HBIM between Antiquity and Industrial Archaeology

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Industrial heritage with secular production activity constitutes a specific field of application to refine digital tools for knowledge within the HBIM (Heritage Building Information Modeling) process. Industrial sites are traditionally linked to the exploitation of local resources, and, not infrequently, are settled by recovering the ruins of ancient buildings and monuments. There is the possibility of creating a diachronic HBIM to investigate a complex industrial heritage, its evolution and production phases, modeling components for this type of architecture, with the deepening of the LOD of BIM (Building Information Modeling) instances applied to machines. The application represents an augmented knowledge process applicable on industrial heritage through modeling instances of machines and industrial processes that would allow regional and transnational cross-sectional studies and the enhancement of fruition and reuse of these sites.

HBIM ArchaeoBIM lost heritage industrial heritage industrial archaeology AIPAI

1. Antiquity from Secular and Enduring Production and Antiquity from Reuse

When the palimpsest of urban and suburban industrial landscapes are observed [1], two modes emerge in which historical industrial heritage is rooted in the historical built environment. Objects may possess their own antiquity from secular and enduring production or be the bearers of an antiquity from reuse. Either way, cultural identity and landscape “heritage” can be expressed in both material and nonmaterial evidences, through historical, political, social, and constructive histories [2][3].

On the one hand, the first category is found in the longevity of productive districts linked to specific resources and deep-rooted skills. To give some examples, we can cite the activity of mining sites, such as the Colline Metallifere [4][5], or mining sites, such as the Apuan marble basins of Carrara, or the Tiburtine travertine basins of Tivoli. From a manufacturing point of view, we can mention the paper districts of Fabriano, Amalfi [6], or the Liri river basin [7].

Concerning the latter, an exemplary case is the paper mill set by the Montecassino Abbey in Sant’Elia Fiumerapido [8], active from 1516 to 1985, in which the mechanical innovations of the Fabriano masters were immediately applied, such as the pestle hammer, and with time, the various organizational and industrial innovations followed one another, including the introduction of the Hollander beater, the wood departments, and the modern paper machines. Another example are the places of monetary production, the mints, which were followed by numerous attempts at mechanization [9]. The mint of Venice [10], for example, hosted the minting in the same site from the

13th to the 19th centuries, and this presence has corresponded to an exceptional architectural story. On the other side, the second category concerns the manufactures that, at least in their first phases, have been realized by reusing pre-existing buildings, through changes of use and functional class, often bringing civil or religious monumental buildings of the past to host craft or industrial functions. It is a continuous process that has corresponded in the great cities of the past, to economic and demographic fluctuations, processes of assimilation of built objects that are part of the processes of morphological constitution of the city [11]. There are also particular cases of incredible cultural depth, in which both processes occur. These are places where ancient archaeological sites have been used for centuries for productive activities. A frequent use in the past of which some examples survive, with the exceptional ability to testify to several fundamental aspects of the millennial journey of humanity, include the archaeological site of the Sanctuary of Hercules Winner in Tivoli, which has hosted over the centuries many uses, including the processing of iron and paper, and has been involved in the production of electricity. For a long time, in these sites, industrial superstructures were considered a temporary accident, and restorations and interventions for the preservation of the archaeological asset have eliminated the memory of the more or less long industrial history, generating what is considered a consistent elision of memory and a decrease in the identity content of the site itself.

This has happened even though industrial archaeology and the category of industrial heritage have become an acquired fact, certainly among those working in the field of cultural heritage. However, this has not been effectively reflected in daily practice, in which we still witness a constant “devaluation” of industrial sites and monuments in which it is difficult to achieve harmonious economic and cultural valorization. Yet, the industrial heritage charters wanted by TICCIH and ICOMOS [12][13] have been an acquired fact for more than 10 years and define industrial heritage through its value.

Transferred to ancient industrial sites, a selective approach, no longer current, has privileged one historical period and its testimonies over other eras closer to us, without taking into account that “The industrial heritage is the evidence of activities which had and continue to have profound historical consequences. The motives for protecting the industrial heritage are based on the universal value of this evidence, rather than on the singularity of unique sites” [12].

If there is no awareness of this value, there is a conflict between the classic archaeological monument and the evidence of industrial use. In order to manage the heritage, it is certainly necessary to have models of knowledge that allow to put into system a large amount of data, in which the single elements, ancient, modern, architectural, or industrial, have assumed in history different functions and meanings related to a wider reading of the evolution of the uses that a given society has made of the cultural heritage.

