and facility elements	collect
		02	Quantify	to express or measure the amount of a facility element	quantity takeoff
		03	Monitor	to collect information regarding the performance of facility elements and systems	observe, measure
		04	Qualify	to characterize or identify facility elements' status	follow, track, identify
02	Generate			**to create or author information about the facility**	create, author, model
		01	Prescribe	to determine the need for and select specific facility elements	program, specify
		02	Arrange	to determine location and placement of facility elements	configure, lay out, locate, place
		03	Size	to determine the magnitude and scale of facility elements	scale, engineer
03	Analyze			**to examine elements of the facility to gain a better understanding of it**	examine, evaluate
		01	Coordinate	to ensure the efficiency and harmony of the relationship of facility elements	detect, avoid
		02	Forecast	to predict the future performance of the facility and facility elements	simulate, predict
		03	Validate	to check or prove accuracy of facility information and that is logical and reasonable	check, confirm
04	Communicate			**to present information about a facility in a method in which it can be shared or exchanged**	exchange
		01	Visualize	to form a realistic representation of a facility or facility elements	review
		02	Transform	to modify information and translate it to be received by another process	translate
		03	Draw	to make a symbolic representation of the facility and facility elements	draft, annotate, detail
		04	Document	to create a record of facility information including the information necessary to precisely specify facility elements	specify, submit, schedule, report.
05	Realize			**to make or control a physical element using facility information**	implement, perform, execute,
		01	Fabricate	to use facility information to manufacture the elements of a facility	manufacture
		02	Assemble	to use facility information to bring together the separate elements of a facility	prefabricate
		03	Control	to use facility information to physically manipulate the operation of executing equipment	manipulate
		04	Regulate	to use facility information to inform the operation of a facility element	Direct

Attribute	Description
Term	A word or phrase used to describe a thing or to express a concept
Objective	The goal, aim or purpose for implementing a BIM Use
Description	An account of the BIM Use including all the relevant aspects, qualities, and properties
Synonyms	A word or phrase that means nearly the same as standardized BIM Use Term. It may have had the same meaning but has since been superseded.

Fig. 8 - Table illustrating the "Uses of BIM" [Kreider, Messner, 2013]

second level mapping;
3) definition of the scheduling of BIM model delivery, identifying levels of model development, responsible parties for implementation and data exchange, interoperability;
4) identification of IT infrastructures, communication and data exchange procedures, Common Data Environment (CDE) to support the implementation of the models.
The first point is undoubtedly the crucial moment for the strategic definition of the parametric modelling goals related to the specific BIM uses. It should be noted that the list of BIM uses proposed was the result of a review of technical literature and a public inquiry among experts in the construction sector, at the end of which 25 BIM uses were identified. These suitably integrated are still today the reference for the drafting of BIM implementation protocols.
However, from a methodological point of view, this approach has some limitations; in fact, if it is easy to classify a BIM use in relation to the specialized disciplines, it is more difficult to establish connections between models of different disciplines within a same information flow with implementation timing often overlapping or working in collaborative ways with models federation. On the contrary a more complex classification criteria of BIM use is proposed in "The Uses of BIM" (Classification and Selecting BIM Uses) [Kreider, Messner, 2013], which goes beyond the simple descriptive approach, taking into account the specific purposes, achieving by the implementation of BIM modelling.
According to a hierarchical structure, a BIM use is classified on the basis of two factors: A. Purposes and B. Characteristics. The "Purposes" are defined as *"the specific objective to be achieved when applying BIM during a facility's life"*, and they are classified in the following primary categories: A1. Gather, A2. Generate, A3. Analyze, A4. Communicate. Every primary category is divided into three or four secondary categories as illustrated in the general BIM uses schema (fig. 7, 8).
The "Characteristics" are defined as *"an element used to define the use of BIM, including its purpose and objective, the facility element, the facility phase, the disciplines and the level of development"*, and they are qualified on the base of: B1. Facility Element, B2.

