BIM model uses through BIM methodology standardization

BIM model uses through BIM methodology standardization

A. Barbero, M. Del Giudice, F. M. Ugliotti, A. Osello
Politecnico di Torino, Turin, Italy

ABSTRACT: Digital transformation is influencing the strategy to develop virtual repository able to collect data from different disciplines and domains in a useful way for the building lifecycle. In this framework, Building Information Modelling (BIM) can be the innovative methodology to optimize the overall workflow including a proper definition and management of geometrical and alphanumerical contents. The article aims to investigate the meaning of standardization according to specific model uses that goes through the identification of the owner's objectives and their operational declination by means of a defined protocol of activities and tailor-made solutions. The study presents a progressive increasing of the complexity of the BIM process, which, starting from the definition of an As-is model, is enriched through the integration with other data domains and improves its usability through customized virtual experiences.

1 INTRODUCTION

The current fragmentation of the workflow related to the design and construction and operation and maintenance processes, both in technical and collaboration terms, lead to an inadequacy of the available information of the heritage. Realizing a digital model representative of the As-built state of a new construction, in fact, provides different solutions and approaches compared to the setting up of an As-is model functional to management and maintenance.

The reason lies in the different way the information is produced according to the specific objectives connected with the construction phases. For a new building, the planned information content is designed to fulfil the user's requirements and to achieve a certain performance. This implies the creation of a detailed As-built model aimed at the construction site. For existing buildings, the information production is aimed at developing a model for the Operation and Maintenance (O&M) step. This As-is model is adopted for updating over time, describing the state of the art of the building at a certain time of the survey.

The need to create a different detailed model from the As-built for existing assets is mainly due to the reliability of As-built data compared to the actual state. In this context, the crucial points of BIM model implementation are based on the set of model uses and objectives that characterize the content of parametric BIM objects. Following this perspective, a lot of research is oriented to define transversal standards to facilitate information management by following international and national legislations.

Currently, the state of the art of this area of investigation provides several definitions, interpretations and enrichments of the Level of Geometry (LOG) and Level of Information (LOI) within the O&M step. Figure 1 below summarizes the main references. These references constitute an initial benchmark to guide the implementation choices of the models, however they need more articulation for practical use. For example, it is not exhaustive to establish a Level of Detail (LOD) for the entire structure to be modeled, but it is necessary to identify different standards for each object in order to control the reliability, granularity and use of the information associated with it. It is therefore appropriate to define information specifications for each project, considering the objectives, documentation and professional and economic resources available. This is also expressed in ISO 19650-1:2019, which introduces the concept of the Level of Information Need. This aspect could be strictly related to the concept of heterogeneous LOD applied to the entire model obtained by application of a specific LOG and LOI for each element category (Barbero et al. 2019). It is strictly related to define standards for the production of the model and the objects according to BIM procurement specifications and documents that allows the definition of operational guidelines.

Year	2013
Reference	PAS 1192 – 2: 2013
Definition	LOD as Level of Model Definition for buildings and infrastructure projects: • LOD (Level of Model Detail) as a description of the graphical content. • LOI (Level of Model Information) as the description of not – graphical content.
Year	2017
Reference	UNI 11337 - 4
Definition	LOD as Level of Development of digital object: • LOG (Level of Geometry) related to the geometrical attribute of each element. • LOI (Level od Information) related to the alphanumerical attribute of each element.
Year	2019
Reference	BIM Forum of AIA
Definition	LOD as Level of Detail and Level of Development of each model's object: • Level of Detail is essentially how much detail is included in the model element. • Level of Development is the dregree to which the element's geometry and attached information has been thought through – the degree to which project team members may rely on the information when using the model.
Year	2019
Reference	ISO 19650 - 1
Definition	Level of information need as the minimum amount of information needed to answer each relevant requirement. Geometric and Alphanumeric information has the same importance.

Figure 1. List of international standard and specifications.

Currently, there are two main documents required to develop a BIM model:

- Employer Information Requirement (EIR) that clarifies the employer's requirements during services' procurement. It should include levels of modelling detail, training/competence requirements, ordinance systems, exchange formats or other employer-mandated processes, standards or protocols (BIM Dictionary, 2020).
- BIM Execution Plan (BEP), based on EIR, that defines how the information modelling aspects of a project will be carried out. It includes other documents that clarify the roles and responsibilities, standard to be applied and procedures to be followed (BIM Dictionary, 2020).