Therefore, concluding this introduction, three aspects emerge, which, coming from different disciplines, must necessarily be considered in parallel to make an advancement in terms of knowledge, management, and use and allow the extension of the results of the case study to other similar ones. Consider the specialists of each sub-disciplinary aspect, that the applied experiences, the case studies, force to move in the shared boundary. Therefore, it will be fundamental to treat the two main sub-themes, heritage and applied digital tools, with their own specificities and needs, so that their encounter, between contents and tools, does not go to the detriment of the methods of both.

Thus, the reflection starts from:

- the recognition of an Italian way of the industrial heritage, already proposed some time ago by Borsi, Tognarini and Bergeron [14][15][16], wherein it is necessary to contextualize the specificities of the scope of application of digital tools, the antiquity of use, and a contemporary reuse to be in a position to later generalize it to other cases.

- the verification the potential that digital tools [17], as they have long been used in archaeology, having to build effective models of representation of palimpsests, a digital model that allows for a comprehensive view of classical archaeology and industrial archaeology. With this in mind, the complexity of information modeling of requests for cultural heritage must necessarily follow the BIM method so that information aspects from manual and archival sources must be associated with a geometric modelling: key parameters, instances, timing, and algorithms will allow for the emergence of phases, groupings, and relationships. Historical studies therefore come into play upstream and downstream of the BIM process.

- the illustration of the specific objectives that with these premises have been set to this research. In the case study, a process that contemplates at least the fourth and sixth dimensions of BIM (time and management) certainly allows for passing from the construction of the instances to the return of the phases from the BIM process.

2. “Italian Way” of the Industrial Heritage

As we have already mentioned [18], in 1980, Renato Covino traced in the journal “Quaderni storici” [19], a first balance of the pioneering years of industrial archaeology in Italy. With two exhibitions in 1978, industrial archaeology had landed in Italy, and the attitude of British scholars was accompanied by “an awareness of Britain’s progressive loss of a leading position among industrialized countries and therefore a desire to preserve the *signs* of a *glorious past*, which constituted a powerful factor of national identity” [19]. All this took place while a process of diffusion of industrial archaeology was underway. In the space of a decade, it spread to Mediterranean European countries, with particular vitality in France, Italy, Spain, and Portugal [19][20][21][22].

In Italy, the starting point is a greater sensitivity towards social phenomena, and the country’s specific cultural background “meant that the debate on its disciplinary field, its chronological limits, its methods and its aims was […] very lively and often saw divergent positions being confronted” [19]. Just on the social studies front, Aldo Castellano in 1977 notes, that in Italy, already at the beginning, the limitedness of the analyses dedicated to the industrial monument from the point of view of social history or technology is cautiously approached, making the study of the monument “scientifically unproductive”. He therefore proposes that industrial archaeology should lead to the “reconstruction of the history of civilization and industrial culture through material documents” [23].

Overall, at the basis of the birth and development of industrial archaeology in Italy, there is a constitutive multidisciplinary nature, as evidenced by the different disciplinary fields that have been interested in it since its origin, from the historical–architectural and technological disciplines to the historical–economic and social ones.

In Italy, as in France and in Central Europe, the processes of mechanization, the complexity of work organization, lead to an extension of the boundaries of interest, not only of the contexts. Eugenio Battisti [24] draws the attention towards the conquests of the Italian Renaissance, both in the genius, the machines, and in the constitution of the capital, of the connected financial system, and in the organization of the job, with Franco Borsi alongside him [14]. If we abandon the theoretical discussion and move among the research related to the understanding, protection, and enhancement of individual sites, we find ourselves operating in a reduced, regional, and local context.

In this context, we can happily record how it is easier to succeed the rigorous experience of the theory, also because we directly experience the collaboration between several disciplines with their own methods. As Covino writes, “the local dimension becomes an element of guarantee of control over the research, whose result can easily be put in circuit and communicated through the associative structures operating in the territory” [19].

As we will see later, the industrial archaeological presences of Tivoli, in the ancient structures of the Sanctuary, are an exemplary case study to experiment with tools of investigation and representation aimed at an integrated and complex concept of industrial archaeological heritage, aware of the long-term paths that over half a millennium have affected the industrial evolution: machine, organization, and energy.

3. BIM and Palimpsests

The use of technology and the BIM process applied to the built heritage is now well established, although this still represents a challenge, both in research and in design practice. The concept of HBIM (Historic BIM) has been declined in different forms starting from its introduction by Murphy [25], going from time to time to detail the specificities of the process adapting it to the single matter. The HBIM methodology has been applied over the years to different types of built heritage: churches, monuments, open spaces, and abandoned industrial sites [26].