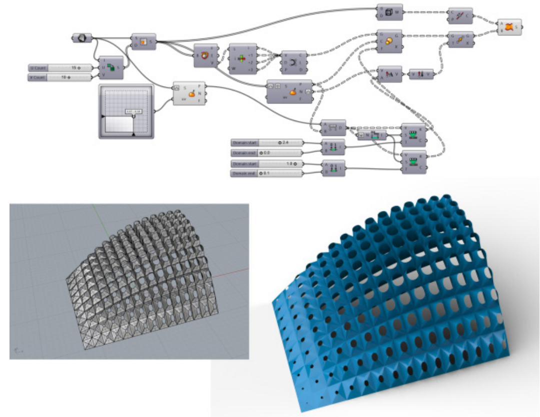

Fig. 9 - Procedural modeling in Grasshopper, generation of a sequence of panels with variable openings, shapes and sizes. All the geometrical features are connected to the generative workflow (Braghiroli A. 2018).

Facility Phase, B3. Disciplines, B4. Level of Development. In essence, BIM use is identified not only on a disciplinary basis and level of model implementation (such type B factors, which are generally taken into consideration), but also and especially in relation to the specific actions that the team must develop to achieve certain objectives.
From this methodological approach it follows that an effective BIM strategy, especially in the context of urban regeneration interventions, must initially proceed to identify the purposes of the project (primary and secondary purposes), which will characterize the *"mission"* of the BIM-based process.
Below, we will try to highlight through the proposed approach as the implementation strategies of BIM-based processes, can be made more explicit for the project teams and more generally for all the subjects involved (owner, designer, builder, etc.), expressing the BIM uses in terms of the requirements to be satisfied by the model and related activities to be performed, overcoming the simple definition of its characteristics.

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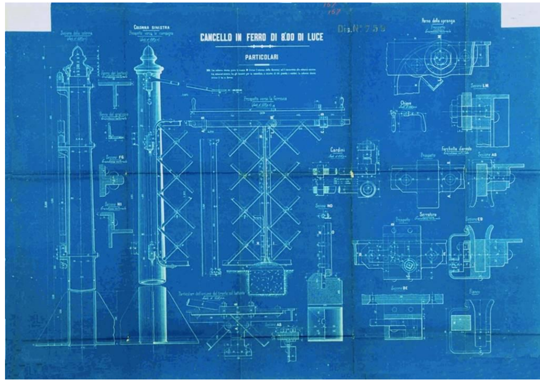
5. FRONTIERS OF THE MODELING AND DATA INTEGRATION

5.1. GATHER. The industrial building presents specific difficulties and issues related to gather information, that the operator in the BIM modeling must face and solve. First of all, it is worth to consider the state of the specific architecture and its characteristics. If the machines and materials it produced are still in place, any survey may encounter large occluded and not measured areas, in this case the “industrial” nature of the building may help, offering most of the time, quite regular modules in the composition of the spaces, making easy to model them replying the sequence of constructive elements. The modular, industrial elements, often prefab and/or defined by clear standard parts can be a vantage in modeling and in the definition of parametric elements. Certain parts, made of well recognizable elements may be controlled and modeled using existing libraries, others should be easily defined creating specific parametric ones. For more complex parts, like for trusses, sheds, and other serial elements, it is possible to foresee the use of specific plug-in integrated in the BIM software, like those based on procedural shapes generation, most of all used for developing new designs, but often fully compliant with the need of modeling an old facility. On this front, the ongoing solutions from Autodesk like Project Refinery Beta (in beta development version at the moment of the writing) are very interesting and may bring soon to a better automatization in the creation of such parts.



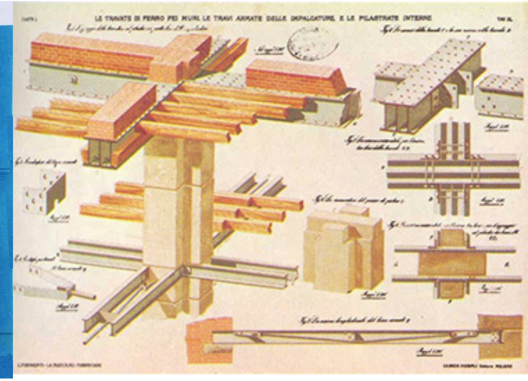


Fig. 10 - A drawing from Railway Technical Office. Ancona, end of XIXth century. This kind of drawings may be used as an indirect documentation source for the creation of BOMs.
Fig. 11 - A graphic table from Technical Handbook, “La Pratica di Fabbricare” of C. Formenti (1893).
Fig. 12 - Some samples where the aspect of the item may influence the modeling process: The Warehouse in Florence made with “Pan de Ferre” Technology, the “Lapis Ligneus” panel in the Montemartini Museum; some complex piping element in a wood factory in Italy (Verdiani G. 2018) and the classical image of the Hennebique concrete construction system.

