Chapter 11

The Integrated Project for the Redevelopment of a Historic Building:

An Example of BIM and IoT Integration to Manage the Comfort of the Building

Liala Baiardi
https://orcid.org/0000-0002-6825-4459
Politecnico di Milano, Italy

Emerson A. M. Ferreira
https://orcid.org/0000-0001-9219-5447
Universidade Federal da Bahia, Brazil

ABSTRACT

In a scenario influenced by innovation and new technologies such as the internet of things (IoT) that have projected us towards industry 4.0, the digital revolution has involved the construction sector and the entire building process. This research activity aims to deepen the tools at the base of the design and management processes to an effective development and respect for the environment. The text will illustrate the example of redevelopment of an existing building in response to new market needs and in line with the circular economy vision. The redevelopment foresees the integrated development of the architectural building project and the management of the building during his entire life cycle. The innovation authors intend to achieve aims to combine building automation with the quality of life through management techniques that exploit the best use of space and control of the eco-system of the building and the services provided.

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INTRODUCTION

In the framework of urban regeneration processes, aimed at answering to the demand of new spaces operators and services, historic buildings represent very interesting opportunities to experiment innovative and unconventional forms of cooperation to foster ideas, products, technologies and business models to configure new possibilities in the use of contemporary space (Gaspari et all, 2017).

The consequences of the redevelopment actions of the existing buildings are able to generate positive effects, not only on the quality of the buildings but on the whole context of reference going to impact on the quality of life of the users and on the trend of the reference real estate market.

The action on historic buildings represents a great opportunity to support the creative and sustainable development of the city within the ongoing transformation involving both the physical and social level (Bianchini, 1993). This depends on several factors: the current environmental and economic crisis, the reshaping of the concept of qualitative urban development, the progressive decrease of contemporary city expansion trends, the waste production and the creation of residual or marginal urban spaces, etc. (Dubini and Di Biase, 2008).

The power of information in new BIM-based systems and the digitization of historical and material data has led to investigate many innovative solutions, improving several types of analysis, such as the rehabilitation process and the monitoring of historic building (Banfi et al. 2017) and the structural finite element analysis (Barazzetti et al. 2015).

The valorization activities, compared to the traditional restructuring and redevelopment activities, pay particular attention to the potential of transforming the property in relation to the context and needs of the reference market. The valorization process has the fundamental objective of increasing profitability by designing and implementing a “new and precise identity” of the historic building. Particular emphasis is given to the intrinsic capabilities of flexibility and re-layout of the interior spaces in order to respond to any need to change destinations in order to achieve maximum efficiency of performance and profitability. Who pursue income objectives, in the investment phase, carefully evaluate the potential profitability of the property, the potential for increasing the value of the property over time and the possibility of its possible relocation to the market. (Baiardi, 2018).

The development of new technologies and plant engineering, and telecommunications have concerned the schemes of the definition of “third and fourth generation”.

BACKGROUND

Current research focuses on the further development of building automation control systems that enable the increase in comfort and efficiency by including smart control strategies (considering the dynamic parameters such as weather, user behavior, Energy/spot prices, etc.), as well as on the overall performance of buildings with respect to new innovative building design concepts (architecture, shape, envelope, etc.) and the role of urban design (building density, functionality, etc.).

The scenario of innovation and technology has brought opportunities for civil construction to improve processes, products and services. The interest is evidenced by the progress in discussions on concepts such as Industry 4.0 and Intelligent Cities, which relate to the Internet of Things (IoT) and Building Information Modeling (BIM).

The term "Internet of Things" was first used by founders of the Massachusetts Institute of Technology (MIT) research group Auto-ID Center (Sundmaeker et al., 2010). The ability to generate impacts on users' behavior has driven IoT's rapid growth (Atzori; Iera; Morabito, 2010).

The purpose of IoT is to enable communication between the real or virtual devices that exist in human daily life through the Internet. It also focuses on providing information about changes in the status of things in real time. (Isikdag, 2015).

It is important to understand the constitutive elements of the IoT to build a vision of its true meaning and functionality. It is possible to identify six main elements that characterize the IoT, as can be seen in Figure 1 (Al-Fuqaha et al, 2015).

Sensors collect and transmit data daily in the context of the IoT (Chen; Mao; Liu, 2014). This scenario translates into the generation of a large amount of data, which must be stored, processed and presented in a clear and efficient way to guarantee its usefulness and allow an easy interpretation of the information (Gubbi et al., 2013, Taherkordi, Eliassen; Horn, 2017)

Cloud computing can promote a virtual infrastructure focused on IoT that integrates monitoring devices; analytical tools; display platforms and provide appropriate interfaces to end users. The cloud based IoT model will enable the provision of end-to-end services for businesses and home users to access information wherever they are at any time (Gubbi et al., 2013).

BIM has brought benefits to civil construction and building automation control systems because of its ability to produce virtual models that are increasingly close to reality represented and to promote the development of more integrated and efficient projects (Eastman et al., 2011).

In recent years, numerous research activities have been carried out aimed at analyzing Building Information Modeling (BIM) methods in order to elaborate possible implementations for the benefit of project management operations (Eastman et al. 2011). From this point of view BIM is seen as a solution for sharing data between multiple systems (Utica, 2010) and, at the same time, the 3D digital approach allows support to the synergic management activity through the high accessibility of an environment 3D (Utica et al. 2018).

Intelligent digital objects enriched in BIM database provide valuable information for those involved in a project, which is a knowledge-based activity (Kensek, 2014).

One potential of BIM is the possibility of dealing with the status of real-world objects in real time, which may occur through their association with the IoT paradigm. BIM models can benefit from the data provided by a network of IoT devices, allowing a contextualized representation of the information.

In the context of the built environment, the BIM model can function as an interface benefited by data provided through IoT device networks (Machado; Ruschel, 2018).

