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# Technological Imagination in the Green and Digital Transition

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ISSN 2365-757X ISSN 2365-7588 (electronic)
The Urban Book Series
ISBN 978-3-031-29514-0 ISBN 978-3-031-29515-7 (eBook)
https://doi.org/10.1007/978-3-031-29515-7



This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

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# Chapter 22
# Digital Twin Approach for Maintenance Management


**Massimo Lauria and Maria Azzalin**

**Abstract** After years of slightest attention to the environment, low productivity, and least rates of technological innovation, the construction sector has started a slow but in-depth review of its statutes and priorities. The ongoing ecological and digital transition opens to new opportunities connected to the implemental policies of Industry 4.0—at now Industry 5.0—and related enabling technologies. Opportunities that strongly reaffirm the need for innovative, responsible, and sustainable governance of the life cycle of buildings, placing it in the new perspective of Digital Twin approach. Starting from this scenario, the paper presents some ongoing upgrade of a maintenance management model expressly aimed at optimizing activities in the operation and maintenance phase from which evident economic, environmental, and social extra costs arise.

**Keywords** Digital twin · Maintenance · openBIM · Internet of things · Cloud

## 22.1 Background

A new "stage" in the historical sequence of Industrial Revolutions is arising, and the current Fourth one—started in 2014 with the launch of Industry 4.0—is now rapidly changing its statutes (Schwab 2016).

The EU report "Industry 5.0: Toward more sustainable, resilient and human-centric industry" strongly affirms the need to speed up the underway digital and ecological transformation to deeply restore environment, economy, and communities. Three are the key-principles: centrality of man, self-sustainability, flexibility, and resilience. A new Collaborative Industry and Super Smart Society evolves

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E. Arbizzani et al. (eds.), *Technological Imagination in the Green and Digital Transition*,
The Urban Book Series, https://doi.org/10.1007/978-3-031-29515-7_22

characterized by intelligent cooperation between machines and humans (European Commission 2021a).

The ongoing transition, digital and ecological, opens to innovate opportunities come from the implemental policies of Industry 4.0—at now Industry 5.0—and related enabling technologies.

Many sectors, from aerospace to aeronautics, from complex industrial scenarios to automotive and medicine too, are using, with increasing pervasiveness, digitization, automation, Digital Twin approaches. After years of low productivity, equally reduced rates of technological innovation and least attention to the environment, also the construction sector seems to have finally begun a slow but in-depth review and innovation of its statutes and priorities as well as of its operativeness.

The urgency of responsible and sustainable governance of built environment is broadly matched by three important challenges of European Green Deal—circularity, digitalization, ecology—and by their related strategic plans: "Circular Economy Action Plan" (European Commission 2020a), "A Europe fit for the digital age" (European Commission 2020b), and "A Renovation Wave for Europe. Greening our buildings, creating jobs, improving lives" (European Commission 2020c).

The first, in promoting the principles of circularity throughout the life cycle of buildings, introduces policies that increase material efficiency, reduce climate impacts, and improve durability and adaptability of buildings in the life cycle (European Commission 2020a).

The second, by encouraging digital transformation, also affirms its role as a tool for managing climate change and achieving the green transition through a human-centered approach (European Commission 2020b).

The third formalizes the goal of doubling the upgrading of existing building stock by 2030, giving it greater energy efficiency and contributing to the decarbonization process (European Commission 2020c).

New challenges that re-address the issues of energy efficiency and sustainability by strongly linking them to a whole life cycle approach and to an increasing attention for operational and maintenance phase, O&M. A new perspective that recognized O&M as the longest and most qualitatively articulated phase of the life cycle, responsible for about 80% of total costs and the greatest environmental impacts (Aghimien et al. 2018).

In this scenario, it is strategic to properly manage an increasing amount of diverse information: from performance data under use conditions to behavioral and experiential aspects related to end users, their well-being, and their level of satisfaction (Bilal et al. 2016).

With specific reference to O&M phase, several tools have long been available: computerized maintenance management system and computer-aided facility management, CMMS and CAFM, building automation systems, BASs. To these tools are now added innovative approaches that exploit new interoperability tools able to facilitate the sharing of all available information and implement the potentialities of managing data acquired by real-time monitoring of building performance.

These tools are based on open standards—Industrial Foundation Classes, IFC (ISO 16739:2018)—and data specifications—Construction Operations Building information exchange, COBie (NBIMS-US-V3.4:2015) that are specifically for the exchange of information between the design and use phases (Cabinet Office 2012).

BuildingSMART (https://www.buildingsmart.org/) has long been engaged in their development and transfer into international standard. The aim is defining common information requirements and languages that could be shared among all different operators involved in each phase of building process and life cycle (ISO 19650-1:2018; UNI EN 17412–1:2021).