Some new acronyms are thus defined, such as AHBIM in the case of BIM application to architectural heritage [27], or the concept of ArchaeoBIM in the case of BIM developments for archeology [28]. In the first case, Brusaporci et al., developed a workflow purely focused on the stratigraphic analysis of the masonry for the architectural heritage, investigating the construction history of the building through the identification of the chronological phases, integrating direct observations of the material structure with knowledge construction techniques and the study of documentary sources [27]; in the second case, Garagnani et al. instead addressed the specificity of the BIM application to archaeology, focusing the workflow on information aspects on the one hand, and on virtual reconstructive modeling on the other [28][29]. This last approach is strongly based on the aspects of cognitive investigation, both material and documentary sources, thus inserting itself in the HBIM research, but being devoid of constructed contexts to be surveyed in their entirety, instead establishing the foundations for a new method of experimental archaeology that allows for a virtuous cycle of control of all the steps: “from the starting data used to formulate the model itself, up to the simulation and post-figuration, that is to the virtual conjectural restitution of a building that actually existed in the past" [28].

The problems of modeling, both informative and geometric, of the built heritage are obviously linked both to the complex system of historical–constructive knowledge, on the basis of manuals and documentary sources, and so not representative for typical software libraries [30], and by the constructional specificities and the evolution over time of the building object, such as, for example, the irregularities in the realization and the manifested degradation. These two specific areas of HBIM pose the greatest challenge of using the BIM tools and process, wherein the standardization logic typical of contemporary construction adapts with some problems to the unicum represented by the individual buildings of the built heritage [31][32].

The topic of information modeling plays a fundamental role when it comes to the built heritage, and even more so in archaeology applications. The information necessary to manage constructive hypotheses and virtual reconstructions can take different forms, can require a greater amount of space, and comes from extremely heterogeneous sources (i.e., reports, drawings, previous surveys, material surveys) [27]. Therefore, the databases currently available on the market do not always adapt optimally to the objectives set at the basis of the HBIM process, and several experiments are under development constituting a central topic of debate.

In general, the shared approach is to implement the information within the model, distinguishing two main research lines: through the development of an ad hoc database, with or without specific interfaces, but which is better suited to the case and the information that they must be questioned [33], or through the semantic implementation of parametric objects enriched by heterogeneous information and the relationships that bind the objects themselves, typical of the definitive building knowledge management (BKM) approach where the central node is that of ontological modeling [34][35]. These approaches represent the basis for the application of the BIM process to the specificity of industrial archaeology. It can be said, paraphrasing the title of a recent volume, that the center of interest of ArchaeoBIM is simultaneously the primary material records and the lost heritage, and this challenge coincides exactly with the research of industrial archaeology [29].

Within the research on HBIM, there are, therefore, numerous current research groups [36] that are interested in the organization of knowledge and ontological modeling [34][35], as well as in the information modeling of data management through interactions multidisciplinary that integrate digital sources and data into a broader BIM process [30][37][38][39][40] whose primary purpose is to guarantee an applied knowledge and collaborative design/management tool. The case presented in this paper falls within the second line of applied research. The research is part of the context, already foreshadowed for many years, for the digital visualization of cultural heritage, with the aims of research, management, and fruition, as highlighted in the London Charter [41] and updated in the Seville Principles [42]. In particular, the need to use the complex digital tool arises from the various factors of inaccessibility, intricacy of the different phases, and disappearance of many components of the heritage of different periods, with the effective opportunities that the digital can offer a simultaneous diachronic vision of even overlapping phases.

Given the challenge of disentangling the virtuous uses of digital representation of cultural heritage from those that are redundant if not ineffective, we are convinced of the preeminence of the second principle, Aims and Methods: “A computer-based visualization method should normally be used only when it is the most appropriate available method for that purpose” [41]. First of all, it was evaluated as to whether the use of digital tools was the most appropriate for the purposes of research and study related to the presence of a complex palimpsest of lost heritage, as well as for the general objective, in the context of a multi-value site, of being able to extract the specificities of the archaeological-industrial evidence and values.

4. Main Objective: An ArchaeoBIM for Industrial Archaeology

This paper takes up the challenge of declining ArchaeoBIM, of which it captures experiences of application to the legacies of antiquity, for industrial archaeology objects and systems. The issue of defining information models for the study, investigation and recovery of built heritage, is a very current and rapidly developing line of research. Within what has been presented in the previous section, it is necessary to focus the attention on a particular type of built heritage, the industrial one.

In the course of 30 years of studies, it has become evident that even in Italy, the centrality of industrial archaeology is the anthropology of a recent past. However, one has to deal with the numerous disciplines that are interested in it, in the historical, economic, productive, technological, architectural, and sanitary fields. The research shows how digital tools allow for the organization of such layered data to increase the possibility of more cognitive synthesis for the various disciplines involved.