Figure 1. Six main elements required for the construction of the IoT
Source: (Al-Fuqaha et al., 2015)

Existing studies have adopted BIM and IoT devices in many aspects such as energy management, construction monitoring, health and safety management, and building management. However, BIM and IoT integration research is still in nascent stages where most studies are theoretically and conceptually proposed (Dave et al. 2018; Gunduz et al., 2017).

Based on these premises, the text, starting from the principles underlying the development, experimentation and innovation project, selected and financed by the Lombardy Region within the Smart Living program, illustrates the possible Integration of Physical Models with BIM Models Using IoT highlighting the synergies with research activities carried out in parallel by the Brazilian University.

The principles of the research project are in line with the H2020 community strategy, aimed at intelligent, sustainable and inclusive synergies with the research activities carried out in this area by the Universities.

The output is the result of the collaboration of the research groups of the Politecnico di Milano and the Escola Politecnica of the Universidade Federal da Bahia.

The research project involves application testing on an existing building subject to redevelopment activities with innovative construction and digital technologies.

AIMS AND METHODOLOGY

Our research aims to implement a model of redevelopment and advanced management of existing buildings through of a centralized building management model (property and facility) and to the use of advanced technologies.

For the elaboration and experimentation of the model we have selected an existing building located in the municipality of Milan which is expected to be redeveloped and upgraded without demolishing the main structure. The redevelopment is carried out giving preference to the use of materials and components that can be easily disassembled and reused.

The concept is oriented towards a circular economy model, based on Corporate Social Responsibility, which sustainably involves the People-Planet-Profit principles, promoting the humanization of the elements of technological innovation Smart Energy Grid Buildings. The circular economy model, is recovery of existing buildings with zero soil consumption is in line with and in accordance with the provisions of the European Directives PON GOVERNANCE and PON SMART CITY (Programma Operativo Nazionale) and Regional Law (L.R. n. 31 of 11/28/2014 issued by the Lombardy Region) which plan to reduce the consumption of soil (25-30% by 2020) and providing for the adaptation of all territorial planning tools: Regional Territorial Plan (PTR), Provincial and Metropolitan Territorial Plans, Territorial Government Plans (PGT).

This law is based on the assumption that the soil is a non-renewable resource. It’s priority objective of reducing the consumption of land takes the form of orienting urban-building transformation activities no longer towards the free areas but operating on the already urbanized, degraded or disused areas, to be redeveloped or regenerated.

The environments designed will be intelligent, inclusive and sustainable with automation systems, advanced manufacturing and ICT (Information Communication Technology) support for the integration of smart and IoT (Internet of Things) systems.

The development of the model includes an operational protocol that has strategic and consequential points: the identification of the property to be redeveloped; the preliminary analysis activity (including the technical-economic due diligence) for the identification of functional adaptation and internal layout in order to improve the building perform and meet the needs of future users; the development of the model with the aid of BIM and the creation of a special control room that interact with the monitoring system to govern and controls the automations, launches the applications and support the users.

The model definition will be presented in the following sections of this paper.

DESCRIPTION OF THE PROJECT

Digital technologies have fundamentally transformed our interaction with the built environment. Mobile devices provide a means to rapidly access and share information.

Smart buildings use technology-based platforms which facilitate the operation of real estate assets.

The platforms may provide information about building performance, or they may directly facilitate or control building services.

PCs, tablets and mobile phones are potential dashboards for controlling electronic functions.

The Internet of Things (IoT) allows objects to be measured (information provision) but also sensed and/or controlled remotely across the existing network infrastructure, creating opportunities to adjust or turn systems on or off remotely. As an example, heating systems can be switched on remotely through a mobile phone app.

Many of the biggest consumer technology companies are now moving into the smart home market. For example, Apple recently released its self-installed smart home ecosystem, called Apple Home.

Google launched the Google Home and its companion ecosystem in 2016, hoping to jump into the voice-activated smart home speaker market, as Amazon with Alexa, that can answer basic queries as well as control smart home devices.

Many more companies deliver innovative building automation and energy management systems that increase comfort, environmental quality and sustainability requirements.

As example, CAME, and Siemens have transformed themselves from traditional suppliers of mechanical goods into developers of home automation and intelligent systems. CAME, for example, develops controls for large public facilities and the management of urban and public areas, offering integrated solutions to meet the needs of people-flow and access control controlling and monitoring. Companies such as CAME, and Siemens have transformed themselves from traditional suppliers of mechanical goods into developers of home automation and intelligent systems. CAME, for example, develops controls for large public facilities and the management of urban and public areas, offering integrated solutions to meet the needs of people-flow and access control controlling and monitoring.

Within the facilities context, these technologies impact both capital project delivery and day to day operations. Computer Aided Facilities Management (CAFM) systems supporting the full range of hard and soft Facilities Management (FM) activities have become ubiquitous.

Enhanced by sensor networks and Internet of Things (IoT) devices, FM teams have access to a breadth of building information in real time. Mobile apps and cloud-hosted file systems further enhance this functionality, providing service engineers with field access to building and equipment information and building occupants to a limited range of self-service activities such as real time room scheduling and issue reporting. (McArthur and Bortoluzzi, 2018)

In order for building to be efficient and to ensure environmental comfort, the basic service inputs (air, water, electricity) and outputs (emissions, sewerage and refuse) need to be consciously managed for health and well-being of the building, its tenants and the local community.

The synergy between recovery and reuse of the existing building, combined with the provision of an infrastructure with a digital interface, favors the implementation of the principles of inclusion, safety, well-being, health, eco-sustainability, smart supply chain.

The objective is to relate the executive project to process and product innovation related to the building's operating mode. The model is based on the interoperability of data capable of managing, in a coordinated form, the entire process, starting from the design and involving, on several levels, all the actors of the supply chain of living in an intelligent and dynamic management format building.

Interoperability is the ability for the various project specialists to 'see' the same architectural model through 'their specific apparatus of tools and software in which they imported, read and elaborated the original Relational Data Base, without re- approximate or decoded digits or interpretations then re-coded of qualitative factors (Arlati, 2007).