The choice of these procedures may slow down the production at their introduction, but after that the solution is acquired and fully implemented, the benefits in speeding up the creation of these kind of models are evident. Thus, any the procedure, it is important to define well the elements under modeling, understanding the real value, design, structural aspects, materials of each part before starting the production of the parametric object.

Especially when using procedural, semi-automatic solution for modeling it is important to define clear ideas and concepts during the decision-making procedure, considering both performance criteria and versatility of the results. The use of these tools can be a very interesting occasion both for modeling of the existing parts and even more for the design of new elements. In the procedural modeling process, the combination of various instructions into a principal elaboration may additionally expand the arrangement of connections on which the conceptual design is based (Fig. 9). This implies, through the digital model, to define a system of conditions, capable to bring to the development of different arrangements of the model which can be called “cases of the model” (Turrin et al, 2009).

New interesting tools like the well promising Faro As-Built plug-in for Autodesk Revit and Autocad, may bring important integrations and speed-up the modelling needs. Thus, a good knowledge of the architecture on which the modelling is undergoing and an accurate planning in the definition of the BIM project should be always the first step and a precious elements in the optimization of the whole final [Masuda, Tanaka 2010].

5.2. GENERATE. One of the weak points in the digitalization of an architecture is that sometimes there can be a misconnection between who gathers the digital survey of the building and who takes care to generate the BIM model; the complete and rich complexity of competencies may be here at a bottleneck: the operator creating the model from the point clouds or from the polygonal mesh generated by photogrammetry may encounter some difficulties in creating elements, developing parts, understanding the real shape of some parts. This because even if the point cloud model is at the best quality in terms of coverage and level of details, the perception in fake colors, or some issues coming from particular materials (rusted iron from a distance, glass in good conditions, broken glass, chrome surface from machines, narrow elements like wires, cables, areas with dense piping) may left various doubts to the operator, stealing time to the effective modeling work. To mitigate this issue, it is possible to plan the integration of the aligned point clouds with extra information, like pictures, scan of notebook pages or drawings and metadata texts, this operation can be easily done using specific tools inside software now well implemented in the main BIM workflows like Autodesk Recap. In this software it is possible to select a point and add a note, in the note it will be possible to include a picture (from a digital camera or a scanned document) and/or a text (like a comment, note or external hyperlink). Including graphical notes, information and images, the previously “limited” point cloud will become more capable to transmit its own shape, the separation of parts and the real characteristic of the building to the human operator processing the data. This procedure may seem quite obvious, but often the amount of extra information and metadata are quite poor in most of the point clouds coming from a digital survey. In this way the understanding of the building receive no help, which thing may become an issue. Just a couple of examples where some additional information can avoid tricky situations: in Firenze, the long abandoned pavilion/warehouse, along the Arno river in the Varlungo neighbour, former belonging to the local public transportation agency (nowadays named ATAF). It was built in 1890 by a Belgian company [Scalzo, 2012], using a French technology named "pan de ferre" (iron made sandwich), where a panel of bricks is arranged inside a frame made of iron beams (Fig. 12). This self-bearing element is then used to build up all the vertical partitions, connected to the main structural system of beams and pilasters, both internal and external. Even if in some parts of the building this technology has been replaced with various "patches" made with other materials, the unicity and specificity of this building is mainly linked to this very rare use of the "pan de ferre" in Italy. Such an element is then in need to be properly defined by a specific parametric model, which requires, first of all to recognize its technology avoiding to confuse it with a simple brick wall built in between the beams. Another example may be found in the former Montemartini Power Station, Rome, now an archaeological museum, built at the beginning of the XX century and then updated and powered more than once until its abandon and further recovering. In this case, in the large machines hall of the plant there are a decorative solution which is described by the most of the bibliographic references like the presence of a series of panels in "Lapis Ligneus" (Fig. 12), with the height of about two meters, running all along the walls [Fiore 2006]. This may appear at first as a stonework, but in reality it is a series of wooden panels painted to simulate the veins of a large stone slab ennobling the working areas. Basing the interpretation only on digital survey and the quite original term used to define this element in books and articles, it may happen to fall into a mistake, bringing to the misinterpretation of these elements for stone slates instead than wooden multi-layered panels. In both these cases a simple note inserted in the point cloud may avoid the production of wrong modeling and the need to go back inspecting the building.

