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Business Process Management and Building Information Modeling for the innovation of cultural heritage restoration process

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***Abstract* – Cultural heritage is a complex ecosystem requiring innovative methods and techniques to facilitate its management and valorization. In detail, restoration processes have to preserve the original characteristics of historical buildings or sites , by involving different professional figures, each one with different roles, responsibilities and skills. In this light, a system that facilitates the information management, supported by new technologies, could allow more precise, efficient and traceable information exchange and could optimize the construction and management operative phase. Starting from these assumptions, this research proposes the application of a new integrated approach to a restoration process of a historical building. It consists in applying BPM technique and BIM methodology to provide valuable insights to optimize the data flow, to gather information and to share knowledge during the restoration process through the lifecycle management, by facilitating the ordinary and extraordinary maintenance, really essential for the Italian heritage.**

I. INTRODUCTION

Cultural heritage is a complex ecosystem requiring innovative methods and techniques to facilitate its management and valorization. In particular, restoration processes result to be very complex, considering that the original characteristics of historical buildings or sites must be preserved and that different professional figures, having different roles, responsibilities and skills are involved.

The correct management of the informative flows and knowledge, which have for decades been produced, becomes fundamental for the cultural heritage enhancement since it is an expression of the ways of living, developed by a community and passed on from generation to generation, including customs, practices, places, objects, artistic expressions and values [1].

In Italy, a country characterized by an extraordinary and unique cultural patrimony in the whole world, the theme of restoring historic buildings is of particular interest. A long and laborious legislative path has resulted in the laws issuance aimed at defining the concept of cultural heritage and its preservation. In Italy, for the cultural heritage, it is currently in force the Legislative Decree no. 42/2004 named "*Codice dei Beni Culturali e del Paesaggio*", which also defines the "minor architectures" as monuments and environmental assets in close proximity of other monumental architectures, by referring to the building's importance, also humble but historical.

In addition, the Franceschini Italian Commission (Legislative Decree no. 310/1964), identified as a new class the historical town centers, defined as "urban settlements that constitute cultural unity or the original and authentic settlements part".

The building cultural interest is not equivalent to the historical-artistic high value, so not all historical buildings are always bound by law [2].

Therefore, the cultural heritage context is quite varied and complex, and involves different actors and different procedural processes in relation to the kind of intervention and the kind of historical building.

Another structural characteristic is that cultural and historical heritage is exposed to a continuing degradation risk that may be aggravated and accelerated by site environmental conditions or catastrophic events and by the lack of adequate forms of continuous monitoring and maintenance.

In Italy, these continuous care practices of cultural assets and the good practices diffusion among institutions have been neglected by owners and property managers. The adoption of maintenance and conservation dynamic plans can, however, give a response to the sector development need by providing cognitive, conservative and economic benefits for the good management of cultural heritage.

The need of new scenarios in the cultural heritage field is suggested by the awareness that maintenance should not be considered as a set of routine activities but it should be considered as a set of complex activities that includes observation, evaluation, registration,

programmed conservation and requires specialist skills during the building lifecycle.

As regards built heritage, historic buildings and monuments, the maintenance activities have always been considered as the prevailing mode of intervention on the existing city, starting from the restoration debate at the end of the nineteenth century, as well as various international Restoration Charter (Charter of Athens 1931, Italian Restoration Charter 1932, Charter of Venice 1964, etc.) [3].

The Legislative Decree no. 42/2004, mentioned above, is the main legislative reference of the sector and includes the following maintenance definition (Art. 29, paragraph 3): "complex of activities and interventions for the control of the cultural heritage and the maintenance of integrity, functional efficiency and the identity of the good and its parts". This definition underlines the idea that also maintenance is based on collection and management of information produced during the activities and the interventions.

Technological innovation, but especially process innovation (new management and prevention approaches) could allow to reduce, delay and, in particular, prevent degradation, and, at the same time, reduce the maintenance and restoration cost.

In this light, a tool that facilitates the information management, supported by new technologies in the Internet of Things and Industry 4.0 era, could allow more precise and traceable information exchange. This paradigm shift could represent the key for processes innovation of the cultural heritage, such as restoration, management and enhancement, by adopting theories and practices usually applied to other fields, such as Business Process Management (BPM) discipline, that manages processes to improve business performance outcomes and operation agility.

The data digitalization, whose properly utilization strongly depends on their analysis and interpretation, could optimize knowledge management and sharing among the multidisciplinary team, according to Building Information Modeling (BIM) approach, which aims to manage the whole building lifecycle in a common data environment.