The originality is given by the evolution of a BIM model of project and construction site with its execution also in the subsequent management and life of the building, completing an example of an integral BIM chain.

The model involves the programming of an operational protocol for the recovery of an existing building that requires the functional adaptation of the internal layout to the new needs of centralized management will be illustrated.

The innovative aspects are enhanced by the model of building management (property and facility) and personal services (building ownership and plant and automation). The management model AIM (Asset Information Model) involves the revision of the entire construction process from the design, to the construction, to the subsequent management operated through a systemic approach that continues along the whole life cycle.

For the elaboration and experimentation of the model, an existing building was selected, which is expected to be reused and re-used without demolition of the main structure and with the use of materials and components that can be easily removed, disassembled and recycled.

The technical administrative due diligence (urban planning and construction) includes the investigation of structural, energy, thermal bridges and 3D BIM output modeling.

The recovery involved the reuse and optimization of existing spaces, respecting the modern principles of urban sustainability and more generally of a global sustainable development.

Particular attention was paid to the choice of materials, their quality, durability and compatibility with new energy-saving parameters, to minimize waste and consumption, in addition to the redesign of all the infrastructures in light of global climate change and the reclamation of damaged soils of the environment and underlying water.

Energy efficiency also has taken into account the European standard EN 15232: 2012 "Incidence of automation, in the regulation of technical management of buildings" promulgated in connection with the implementation at European level of the directive on the energy performance of buildings (EPBD - Energy Performance of Buildings Directive).

The standard, applicable both for the design of new buildings and for the verification of existing ones, highlights how the inclusion in buildings (residential and tertiary) of control and automation systems involves a reduction in energy consumption in general and proposes a method, based on energy efficiency factors.

Building Automation and Control Systems (BACS) allow quantitative determination of the efficiency and energy savings due to the application of automation systems in buildings and to evaluate this saving by defining 4 efficiency classes.

- Class A corresponds to "high-energy performance BACS and TBM". It involves levels of precision and completeness of automatic control to guarantee high energy performance at the plant. Room controllers must be able to interact both with HVAC control (for example adaptive set points based on the detection of occupancy, air quality, etc.) and with other services such as electricity, lighting, sunscreens, etc. Building Automation and Control Systems (BACS): provide effective control functions of heating, ventilation, cooling, hot water and lighting equipment, etc., which lead to improved operational efficiency and energy. Energy saving functions are integrated and can be configured based on actual use and according to the actual needs of the users, in order to avoid energy waste and CO2 emissions. Technical Building Management (TBM): works as part of Building Management (BM) to provide information on the operation, maintenance, services and management of buildings. Energy management provides the requirements for documentation, control, monitoring, optimization, configuration and support of corrective actions and preventive actions to improve the energy performance of buildings.
- Class B corresponds to "advanced BACS and some specific TBM functions". It includes the systems controlled with a bus automation system (BACS) but also equipped with a centralized and coordinated management of the functions and individual plants (TBM).
- Class C corresponds to "standard BACS". It includes automated systems with traditional control devices or with BUS (Binary Unit System) systems. It is considered the reference class because it corresponds to the minimum requirements of the directive (EPBD Energy Performance of Buildings Directive). The room controllers must be able to communicate with the automation system.
- Class D corresponds to "non-energy efficient BACS". It includes traditional and non-automated technical systems that are not energy efficient.

THE DIGITAL MODEL

The elaboration of the digital model is based on the general international principles regarding the implementation and use of the BIM in the design, construction and management phases of the built environment.

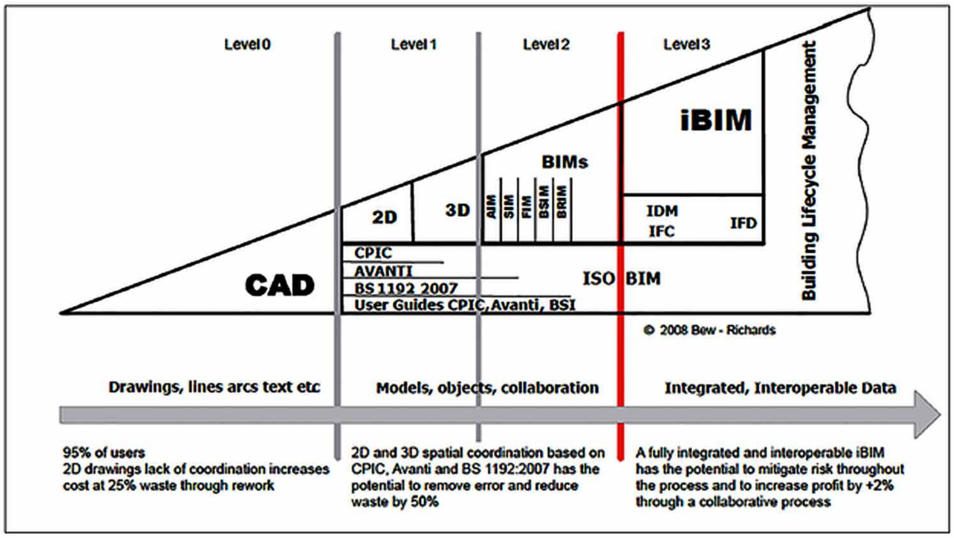
The ramp representation of the BIM Maturity Diagram (Bew-Richards, 2010) illustrates a systematic transition of BIM maturity levels (Figure 2).

At "level 0", the realization and management of projects / assets is basically paper based and based on two-dimensional (2D) information.

The "level 1" migrates from a paper environment to a 2D and 3D environment, with a focus on collaboration and information sharing.

At "level 2" we move to a common method of producing, exchanging, publishing and storing information. At the same time, along the "level 2" ramp, the inclusion in the intelligence model and additional metadata begins. This level is sometimes referred to as "pBIM" and refers to proprietary models focused on individual disciplines. Model integration is based on a common data environment (CDE, Common Data Environment).