5.3. ANALYZE. The management of structural risk (especially seismic risk in Italy) is a huge question concerning the reliability of the information available on the existing building heritage. This has led to a growing demand for digitization of the data referred to predictive models to analyse the structural performance. Building information modeling can assume the important role of database, both geometric and analytical, usable by the properties owners to develop the required structural analyses. It may be strategic tools in the design approach on industrial heritage, giving a significant help on the understanding of the structural conception of the building.

A large part of the industrial archaeology patrimony is made of iron/ghisa, concrete and bricks elements, sometimes decorated, even with stone parts. In particular, the reinforced concrete structures used

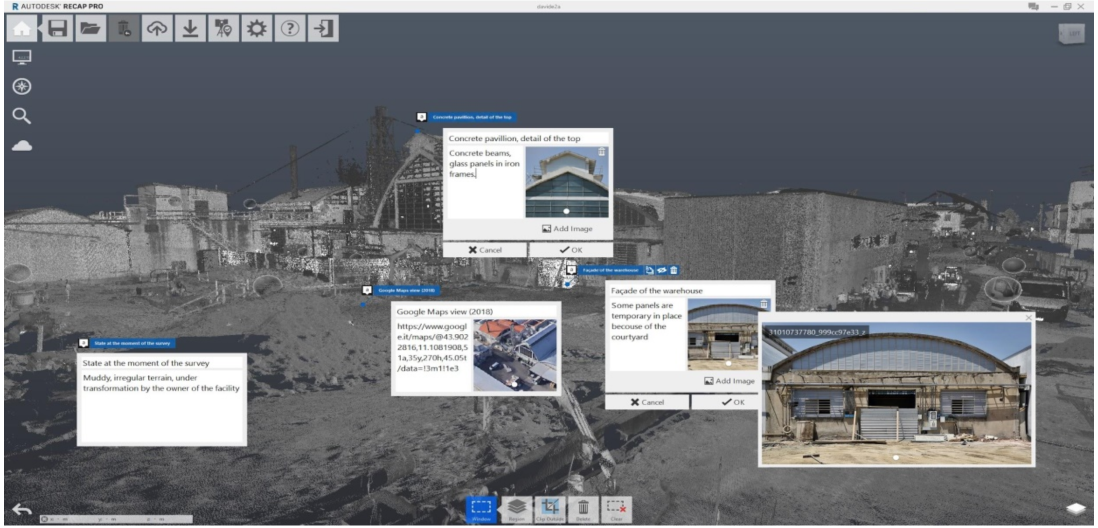
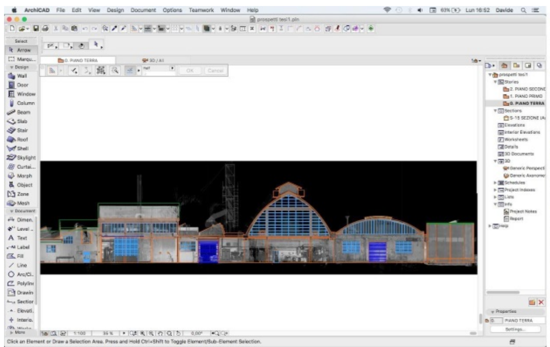


Fig. 13 - Industrial plant in Prato (Ricceri's Wool Factory). Insertion of images and notes to clarify the architectural aspect of the building using Autodesk Recap.