Both IFC and COBie have been assumed as tools to support Service Life Planning (ISO 15686 Series), through the definition of "sets of IFC properties" (ISO 15686-4:2014) that may be used in the application of service life assessment methods (Factor Method, ISO 15686-2:2012), in defining environmental impacts (ISO 15686-6:2004 Withdrawn), in Life Cycle Costing (ISO 15686-5: 2017), in structuring of feedback of data from practice (ISO 15686-7:2017) (Patacas et al. 2015).

Now, interoperability tools, building information modeling, BIM, Internet of Things, IoT, domotics and building automation control systems, BACS, open to innovative paradigms and opportunities related to Digital Twin approach in buildings.

## 22.2 Digital Twin Approach

In 2011, Michael Grieves introduced the term Digital Twin, DT, to define the synchronization between two realities: physical objects in real space, virtual objects in virtual space (Grieves 2011).

Physical and virtual objects are linked through the mutual exchange of data throughout the entire life cycle, both in real time and asynchronously (Bouchard 2016).

In 2019, the Gartner Inc. placed Digital Twin among the five emerging trends that would drive technology innovation for the next decade (Gartner Inc. 2019).

Nowadays, Digital Twin is one of principal technological nodes of Industry 5.0, capable of interacting physical and virtual objects, Big Data, IoT, blockchain, machine learning, and artificial intelligence, AI (Evans et al. 2019).

In the construction sector, Digital Twin permits optimizing the life cycle of buildings and infrastructures through the management of all available information including that acquired through performance simulation and real-time monitoring.

It allows predicting future performance; experimenting, simultaneously, changes and/or improvements without having to test them on the product itself or on special mock-ups; developing simulations in use with changes in state and boundary conditions, and machine learning.

Its application gets concrete and precise usefulness at O&M phase in structuring decision-making processes, planning predictive maintenance strategies, reducing the impact on the environment, improving the comfort and satisfaction of end users.

Furthermore, the real-time update of data from the IoT system and sensors allows continuous detection of state of health, operational conditions, anomalies, downtime and inefficiencies, preventing potential risk situations.

Three are the essential elements of a Digital Twin for the construction sector.

- Smart Building—physical object equipped with sensors, software, and technologies capable of gathering data or accessing information.
- BIM model—digital object holding geometric, physical, functional, and behavioral data related to physical object.
- IoT—a network of objects interconnected through the Internet integrated with analytical data communication network.

BIM model and Smart Building concern purely technological and operational aspects. Although fundamental, nevertheless they represent only partial components of the whole digital ecosystem that comprehends also human aspect (Pasini et al. 2016).

Digital Twin allows interaction between people and buildings maximizing the user experience and transferring it into life cycle and O&M decision-making processes, calibrating needs, methods, times, and costs.

## 22.3 Digital Twins for a Maintenance Management Model

BIM model makes already possible: to identify and correct detections and/or interferences between architectural and/or structural and/or plant engineering projects; to increase efficiency in time management during construction phase; to verify accuracy and completeness of information and their circulation among various operators.

In O&M, phase is not the same yet.

Nowadays, the Digital Twin approach applied to O&M represents an area with still many criticalities nevertheless extremely challenging too (Delgado and Oyedele 2021).

The recent EU report on "Digital Building Logbooks," DBL, encourages the use of Digital Twin approach. It deals with the definition of a common European approach covering all relevant building information, enable to synergies, interoperability, data consistency, and information exchange. It supports the widespread use of DBLs across Europe as tool able to contribute to several high-profile policy initiatives already mentioned in the paper (European Commission 2020a, b, c, 2021a, b).

In Italy, the National Recovery and Resilience Plan and the National Research Plan 2021–2027, albeit from different perspectives, affirm the strategic importance of the Digital Twin approach for permanent monitoring of structural integrity and operational functionality of buildings and infrastructures, as well as for realization of smart grids, smart infrastructures, smart buildings.

The diffusion of BIM methodologies, their integration with IoT technologies and related applications through Digital Twin approaches, the development of open standards, IFC and COBie, as well as the availability of properly structured, accessible

and updatable data and the adaptation of legacy systems represent the frontier of the new challenges of research and standardization.

They also constitute some focuses of R&D actions carried out by BIG srl, Building Innovative Governance, Academic Spin-off of which the authors are two founders.