Figure 2. Model of maturity BIM, Bew- Richards
Source: (Bew, Richards, 2010)



At “level 3” “iBIM” is completely integrated and characterized by the use of a single model accessible to all team members. This level of BIM develops the 4D, 5D and 6D environments (management of the life cycle of the building, Facility Management). The 4D includes the planning and management of the construction phase, including logistics and site operations. The 5D adds the possibility of performing economic forecasting analysis and contains information such as quantity, unit costs and total materials. The 6D environment extends the model to Facility Management.

Several studies concerning the BIM methodology based on 3D parametric tools have shown how the application of BIM models is able to reduce the costs of the design and construction phases of a 15-20% building, as instrumentation born precisely to support these two phases of the process and improve their efficiency, through a transformation, especially at the methodological level, of the way a building is designed.

Recent research is also highlighting how this methodology, implemented and improved, can bring enormous benefits even at the next level (4D, 5D, 6D) in the use and management phase.

If during the development of the work all the necessary updates are correctly carried out, once the model work is completed it can be of “as built” type and contain all the management and maintenance specifications, for future operation.

Interoperability is a basic condition for BIM to allow communication between different systems of analysis, as well as communication between different disciplines of a project throughout the life cycle of the building. It is necessary that the models be interoperable so that it is possible to simulate, analyze and evaluate scenarios, as well as verify operations and maintenance interfaces (Addor et al., 2010). Problems of low interoperability become obstacles to the use of BIM because they make it difficult to exchange information (Andrade; Ruschel, 2011).

Digitalizing cultural sites and objects and creating digital models is an important task to preserve Cultural Heritage. This implies a need for a spatio-temporal monitoring to identify regions of potential material degradation, unstable structuring conditions, localize spatial modifications and detect environmental damages. (Doulamis et al., 2018). During the design phase, in the case of renovations, it is useful to start from the digital model of the building in the current state on site. For this purpose, it is possible to use the connection between the laser scanning and the technology for video or 360 degree camera for the representation of as-built images connected to a model. Thanks to the SCAN-to-BIM method that transfer the morphological and typological characteristics of the surveyed building to a shared cloud system, it will be possible to support specialists in the documentation and preservation of historical uniqueness of the building with a new level of information sharing. (Banfi et al, 2018).

A detailed specification for the execution of architectural surveys with agreed results and degrees of precision is critical to the success of converting a 'physical' environment to a 'digital', modelled one.

During the operation and maintenance phase of a project BIM can used to:

- Plan, prevent or correct the maintenance of building components;
- operate the asset in its optimal capacity as per the business requirements of the owner and consistent with design intent • plan space and occupancy and optimize portfolios;
- Proactively manage, monitor and adjust building functions in a more energy efficient way against a baseline performance model;
- Monitor building sensors and real-time control of building systems;
- Eliminate or minimize energy waste while maintaining a comfortable and safe environment, increase efficiency and reduce costs;
- Plan and prepare for evacuation and other emergency crises;
- Make renovation, retrofit and demolition decisions using accurate as-built information.

To perform these functions, it is crucial to connect the accurate as-built record model of the building with several other hardware and software technologies. Integration with the sensor network and the asset or building management system is crucial. (RICS, 2014).

In addition, the British government has introduced the BIM Policy (National BIM report, 2012) and the concept of GSL (Government Soft Landing) in order to facilitate a closer alignment of the planning and construction phases with the management and management of the property. The GSL establishes the centrality of the end of the property from the design and construction phases up to the delivery and operation, ensuring an early involvement of the end user. Through the GSL, the design and construction teams assist the end user in completing the use of the property, as well as in the post-occupation assessment and feedback phase (Post Occupancy Evaluation - POE).

THE POST OCCUPANCY EVALUATION - POE

The POE (Post Occupancy Evaluation) is a methodology for evaluating the "performance" of a building used. It is a general approach of obtaining feedback about a building's performance in use, including energy performance, indoor environment quality (IEQ), occupants' satisfaction, productivity, etc. (Peixian, et al. 2018).

The post-employment evaluation represents a moment in the design process of a building that is normally structured in five distinct phases: investment planning, technical-economic planning, design (planning), construction, occupation of the building and its management over time (Facility Management).

The objectives and the fields of application of the POE can be for example:

- Collect information on buildings that offer optimal performance in order to offer solutions already tested in response to the problems of a location;
- Monitor how the property is used to define any inefficiencies or problems;
- Perform Audit on performance, in particular in relation to the use of space (sqm / employees, management costs / sqm or per employee);
- Document the successes and shortcomings of the building so that an objective assessment tool can be available that in the future can guide any improvement choices.

It is a rigorous and systematic process of assessing the use of buildings that allows focusing attention on occupants and their needs, providing judgments whose main purpose is to establish precise information to improve the overall performance of the workspaces and therefore determine a higher level of comfort, safety and perception of the work environment.

From the analysis, qualitative data are extrapolated which, compared with the actual performance of the buildings, determine the "evaluation" given by the difference between the predetermined standard quality levels and the performances expressed by its occupants.

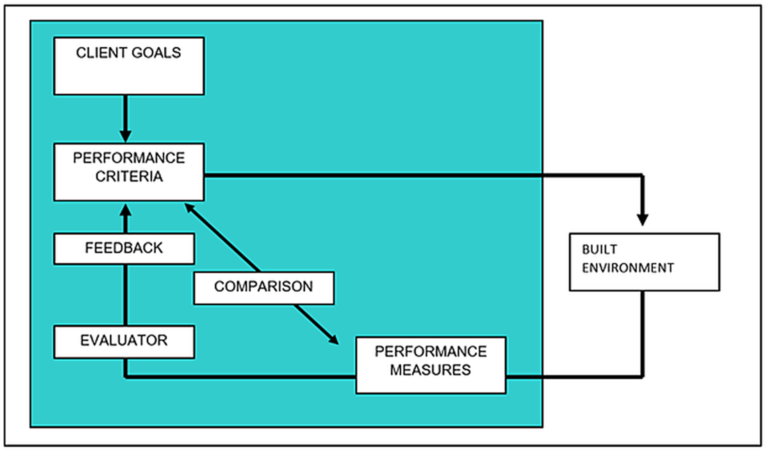
The performance of a building is measured by comparing the predefined "Performance Criteria" based on the objectives of the client and the characteristics of the building, its performance, conducted through the analysis of the perceptions of users / users. (Figure 3)

The "Performance Criteria" are subdivided into quantitative and qualitative criteria, the first ones being easier to define as they can be objectively measured with defined systems and procedures, while the second ones are more difficult as an expression of points of view, subjective opinions.