Clearly, both of the two documents include BIM standards for modelling and information management for private and public sector. Their definition changes according to the specific national legislation: for example, the Italian technical report UNI11337 – 6 defines the content of the "Capitolato Informativo" (CI), based on the EIR's structure. These documents represent the basis for the identification of the graphic and alphanumeric content required for a properly structured BIM model during the services' procurement. However, this content, as previously mentioned, needs to be enriched with several operational requirements to achieve the defined practical uses (Ashworth et al. 2016). BIM uses for Facility Management (FM) require indeed both the data content upload and extraction according to the day-to-day needs as the model represents a valuable database for maintenance activities. For this reason, the concept of BIM guidelines was born. This documentation contains the BIM procurement dispositions, enriched with a series of technical standards, on which operating protocols that should be followed to achieve defined BIM uses are based.

2 METHODOLOGY (Matteo Del Giudice)

This paper aims to evaluate the creation of a BIM methodology standardization in the meaning of defining the activities necessary to start a digitization process aimed at using BIM models in management activities. Specifically, the definition of different model uses is preparatory to the correct geometric and alphanumeric definition of the objects. In this contribution, the digital twin of the building has been assessed in function of the role within maintenance activities, identifying the milestones to be satisfied for the development of proper guidelines. They can be considered as an integration of the contractual documents that allow the definition of the operational requirements for the achievement of the owner's objectives. They consist of a sort of protocol issued by the employer to allow the creation of models. They are developed through continuous updating and implementation loops during the entire BIM process, thanks to the collaboration and the joint analysis with all the actors involved.

According to various BIM standard investigated, the proposed workflow starts from the analysis of the objectives and uses of a certain project, starting from the employer's requirements. Figure 2 summarizes in a methodological schema the main contents that have to be followed for the BIM development for FM. One of the most important actions to ensure decision in the BIM model development consists of involving the owner at the beginning of the entire process. In this way, these decisions are "based upon accurate and relevant information and data, and their impact on operational needs has to be understood before they are committed to construction work and/or installation" (BSi, 2015). Therefore, the proposed methodology begins from the definition of the level of information need (ISO 19650, 2019), highlighting the model purposes in order to define BIM model uses. In this contribution, three model uses were selected (Kreider et al, 2013): i) As-is model; ii) Database integration; iii) FM system over Virtual and Augmented Reality (VAR). Clearly, each of these uses requires different kind of Level of Graphical information (LOG) and Level of Information (LOI) useful to achieve the BIM objectives. The development of the BIM model oriented to each use culminates with the definition of model requirements that have to be included in standards and guidelines, creating BIM specifications for the O&M step.

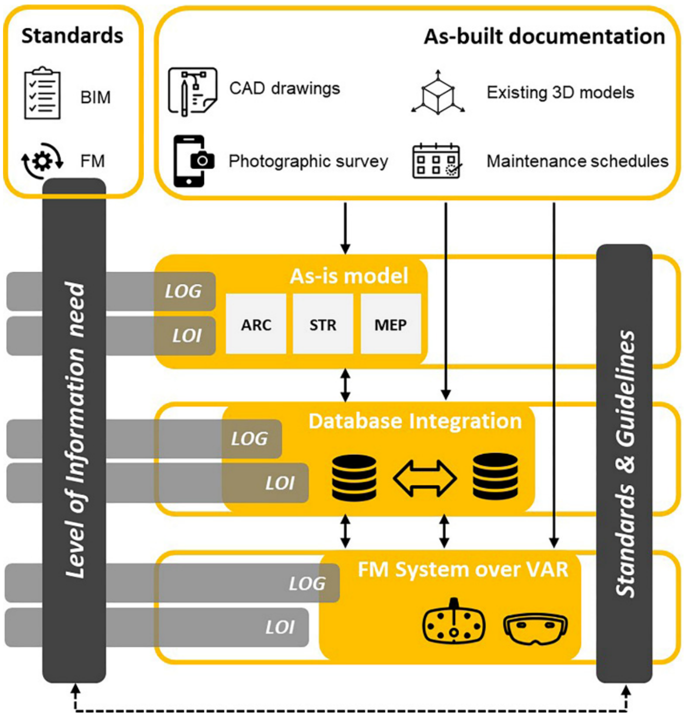

Figure 2. Methodological workflow.