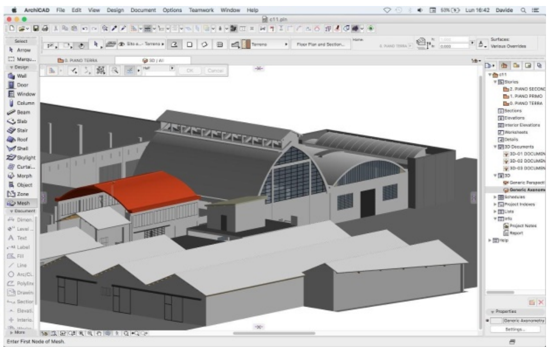


Fig. 14, 15 - Industrial plant in Prato (Ricceri's Wool Factory), modelling the BIM digital model in Graphisoft Archicad, for some elements not compliant with the available libraries it has been used the command "morph" to create the shapes of concrete vaults and structures.

frequently to cover the large factory spaces were built using experimental technologies, which today show all signs of rapid degradation. The BIM modeling must therefore reach an adequate level of development, which does not only concern aspects of geometric detail, but above all of information content of the elements particularly on the technical characteristics of the materials. To enrich the model of such information, these can be deduced from on-site tests, material sampling and laboratory tests. However, to this end the consultation of both direct documentary sources if available (original project drawings, tender documents, price lists, technical and descriptive specifications, etc.) (fig. 10), and indirect ones (treatises, coeval technical manuals, magazines((fig. 11) can be of great interest to extract useful information for the implementation of the BIM model. In example, for the elements in reinforced concrete, the importance of a correct interpretation may be double: from one side there is the need to understand their conditions and their need of intervention/restoration [Bertolini, 2011], then there are their significance and value, sometimes these elements may present old but interesting aspects, an element using the original Hennebique patent or similar "pioneeristic" solutions may be even worth of a proper valorization (Fig. 12). The correct modeling and reading of the original concrete structure may benefit from "under the skin" diagnostic survey, like it may happen with the use of local georadar mapping [Barrile, Pucinotti 2005].

A solution to read the condition of the structure and then apply proper evaluations for the structural calculation and re- design [Hellebois, Espion, 2013]. Such data should be linked directly to the digital survey base, using simple procedures, like the just described "notes/links" used in Autodesk Recap.

The parametric modeling to analyse building performances foresee an approach to "federated models" [Biagini, Ottobri, 2018]. The model has to be disjointed into several models related to different specialization from which are derived other models for the related simulation (analytical models). There are still numerous problems inherent in the geometric correspondence between the "analytical models" and the "structural model", while interferences and discrepancies between "architectural model" and "structural model" can already be effectively managed with specific model checking procedures.

5.4. COMMUNICATE. 3D digital models have long been used to communicate the quality of new design solutions or to represent existing buildings. The quality of today's images extracted from digital models is often so high as to make them hardly distinguishable from a photograph. Even BIM models

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Fig. 16 - The grain silos: history and design
Fig. 17 - Building reuse for assisted sanitary housing: visualization of interior design from BIM model

can reach a similar photo-realism, however visualization is only one of the modalities that characterize the objective of communicating information on the building among the players of the project process. In the reclamation of dismissed industrial buildings BIM models can find their specific application in the technical illustration, as a communication tool between the owner, the project team and the site management operators. The representation requirements for the technical illustration are different compared to the photo-realistic display: for example, the colors often stand for different plants and parts of buildings, rather than the actual materials. This increases the effectiveness of the representation that is enriched by further meanings in relation to the specialized discipline addressed.

5.5. REALIZE. For obtaining a complete management in the BIM logic and benefit, the setup of the project should consider a specific aspect of the industrial building: the need for decontaminating the area from toxic materials, oils and possible unexpected "burial" of polluting materials [D'Arcy et al., 2017]. In this perspective the BIM implementation in all the procedures for 4D and 5D management can realize a full control on the shape of the terrain and material quantity, so to allow the possibility of planning and control the removal of small or large amount of them. According to the products treated when the industry was operating, the soil inside the former industrial facility and in its nearby should have received oils (from the machines) or other polluting liquids. The removal of one or more meters of ground is quite often a need to avoid possible risks to the future users and to the environment (pollution of the underground waters, difficulties in the growth of new planted trees). If we consider a generic situation of intervention in a former industrial area/building, it comes clear that there will be a generous production of waste during the renewal site: terrain, walls, machines, materials from past storage areas, ruins of fallen/altered parts. Such a process should be integrated in the general management of the design planning, with a significant reduction of the impact of the site itself over the nearby areas [Gray, 2018].