Quantitative criteria: acoustics, thermal comfort, luminous comfort, quality of materials, size and subdivision of the space (square meter ratio per employee), etc.

Quality criteria: quality of space (external openings, etc.) furnishings, quality of services to people, etc.

Figure 3. Model for measuring the performance of a building



CONTROL ROOM AND IoT INTEGRATION

The BIM model is able to support the building process in all its phases (design, planning, execution, management). A correct collection of information during these phases is of fundamental importance throughout the entire life cycle of the building, significantly influencing the management phase. The interaction between a BIM software and particular applications allows to evaluate in the design phase all the possible solutions according to the particular needs initially expressed: for example, starting from the model generated by the BIM software and integrating it with suitable software and sensors, we have the possibility of evaluating the energy performance of the building and acting at its best in improving choices. At the same time, the objects used in the building model present information that allows identifying and defining its characteristics, not only graphic and dimensional, implementing the model database. The possibilities for optimizing the performance of buildings depend on various factors which include the construction characteristics and the methods of use and management of the buildings.

The correct functioning of the building is supported by solutions consisting of efficient management systems that allow the integration of the technological systems of a building (lighting systems, protection from the sun, heating, ventilation and air conditioning, as well as other systems required to meet the needs of the client), can make a decisive contribution to the use of conservative energy based on real needs.

The possibilities of application are multiple and can be connected, for example, to the use of the single environments (local presence control), to the automatic switching off regulation of the utilities according to a time schedule or based on environmental parameters (brightness, temperature etc.), to the automatic control of the solar radiation protection systems and the opening closing of the frames.

All the facilities included in the management model are monitored by a control room that can be remote or local.

The “Control Room” represents a “model reference” that can also be used remotely and is able to survey technical, energetic, cadastral and accounting data, taxes, maintenance and guarantees, with the following functions:

- Cloud integration of a shared “network” 3D environment.
- Web browsing (via browser without specific plug-ins / software). Custom Web application that governs the structures, monitors them via webcam, controls or controls home automation, starts applications and supports customers.
- The Web application stores data in a database.
- Possibility to make a navigable and three-dimensional view of the building, monitoring of access and geolocation of people.
- Data return by type of user, the platform will return information on individual devices at different levels of detail.

From the Control Room the Operators have access to a customized Web Application that governs the structures, monitors them via webcam, commands or controls the automations, launches the applications and supports the customers.

The web application stores data in a database.

PC, tablet can interact with the control room as a dashboard for the control of electronic functions.

The Internet of Things (IoT) makes it possible to measure objects (information provision) but also detected and (or) remotely controlled through the existing network infrastructure, creating opportunities to regulate or activate or deactivate systems remotely. For example, Google 2014 the acquisition of Nest to create a Google IoT division was considered significant at the time.

The control room can be connected to a large amount of data, improving the decision-making power of the actors that make up the project and management team. The project can be facilitated by the presence of sources of information in real time, for example data on the supply chain, on the prices of materials and services, marketing data, data coming from the sensors, data on the cloud, stratifications on safety and preferences of the users.

In the building management phase, thanks to the interaction with the Web Application the Operators can:

- Launch applications;
- Mapping of maintenance over time;
- Collect and manage requests for guest services;
- Have visibility through the web of the common areas of the structures;
- Resolve real-time customer requests;
- Manage maintenance tickets (web form in workflow);
- Check the climatic data of the building;
- Interact with the building's home automation;
- Check the logs of all transactions (web form);
- Read the object's direct properties;
- Map user usage data (entry, exit, etc.):
- Manages the database.

MONITORING SYSTEM

The monitoring function is particularly important in buildings. In order to meet and maintain the planned operational performance demand of buildings, facility managers are required to guarantee an up-to-date maintenance status of the equipment, which is dependent on the continuous feedback from the building sensors, controllers, and facility management information systems during the O&M phase (Operation and Maintenance).

It also increases the accuracy of maintenance data required for decision making with the assumption that the collected data is relevant, used correctly, and is of high quality. The quality of data is extremely important because accurate information is vital for decision making. One important factor that affects the quality of maintenance data is the user's interaction with maintenance systems and tools

For example, the installation of a valid measurement and monitoring system for electrical quantities, capable of counting consumption in detail, and collecting them in a single analysis system, makes it possible to intervene effectively in order to increase overall energy efficiency and eliminate any waste factors. A well set up system also facilitates the management of absorption tips and the adoption of those devices that are necessary if particular maximum values are reached, such as automatic disconnection of loads considered to be less priority.

Measurement and recording of consumption are a significant indicator for scheduling maintenance since it allows identifying the lines and equipment that are most requested, providing useful information for the preparation of the preventive and planned maintenance plan.

Furthermore, the possibility of promptly detecting any unexpected variations in consumption has the advantage of quickly highlighting any malfunctions and activating maintenance and / or service interventions, thus limiting the sudden emergencies and the consequent costly production blocks.

The supervision of all functions and energy consumption is centralized and is carried out by PC.

The control system supervises the overall situation of the site and oversees the integration between the building automation system based on the bus network and the surveillance and control system based on detectors, sensors, actuators and cameras.

Sensors

The Wireless Sensor Networks (WSNs) have recently gained importance worldwide, driving the development of intelligent sensors. These sensors have some advantages over traditional sensors because they are small, use few computational resources and have a comparatively lower cost. Smart sensors are used to detect, measure and collect environmental data that is processed and transmitted to users based on requests.