This kind of output aims to ease the supplier in following the procedures indicated in the EIR. To achieve the goal of information management during the FM step, the three model uses have been analyzed basing on the exploiting of data, according to the end user. Therefore, a set of activities related to the development, management and visualization of the model have been listed in Figure 3.

	Activities	As-is model	Database Integration	FM system over VAR
1	Statement of purpose	x	x	x
2	As-built documentation analysis	x		
3	National regulation adoption	x	x	
4	Collaborative BIM Working	x		
5	Graphical and information data delivery	x		x
6	Data sharing	x	x	x
7	Model breakdown structure	x		
8	Modeling rules	x		
9	Model accuracy	x		
10	Folder Structure and Naming Conventions	x		
11	Model checking	x		x
12	Code checking	x		
13	Data validation	x		
14	Import/export data transfer		x	
15	Database integration with other datasets		x	
16	Geometrical data update		x	x
17	Alphanumerical data update		x	x
18	Presentation style	x	x	x
19	Data communication			x
20	Supporting maintenance activities		x	x

Figure 3. List of activities for model uses.

The results produced by each activity have been collected and summarized for the drafting of an operating standard to support the parties involved in the BIM process.

The above methodology can be generalized to each case study. The model uses mentioned in the following paragraph refer in particular to a case study summarizing the obtained results as an example. The case study concerns an existing venue for outdoor sports, a huge structure characterized by many aspects that require specific building registry definition and maintenance activities. Autodesk Revit software has been used for this study for its diffusion on the international market and for its multidisciplinary nature.

2.1 *As-is model* (Francesca Maria Ugliotti)

As O&M represents a significant part of the building lifecycle, the creation of an effective BIM model can contribute to streamline processes helping the Facility Manager/Department to control costs and manage data. For this purpose, it is not enough to implement all the objects and their properties, but it is necessary to organize information so that it can be functional in retrieving data for specific activities. The model breakdown, and consequently the database that can be extracted, is a decisive factor to consider carefully at the beginning of the modelling phase, as subsequent variations can be very complex and often result in a loss of information. Different strategies are possible depending on the complexity of the building and its purpose of realization. In the case study analyzed, a federated model (Barbero et. al., 2018) has been set up to articulate the model to the multiple disciplines investigated. Despite the fact that the parametric model is a database in itself, consulting it may not be immediate, especially for people who are not expert in using this kind of software. In these terms, governing the elements in a unique way through coding, classification, decomposition and georeferencing systems that facilitate their precise identification and management is fundamental. At the same time, the use of schedules, themed plans, and three-dimensional views is exploited to promote a structured building registry and ready and user-friendly access to the data. The utilization of schedules facilitates the listing of rooms for spaces management, likewise, building components for refurbishment or energy efficiency evaluation and assets for maintenance activities. By an appropriate use of shared parameters and equations, it is possible to make the most of their format for each different purpose, from analysis to managing or reporting. In the case of existing buildings, it is extremely useful to map the main components subject to periodic maintenance, by adopting a reasonable Level of Detail in function of the complexity of the structure.

