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BIM methodology standardization for Facility Management:

data organization, integration, and visualization for a new concept of stadium

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Summary

Nowadays, the increasing complexity of buildings highlights the need for the Architecture, Engineering, Construction and Operations (AECO) sector to manage a large amount of data. In this scenario, the process of building digitalisation offers the opportunity to create virtual databases able to collect data from different disciplines and domains in a useful way for the building lifecycle. For this reason, Building Information Modelling (BIM) represents the innovative methodology capable of optimising the entire building process. Its application has been studied and documented in the design-to-construction phase, but it is important to underline its importance also in the Facility Management (FM) sector. Thanks to the creation of an integrated database, able to dialogue with Integrated Workplace Management System (IWMS) platforms and to manage a large amount of data, the adoption of this innovative method could overcome the existing gap in the building process between the implementation and management phases. Currently, the main challenges in the FM sector derive from the application of a traditional method based on a fragmented database characterized by a great data loss, while the main issues in the adoption of BIM methodology are mainly procedural and not technical, due to a lack of standardization.

Based on these considerations, the research thesis aims to analyse the definition of a BIM methodology standardization for FM based on the identification of a series of operating protocols which enrich the BIM procurement documentation through the development of proper guidelines. The results achieved may contribute to the creation of an operational background, composed of examples able to overcome the actual lack of standardization, making the proposed method more effective and highlighting its potential.

In order to investigate the proposed standardization, the definition of the BIM model uses connected to the FM field becomes essential. For the research case study, represented by the Allianz Stadium, the defined model uses are: the implementation of an As-is Model for FM, the Integration with an IWMS platform and the possible future implementation of FM system over Virtual and Augmented Reality (VAR). These could be reached through the operational declination of the corresponding objectives of Data Organization, Data Integration and Data Visualization.

The proposed methodology starts with the analysis of the As-built documentation and the investigation of existing FM and BIM standards to define the Level of information need for each model use and objective. The implementation of the BIM models oriented to these purposes is based on the definition of requirements that should be included in standards and guidelines. The developed BIM guidelines for FM contains the investigated methodology standardization defined as a set of activities related to the development, management and visualization of models. Their application allows the definition of operating protocols for the new concept of stadium 2.0.

The application of these activities for the Data Organization allowed the development of a possible As-is model of an existing building, based on an information database suitable for carrying out FM activities. On the other hand, the analysis concerning Data Integration identified several technical standards that should be considered for correct integration with the IWMS database, minimizing the loss of information. Due to the large amount of data and their central role, an automated BIM Model Checking (BMC) validation process of alphanumeric information, based on Visual Programming Language (VPL), has been implemented and connected to the concept of Data Validation. Finally, the study of possible uses of VAR applications highlighted their potential for consulting the information content during maintenance activities and as a possible validation tool.

The results of the thesis highlight the advantages of the application of the BIM methodology in the field of FM, proposing the developed of specific guidelines which are a tailor-made solution based on technical protocol, usable for other case studies with the same model uses. In this way, the lack of standardization is overcome and the operating content may vary if the objectives and uses change, but the methodology remains the same, enriching the second level of BIM maturity. The analysis of the digitalization process of the building sector carried out allows defining the new concept of stadium 2.0 that will be implemented in the future, representing the starting point for the digital "archive of the future".

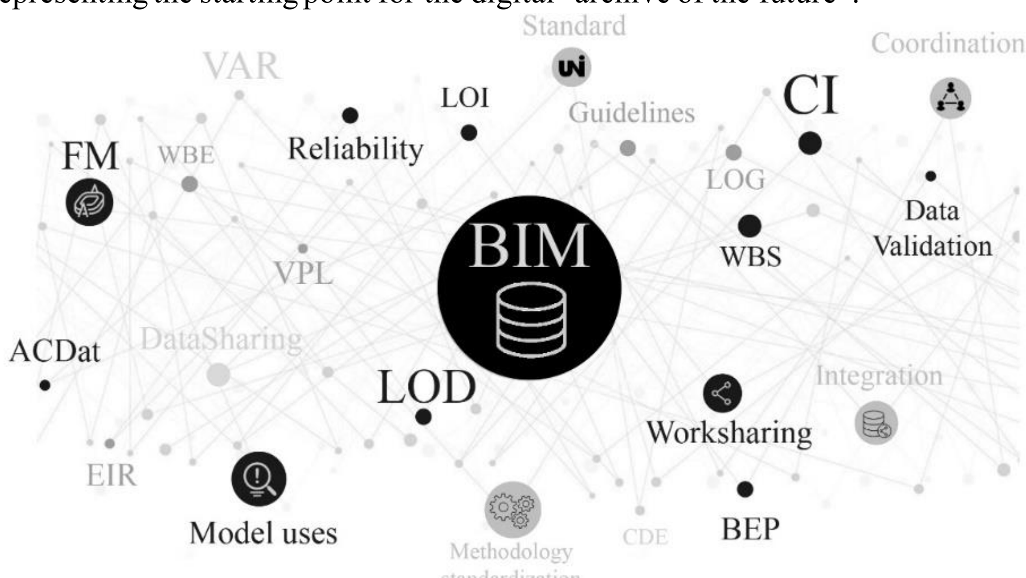

Figure 1 – Keywords of the research activity

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I would like to acknowledge with all my heart Professor Dr Anna Osello and Professor Ing. Fabio Manzone for always believing in me and in my abilities, stimulating me to always achieve the best possible result. Their teachings have been essential for my human and professional growth during my doctorate and I hope to have the opportunity to continue to work with them in the future.

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A special thanks also to myself, for never hesitating in following my dream, the BIM project of the stadium that I loved so much, that made me work hard but that finally became reality. Now this chapter is closed and nobody knows what waits for me in the future, but surely the passion and determination I have always had will not be lacking.

To my family,
To my friends,
To my love,
To me

"The study and research of truth and beauty represent a sphere of activity in which it is allowed to remain children for a lifetime".

Albert Einstein

Contents

List of abbreviations

Acronym	Full name
A1	Supplier 1 - Architectural
A2	Supplier 2 - Furniture
A3	Supplier 3 - Electrical
A4	Supplier 4 - Mechanical
A5	Supplier 5 - Structural
ACDat	Ambiente di Condivisione Dati
AEC	Architectural, Engineering, and Construction
AECO	Architecture, Engineering, Construction and Operations
AIM	Asset Information Model
AIR	Asset Information Requirement
AR	Architectural
AR*	Augmented Reality
BAS	Building Automation System
BCF	Building Information Modelling Collaboration Format
BEP	Building Information Modelling Execution Plan
BIM	Building Information Modelling
bim	building information model
BMC	Building Information Modelling Model Checking
BMS	Building Management System
CAD	Computer Aided Design
CDE	Common Data Environment
CI	Capitolato Informativo
CMMS	Computerized Maintenance Management System
COBie	Construction Operations Building information exchange
EIR	Employer Information Requirement
EL	Electrical
FM	Facility Management
FN	Furniture
FP	Fire Protection
GIS	Geographic Information System
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communication Technology
IFC	Industry Foundation Classes
IWMS	Integrated Workplace Management System
IoT	Internet of Things
IPD	Integrated Project Delivery
J	Juventus - Owner of the project
KPIs	Key Performance Indicators
LOD	Level of Development
LOG	Level Of Graphical Information

LOI	Level Of Information
MC	Mechanical (System sources)
MEC	Mechanical System (the union of FP, VE, TE, PL and MC)
MEP	Mechanical, Electrical, and Plumbing
MIDP	Master Information Delivery Plan
MR	Mixed Reality
NBIMS	National Building Information Modeling Standard
O&M	Operation and Maintenance
ODBC	Open Database Connectivity
OIR	Organizational Information Requirement
PIM	Project Information Model
PL	Plumbing
PT	Politecnico di Torino
RACI	Responsible, Accountable, Consulted, Informed
RegEx	Regular Expressions
ROI	Return of Investment
SIGeM	Sistema Informativo per la Gestione della Manutenzione
SIM	Security Information Management
ST	Structural
TE	Thermal
VAR	Virtual and Augmented Reality
VE	Ventilation
VPL	Visual Programming Language
VR	Virtual Reality
WBE	Work Breakdown Elements
WBS	Work Breakdown Structure
WIP	Work In Progress

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Chapter 1

Introduction

1.1 The problem statement

The resulting product of the building sector is the work, as the change of the natural environment, a building, or an infrastructure. These works are physically and digitally connected to the territory on which they stand, and their information structure regards different aspects, tangible and intangible (UNI 11337-1, 2017). Starting from these considerations, the increasing of building complexity is pointing out the need for the Architecture, Engineering, Construction and Operations (AECO) sector to **manage a large amount of data** (Barbero, Ugliotti, & Del Giudice, 2019). This aspect highlights the importance of their information content during the construction phase and the management process.