There is a wide variety of mechanical, thermal, biological, chemical, optical and magnetic sensors to measure the properties of the environment. Depending on the application and the type of sensors used, the actuators can be incorporated into the sensors (Yick; Mukherjee; Ghosal, 2008). In the context of a built environment, for example, the sensors are able to monitor conditions such as temperature, gas levels, pollutants, humidity, door and window conditions, room occupancy and conditions of different systems (Underwood, Isikdag, 2011).

Actuators

An actuator, in turn, is an electromechanical device used to exercise control over several components of a system. Actuators can act together with different detection devices, make sensor parameter adjustments, promote movement or monitor microcontroller energy. In the context of a built environment, the actuators are able to perform actions to influence the environment by emitting sounds, lights, radio waves and even odors (Whitmore; Agarwal; Xu, 2015), as well as movements.

RFID

RFID is a remote identification technology that supports a large number of unique IDs and whose reading systems can distinguish many different tags located in the same area without the need for human assistance (Want, 2006). A typical RFID structural system consists of a reader; an electronically programmed tag (transponder) and control software (Oliveira; Serra, 2017; Finkenzeller, 2010).

The tags that work with this technology can be divided into two classes: active and passive. Active tags are those that require an external power source or that use the energy stored in an integrated battery. In the case of battery usage, in addition to an increase in costs, the duration of the tag is conditioned by the energy stored and the number of read operations performed (Al-Fuqaha et al., 2015, Oliveira, Serra, 2017; Want, 2006).

“This technology can be applied in many areas for the control of the warehouse, the location of materials and people, the control of entry and exit of products, vehicles and people, the identification of instruments or animals” (Oliveira, Serra, 2017).

According to Oliveira and Serra (2017), the construction industry has shown interest in the use of RFID technology in processes in its production chain, so there is a market demand. However, the lack of knowledge about the potential use of this technology is a factor that still limits its widespread use.

An important feature of the IoT is the ability to communicate between sensors, actuators and RFID tags, as well as their integration with wireless networks to monitor and control physical spaces. This integration must have adequate modulation characteristics; confidence; flexibility; robustness and scalability.

As confidence control systems must guarantee user safety, privacy and security.

Flexibility and Extensibility: BIM platforms have comprehensive, well-documented Application Programming Interfaces (APIs), and support for interactive programming languages that can be used by developers to customize, add functionality, or automate tasks. This characterizes its extensibility. This feature works is important for generating specialized functions, as well as allowing the programming of interfaces to other applications, enabling interoperability (Eastman et al., 2011).

Scalability allows BIM to remain responsive regardless of the number of 3D parametric objects in the project. This allows it to maintain the ability to handle large-scale design combinations even though modeling is done with high levels of detail. Scalability, however, will depend on the capacity of the computer and the operating system used (Eastman et al., 2011).

The energy consumption monitoring system includes capillary interventions in several areas. The points of consumption can be divided between production machines and auxiliary services (PCs, printers, aspirators), covering the entire spectrum of building requirements.

The consumption data recorded (energy and power, in various forms) are conveyed to the central supervision system which analyzes them in real time and compares them with historical data.

By supervising the operation of the systems, the Building Automation System can maximize the efficiency of energy consumption. Furthermore, the possibility of promptly detecting any unexpected changes in consumption has the advantage of quickly highlighting the possible need for maintenance and (or) service interventions, thus reducing sudden emergencies and consequent costly production blocks.

The lighting systems, external and internal, are managed by twilight switches, presence sensors, switch-on and switch-off times according to well-defined scenarios: night, alarm, normal production activity, holidays, holidays.

The system integrates safety and security actions and, through remote monitoring, guarantees efficiency in intrusion detection, access control and video surveillance services.

The main steps taken to implement the monitoring system can be summarized as follows:

- Installation of meters applied to air conditioners, compressors and aspirators, electrical sockets and internal and external lighting systems.
- Installation of interface for meters for the collection of all data collected.
- Creation of a real-time consumption tracking system aggregated by module-area and time unit.
- Creation of a database, with analysis and statistics that allow the comparison between current and historical consumption.
- Display of energy savings obtained, expressed in kWh, Euro, tons of CO2 and corresponding equivalent, expressed as the number of cars eliminated and / or trees planted.

The most significant components used are:

- Direct-insertion electronic meters for detecting absorbed energy, in its active and passive components,
- Modules with infrared interface, (for the connection of the meters with the automation system) that allow to acquire, through the system bus, data on consumption and the values of other electrical quantities detected, such as voltage and current
- Network analyzers for analyzing the quality of electricity consumed. Through the verification of the nature and extent of the phase shifts, any anomalies in the electricity network and the problems relating to consumption are identified and located.
- Actuators for the management of loads of users, such as the control of the switching on and off according to the production times.

RESULTS

The integration of BIM software with management and detection systems entails the development of a single software architecture able to return the combined and navigable data on the building, with different levels of detail and interaction.

A Batch association was therefore structured, based on intelligent selection of types and multiple assignment and structured input file on the COBie model (Constructions Operations Building Information Exchange.)

COBie is a standardized approach that allows the incorporation of essential information in the BIM process to support the operations, maintenance and management of assets by the owner and/or property manager. The approach is centered on entering the data as it is created during design, construction and commissioning of the facility.

The information defined within the COBie standard can be compiled during different phases of a project and by different operators: architects, engineers, builders, producers, managers, etc. Only some of the information defined in the structure of the COBie standard can be managed through a BIM software.

The COBie standard defines the specifications for the exchange of information throughout the entire life cycle of a Facility. The use of the COBie standard ensures that the information is prepared and used without the need to have knowledge regarding the particular methods of collecting and receiving information from the various applications or databases. It also ensures that the exchange of information can be checked and verified in terms of compliance, continuity and completeness.