6. STUDY CASES AND OPERATIVE/ENHANCED WORKFLOWS BY BIM MODELING

6.1. In the study case of the “Lanificio Ricceri” (Ricceri’s Wool Factory) in Prato, Italy, developed for

Fig. 18 - "Tobacco Factory" in Arezzo. Overall view

study and research purposes, the presence of buildings from different periods, with some of them with specific appreciable formal qualities, in front of developing a re-design of the productive spaces together with the opportunity in giving access to visitors for exhibition and learning occasions, put in evidence the need to develop a BIM model to manage the conditions and the planning of the structure, keeping the differences between the different parts, the machines and the reorganization of the productive activities. The use of metadata, pictures, textual notes and extra graphic connected to the 3D point cloud coming from the digital survey allowed to produce a versatile base, useful in all the 3D modeling and BIM development (fig. 13, 14, 15).

6.2. The "Pagliere factory" is a proto-industrial architecture, built in the second half of the nineteenth century in Florence on the occasion of the urban reorganization of the Poggi Plan. It was built on architect Barberis's design and had to respond to the needs of the royal stables that had been transferred from the central area of San Marco, to the Porta Romana district along the new urban avenues. The complex consists of a central body a and two side wings organized on two levels. The ground floor originally consisted of a single large room with the function of sheltering horses, punctuated by pillars and covered by vaults, the upper floor preceded by a porch was instead the warehouse of the hay, aerated through arched openings, enclosed by the typical terracotta grilled. Currently only the ground floor is used sporadically for temporary exhibitions. This BIM implementation is a typical H-BIM modeling for documentation and enhancement of the cultural heritage (fig. 3, 5). In this case, the BIM model constitutes a database in which both geometric and informative data can be stored. Particular emphasis should be placed on the generation of BOMs relating to pre-modern construction techniques, developed at a level of detail adequate to guarantee a high quality of model visualization (fig. 4, 6).

6.3. The grain silos of Arezzo was built according to the engineer Ubaldo Cassi's design in the context of the autarchic policy pursued by the Fascist regime in the 1930s, which made mandatory the collective stockpile of all the saleable granular production (fig. 16). The architectural language is inspired by the forms of the second Italian Futurism with clear references to the coeval railway architecture of Angiolo Mazzoni [Cresti, 2003]. The building is divided into a large central factory building, which housed the wheat cells, with a forepart intended for the wheat lifting system and access stairs to the roof; on the ground floor a large platform roof covers the work spaces. The silos structure was made entirely of reinforced concrete cast in situ with compact slabs and vertical walls. Currently the building is in a abandon state. The grain silos reclamation project has been addressed through the implementation of a BIM-based design process. The new forecasts of intended use as assisted sanitary housing are set in a larger project of urban regeneration of the entire area (fig. 17). BIM modeling has focused on the development of optioneering design solutions and the subsequent integration between the architectural model and the structural model and simulation.

6.4. The reclamation intervention of the former "Manifattura Tabacchi" (Tobacco Factory) in Arezzo should be framed within a regional experimentation on co-housing for not self-sufficient elderly people. The strategic position of the building within a district with emerging urban decay has made it the center of a wider regeneration district plan (fig. 18) by the municipal administration [AA.VV., 2018]. The building dating back to the '30s, consists of a main body arranged with the principal facade along the urban road and other secondary bodies connected to its back front. It was built with traditional masonry walls and a roof supported by iron trusses with secondary wooden framework (fig. 19).

Fig. 19 - "Tobacco Factory" in Arezzo. The roof frame

In the early intervention design phases, the problem of the reclamation of asbestos-cement building components had to be addressed, which had been used in post-WWII retrofitting works; furthermore, the parts of the building to be demolished were selected, as they were incongruous with respect to the original configuration, and the performance of the load-bearing structures was verified in relation to the seismic risk.
The BIM process implementation workflow took into consideration BIM uses related to model generation, to the analysis of functional (fig. 20, 21), structural and MEP performances (fig. 22), to the communication of project information to all the subjects involved in the reclamation intervention (designers, owners, builders, administrators).