Starting from these assumptions, this research proposes the application of a new integrated approach to a restoration process of a historical building. It consists in applying BPM technique and BIM methodology to provide valuable insights to optimize the data flow, gather information and share knowledge during the restoration process through lifecycle management. In detail, BPM technique enables the processes modeling and the identification of roles and relationships among different stakeholders, while BIM methodology enables a collaborative common environment where a 3D virtual model is the building data container.

The paper is divided into n° 5 Sections, including the introduction. Section II presents a brief review of the background focused on the methodologies and approaches for the innovation of cultural heritage restoration process. Section III introduces the research settings and the methodology. Section IV presents the application of BPM techniques and BIM methodologies for the optimization of the restoration process, and finally, section V discusses findings and concludes the paper with a discussion on the challenges identified and on future developments.

II. BACKGROUND

The new methodologies and technologies can be the key to cultural heritage process innovation, by adopting also theories and practices usually applied to a limited phase of the process or in others fields.

The Building Information Modeling, defined as a process related to the creation and use of digital models for design, construction and operations of projects [4] has changed the paradigm of construction industry as regards not only technological aspects (software and design tools), but also the approach by users and stakeholders that are becoming more closer to the concept of standardization [5]. As the BIM model is a “shared information repository for collaboration throughout the facility’s lifecycle” [6], it allows all design team members (owners, architects, engineers, contractors, suppliers, etc.) to collaborate more efficiently than using traditional processes [7]. Recently an emerging concept, the Building Lifecycle Management (BLM) [8] [9], aims to transfer and improve information sharing to all the phases of the building process by providing an integrated IT environment to manage the whole building lifecycle [10].

Even if BIM/BLM technology is usually adopted by the scientific community for the design and lifecycle management of buildings, some researchers focused their studies on the value of BIM in the management and documentation of cultural heritage monuments [11]. According to Maddigan [12], the following benefits could be obtained by a 3D BIM environment:

- remote reviewing of the building;
- possibility to study the new structures in the environmental context;
- having surveys of different periods of time;
- better structures analysis thanks to images that gives information about texture, massing and form;
- estimation of restorations and adaptations costs and effects before construction operations start;
- better comprehension of the building.

So, BIM methodology gives a further contribution in order to improve the sustainable valorization of the cultural heritage.

Historic Building Information Modeling (HBIM) is a solution that allows to create parametric objects from the analysis of historic data to represent architectural

elements. The design of these parametric objects is based on architectural manuscripts ranging from Vitruvius to Palladio to the architectural pattern books of the 18th century. The virtual architectural elements contain information about their methods of construction and the materials used. Through a semi-automatic method, using a system of cross software platform management, the 3D historic building information model is realized by mapping the parametric objects onto the point cloud and image survey data [13]. "Very little work has been done in relation to modeling historic buildings and also generating BIM models from laser scan survey data" [14]. However, thanks to the diffusion of laser scanning and photogrammetry for recording cultural heritage sites and to the evolution of digital information systems, the HBIM approach is becoming a topic of great interest.

Likewise useful is the Business Process Management (BPM) discipline, that manages processes to improve business performance outcomes and operation agility in the manufacturing sector. In addition to that, the approach creates and delivers value by linking together people, information flows, documents, changes, systems and others assets. The Business Process Modeling Notation (BPMN) provides a detailed top-down description of a business process model, along with information flows between activities. The model is described by graphical notations in a Business Process Diagram (BPD) [15]. BPMN was developed to help businesses to understand their external and internal procedures, so that decision makers see their processes globally, and to communicate these procedures according to specific standard [16] [17].

To pursue one of the goals of the paper, namely the modeling of a cultural heritage restoration process using BPMN language and BIM methodology, a research among literature works was carried out: a set of keywords were chosen and then used to search papers in Web of Science and Scopus bibliographic database. Very few papers that correlate BIM and BPM or BPMN were found and no one about the application of BPM/BPMN to HBIM processes.

Therefore, papers found are referred to the application of BPMN and BIM to different topics related to the construction industry. For instance, they deal with the development of a Process Mapping Procedure for planning BIM implementation on a project [17], the development and validation of a holistic energy performance evaluation framework [18], the investigation of the requirements for BIM governance and the development of specifications for a cloud-based governance platform [19], the analysis of work process and information exchange in construction projects by focusing on the project owner [20], the definition of a Building Materials Reuse Workflow [21], the encoding of regulatory knowledge related to fire safety into a computable representation [22].

Whilst papers analyzed integrated BIM and BPM concepts for different purposes, they all agreed that mapping processes by BPMN improve the information exchange among stakeholders [20], describes business processes in detail [21] and supports transition to BIM implementation [18].