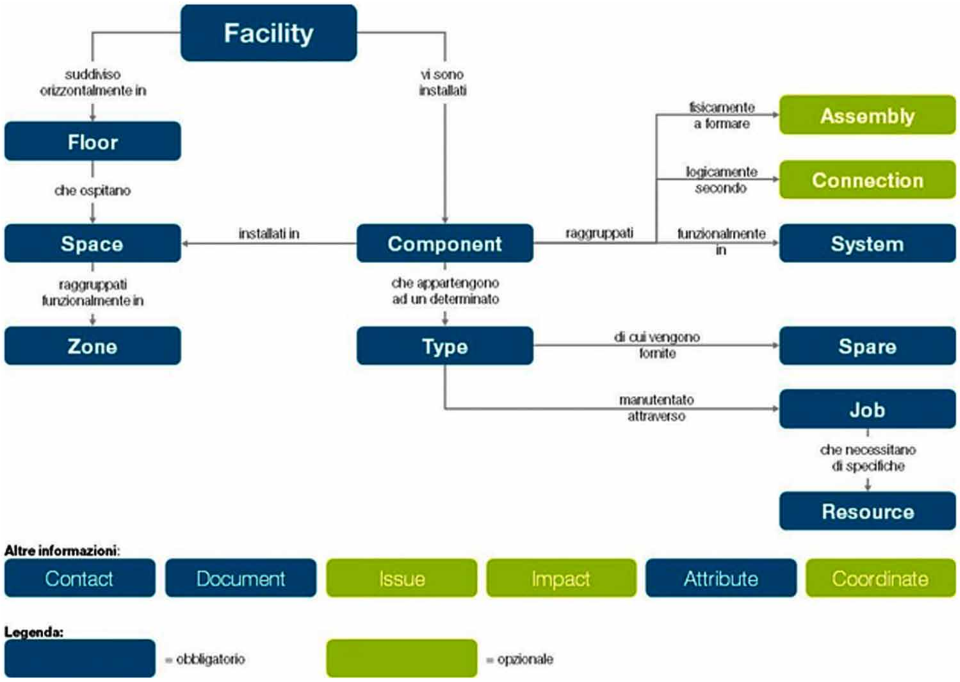
The purpose of the exchange of information is given by the type of facility, which can be a building or a part of an infrastructure. The COBie standard collects information relating to the spaces and installations and components that make up the building or infrastructure.

Interoperability can be achieved by using an open and publicly managed scheme (dictionary) with a standard language. A common example of a scheme is that conceived by BSI (Building SMART International) and by COBie (Constructions Operations Building Information Excange) to support the exchange and management of data, in the sector of the built environment.

The COBie scheme allows the interoperability of essential information in the BIM process (Figure 4).

The approach focuses on entering data when they are created during the design, construction and commissioning phases of the structure. The acquired data is recorded in neutral format and can be exchanged between the various players in IFC format (Industry Foundation Classes).

Figure 4. Example of data structure of the COBie standard produced by the BIS-LAB research group of Contec Verona



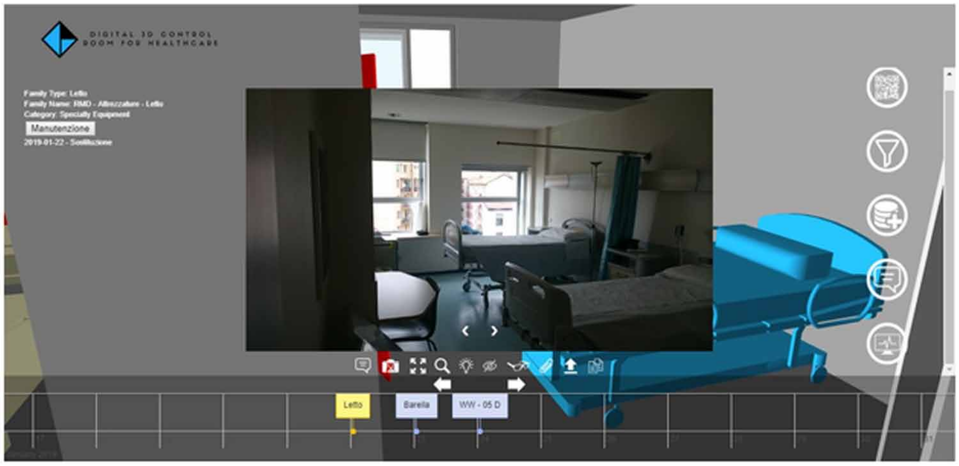
The basic structure of Digital 3D solves the limitation of the COBie standard inherent in the object-oriented environment (Object Oriented Modeling). In this perspective, the definition of the minimum and maximum units of components may not coincide with the structuring of the model in the maintenance phase, which in the case of complex structures may require groups of objects.

The key object of the developed interface is a timeline, with customizable form and extension, which allows to "map" over time and spatially a series of events, which can be external or internal to the system.

To the integration functions between databases, the system adds those of direct online interaction, made visible in the timeline. In this sense, a work of mapping of the rooms, for example, allows physical positioning of rooms in 3D vision that frame the identified maintenance object. At the click on the interested part, the model "moves" to go there. And it shows, in addition to local data, in this case in particular detail photos, memorized for time and reference room / environment (Figure 5).