As defined by the Italian legislation, the information process of the constructions is composed of a sequence of phases that constitute the entire life cycle of the work itself. It is a cyclical one that starts from the expression of the owner's needs until the end of the useful life of the structure. The data content developed in each step has a strict connection to those of the previous and next one, following a specific logical and temporal development (UNI 11337-1, 2017). In particular, the management phase of work requires an **integrated approach** necessary for the execution of its functions that interact in the management of a building. This step represents the structured set of information contents related to the service activities that follow one another, starting from the end of the work's construction. These activities aim at ensuring the correct functioning and maintenance of the intervention until the natural end of its life cycle.

The control of all actions concerning the management of buildings and related systems of an organization, whose primary objective is the coordination of the physical workspace with human resources and the activity of the company itself, is part of the science known as **Facility Management** (FM). FM is an integrated approach that presupposes the development of policies, standards, and processes that support primary activities, making the organization able to adapt and improve

(Osello & Ugliotti, 2017). For this reason, it becomes essential to have an information system able to provide the necessary information to the various parties involved in management activities. At the same time, it is necessary to keep all this data always up-to-date. This system should be based on a unique digital database, capable of containing and manage different types of heterogeneous data, providing at the same time the possibility of their extrapolation and integration. Thanks to the availability of a common and integrated database, it is possible to have the information bases for making appropriate choices for the owner's needs in terms of effectiveness, economy, and efficiency, reducing the costs of running the building.

In this scenario, digital transformation is influencing the strategy to develop a virtual repository able to collect data from different disciplines and domains in a useful way for the building lifecycle. **Building Information Modelling** (BIM) can be an innovative methodology to optimize the overall workflow including a proper definition and management of geometrical and alphanumerical contents (Barbero, Del Giudice, Ugliotti, & Osello, 2020). As widely investigated by many researchers, the acronym BIM such as Building Information Modelling and not only as building information model (bim) can have many meanings. Two of the principal definitions should be:

- "*Building Information Modelling is a method that is based on a building model containing any information about the construction. In addition to the contents of the 3D object-based models, it gives information about specifications, building elements specifications, economy and programmes*" (Digital Construction, 2007).
- "*Building Information Modeling has become a valuable tool in some sectors of the capital facilities industry. However, in current usage, BIM technologies tend to be applied within vertically integrated business functions rather than horizontally across an entire facility lifecycle. Although the term BIM is routinely used within the context of vertically integrated applications, the National Building Information Modeling Standard (NBIMS) Committee has chosen to continue using this familiar term while evolving the definition and usage to represent horizontally integrated building information that is gathered and applied throughout the entire facility lifecycle, preserved and interchanged efficiently using open and interoperable technology for business, functional and physical modeling, and process support and operations*" (National Building Information Modeling Standard, 2007).

Starting from these definitions and state of the art, analysing and implementing the application of the BIM methodology is necessary to the entire building life cycle, in particular for the maintenance and management phase, enriching the definition of BIM for FM, highlighting its potentials. As defined by many researchers, book authors, and facilities managers, there are a lot of advantages in the application of BIM in this fields: space management, the employment of the BIM models for operating simulation, the extraction and employment of the BIM database during operation, saving time and money (Eastman, Teicholz, Sacks, & Liston, 2011), maintenance scheduling, and asset management (Kreider & Messner, 2013). The model can provide a large amount of data necessary for the commissioning of the building, especially if the FM is articulated in the early stages of design (Wang, Wang, Wang, Yung, & Jun, 2013). At the same time, it gives a better view of the system components, the ability to filter data (Chong, Wang, Shou, Wang, & Guo, 2014), and the advantages of a unique coordinated system with integrated BIM and FM (Kensek, 2015). In this way, the **reliability of data**, which emphasizes its importance throughout the entire life cycle of the work becomes essential. For these reasons, the BIM for FM allows extending the concept of BIM to its meaning of management by enhancing the operation phase, directing maintenance strategies starting from the design and construction phases (Osello & Ugliotti, 2017).

In this context, BIM modelling enables the implementation of the knowledge degree of the building through the reliability definition of its information content, updating data over time allowing the description of the building state of the art. The crucial points for these activities are the definition of the set of objectives and **model uses** that characterize the content of 3D parametric BIM objects. Following this perspective, a lot of researches try to define transversal standards (BIMFORUM, 2019) to facilitate information management by following international and national legislations (Barbero, Del Giudice, Ugliotti, & Osello, 2020). These standards are contained in the BIM procurement dispositions (Del Giudice, 2019) which are essential for the identification of the graphic and alphanumeric content required for the services' procurement. These references are an initial benchmark for the implementation choice of the models, but, at the same time, this content needs to be enriched with several operational requirements and **standardization** to achieve the defined practical uses (Ashworth, Tucker, & Druhmann, 2016). In fact, BIM uses for FM require both the data content upload and extraction indeed according to the day-to-day needs as the model represents a valuable database for managing activities for owners (Barbero, Del Giudice, Ugliotti, & Osello, 2020). For these reasons, this research bridge the gap between BIM procurement dispositions with a series of **operating protocols** based on **technical standards** that should be followed in order to achieve the defined BIM model uses.

1.2 Motivation, objectives, research questions

Based on the problem statement, the research activity focused on the analysis of the potential coming from the application of BIM methodology in the FM field, allows in this way the application of this methodology to the entire life cycle of the building. Currently, the operational phase of the building lifecycle is increasing more and more over time. Consequently, the management activity is progressively increasing its importance both from an economic and organizational point of view. In detail, for these reasons, FM is defined as "*The company discipline that coordinates the physical workspace with human resources and the company's* *activity. It integrates the principles of economic and financial management of the society, the architecture, and the behavioural and engineering sciences*"[1]. FM also represents "*The management strategy of the society's instrumental properties and the services at the base of the business, divided into building, space, and people facilities*"[2]. At the same time, maintenance is defined as "*the combination of all technical, administrative, and management actions, during the life cycle of an entity, designed to maintain or restore it to a state where it could perform its required function, defined at the project level*" (UNI EN 13306, 2018). Based on these definitions, the complexity related to the FM sector shows why it is not only connected to maintenance activities, but a whole series of connected actions enrich it.

The increase in building complexity leads to a consolidation of the considerations above, with consequent impact on work cost and importance of data knowledge, carrying out various management activities. Several studies demonstrate that, with the ever-increasing useful life of buildings, management costs could far exceed the construction value of the work itself, regardless of work nature. Therefore, during the last years, the need to have an innovative operating methodology was born to optimize the management of the entire process, based on an integrated database. In this context, the BIM methodology represents an opportunity for the AECO sector, allowing an integrated approach that is able to cover all the features of FM.

While the application of the BIM methodology is well documented in the design-to-construction phase, in recent years, different studies also highlight the benefit of its application in the FM environment. As illustrated within the construction information process (Figure 2), it becomes essential to have a unique database of the building throughout its entire life cycle. In this way, it is possible to avoid data loss in the transition between "the information model - of the project" related to data creation and "the information model - of the operation" during which the data is used and maintained over time. In addition, this solution enables to ensure that the passage of data content between the two different types of information models takes place in a continuative way. At the same time, it would also be possible to fill the **existing gap** at the process level, which today sees the implementation and management phases as separate sections.

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1 Definition of FM taken from the website of the International Facility Management Association: http://www.ifma.it/index.php?pagina=articolo.php&id_articolo=25&var_id_menu=68&nodata (last consultation on the 21st of August, 2020).

2 Definition of FM taken from the website of the International Facility Management Association: http://www.ifma.it/index.php?pagina=articolo.php&id_articolo=25&var_id_menu=68&nodata (last consultation on the 21st of August, 2020).

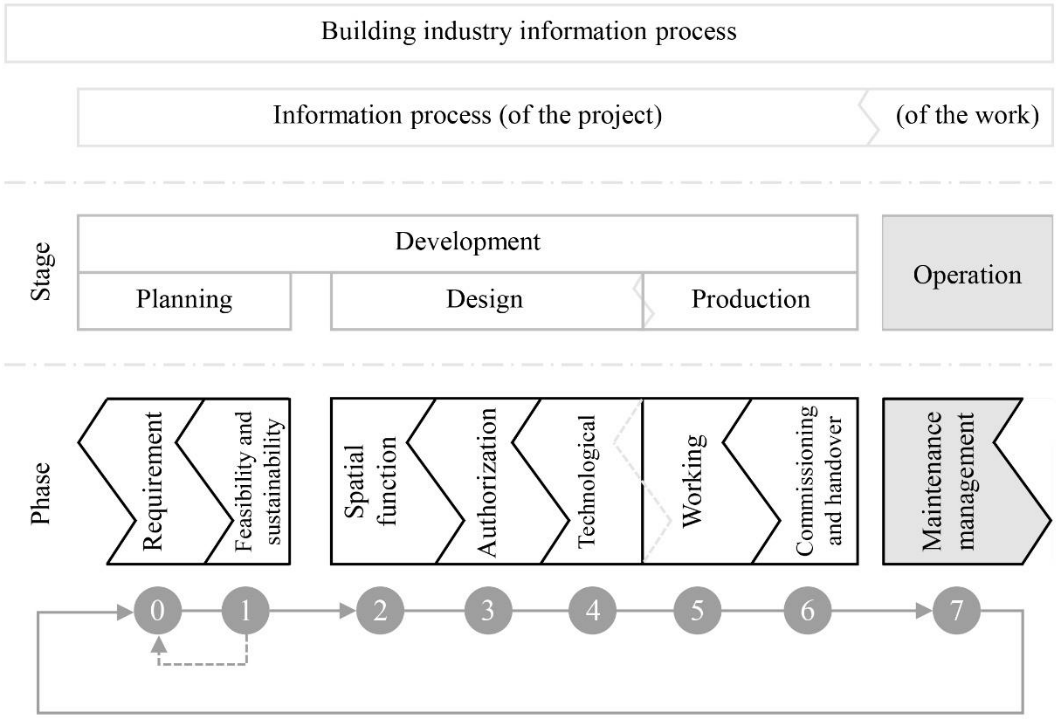

Figure 2 – Building industry information process (UNI 11337-1, 2017)