In this light, it would be useful to apply BPMN to HBIM process in order to point out critical points of traditional processes and to underline strengths and weaknesses of the same processes in a BIM environment. Mapping a HBIM process using BPM method results to be strategic and acquires relevance considering that very little has been done in this field.

III. METHODOLOGY

The first stage of this work was to study the actual restoration process of a historical building. Guidelines for the modeling of the analyzed process are those given by the Italian legislative framework. In detail, the Legislative Decree no. 42/2004, above mentioned, the Legislative Decree no. 380/2001 (*D.P.R. Testo unico delle disposizioni legislative e regolamentari in materia edilizia*) and the Legislative Decree no. 50/2016 (*Codice dei Contratti Pubblici di Lavori, Forniture e Servizi*) were complied with. To map correctly the restoration process the regulation code was therefore studied and information was integrated with data collected through qualitative interviews to architects and engineers. These interviews involved unstructured and open ended questions in order to acquire knowledge from current practice.

The process was first divided into macro-phases and for each macro-phase actors involved, their roles and responsibilities, activities and their interconnection, information exchange, resources were identified. Particular attention was given to documentation produced during activities, format used and to the sharing mode. It is in fact in this area that benefits could be significant as a BIM based system optimizes time and costs related to paper consumption, re-digitation of data, redundant information and archived data for future works.

In the second stage BPMN notation was used to represent graphically and in a standard language the traditional cultural heritage restoration process, in the As Is BPD. The authors translated and integrated Italian regulation codes and stakeholders activities into BPMN language, classifying process information in levels of detail, in order to give a graphic representation of the process at different informative layers.

After a critical analysis of the current process (As Is), weaknesses, bottlenecks or possible legislative code integration were identified and studied in depth. To improve restoration process management in the specific field of cultural heritage, HBIM requirements were

investigated and, by applying a deductive approach, changes in the traditional process were proposed. Accordingly, the final stage of the research work consisted in a To Be cultural heritage restoration process proposal, which integrates HBIM methodology and Business Process Management and which is illustrated in BPMN language.

IV. CASE STUDY

The described methodology could be applied to different processes in the construction field and specifically to cultural heritage processes.

To give an example of how processes modeling could be an useful communication tool and a analysis tool, authors chose a specific case study, hypothesizing that the process analyzed is that one referred to a private property building, identified by law as a building having historical, cultural or artistic value. Furthermore, it was supposed that architectural, structural, plant engineering projects were managed by a design team. Construction works were supposed to be given to a building contractor which was external to the design team.

The specific process was then studied and mapped in BPMN language as it is in current practice, and weak points were identified and analyzed in a critical light. Observations made were then used to design the new restoration process (fig. 1), integrated with HBIM methodology. Both the As Is and the To Be processes were mapped using Signavio Software and hypothesizing a starting simplification, namely that all professional figures accept their designation by the owner.

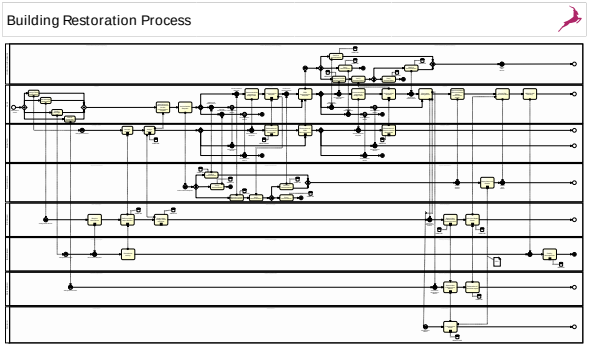

Fig. 1 Historical Building Restoration Process BPD

Even if the BPD illustrated in fig. 1 is not readable because of dimension limitations, it shows the process complexity with actors involved and their interactions in the regulatory Italian framework.

The BPD is a high level representation and sub-processes linked to some activities, indicated in the diagram, were mapped but they are not illustrated considering paper length limitation.

New professional figures were introduced, namely the BIM Manager and the Facility Manager, in order to have a BIM process supervisor and a manager for use and maintenance phase management.

Another change to traditional process is the introduction of a common database, the HBIM DB (fig. 2), that contain the HBIM model, a 3D parametric and informative model and the relative documentation, which are dynamically uploaded by actors involved in specific phases. In this way information sharing is in real time and data are traceable, avoiding waste of time and optimizing costs.