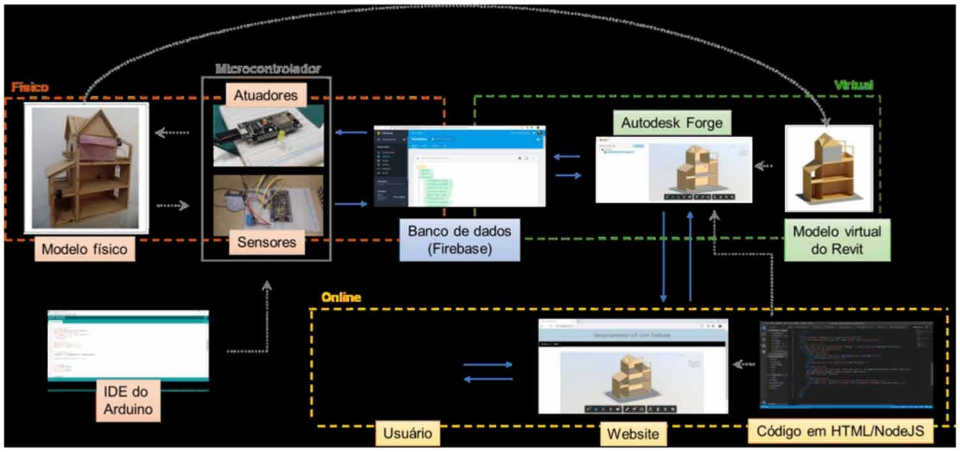
The BIM model was translated and represented locally in the WEB browser through the Autodesk Forge Application Programming Interfaces (APIs) and subsequently hosted on the website. Its connection to the database was established through communication protocols in HTML and NodeJS. NodeJS is an open-source and cross-platform JavaScript runtime environment which through Firebase receives a real-time database and backend. The Firebase service allows application data to be synchronized across clients and stored on Firebase's cloud. Once the reading of the physical sensors is sent to the Firebase and stored, a processing of the data is performed and this information is displayed in the model itself through graphs, texts or other representations. Similarly, user interactions with the BIM model are stored in the database and sent to the actuators of the physical model, creating an information cycle. The general process adopted to integrate the models is shown in Figure 6.

Figure 5. Example of direct online integration on the Open Control Room model of the "maintenance tour". Authorship



Family Type: Letto
Family Name: RMD - Attrezzature - Letto
Category: Specialty Equipment
Manutenzione
2019-01-22 - Sostituzione

Figure 6. Integration of the physical model with BIM Model
Source: (Araújo et al., 2019)



CONCLUSION

The innovation of the management model (facility and property) involves the rethinking of the entire building process, from design, to construction, to maintenance. The approach of the initiative is systemic and sees all the elements participating in a systemic and interdependent way.

The combined synergy between intervention on an existing building with attention to the principles of circular economy (considering for example energy consumption, carbon dioxide emissions, waste, etc.) promotes and guarantees the implementation of the principles of inclusion, safety, well-being, health, eco- sustainability, smart supply chain, recovery and re-use of buildings.

BIM concern issues of information sharing, interoperability, and efficient collaboration throughout the life cycle of a building, from feasibility stages to the demolition and recycling stages (Isikdag, 2015).

With the emergence of technologies associated with the Smart Built Environment (SBE) concept, in which intelligent objects are connected and interact with integrated installations, it is necessary to study the role that BIM can play in this context, helping to increase the efficiency, safety and user comfort of future intelligent buildings.

The future success of IoT depends on the effective integration of Big Data and cloud computing, as the IoT's data processing capacity lagged behind the volume of data collected. While on the one hand the widespread implementation of IoT stimulates the high growth of data that increases Big Data, on the other the development and application of Big Data technology also accelerates research relating to IoT.

The benefits connected to the use of digital technologies to support the intelligent Living BIM, Cloud Computing, sensors and Web Application allow to expand the specificity, quantity, coordination and accessibility of data and reasoning useful for improvement and enhancement of safety, functionality, economic sustainability and comfort of buildings, optimizing the work of all the players in the supply chain.

The developed organizational model increases the following aspects:

- Possibility to design efficient buildings with low environmental / economic impact;
- Possibility of managing and optimizing the construction phases of the project;
- Possibility of having a dynamic and aware management of the existing building;
- Control and reduction of consumption in building management;
- Efficiency in the management of energy and economic resources with targeted maintenance interventions.

This high sustainability valorization project of an existing building may constitute a socio-economic example of smart building.

In fact, we believe that responsible planning will help to balance the social, economic and environmental problems we are experiencing in the future. The use of Building Information Modeling (BIM) in highly complex projects represents the main strategy for achieving quality design and construction.

The use of BIM favors a more harmonious work environment for all the design teams involved, reduces project conflicts, allows for greater efficiency, and optimization of all layouts even under tight deadlines.

The association of the BIM with a centralized management model able to use the data coming from the advanced sensors 'IoT' (which allows to obtain the "big data" directly from the building-user system) significantly improves the management of the building during its life cycle positively affecting the reduction of management costs and the improvement of users' living conditions.

With access to elastic computing resources (Cloud computing) the built environment sector will be able to use the latest hardware and software technologies. Pervasive computing will become possible and construction sites will no longer struggle to receive and send real-time information.

With the advancement in the field of big data and business analytics the built environment sector will be able to utilize advanced analysis tools to develop support for decision making during the life cycle of the asset. Simulation of various scenarios using vast amounts of data will allow meaningful risk management and advanced decision-making processes.

The built environment sector will be significantly impacted by the availability of BIM on mobile platforms making BIM to field and field to BIM possible. Coupling of mobile devices with sensor technology and laser scanning technologies will further make the 'physical to digital' and 'digital to physical' vision possible.

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KEY TERMS AND DEFINITIONS

Building Automation: Is a system, or set of systems, that provide automated control and monitoring within a building. Control is centralized, meaning that these systems can be monitored and adjusted from a small number of stations located throughout the building.

CAFM: Computer-aided facility management, is the support of facility management by information technology.

Control Room: Is a “model reference” that can be used remotely and is able to survey managing activities about as example technical, energetic, cadastral and accounting data, taxes, maintenance of a building.

Corporate Social Responsibility: Is how companies manage their business processes to produce an overall positive impact on society. It covers sustainability, social impact and ethics.

FM: Facility management, is a professional management discipline focused upon the efficient and effective delivery of support services for the organizations that it serves.

IOT: Internet of Things, is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers.

POE: Post Occupancy Evaluation) is a methodology for evaluating the “performance” of a building used.

Safety: Is defined as the condition of being protected from danger or risk.

Security: Is defined as freedom from danger or fear.

Valorisation: Redevelopment activities that pay particular attention to the potential of transforming the property in relation to the context and needs of the reference market.