In an operational workflow, these are linked together, and only when the transition between them occurs, the building stops being a goal of the construction phase and becomes a tool of the management one. The avoidance of this detachment may only occur through correct information implementation. Therefore, starting from the presence of this relationship, the existing gap can be overcome by an integrated approach that allows anticipating many of the management needs in the design and structuring phase of the information database, based on data uniqueness. The actual fragmentation of the workflow between the design and construction, and the operation and maintenance processes, lead to an inadequacy of the available information of the heritage, both in technical and collaboration terms (Barbero, Del Giudice, Ugliotti, & Osello, 2020). Creating a BIM model representative of the As-built state of a new construction generates different solutions and approaches compared to an As-is model of an existing building, functional to management and maintenance activities. The reason lies in the various ways that are useful for the information production according to the specific objectives connected with these different phases (Barbero, Del Giudice, Ugliotti, & Osello, 2020). In the first case, the anticipation should take place in the design phase of the work where the planned information content is designed to fulfil the user's requirements and to achieve a particular performance, necessary for this phase. This aspect implies the creation of a detailed As-built model aimed at the construction site and to the building creation. For new buildings, the topic to analyse will become the definition of how to manage the interaction and enrichment of the data content of the As-built model in order to allow its use during its entire life cycle, obtaining an As-is one with defined data content. On the other side, in the second case related to existing structures, these questions should be considered during the structuring phase of the digital models, starting from already existing information, with different reliability. The information production is focused on the creation of an As-is model for the FM step, able to ensure the data updating over time, describing the state of the art of the construction during its entire life cycle. The need to create a different detailed model from the As-built one for existing assets is mainly due to the reliability of As-built existing data compared to the actual state (Barbero, Del Giudice, Ugliotti, & Osello, 2020). In these cases, it is necessary to define how As-built documentation, generally composed of Computer Aided Design (CAD) drawings, photographic surveys, existing 3D models, and maintenance schedules can be used for the database creation. As can be seen in the next chapters, the issue of data reliability becomes essential due to its connection with the **relief activities** and their details, to define the real building knowledge.

Due to all these considerations and analyses, the fundamental points of BIM model implementation are based on the BIM model uses and objectives that characterize the data content of parametric objects (Barbero, Del Giudice, Ugliotti, & Osello, 2020). This definition allows the BIM database structuring and the development of the first research question:

What is the information content of a BIM model aimed at Facility Management? Do the model uses have an impact on the creation of the database itself?

The application of this methodology to the FM environment allows the creation of a dynamic database, from which it is possible to extract data, manage spaces through the direct use of the model and respond in advance to maintenance problems (Report SmartMarket, 2015). It is therefore essential to define the geometric and alphanumeric information content necessary to achieve the set objectives for each object contained within the model. This activity should be done from a detailed analysis of the **level of information need** (UNI EN ISO 19650-1, 2019). It is strictly related to the concept of heterogeneous Level of Development (LOD) defined during the research activity and applied to the entire model obtained by application of a specific value for each element category (Barbero, Ugliotti, & Del Giudice, 2019). The objectives identified are strictly related to the definition of the model uses that need to be analysed, highlighting how they affect the structure of the model itself. In the author's opinion, the assumption that a BIM model should contain as much information as possible is wrong because each model must be appropriately structured for its uses. In detail, the concept of "BIM model uses", in international literature, can be defined as follows:

- "*A BIM Use is defined as a method of applying Building Information Modeling during a facility's lifecycle to achieve one or more specific objectives*" (Kreider & Messner, 2013).
- "*A BIM Use is a task, outcome or deliverable that a BIM model is used for. A particular BIM Use must have a useful real-world outcome. It should only*

be listed as a BIM Use for a project if there is a specific reason to do it; a specific party who will do it; a specific party who will receive the results; a specific outcome that aids the design, building or operation of the project facility" (Practical BIM, s.d.).

In this context, an essential factor for the achievement of the pre-established objectives is the appropriate approach to collaboration between the different actors involved in the process through the implementation of data sharing and worksharing. These aspects allow managing a large amount of data that will be accessible and usable for different users and different purposes at certain times (Barbero, Ugliotti, & Del Giudice, 2019).

As the BIM process is always considered a collaborative method to exchange information between all the actors of the building industry, it is based on a 3D parametric model as a common platform where different users fill in and extract data. Based on the analysis of the possible activities that can be carried out by exploiting the geometric and alphanumeric data content from the BIM model, a further requirement of FM activities emerges: the need to employ a tool that allows the management of the information system for maintenance activities. Many researchers investigated its strengths related to multidimensional and multi-disciplinary models to use data stored in BIM graphical database for different applications. These should be Time, Costs, and Facility Maintenance (Ding, Zhou, & Akinci, 2014), useful for the whole life cycle building. This goal requires, in each different topic, the employment of proper applications based on closed standard exchange formats, with a lot of issues in the data integration workflow. If for the management phase, data extraction and querying could be done directly from the BIM database, the reference legislation contemplates the adoption of a specific process called the "Sistema Informativo per la Gestione della Manutenzione" (SIGeM) for the maintenance step. It allows the management of the information belonging to these activities within the FM field. Its definition is: "*a set of rules, procedures, and tools to collect and process the information necessary for the management of maintenance activities and for monitoring the activity of the building systems*" (UNI 10584, 1997) (UNI 10951, 2001). This information system should be structured in order to allow its development over time and the possibility of access to it by all the different actors involved in the maintenance activities. This system is based on a database repository for carrying out specific actions represented at a geometric and alphanumeric level by the BIM model. According to the regulations disposition, the tool employed in the SIGeM process has a series of objectives to pursue: i) the recording of the performance and maintenance history over time; ii) the restitution of the updated state of the building's consistency and preservation; iii) the support to maintenance activities through operational indications; iv) the creation of a database capable of supporting strategic decisions. The achievement of these objectives is based on a series of requirements that SIGeM should meet (UNI 10951, 2001): i) the management of operating modes; ii) the availability of data; iii) the possibility to update data; iv) the integration of data belonging to different management platforms; v) the compatibility of the information as the maintenance of data over time, without incorrect duplication; vi) controlled access to the database system.

A suitable tool for this purpose is an **Integrated Workplace Management System** (IWMS) **platform**, which is an advanced technology designed to manage more effectively the core functional areas within an enterprise, including FM, overcoming the simple data visualization. These platforms allow simplifying the access to the information of complex asset through an integrated alphanumeric and geometric database. At the same time, this tool enables the management of a large quantity of data through a series of activable modules that constitute the software itself (Lo Turco, 2015). Therefore, it is necessary to establish the model goals and its use, developing a flexible BIM model ready for the FM step, in order to have a data repository correctly structured for all the actors involved in the process, able to allow the data integration with the IWMS platform. From these considerations, the second research question arises:

Does Data Integration with an IWMS platform have an impact on the setting's rules of the BIM model?

The integration with an IWMS platform should be identified from the beginning of the process since it requires a series of procedures to receive the information of the BIM models, which must have specific characteristics at the data organization level.

The third and final question of the research activity has been identified starting from the analyses carried out so far: it is aimed at the improvement of the **BIM procurement documents** allowing a correct structuring of the models for the prefixed uses.

Is it possible to define a methodology standardization based on the BIM models uses, able to fill the actual lack of standardization related to BIM procurement dispositions?

The research activity has been focused on the identification of a possible **methodology standardization**, maximizing the importance of BIM methodology in the field of FM. Nowadays, as mentioned in this chapter, the method and tools are in place, but there is a lack of guidelines to optimize and make the process operating within an integrated strategic vision. (Barbero, Ugliotti, & Del Giudice, 2019). Based on the definition of a series of activities necessary for the employment of BIM models in the management stage, this methodology standardization allows the implementation of the BIM procurement standards with specific operational requirements, creating **BIM guidelines for FM**. These allow enriching the BIM model objectives, with the declination of defined protocols of activities and tailor-made solutions.