7. CONCLUSIONS

We are living in years of great technology renovations, the digital impact on previous consolidated procedures is bringing to the evolution and renovation of the relationship between all the levels of the building market and the strategies of knowledge and intervention/design. The industrial heritage seems a very interesting environment in

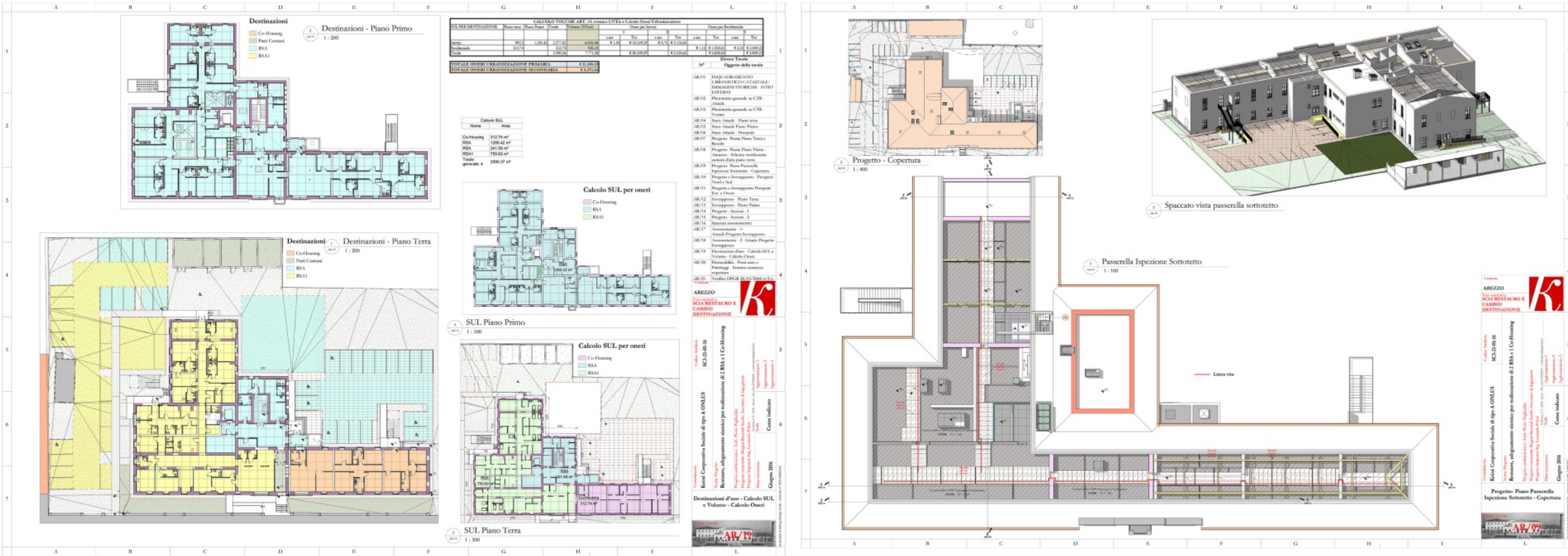

Fig. 20, 21 - BIM modeling for project management

which more complex issues (like for Historical Built Heritage) and well promising solutions (like for new designed architectures) may meet and improve the general approach in modeling and managing, generating the ideal context for BIM environments. Many tools, quite strategic in fulfilling the tasks are apparently far from reaching a consolidated position in this process, giving correct guarantees about their being compliant with modeling teams and avoiding rapid obsolescence. Even if for completing such an evolution the timeline should be quite long, a first exploration of the features of the actual state of development in the BIM tools for the representation, documentation and integration of the historical industrial heritage appears extremely useful in orienting the approach to this scenario. The environment of the Industrial Heritage subjects seems extremely appropriate for applying, developing and testing contemporary BIM solutions, while it mixes many needs regarding the Built Heritage with more robust possibilities of intervention and re-design, together with frequent needs of reclamation and redevelopment.