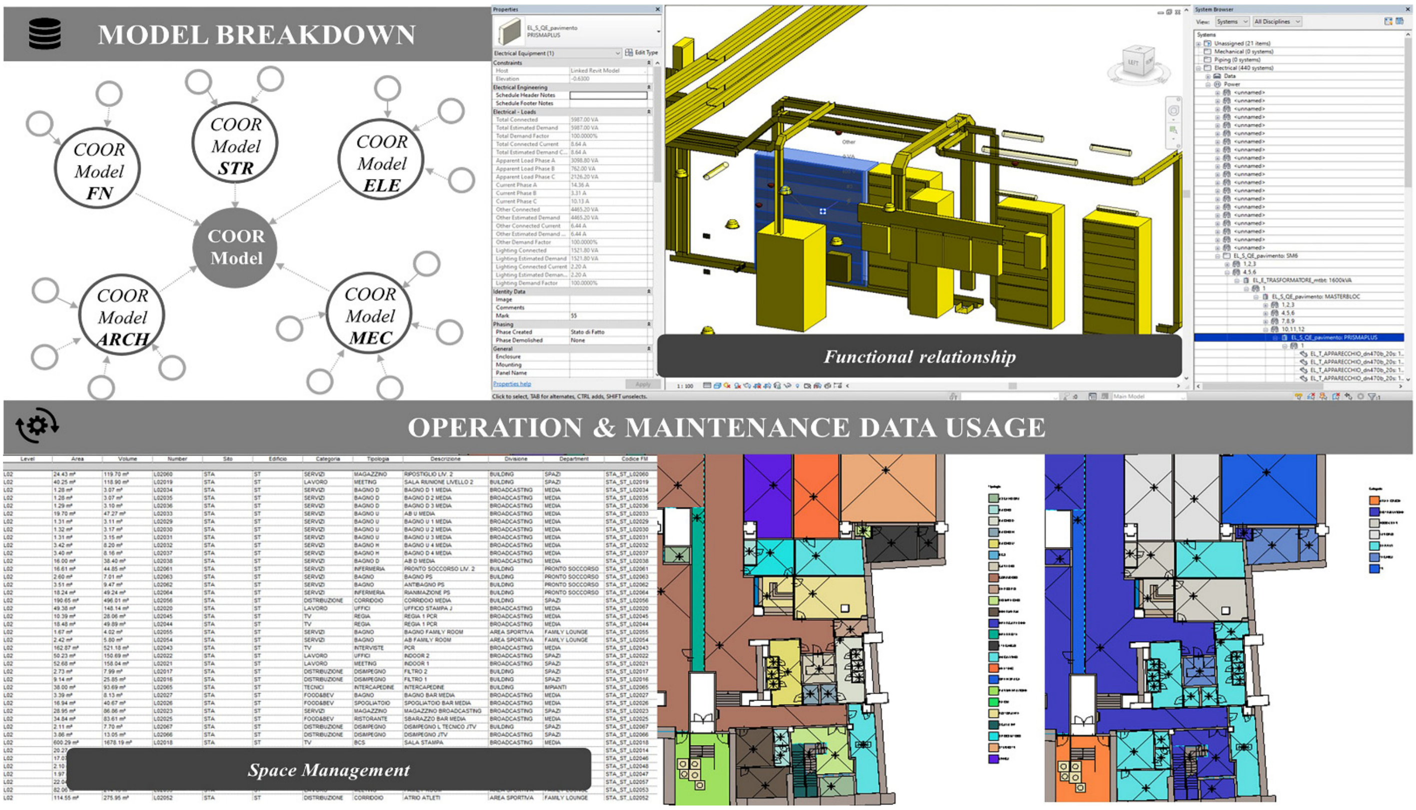

Figure 4. As-is model data usage.

Generally, reinforced concrete structures do not require special maintenance. Therefore, they can be modelled with a low Level of Detail giving them the correct function, the type of use (e.g. foundation, elevation) and materials. With regard to steel structures, the identification and coding of the most significant structural elements and connections (e.g. reticular beam, column, and node) is relevant.

Despite the representation of these elements being very complex, it is not useful to achieve a high level of graphic detail for existing buildings, but it is appropriate to link the elements to technical details and maintenance procedures.

According to the architectural part, the model must provide reliable information regarding the areas and surfaces of the environments and materials used. For this reason, maximum attention needs to be paid during the modelling phase to ensure a correct calculation method. Walls and windows are some examples of critical elements. The outer layer of the wall defines the finish, so modelling it as needed becomes important (e.g. tiles to be cleaned, surface to be painted). While for the fixtures, the possibility to estimate the incidence of the glazed part on the frame is useful for cleaning. In this way, it is possible to distinguish between the opaque surface and the transparent surface for a facade.

Through specific plugins like Autodesk Roombook, Areabook, and Buildingbook or computational design platform such as Dynamo for Autodesk Revit, an accurate model take-off can be achieved. The summary of the room-related surface areas and interior finishes of walls, floors and ceiling elements as well as a comprehensive floor area calculation and material-related quantities of constructive building parts can be exported, providing valuable quantitative indications for cleaning and maintenance activities.

As BIM can play a big role in space management, the model has to properly map spaces and include all the information needed to ensure a great operational control in terms of use, occupancy, and maintenance of the building. Enriching the database with a punctual and up-to-date knowledge of these entities allows managers to control services in an increasingly thoroughness and to obtain facility management and key performance indicators (KPIs) useful for evaluating cost chargebacks, the utilization rate as well as performance measurement of the maintenance activities (Osello & Ugliotti 2017).