For the case study of the research activity, the established BIM model uses defined with the owner are:

- *As-is model for FM* aimed at carrying out the activities required by this discipline such as the management of spaces, the construction of the registry required for maintenance activities, and the management of building systems. In detail, particular attention has been paid to the activities of the Operation&Maintenance (O&M) sector, analysing the related existing documentation (As-built 2D drawings, maintenance schedules) in order to define the operating methods for a proper methodological approach, including a series of "predispositions" for other FM uses, as illustrated in next chapters.
- *Integration with an IWMS platform.*
- *FM system over VAR* connects to the analysis and employment of Virtual and Augmented Reality (VAR) tools during the visualization of data for different purposes.

The proposed methodology standardization aims to develop the following objectives to achieve the defined model uses: **Data Organization**, **Data Integration**, and **Data Visualization**. The fulfilment of these goals applied to the FM field allows the definition of a new concept of stadium. As explained before, this concept is based on the implementation of an integrated database that combines the BIM model for FM with an IWMS platform enabling the operational management of maintenance activities and other FM ones. On the other hand, as set out in the conclusions and future developments, the results of this research activity will provide the foundations for a new way of managing infrastructures that will offer an innovative and user-friendly approach, combining the urban network with the proper activities of a building. The development of a **Stadium 2.0** digital model is therefore focused on the revaluation of urban sports venues where meeting, dialogue, integration, and social inclusion will take place (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019). The interaction between society and the built environment will be based on an interoperable process founded on communication protocols able to share information content at different levels, avoiding data loss. The urban citizen will be able to use, in an interactive way, part of this data collection concerning the life of the stadium and, with a view to the future, of the district, allowing to reach the declination of the concept of "archive of the future" based on 360°+5 scenarios (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019).

In a more general view, the research presents a progressive increase in the complexity of the BIM process, which, starting from the definition of the model for the FM step, is enriched through the integration with other data domains and improves its usability through customized virtual experiences. In this way, it is possible to obtain an effective example of BIM model 6D, based on the tailor-made solution illustrated during the research activity.

The definition of the objectives and model uses on which the research activity is based has been carried out in cooperation with the company that founded the PhD: the Juventus Football Club. The collaboration was born due to a series of company needs as the owner of its real estate assets. The case study of the research is the Allianz Stadium which represents the more complex and characteristic asset of the owner. It is continuously evolving and, at the same time, it represents the place where a whole well-defined series of FM activities are carried out since the first day. For these reasons, FM and maintenance activities in detail become fundamental aspects of the improvement of productivity and business. They are also the most significant indicator for the monitoring of the ageing, which presents a well-defined set of costs. If these ones are compared with the construction cost of the building itself, it is easy to highlight their great importance. Figure 3 shows the incidence of some of the highest and impacting costs of the FM, year by year, defined concerning the guaranteed value of the asset and not its construction cost. The insured price is a variable value from year to year, and it takes into account both the depreciation of the building and subsequent investments that could have a considerable impact, both positive and negative, on maintenance fees. As visible, the incidence of FM activities is around 3% per year, and it is associated not only with the degradation of the structure which increases the maintenance weight but also with the levels of service desired by the company. The case study is a recently constructed building, and it is at the beginning of its useful life, so the illustrated considerations do not change. Over time, the impact of these costs could increase significantly compared to the calculation concerning the construction cost. This consideration is linked to the constant value of the realization cost, while the guaranteed value tends to decrease according to the age of the asset unless possible investments made in terms of technological innovation. Assuming only these costs, in 20/25 years the total amount of the FM cost will be equal to the construction price, based on the estimated increment of maintenance costs of the asset, which, in absolute value, will assume an amount equal to 4-5%, following the depreciation of the asset itself. This consideration highlights exactly the importance of the FM sector in the entire life cycle of a stadium and, in a more general way, of a building.

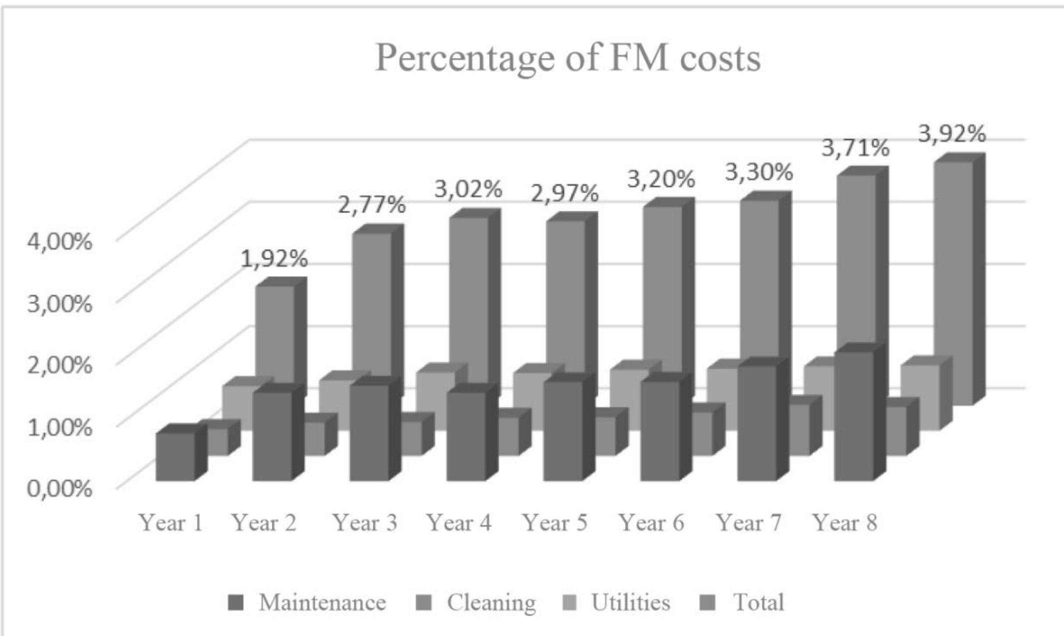

Figure 3 – Percentage of FM costs of the case study (Berchialla, 2019)

For these reasons, the strengths of the research project are represented by: i) the definition of common objectives of the Service Area and the Commercial Area of Juventus that contribute to the structuring of the model itself, highlighting its potential; ii) the involvement of the suppliers in the development of the project; iii) the possibility of defining the new concept of Stadium 2.0 which will have a new diversification of the commercial product "Stadium" also based on its virtualization, starting from the analyses carried out during the research activity. For the achievement of these aspects, the owner has decided to modify its methodological approach, based on a non-integrated 2D geometric and alphanumeric database, adopting the BIM methodology.

1.3 Methodological Approach

The research thesis is located within the field concerning the application of the BIM methodology for FM. This study aims to analyse and evaluate the definition of a methodology standardization in the meaning of defining the activities necessary to start a digitization process aimed at using BIM models in management activities (Barbero, Del Giudice, Ugliotti, & Osello, 2020). The starting point has been represented by the operational declination of the first owner needs, which could be summarized as follows:

- The definition of an integrated methodology for FM activities.
- The creation of a single database accessible to all actors involved in the process, based on **data uniqueness**.
- The improvement of data reliability necessary for the FM and the O&M, starting from the existing As-built documentation and their implementation activities, carried out during the building's lifecycle.

Based on these requirements, the definition of different model uses is preparatory to identify the milestones to be satisfied. As illustrated, for the research activity, the defined model uses are: i) As-is model for FM; ii) Integration with an IWMS platform; iii) FM system over VAR. One of the most important actions to ensure decisions in the BIM model development consists of involving the owner at the beginning of the entire process (Barbero, Del Giudice, Ugliotti, & Osello, 2020). 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 8536-1, 2016). Therefore, the proposed methodology, as visible in Figure 4, started from the analysis of the As-built documentation and the investigation of various BIM standards in order to define the level of information need (UNI EN ISO 19650-1, 2019) for each model uses and corresponding objectives. Each of these uses requires different kinds of Level of Graphical information (LOG) and Level of Information (LOI) useful to achieve the BIM objectives (Barbero, Del Giudice, Ugliotti, & Osello, 2020). The development of the BIM models oriented to each FM use is based on the definition of model requirements that have to be included in standards and guidelines.