Although, from the point of view of the systematic approach to the generation of informative models, the applications on cultural heritage could share various aspects (i.e., multiscalarity, integrated surveys, scan-to-BIM process, and the automation of processes semantic recognition of geometric elements), there are others instead strictly characterizing the industrial heritage: possible decontaminating the area from toxic materials; use of industrial elements and/or experimental technologies; and industrial production nature reflected both in function layout and spatial form, then in the presence of machines.

We do not dwell in this paper in the discussion of known problems on the definition of informative models for cultural heritage in general, now a subject of daily debate in research, but as regards the common themes, we certainly need to mention the relevant possibility of using technologies (i.e., UAV) that allow for the convergence of large distances, usually characterizing industrial sites, as well as the possibility of accessing unsafe or partially collapsed areas, as often happens with this type of heritage [43][44].

Analyzing instead the points that characterize the industrial heritage, we need to start from the first point, concerning the contaminated areas. Biagini et al. [45] consider the need to decontaminate the area from polluting materials (i.e., toxic materials and oils, possible unexpected “burials” of hazardous substances) as one of the most recognizable aspects to be managed through the BIM process. This aspect is fundamental in reducing the impact of the industrial site on neighboring areas during the redevelopment processes, as well as for the reuse of the asset itself, since the products treated when the industry was in operation (i.e., machine oils or other polluting liquids) may have spilled into the ground, causing possible risks for future users and for the environment (i.e., groundwater pollution, difficulties in growing new trees). The 4D and 5D management can realize full control over the shape of the terrain and the quantity of material, so as to allow the possibility of planning and controlling the removal of small or large quantities of them, correctly integrating these operations into the design [45].

The second characterizing point, concerning the construction area, represents a critical aspect of dual significance. While on the one hand the use of industrialized components goes well with the construction logic of BIM models and the standardization of the components, on the other hand, these constructions are often characterized by their experimental techniques, for which it is complex to find exhaustive information.

Given the high degree of industrialization of the components for industrial building, modular elements are often used, some prefabricated, and this can represent an advantage in the modeling and definition of parametric elements. Much of the heritage of industrial archaeology is made up of elements in iron or ghisa, concrete, stone, and brick, sometimes decorated, for which it is necessary to adapt the modeling of ad hoc parametric elements. Among these, it is certainly worth mentioning the reinforced concrete structures, often built with experimental technologies to cover the large spaces of the factory, and that today often show advanced signs of decay [45].

The third aspect concerns the spatial configuration of these buildings, strictly interrelated with the production layout. The definition of information models is a fundamental tool for understanding this aspect through the possibility of investigating on the one hand the geometric complexity and on the other a reconstruction of the production process that has defined its shape and space.

Function and shape are two important factors in the evaluation of this type of architectural space, given that the factory is an environment created for industrial production and therefore intrinsically linked to the productive activity that took place within it [33]. Furthermore, if the machines and materials of the production are still, at least partially, present on site, the survey can encounter significant difficulties linked to large, occluded areas that cannot be measured. These complexities can be overcome with a careful study of the “industrial” nature of the building, wherein the regularity in the composition of the spaces or the understanding of the production processes can integrate the measurements for the modeling of the building elements [45].

With regard to the second and third aspects, it should be immediately highlighted that the challenge of the present research becomes somewhat more arduous as it is confronted with spatial configurations and building systems representative of that category of antiquities for reuse illustrated in the introduction. As will be seen in the discussion, this makes it possible to highlight central themes and characteristics for an ArchaeoBIM of industrial heritage. Next to the basic instances of the industrial heritage, there are in fact the instances of the lost heritage of the sites within which it falls, as well as those of the many phases of life in the centuries or millennia of anthropization, abandonment, and reuse.

Finally, in all cases, the fourth aspect, central to all industrial heritage, comes into play: machines. The possibility of creating AS-BIM (As Built) models must necessarily include the implementation of the information relating to the machinery that characterized the industrial process of those places, defining their architecture. The machines are not always kept inside the places, and thus in this approach, the management of the fourth dimension of BIM becomes fundamental, allowing for the defining of the evolutionary phases of the building and therefore of the presence of the machines up to their decommissioning, degradation, partial ruin, or complete absence.

After these specifications are defined, the industrial heritage can therefore be evaluated as a special field of experimentation for HBIM applications, capable of passing from degradation to a resource or, if neglected, of being lost forever [45]. In this aspect, it is possible to read a parallelism with the application of ArchaeoBIM, in the purposes of digital and informative reconstruction of an aspect, in this case, the industrial process, which has been lost over time.

In virtue of the opportunities offered by the collaborative digital platform, the research has been focused on the second, third, and fourth aspects of the industrial heritage, a deepening opportunity methodologically allowed by the environment in which we are working that enables each operator to implement the model according to his expertise.

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