Among current activities, carried out in partnership with ACCA Software Spa, there is the proposal of a maintenance management model, MMM, for innovative governance of real estate assets (Lauria and Azzalin 2020). The MMM promotes an active dialogue between the actors and operators involved in O&M phase, allows sharing all available information, introduces innovative ways of collecting, processing and management data aimed at activating predictive maintenance strategies. Thanks to real-time monitoring features, it also configures a potential "observatory" of over the time changes of building components and products, of their operation and modes of use.

The MMM uses Digital Twin approaches, enhancing the potential of ICT and Geographic Information Systems, GIS. It offers the integration between BIM model, IoT technologies domotic and building automation control systems, for monitoring of performance in use, acquisition and real-time recording of data.

It operates in a digital cloud environment, usable with a browser, putting together viewer technologies, virtual reality, and augmented reality (Fig. 22.1).

Its level of technological maturity is at now a TRL 6 (Technology demonstrated in a relevant environment).

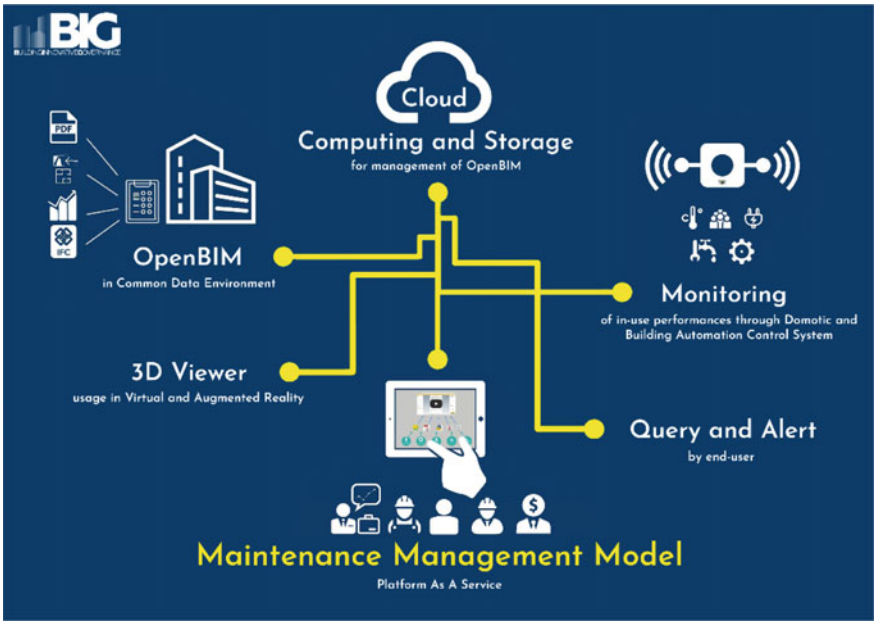


**Fig. 22.1** Maintenance management model. *Source* By Authors (Lauria and Azzalin 2020)

The MMM is part of the proposal related to the start-up of BIG srl financed with POR Calabria Region funds (2019/20); recently it has obtained two-year funding under Smart&Start Italia Facilitation Program of Invitalia spa, for its implementation, prototyping, patenting, experimentation, and marketing.

It has also received several awards confirming the innovativeness of the proposed idea and won two separate editions of the "Innovation Award" of the Chamber of Commerce of Reggio Calabria in 2019 and 2021.

Closely related to the MMM upgrade actions is the research activity: Infinity BIM research. Design, construction, and maintenance of digital building model for the Digital Twin, funded by MISE, whose general objective is to create new products for the AEC sector supply chain through the application of BIM methodologies.

The experimentation of the MMM, currently in progress, is at now applied to two study cases: the Citadel of the *Mediterranean* University of Reggio Calabria (Fig. 22.2), and the industrial plant of Mangiatorella spa, a mineral water bottling company, one of the most important in southern Italy (Fig. 22.3).