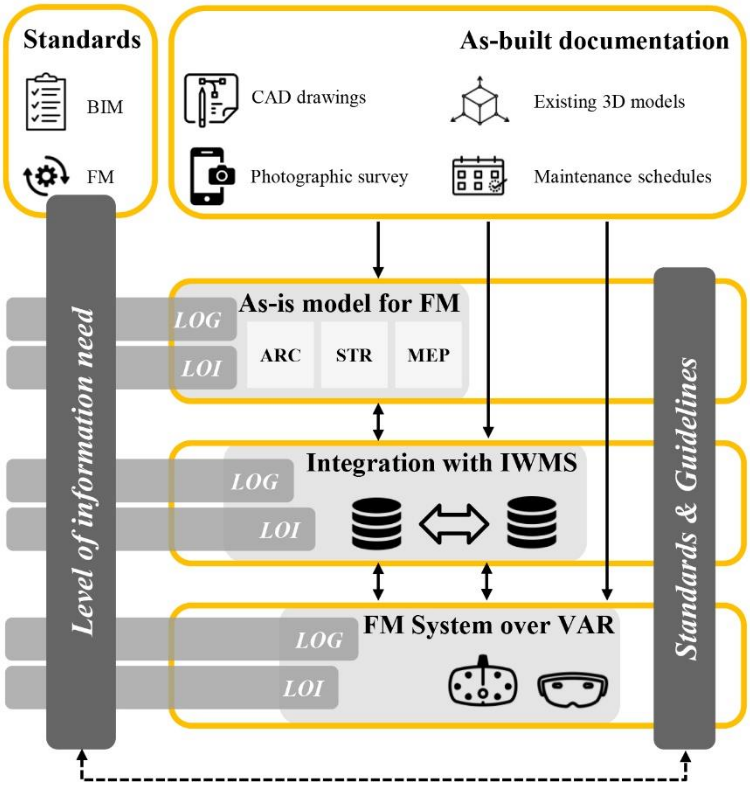

Figure 4 – Methodological workflow of the research activity (Barbero, Del Giudice, Ugliotti, & Osello, 2020)

The definition of specific BIM guidelines for FM contains the BIM procurement dispositions, enriched with a series of technical standards. On these, operating protocols are based and they should be followed to achieve defined BIM uses for FM (Barbero, Del Giudice, Ugliotti, & Osello, 2020). These protocols issued by the owner are the results produced by the application of defined activities related to the development, management, and visualization of the model as visible in Figure 5.

Figure 5 – Activities of the BIM methodologic standardization for FM

These activities are based on the project objectives defined for the achievement of model uses. These aims represent the base on which the various activities have been analysed during the research activity:

- **Data Organization** refers to the definition and the structure of the data content related to the implementation of an As-is model for FM. This point is essential for the proper use of BIM models due to the central role of information and their amount.
- **Data Integration** refers to the development of different tests that aim to identify specific characteristics that data should have in order to integrate correctly the IWMS platform, represented for the case study by Archibus©, which allows organizing data of a real estate portfolio managing the specific services of facilities. These aspects can also have a significant impact on the structuring of the models themselves, and it is necessary to report them within the BIM guidelines clearly.
- **Data Visualization** refers to the implementation of the model in order to allow the visualization of geometric and alphanumeric information with a predefined tool. For the research activity, some possible application with VAR tools has been analysed for future development related to maintenance management, operational training, virtualization of environments, and immersive navigation.

All of these activities represent the proposed methodology standardization for FM, which aim to ease all the actors involved in the project in following all the disposition necessary for the correct implementation of BIM models. The defined BIM guidelines have been developed during the entire digitalization process through continuous updating and implementation loops, thanks to the collaboration and the joint analysis with all the actors involved. Their application, according to the definition explained before, allows the definition of the new concept of stadium 2.0.

Furthermore, during the research activity, the issue related to Data Validation has been analysed. It could be an essential aspect to achieve a correct organization and integration, starting from the relevance of the alphanumeric content and of its structuring at a formal level. About this aspect, BIM is all about the data (Teicholz, 2013), as the "I" of information is the fundamental feature to enrich FM goals (Vergari, et al.). An automated process for checking information within a BIM model plays a role of fundamental importance, increasing the model's reliability, performing data integration, and reducing the time of working. For these reasons, a methodology based on a **Visual Programming Language** (VPL) for an automated BIM **Data Validation** process of alphanumeric information has been analysed and implemented during the research activity. This strategy has been tested on a considerable amount of data developed by different actors of the project, obtaining summary reports which verify the application of defined modelling disposition contained in BIM guidelines. The illustrated methodology is structured to verify the alphanumeric content defined in the planning stage and the developing phases of

BIM models, describing the Data Validation concept in the BIM Model Checking (BMC) scenario (Hjelseth, 2015). It allows the implementation of BMC concept as the sum of Code Checking, Clash Detection, and Data Validation (Vergari, et al.). This validation activity becomes essential when data and its reliability are fundamental for specific BIM model uses, as the FM one (Teicholz, 2013). Starting from the literature, in the validation area investigated by Hjelseth, the most relevant checking mentioned regards a geometric based approach, widely known as Clash Detection, and an alphanumeric one for verifying codes, regulations, and standards, named Code Checking (Hjelseth, 2010) (Hjelseth, 2015) (Hjelseth, 2016). The first one aims to identify geometric clashes between BIM objects inserted in models (Hjelseth, 2016), while the second one allows controlling if elements are following codes, regulations, and external standards (Nawari, 2018). Compliance with these definitions, the research activity has pointed out a lack of Data Validation activity in BIM procurement documents and BIM guidelines specifications (Vergari, et al.) related to internal standards.

Despite standards and codes change from country to country, the alphanumeric content varies from project to project because it is connected to the specific objectives. Due to these aspects, VPL (Amoruso, 2016) could be analysed as a proper tool for the validation activity because it allows an unlimited potential in data analysis, thanks to its structure based on boxes and logic arrows (Vergari, et al.), allowing at the same time the implementation of specific types of control.

The proposed BIM Data Validation process follows the structure illustrated in Figure 6, where the main steps are (Vergari, et al.):

- Identification of project's meaningful information
- Definition of a checklist
- Definition of rulesets
- Processing of rules
- Output generation

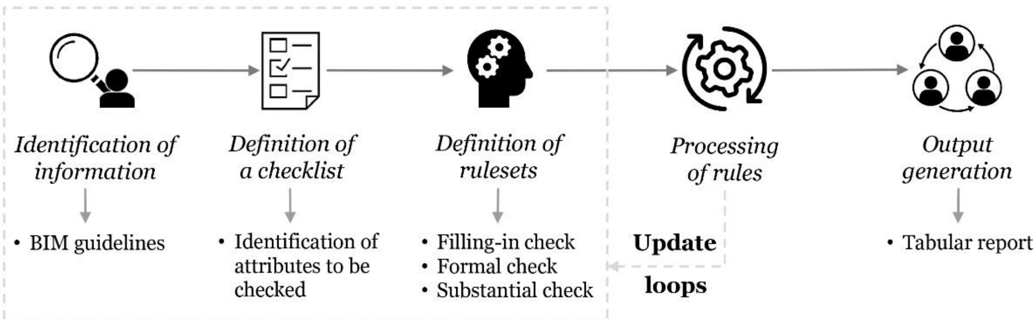

Figure 6 – Methodology workflow for the Data Validation process (Vergari, et al.)

The logic associated with the Data Validation process becomes part of these documents (Vergari, et al.). In the age of big data, the availability and reliability of information gain an economic value. For this reason, the management of this aspect from the beginning of the process became essential. It could be reached through the development of BIM guidelines that allows the implementation and activation of a rigorous validation procedure.

As mentioned in conclusion, the above methodology can be applied to different kinds of case studies, with the same model uses of the proposed research activity. The obtained results are summarized in the next chapters, and they show their tailor-made characteristic for the stadium, which is a huge structure characterized by many aspects that require specific building registry definition and maintenance activities. In detail, for project development, Autodesk Revit software has been used for its diffusion on the international market and its multidisciplinary nature. For the Data Validation process, Autodesk Dynamo has been chosen for its connection with Autodesk Revit. Autodesk Dynamo is an open-source computational design platform for BIM that enables the creation of algorithms defining a step-by-step set of actions that follow a basic logic of input. It is based on the employment of Python language and its visual, systemic, and geometric characteristics allow collaboration between all the parts involved.

1.4 Structure of the thesis

This thesis is structured to illustrate a general overview of the research field before analysing the proposed methodology and the results achieved for the case study. The structure of the thesis is summarized in Figure 7:

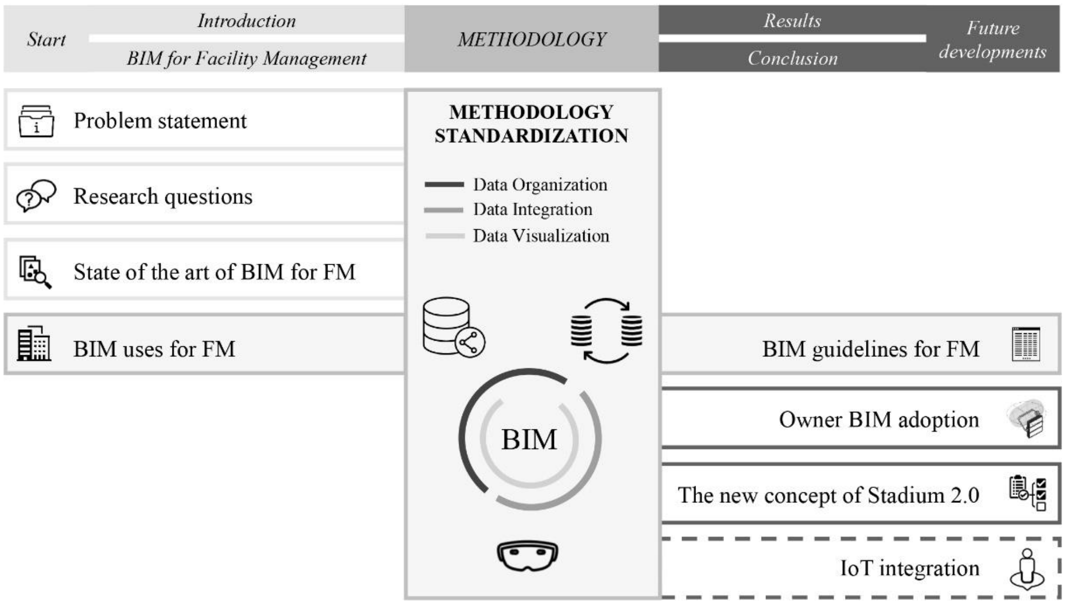

Figure 7 – Structure of the thesis

Chapter 1 introduces the problem statement, the main motivation and objectives, summarize the research questions, and introduces the methodological approach in a general way.