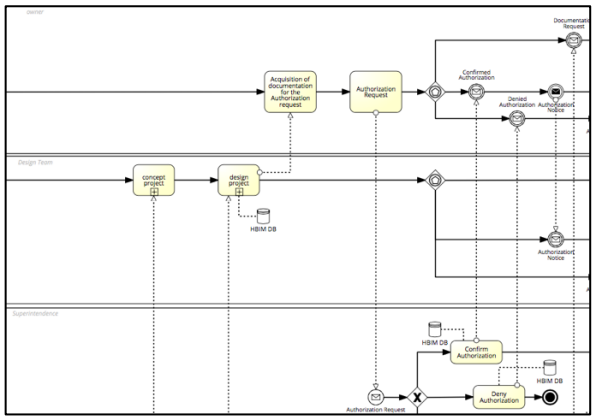

Fig. 2 Process Detail: The HBIM Database for data sharing

According to BIM logic, the BIM manager elaborates a BIM Execution Plan (BEP) to describe and establish the project requirements, that must be communicated to the design team and to managers involved at each level within the organization. To give a building lifecycle vision to the project, the Facility Manager has a role in the design phase and give a contribution in order to define the BEP (fig 3).

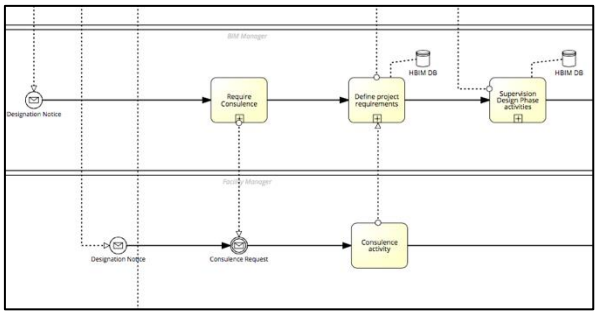

Fig. 3 Definition of project requirements (BEP)

The Facility Manager is a relevant figure within the new process because a great importance was given to building preservation, conservation and maintenance. The Facility Management is in fact enabled through the HBIM model, delivered by the owner to the facility manager (fig. 4).

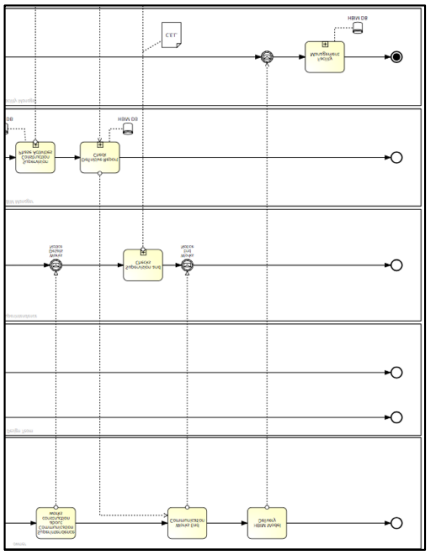

Fig. 4 Facility Management Phase

V. DISCUSSIONS AND CONCLUSION

After an analysis of current cultural heritage restoration process, this research describes a methodology proposal for improving the As Is process, consisting in the mapping of the To Be process using BPM technique and HBIM approach. The main goal was the optimization of current procedures and activities. BPM approach allowed to study in depth the process related to the restoration of a historical building, by fostering activities standardization and facilitating the identification of stakeholders, documents, procedures and bottlenecks that would be otherwise hardly identified. This analysis included the optimization of the process thanks to the integration of the BIM methodology focused on the creation and management processes of a digital model that allows knowledge sharing among all the stakeholders involved in the whole building lifecycle and facilitates document exchange during the lifecycle of the building.

This methodology also allows to integrate into one single process different laws that are not connected to each other, although all these laws are referred to restoration processes.

The use of an open standard graphical approach, such as BPMN, facilitates communication and makes easier the full comprehension of processes by stakeholders. Nevertheless BPMN language is not considered adapt for the detailed description of documental exchange.

The methodology proposed is replicable, since it could be applied to other similar processes in the construction industry, as new construction, urban renovation, etc..

Furthermore, the link with HBIM environment simplifies the documentation, archived in the HBIM Database, and operations management related to the historical building, by enabling ordinary and extraordinary dynamic maintenance. This aspect is an important objective for the management of the building historical heritage.

In fact, particular attention has been given to the management of use and maintenance phases in order to cover all the dimensions related to the building, giving to the construction industry sector methodologies and tools to innovate processes and increase construction processes sustainability.

The next steps will focus on the process improvement, the analysis of other processes related to cultural heritage and on the automatization of some HBIM functionalities for document exchange among different stakeholders.

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