Furthermore, information about systems component and equipment are crucial. Thanks to the parametric nature of the objects, it is possible to identify the functional relations between the elements, allowing to map and manage circuits and branches. For example, in the case of a lighting device, it is possible to know to which electrical switch is connected, to which electrical panel and consequently to which electrical substation. Since in the case of an existing building is very difficult to get reliable scheme and technical drawings, the essential aspect lies in establishing the functional and spatial relationships among the elements, not detailing the graphical representation.

2.2 *Database integration* (Andrea Barbero)

Starting from the literature definition of a BIM model as a geometric and alphanumeric data repository, another possible BIM use within the O&M field is represented by the Database integration (Kensek, 2015). This case can be achieved in the same way using the protocol and specifications indicated in the BIM guidelines. The Database integration is based both on the need to update data from the As-is model and increase information related to the specific aim of the project. This aspect is strictly connected to one of the major strengths of the BIM methodology represented by the uniqueness of data, which must be maintained during the building lifecycle.

The database extrapolation is the first step to manage BIM data in different external or integrated management platforms. For this research, the Open Database Connectivity (ODBC) structure has been investigated as it allows to test both possibilities that have been recalled. Monitoring the effective transition of the information contained in a BIM model is an essential phase as it has an impact on subsequent actions. Obtaining data in a usable format is part of the standard identification of the guidelines. The second step is therefore represented by the identification of the platform that is necessary to use to reach the specific purpose of the BIM model. In this study, MS Access has been used for the visualization and updating of data, while an Integrated Workplace Management System (IWMS) has been identified for the integration with other management information, according to different model uses.

The ODBC export activity of the database can be done, as know from the operational guides of Autodesk Revit, through the Revit DB-Link plug-in with the direct connection with MS Access or by the general ODBC connection format. As the purpose is the employment by different actors, the definition of each Autodesk Revit type of parameter should be done according to the effective daily operational usage of information. For this reason, two other aspects become essential: the bidirectional data update and the possibility to create a custom mask, that enables information consultation in a simplified way. The first one is ensured by the Import/Export tool of the ODBC format that allows to bring in the BIM model all the implementation that has been done by users directly in MS Access, overwriting the entire database. The second one is based on the flexibility of the data content and structure in the management activity. The requirements to ensure data usability by different kind of users and their ability to visualize and modify this information constitute an important issue for FM environment. For these reasons, specific MS Access queries have been created to connect, between them, different data spread over separated tables.

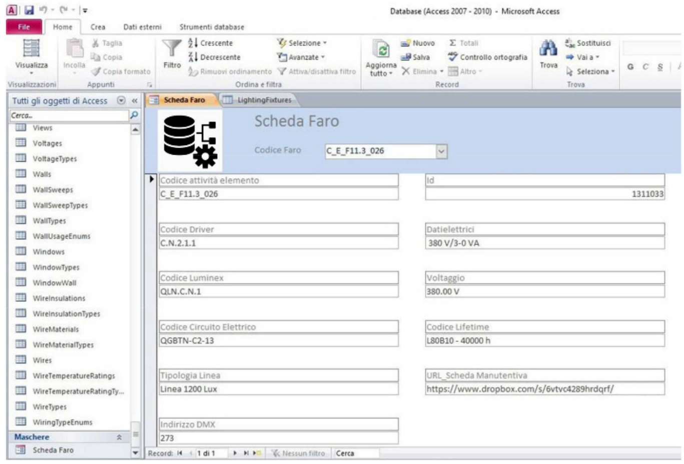

Figure 5. The consulting mask in MS Access for data integration (Barbero, 2016)

The ODBC exchange format respects the table structure of a BIM model database, and every single table could be imported and exported massively through the direct integration with MS Excel. User-friendly masks have been designed to allow data consultation. Figure 5 shows as an example, the consultation interface set for lighting devices. It has been created with specific labels that allow the selection of individual information of an element by its own identification code. This field acts as input for the display of the other object's parameters since it is a primary key. All this information is editable directly from the MS Access query thanks to the insertion of the update data in the relative fields. Managing the mask structure, the user could identify and visualize specific fields that will be visible and used to show the desired information from the data content. In this way, data visualization and its updating could be done with some specific operation without the interaction with the table structure of the database. Initially, these updates will be only saved in the ODBC connection format without real-time effects on the BIM model. For its synchronization, it will be necessary to follow the import procedure as previously mentioned. During this input activity, the data owner could check what information has been updated, preventing data loss, monitoring its change during different O&M activities.