Chapter 2 illustrates in detail the field of the BIM methodology for FM, the case study of the research activity, the state of the art of the BIM adoption for stadiums, and the identified BIM uses for FM.

Chapter 3 refers to the analysis of the problem statement highlight at the research level, investigating the current state of the art critically, reaching the definition of methodological standardization. The different activities defined for the case study, starting from BIM uses and relative objectives, are then illustrated: their development allowed the execution of a digitalisation process of the stadium, focused on FM.

Chapters 4, 5, 6 discuss in detail the methods developed to carry out each activity for every prefixed objective: Data Organization, Data Integration, Data Visualization. These represent the applicative part of the thesis, supported by the results achieved for the case study. The activities investigated in these sections, related to the general framework provided in chapter 3, concern those analysed by the author of the thesis with the collaboration of the other member of the "Politecnico di Torino" actor, as indicated in the acknowledgement. As detailed, some of the illustrated activities has been analysed also with the collaboration of the other actors involved in the entire project. Chapter 6, on the other hand, reports the results deriving only from a first design for the achievement of these aims, without the detail of previous chapters, highlighting possible future developments.

Chapter *7* summarizes the obtained BIM guidelines for FM, providing a brief explanation of their structure. It also contains a global recap of the owner digitalization process, which shows how the methodology has become an integrated part of the FM process for the development of the new concept of stadium.

Chapter 8 offers a discussion of the results investigated during the research activities and the identification of further and possible future developments related to the new stadium 2.0 concept.

Chapter 2

BIM for Facility Management

2.1 Definition and state of the art

As highlighted in the previous chapter, the application of the BIM methodology inside the building process is the object of research and analysis activity, especially in the field of FM and the management stage of the work. Lots of studies have been carried out to investigate the employment and the structure of the BIM model database for this purpose. It is based on the implementation of 3D parametric objects enriched with geometric and alphanumeric information that enables the definition of an integrated relationship database, base on the uniqueness of data. The knowledge of a clear definition of what BIM methodology represents is necessary to understand its real potential, starting from what illustrated in the introduction. Nowadays, several definitions of BIM available at international level describe it as:

- "*A computer-generated model containing precise geometry and relevant data needed to support the construction, fabrication, and procurement activities needed to realize the building*" (Eastman, Teicholz, Sacks, & Liston, 2011).
- "*A collection of defined model uses, workflows, and modelling methods used to achieve specific, repeatable, and reliable information results from the model. Modelling methods affect the quality of the information generated from the model*" (BIM, 2014).
- "*A data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analysed to generate information that can be used to make decisions and improve the process of delivering the facility*" (Lucas, Thabet, & Bowman).
- "*An information-based system that builds long-term value and advances innovation*" (Jernigna, 2007).

From these definitions, it is possible to affirm that BIM means a series of activities that start from the creation of a graphical database composed by 3D objects rich of information to be used in the different steps of the building process (Osello, 2012). The created database is represented by the bim, which is a digital representation of a building based on components like doors, columns, MEP elements, with specific attributes and properties. This methodology is not only a new digital representation process, but the creation of simulations and virtualizations of buildings indicates that it goes beyond, conditioning the entire life cycle of the structure. It allows the fragmentation reduction of the building process, reaching an integrated approach and management workflow based on information, collected to enrich specific BIM model uses. For this reason, the acronym BIM assumes the different definitions of Building Information Modelling, Model and Management, always based on the data content. In this perspective, the model information content constantly evolves at the dimensional level starting from the 3D to the 4D for time management, the 5D for cost analysis, the 6D for operating and management step, the 7D for sustainability assessment (UNI 11337-1, 2017).

The central role of data is one of the significant features of this methodology based on the information knowledge of the building, which should be guaranteed during the entire building lifecycle. For this reason, as highlighted in the introduction chapter, the application of BIM approach to FM allows overcoming the actual gap existing inside the building process. Its application represents the starting point for an innovative methodological approach of a transition period which enables the construction sector to fill in some existing efficiency gaps. The topic of information knowledge has different meanings concerning the operation stage of the building process and, in particular, whether it is a new building or an existing one. For the different cases, the importance in the knowledge and the employment of a knowledge-based system lies in the capability to predict a possible future behaviour of the building and to have a greater awareness of critical issues (Talamo & Bonanomi, 2015). In this way, it could be possible to achieve the expected FM results such as time and cost reduction and the optimization of the entire process. For these reasons, the AEC Industry need to innovate itself is increasing in the last few years. This aspect could be managed through the adoption of forefront methodologies based on the optimization of data management both for new and existing buildings (Barbero, Del Giudice, & Manzone, 2018).

As defined in the literature, BIM, therefore, represents the best approach in the field of construction for the structuring of a central database, whose knowledge is the starting point for the FM performance activities. This expected result is represented, as visible in Figure 8, by the synergistic relationship of the three main areas: (i) legislation, (ii) data management and (iii) work environment. In detail, **Data Management** involves the implementation of workflow process founded on the specific legislation and regulations of this field (BS 1192, 2007) (PAS 1192 - 2, 2013). On the other side, this aspect is also based on the definition of suppliers' document, requested by the owner. The combination of these areas enriches the expected results of the application of BIM for FM such as (i) maintenance process optimization, (ii) reduction of cost wastage and (iii) time saving (Barbero, Ugliotti, & Del Giudice, 2019).

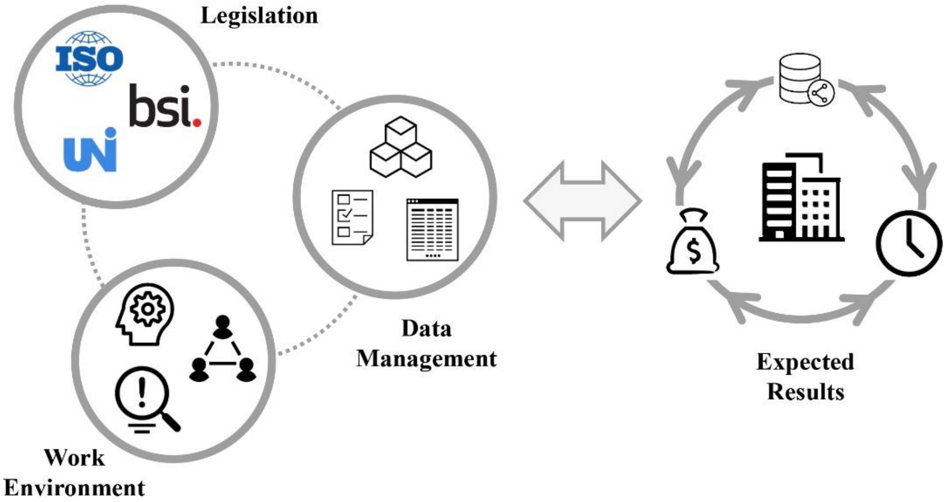

Figure 8 – Area of interest and expected results of the BIM methodology for FM

The employment of BIM methodology respect to the traditional operating methods represents a relevant revolution since it enables the implementation of a digital model of the construction inside which data is unique. Additionally, the complexity increase of building has emphasized the need for this sector to manage a large amount of data both during the construction process and the management phase (Barbero, Ugliotti, & Del Giudice, 2019). The core of the facility, therefore, becomes the **data** intended as "*information, especially facts or numbers, collected to be examined, considered and used to help decision-making, or information in an electronic form that can be stored and used by a computer*"[3]. "*For the building sector, the term 'data' describes discrete facts and can be structured to create information, organized to produce knowledge and applied to give wisdom, for example, allowing decisions to be made*"[4].

In recent years, data implementation for all stages of building lifecycle increased so much that different researchers started to speak about big data also for the construction sector (Isamil, Bandi, & Maaz, 2018) (Bilal, et al., 2016) (LetsBuild, 2019). In the international literature (Correa, 2015), this issue is under analysis, and numerous researchers aim at including BIM methodology in this field. Nowadays, the main question is to establish if the amount of information collected during the setting of a BIM database is a sufficient value to be compared with the traditional areas associated to this topic such as social-media, energy monitoring, structural analysis (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019). With the BIM method, the building data content is created and implemented over

[3] Definition of data taken from the website of the Cambridge Dictionary website: https://dictionary.cambridge.org/dictionary/english/data (last consultation on the 31st of August, 2020).