Strategies should develop towards the creation of repeatable solutions, using tools and combining disciplines in a positive and advanced system. After a phase of theorization about the correct approach, it is time for pilot case studies, results, analyses. This should be faced in three different and interrelated contexts, the first is the academic/teaching environment, the second is the professional scenario, the third is the software development/ commercialization. In the first one the tools and solutions may be experimented, tested and refined. In this way the procedures will be defined, tested in research projects and teaching experiences, then they will be published and shared. This is ongoing and is creating the cultural reference base of this renovation. Its impact see the Industrial Heritage as a specific, thus not main subject. One of the many situation of development and research. In the second the need of economical sustainable solutions is fundamental, both from the point of view of the learning times and of the practical solutions. A project with a deadline will not wait for software development/evolution of the next step in procedures, the team working will find some sort of solution, even if it is not fully "framed" in a procedure or correct, if it solve a present problem, it will be adopted. In the third there will be a lot of strategic events, influencing continuously the other two environment. It is important to remember that the architects/civil engineers/technical building operators are "final users" of these tools, getting what they find on the "shelves" of the software market. Speculations and hypothesis from the academic environment and feedbacks from the professional one can influence and give direction to the software developments (sometimes to the hardware too) but until a solution becomes a standard, most of the experiments are simply designated to a rapid obsolescence. Each of these environment should look at the others and gather, combine, integrate and finally benefit from

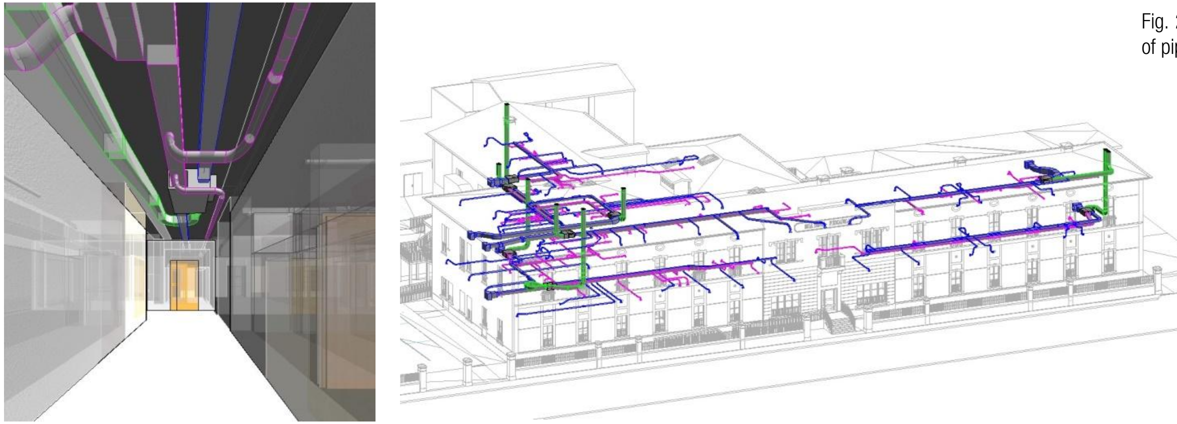

Fig. 22 - Implementation of BIM model for MEP project. Visualization of pipe paths and clash detection with structural element.

the relationship. Thinking to these environments as separate is a possibility, but is risk too. The academic needs to consider the building market and the real job opportunities for their students/classes, the firms and single professionals need to understand the learning offer and use economically compliant solutions, the software development must propose well integrated solution, giving guarantees about preventing obsolescence of the products and offering a sustainable license policies.

The industrial heritage may be a perfect field for experimenting, it combines all the difficulties and issues a BIM project may encounter when it is matter about working on the existing. The procedures, strategies and software developed with this working context in mind, may have a great potential in terms of impact on other kind of interventions.

While quite soon, in this quickly evolving context it will be impossible to procrastinate any longer the definition of well consolidated procedures.

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The presented article has been drawn up jointly by the two authors, but in a specific way Carlo Biagini has edited paragraphs 3, 4 and 6, while Pelin Arslan paragraphs 2 and 5. Paragraphs 1 and 7 are in common between the two authors.

NOTES

(*) Images retrived from https://sidewalklabs.com

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