On the other side, an ODBC Database integration can be achieved with IWMS systems, an advanced technology designed to manage more effectively the core functional areas within an enterprise, including FM management, overcoming the simple data visualization. For this purpose, the BIM building registry must be transferred/synchronized according to the final database structure. The object - level association strictly connected both to 2D visualization performance and maintenance activities represents one of the main issues. Furthermore, this kind of platform is essential to investigate the correct exportation of the Autodesk Revit parameter type and their mapping in the IWMS structure.

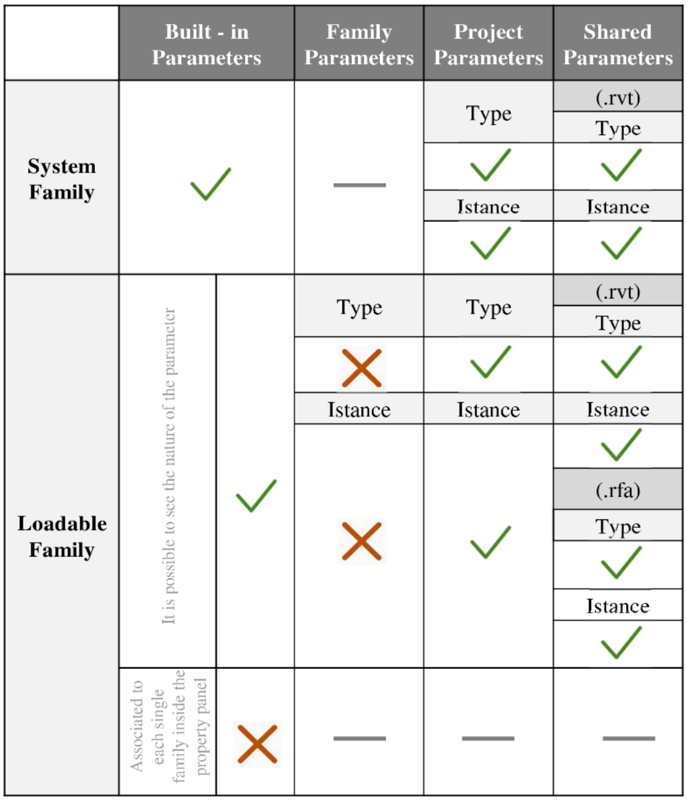

Figure 6. ODBC exchange tests.

In this context, the knowledge and definition of denomination rules for parameters become essential to avoid special characters that can generate possible export errors. For this research, a series of tests have been done to identify the correct interoperability of different type of attributes: i) Built-in parameters that already exists in an Autodesk Revit file; ii) Family parameters which are created and related to a family (.rfa); iii) Project parameters which are generated directly inside a BIM model file (.rvt); iv) Shared parameters that belong to an independent file and can be shared among different models and families.

In addition, another factor considered is related to the "Type" or "Instance" nature of the parameter. This aspect affects both the table in which a parameter is located in the BIM database and the corresponding table in the IWMS platform. The achieved results are visible in Figure 6. For example, to ensure a correct transfer of shared parameters they need to be created in the .rvt file as a project parameter even if they are contained within a family (.rfa).

2.3 *FM system over VAR* (Anna Osello)

The last case concerns the connection with tools able to communicate more directly and effectively through VAR technologies (Swanström Wyke et al. 2019). This approach aims at highest usability of the graphical representation for visualization purposes but finds its maximum potential in the dynamic interrogation of objects. Currently, the interoperability process is not able to transfer the associated database, therefore a subsequent programming activity is required. For this reason, at the moment, only the requirements related to the graphic component of objects can be identified. The tested model uses are focused, on the one hand, on verifying the correspondence between the digital representation and reality and, on the other hand, on the creation of discovery virtual tours. In the first case, the geometric model check is carried out by simultaneously displaying the real configuration through the employment of Mixed Reality (MR) applications.