[4] Definition of data taken from the website of the Designing Buildings Wiki website: https://www.designingbuildings.co.uk/wiki/Big_data_for_buildings (last consultation on the 31st of August, 2020).

time, thanks to different actors involved during the various stages of its lifecycle with different purposes.

For this reason, it is possible to affirm that all **actors** involved play a specific and essential role in each disciplinary field in function of their needs. The identification, at the beginning of the process, of the users' needs on which project goals are based became essential and connected to the employment of proper tools (Barbero, Del Giudice, & Manzone, 2018). A hypothetical workflow that summarizes the whole operational process is represented in Figure 9, where the optimal BIM adoption depends on the model uses.

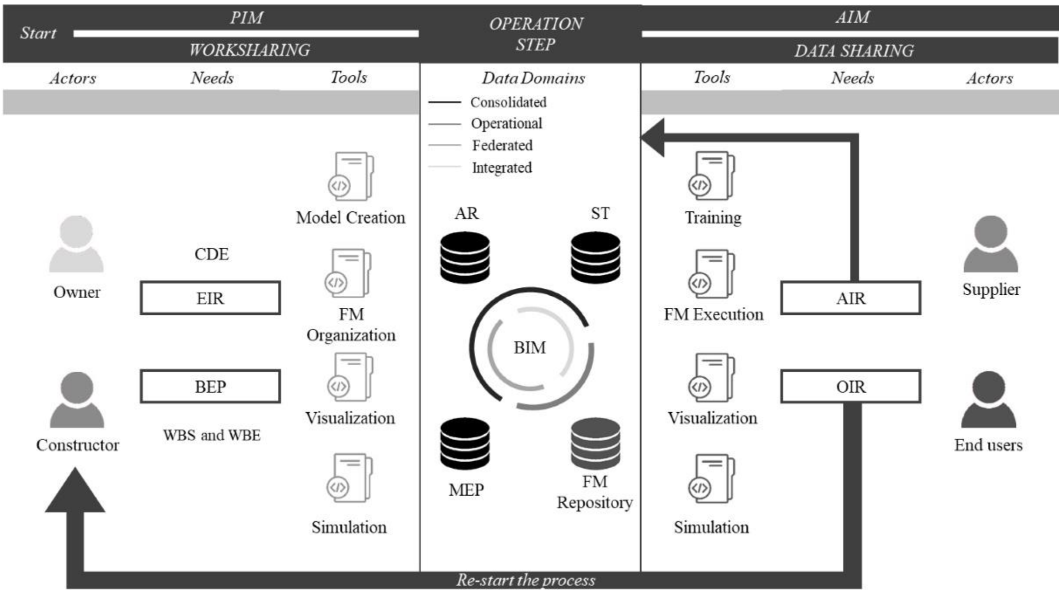

Figure 9 – BIM methodology workflow for the operational phase (Barbero, Del Giudice, & Manzone, 2018)

In this way, it is possible to have an integrated database, accessible and usable by different actors, born from the identification of the necessary information. This data content allows the satisfaction of their needs through the employment of various tools that enable to make the asset lifecycle continuous, without informative gaps. Connected to this theme, as visible in the following operationally chapters, it is also necessary to define how the data collection and its implementation will be managed in BIM models, especially for existing construction.

Due to the need of a constant updating of the database represented by the BIM model, its implementation should be necessarily based on **Data Sharing** and **Worksharing** between the figures involved in its modelling. Various collaboration systems have been implemented on the market to enrich, exploit and reuse collected data into multi-disciplinary models during the operational step (Shafiq, Jane, & Lockley, 2013). These platforms generally offer only a shared space between the various actors in function of the project requirements (Grillo & Jardim-Goncalves, 2010), without specification on the collaboration workflow necessary for the management of the implementation phase (Barbero, Del Giudice, & Manzone, 2018). International studies illustrate different approaches to achieve Data Sharing (Comiskey, Jaffrey, Wilson, & Mordue, 2017) and Worksharing (Grillo & Jardim-

Goncalves, 2010) but, in many cases, there is a lack in the definition of the BIM models data content (Barbero, Ugliotti, & Del Giudice, 2019).

For this reason, the identification of the goals at the beginning of the process becomes essential for the achievement of the needs of owner and management through the employment of proper tools (Bocconcino, Del Giudice, & Manzone, 2016). One of the first analysis of the research activity regards the definition of the **Building Integrated Management Matrix** (BIMMatrix). This matrix identifies the connection between the BIM methodology and the Data Management-Worksharing environment, based on the illustrated background (Barbero, Ugliotti, & Del Giudice, 2019). As envisaged by the BIM process, the data input is represented by the collection of information (Step 1) belonging to different domains (i.e. Building registry, Maintenance and Monitoring) and by their restitution in a graphical and alphanumeric way (Step 2). This activity arises in the development of objects (i.e. Wall, Beam, or Light) with features that optimize the BIM environment. The obtained "DB" and "Modelling" sections are connected and enable the optimization of the "Management" phase (Step 3) during the entire building life cycle. The two starting sections support also the "O&M" (Step 4)) activities, completing the quadrant of interaction between inputs and outputs of the matrix. After that, the outcomes can be investigated evaluating three different questions about actions: "Who" fill or extract data (Actors), "What" are his objectives (Needs) and "How" this information can be visualized (Tools). The fundamental rule to allow the convergence of the aspects characterizing the two processes is the definition of a bidirectional relationship between Data Sharing and Worksharing. Data Sharing could be considered an output of Worksharing, but, at the same time, it represents an input for data management carried out by different actors. Thanks to this analysis, the potential of the BIMMatrix is highlighted (Figure 10). This graph connects the BIM methodology to the Data Management-Worksharing environment, ensuring the continuous and coordinated updating of the data content (Barbero, Ugliotti, & Del Giudice, 2019). As can be seen in the next chapters, this BIMMatrix concept has been applied to the case study, to analyse the approach based on specific "Needs", "Tools" and "Actors".

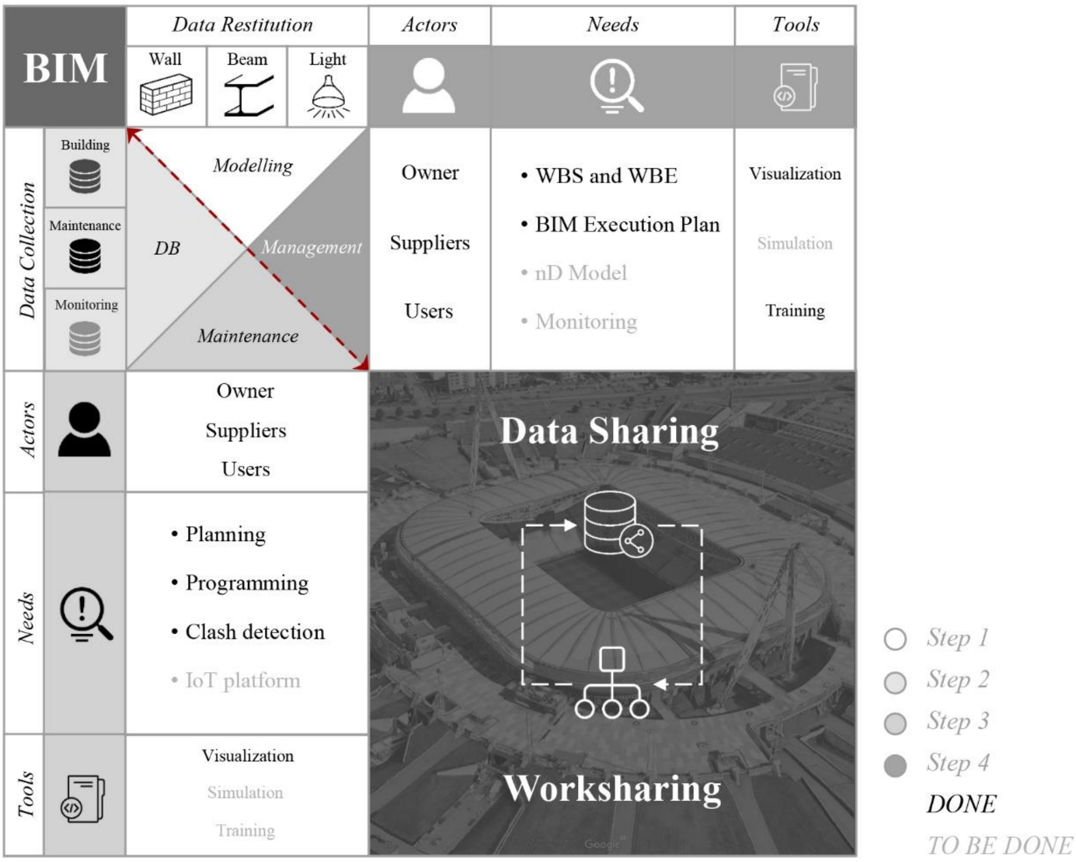

Figure 10 – The BIMMatrix: interaction between BIM and Data Management-Worksharing environment (Barbero, Ugliotti, & Del Giudice, 2019). (Image source of the stadium: Google Earth)

2.1.1 Strengths and research gaps

Completed the analysis of the features of BIM application for FM and following several experts of these issues, the main strengths of this topic are:

- The **preservation of data** related to a building during its entire life cycle, thanks to proper structuring of the relational database (Gu & London, 2010). This feature is an essential aspect for understanding the potential of the BIM methodology applied to FM since both environments are based on specific connections between different kind of information (Lo Turco, 2015).
- The introduction of the **data reliability** concept which could be defined as the degree of knowledge of an object composed by a set of geometric and alphanumeric information. For the research case study, this concept has been associated to every single instance of BIM models, providing an overview of the building knowledge at state of the art. The structuring of a unified database allows a reduction in information search times, thus optimising management and maintenance operations.
- The **utilisation of the data** content for the employer training who have to develop specific activities on the building itself.