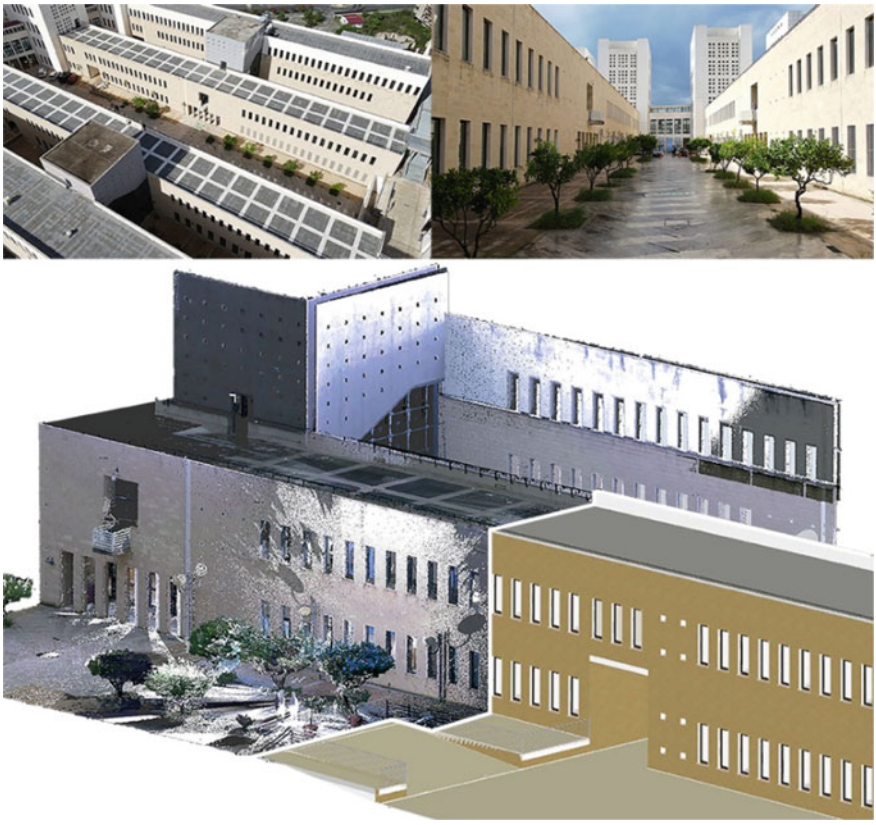

**Fig. 22.2** Citadel of the Mediterranean University of Reggio Calabria, Italy. *Source* By Authors

**Fig. 22.3** Mangiatorella spa, a mineral water bottling company, Stilo, Italy. *Source* By Authors

In particular, two ongoing activities are strictly functional to the upgrade of the MMM: structured collection of information and digitization of all available information. They both constitute the already operative services delivered and commercialized by BIG srl.

In a digital twin approach perspective, the two aforesaid activities permit advanced use and share of available information by different types of operators/users with mobile technology, cloud, RFID tags.

At now, the implementation of BIM model (openBIM format) is carrying out through the definition and writing of specific parameters for maintenance activities planning—a Digital Twin for maintenance—with a first level of connection between interoperability systems and informative capital (IFC format).

Since now, referring to collecting information, the outcomes confirm the criticalities expected and expressed in EU Report on DBL (European Commission 2021b), concerning the lack of organized and structured archives that make existing information not only available but also above all easily accessible and usable.

Regarding digitization, the possibility of using reverse engineering approaches—"scan to BIM" procedures—allows the control and integration of information derived from the project documentation made available by the client.

The two activities introduced—structured collection of information and digital modeling—both converge in the experimentation of Digital Twin for maintenance and in the related definition of the MMM. It is based on a preliminary deductive action that, starting from the classification of building elements as codified by UNI 8290, aims at verifying the possibility to identify homogeneous families of sets of specific properties (characteristics, performance, failures, anomalies, controls, etc.).

These will be assumed for the purposes of interoperable management of information in the O&M phase, also according to the information required for compiling the three operational documents of maintenance plan—a mandatory document at Italian normative level (DPR 207/2010 art. 38).

A delimitation of application field referring to window and thermal conditioning system has been assessed. Such delimitation has been assumed with the aim of defining the relative need and/or the necessary information contents.

The quantity and degree of confidence of the information to be included in the BIM models refers to an open process of continuous implementation. All available information will be used in relationship with those required from national standards (UNI 11337-4), from new definitions of Information Needs (ISO 19650-1:) and from the structuring of specific Information Delivery, IDs (UNI EN 17412-1:2021).

The experimentation, after the phases above introduced and subsequent validation of specific IDs, will provide for verification of its replicability.

## 22.4 Conclusions

The first results of research activities underway show the need to define since the beginning the correct flow of information with respect to each of the operators involved (who); the timing (when) with respect to which this information must be included and/or must be available; the methods (how and where) of sharing. Needs confirmed in the mentioned EU Report on DBL (European Commission 2021b).

Today, the technologies and the various hardware, software and cloud applications are increasingly powerful, able to manage and process a greater amount of information, favoring its sharing.

Unresolved nodes remain, however, the precise information framework to refer to, the interoperability of information, as well as the management of bidirectional interoperability between modeling and simulation software.

Issues that represent the goals of the ongoing activities, here only in part introduced, and carried out by the research group.

These aims, as also stated by BuildingSMART at the various national chapters, refer therefore to a basic criticality, not yet resolved, which is the need for coding and/or shared classification of information. A theme that is certainly crucial from

the point of view of the use of interoperability formats and so for the development of the Digital Twin approach for O&M phase.

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