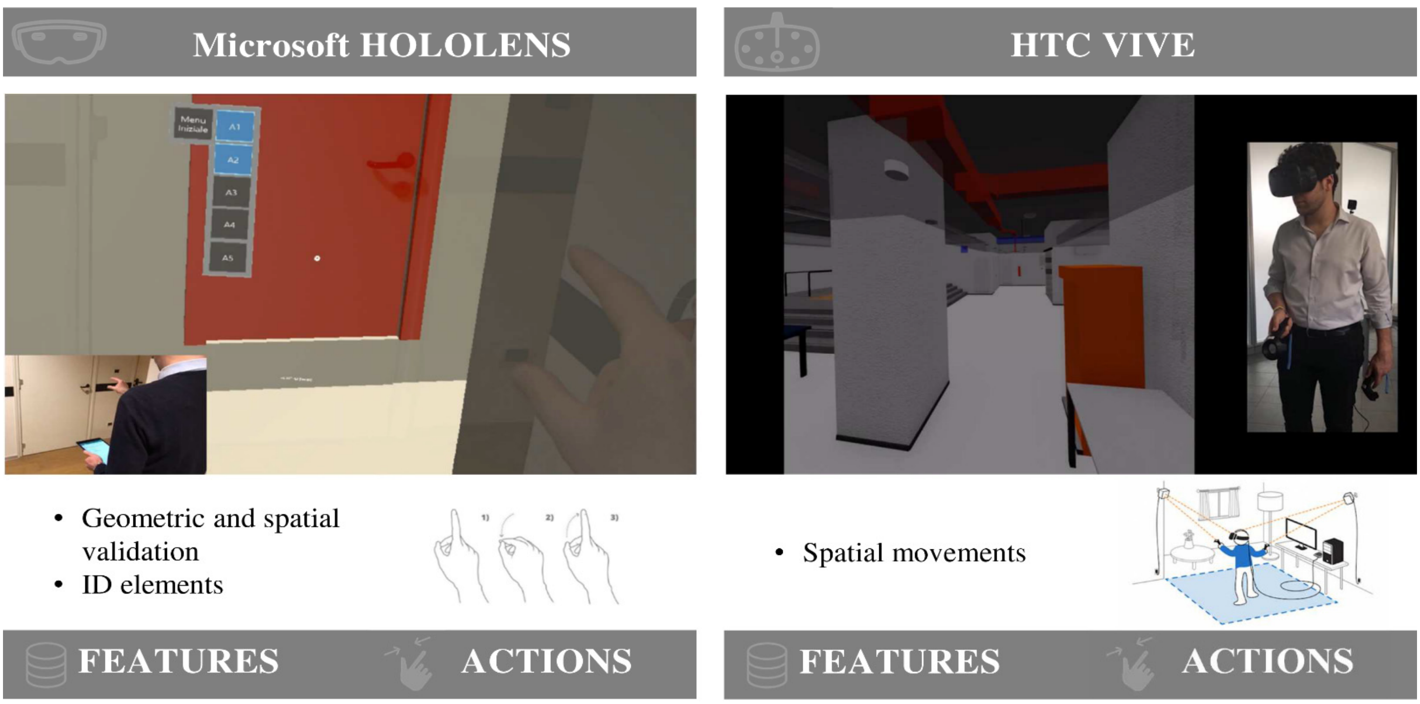

Figure 7. Virtual data usage.

Specific instrument such as Microsoft HoloLens allows to overlap the virtual model into real one according to a real scale environment (Viale, 2019), as visible on the left side of Figure 7. To achieve this use, great attention must be paid to the multidisciplinary management of the model and the reliability associated with the elements.

The second application conceives the model as a visual cognitive resource that can be explored through Virtual Reality (VR) tools such as HTC Vive viewer. The issue is to set up a navigation mode functional for maintenance and training. For this purpose, it is necessary to pay more attention compare to an As-is model in the realization of the geometric component not only increasing of Level of Detail, but also in terms of graphic performance. The more the model is likely to be realistic, also in terms of appearance, colours and materials, the more usable the customized exploration will be. As shown in the right side of Figure 7, the setting of the visibility of objects is used, for example, to make accessible systems and components that are not visible in reality, such as the Heating, Ventilation and Air Conditioning (HVAC) conduit behind ceilings, and that can therefore be consulted. Furthermore, the representation of the furnishing elements, often overlooked in the digital restitution of buildings, becomes a fundamental element for the management of interior design configurations according to the event scenarios.

3 RESULTS AND CONCLUSION

This paper aims to evaluate the challenge for developing BIM guidelines able to support the definition of a building registry in line with technical due diligence. Different analyses have been done to identify the main issues that characterize the workflow to preserve and to manage geometric and alphanumeric contents. This investigation process has facilitated the fulfillment of the model uses defining the specific requirements of each by the analysis of the protocol and its activities. As shown in the cases discussed above, a progressive increasing of the BIM system complexity is achieved, starting from the As-is model definition to Database integration and virtual experiences setting. The synoptic overview above shows the current strengths and weaknesses characteristic of each purpose and the related modelling efforts to achieve a correct data extrapolation.

The resulting BIM guidelines are tailored to the individual project and the owner's purposes, overcoming the actual lack of standardization among BIM procurement documents. In this way it is possible to customize them, answering to the increasing complexity of BIM systems, analyzing BIM uses at the beginning of the building lifecycle.

Model Uses	Strenghtness	Weaknesses
As-is model	Digital building registry; Data management optimization; Discipline model coordination; KPIs control;	High modelling effort; Employee BIM training; Tailored rulesets; Resistance of change;
Database Integration	Efficient data update; Data source integration; Bidirectionality data sharing; User-friendly interface;	Data exchange issues; Open standard limitation; Lack for employee expertise; Daily database updating;
FM system over VAR	Virtual tour; Virtual/Real checking; Effective data visualization; FM process optimization;	Data loss Not fully automation data update; Increase of model accuracy; Lack of rules for enabling FM with VAR;

Figure 8. Strengths and weaknesses matrix.

The proposed methodology can contribute to the continuous research definition and refinement of the second level of maturity of BIM aimed at a collaborative and interoperable use of data.

REFERENCES

Ashworth, S., Tucker, M., Druhmann, C. 2016. *The Role of FM in Preparing a BIM Strategy and Employer's Information Requirements (EIR) to Align with Client Asset Management Strategy.* 15th EuroFM Research Symposium.

Barbero, A. 2016. *BIM 4D – pianificazione e gestione della manutenzione: il caso studio dello Juventus Stadium.* Master degree thesis, Politecnico di Torino.

Barbero, A., Del Giudice, M. & Manzone, F. 2018. *BIM model methods for suppliers in the building process*. eWork and eBusiness in Architecture, Engineering and Construction, proceedings of ECPPM 2018: 291-296.

Barbero, A., Ugliotti, F.M., & Del Giudice, M. 2019. BIM-based collaborative process for Facility Management / Impostazione di un processo collaborativo BIM per il Facility Management. *Dienne* Volume 4: 6-14.

BIM Forum. 2019. *2019 LOD Specification.*

BSi. 2015 *BS 8536-1:2015 Briefing for design and construction. Code of practice for facilities management (Buildings infrastructure)*. Retrieved January 6, 2016, from www.shop.bsigroup.com.

ISO. 2019. *19650-1:2019, Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) - Information management using building information modelling.*

Kensek, K. 2015. *BIM guidelines inform facilities management databases: A Case Study over Time.* Building: 899-916.

Kreider, R.G. & Messner, J.I. 2013. *The Uses of BIM Classifying and Selecting BIM Uses Version 0.9* Penn State: Computer Integrated Construction.

Osello, A. & Ugliotti, F.M. (edited by) 2017. *BIM: verso il catasto del futuro. Conoscere, digitalizzare, condividere. Il caso studio della Città di Torino*. Roma: Gangemi Editore spa.

PAS 1192 - 2: 2013. *Specification for information for the capital/delivery phase of construction projects using building information modelling.*

UNI, 2017. *UNI 11337-4:2017. Edilizia e opere di ingegneria civile - Gestione digitale dei processi informativi delle costruzioni - Parte 4: Evoluzione e sviluppo informativo di modelli, elaborati e oggetti.*

UNI, 2017. *UNI 11337-6:2017. Edilizia e opere di ingegneria civile - Gestione digitale dei processi informativi delle costruzioni - Parte 6: Linea guida per la redazione del capitolato informativo*.
Viale, R. 2019. *BIM and Mixed Reality for Facility Management. Case study: Allianz Stadium.* Master degree thesis, Politecnico di Torino.
Swanström Wyke, S. C. & Svidt, K. 2018. *Virtual Reality based Facilities Management planning*. CIB Proceeding, 36th CIB W78 2019 Conference: 965-973.