- The possibility to carry out **simulation** and **analysis** of the construction, optimizing management, reducing its costs at the same time. These can be achieved through the reduction of operating and maintenance fees, providing more precise control systems and efficient services for building occupants (Davtalaba & Delgadob, 2014). The BIM methodology applied for these purposes also allows the development of energy and sustainability simulations as well as hypothetical scenarios of emergencies (Xhembulla, 2018).
  In a more general view, the BIM model could represent a useful tool for the digital representation of the environment in which activities, such as maintenance, are carried out, allowing a preventive analysis of different configurations and features. This goal is based on the visualization feature of the BIM model that also allows innovative management of spaces through immersive digital technologies.
- The **space management** which is the core of the FM's activities: the BIM methodology allows its optimal execution, leading to an improvement in the project organization that affects the project phase and its requirements of the several associated services (Osello & Ugliotti, 2017). At the same time, it is also possible to know the asset collocation inside the building spaces, making their characterization and maintenance activities easier.
- The possibility of getting an overall and **multidisciplinary** view of the construction, which allows its management as an **entity**. In the field of maintenance, an entity is defined as "*a part, component, device, subsystem, functional unit, equipment or system that can be described and considered individually*" (UNI EN 13306, 2018). This approach can be implemented through possible applications developed with **VAR** technologies that enable a more direct and significant connection to the database (Swanström & Svidt, 2018). This approach is primarily based on the geometric database and the visualization of the elements, but it finds its maximum potential in the dynamic interrogation of objects and the superimposition of the digital model on reality (Barbero, Del Giudice, Ugliotti, & Osello, 2020).
- The implementation of the geometric and alphanumeric database through the **integration** with FM systems like IWMS, Building Management System (BMS), Building Automation System (BAS) and the real-time connection with **Internet of Things** (IoT) devices for the management of information coming directly from the real environment.

The application of the BIM methodology for FM is, therefore, an innovative area of research because, understanding the potential of the method, is necessary to investigate and analyse how to develop its structure. In this context, it becomes essential to define how the BIM methodology should be used to contain geometric and alphanumeric data, how the database structuring must take place, which standards should be used, how data should be organised in order to be integrated with an FM system and how operators could be involved in the whole process to maximise possible benefits (Teicholz, 2013). As mentioned in the introduction, the illustrated context represents the research field, focused on a particular building, such as a football stadium. According to the analyses conducted at international level and other reference studies (Naghshbandi, 2016) (Yalcinkaya & Singh, 2016) (Ugliotti, 2017), the main **research gaps** of this sector are represented by:

- The impossibility to define a **transversal operating procedure** for the BIM application for FM since the model setting and the information content depend on the objectives to be pursued. This aspect is also highlighted in the activities of other researchers who illustrate and analyse a lack of similar reference or similar case studies, often investigated only from a theoretical point of view and concerning new buildings (Bocconcino, Del Giudice, & Manzone, 2016), (Talamo, 2014), (Lo Turco, 2015), (Di Giuda, Villa, Teicholz, Sacks, & Liston, 2016), (Erba, Osello, Semeraro, & Ugliotti, 2015). As highlighted in the methodology approach, from these considerations arises the need for a methodological standardization that identifies the operational activities and technical requirements to be used to achieve specific uses of the BIM model in the FM field. Their definition could be implemented within specific BIM guidelines for FM, organized from the structure of BIM procurement documents. This operational disposition could be used by owners to give the developing disposition necessary for proper structuring of the database. Linked to this aspect, however, there is a gap of similar documentation examples that often focus mainly on the application of the BIM methodology during the design and construction phase, covering only in a general way the issue of integration with FM activities (GSA, 2011), (Lopez, 2019), (National Insitute of Building Sciences, 2015), (USC, 2012) (Schley, Haines, Roper, & Williams, 2016) (Kensek, 2015) (Lo Turco, 2015). This focus highlights how the application of the BIM methodology in this field of the life cycle represents an innovative research activity.
- The issues associated with correct **data integration** between the modelling software and the FM platform. At state of the art, there are still some limits linked to the maturity of the software that will be implemented in order to achieve all the results expected from the application of an innovative process in this sector, with subsequent trouble in the information transition. Currently, for the case study, the integration between the modelling software and the IWMS management one involves the passage of the geometric and alphanumeric database through the direct reading of the native format and/or, only for the alphanumeric information, exporting the database in Open Database Connectivity (ODBC) format. In this way, there are two different databases connected by a passage of information. For this purpose, the issue of the bidirectional relation in data transfer is an important research topic, together with the need to establish which is the most appropriate database that contains a specific kind of data. As discussed in the

corresponding chapter, to achieve correct data integration, it is necessary to proceed with a series of analyses aimed at identifying the proper data structure to avoid their loss. For this reason, the Construction Operations Building information exchange (COBie) format has been analysed during the study of state of the art (Patacas, Dawood, & Vukovic). However, this format is a very complex one, and it contains much more information than needed for the research case study. The topic of data exchange and the possible loss of information in the transition from one software to other falls within the field of interoperability, which is undoubtedly a broad topic of investigation and analysis by the scientific community. Currently, the only one exchange format OpenBIM recognised by BuildingSmart is the Industry Foundation Classes (IFC), which has not been analysed for this research activity (UNI EN ISO 16739 - 1, 2020). The FM software, indeed, does not support the database directly in this format but allows a straight connection interface with the Autodesk Revit modelling software (ARCHIBUS Inc.). Moreover, since the owner is a private company, according to the Italian regulation, the demand for the open format is not mandatory, but it is certainly a topic for different kind of future analysis and studies.

- The need to better understand **FM**'s activities **value**, due to its importance in the construction sector. This gap can be overcome through an integrated vision of the entire process, bringing the requirements and needs of the management and maintenance phase into the design step of the construction process. The construction phases and in particular the design one have a specific impact on FM. For this reason, the concept of information reliability is strictly linked to FM: as the model database is unique, it is necessary to analyse each aspect from the beginning of the building's life cycle, to know the consequences of using this information for a given activity.
- Defined the geometric and alphanumeric content of the As-is model finalized to FM, several difficulties are related to the definition of the BIM **data structure** linked to the entire building lifecycle. It provides, for new construction, the transition of the proper characteristic of an As-built model defined for specific purposes to the ones typically required for an As-is one for FM. It is, therefore, necessary to establish how the two different levels of detail, both from a geometric and alphanumeric point of view, could coexist within the structure of the integrated database as these are developed in different phases of the process.
- Nowadays, a critical point related to the application of the BIM methodology is the absence of an economic value connected to the adoption of this strategy. Besides, there are not reference examples that show the characteristics linked to the return on investment of the implementation and application of BIM models for the integrated management of assets. Starting from the MacLeamy curve which compares the traditional project method with the BIM one (Bocconcino, Del Giudice, & Manzone, 2016) (Talebi, 2014) (Del Giudice, Manzone, Rebaudengo, & Barbero, 2017), several studies about the definition of the BIM **Return of Investment** (ROI) could

be developed. An example available in the literature, set on the present case study (Campanella, 2019), defines the parameters necessary to identify the time and costs for the implementation of the Project Information Model (PIM) of the case study (PAS 1192 - 3, 2014). Thanks to these analyses, the indicators needed for the ROI calculation has been estimated, based on costs, revenues and productivity effects in the use of the BIM methodology, highlighting the critical points and strengths.

The application of the BIM methodology to the FM field generates a change in the way this discipline is managed. FM, as defined in legislation (UNI EN ISO 41011, 2018) and the introduction, represents "*an organisational function that integrates people, places and processes in the built environment to improve the quality of life of people and the productivity of the main activity*". The core of FM activities is represented by the building that could be defined as "*a system of facilities, equipment and services necessary for the functioning of an organisation*" (UNI EN ISO 41011, 2018). **FM** is, therefore, an **integrated approach** which aims to increase the effectiveness of the organisation through the design, planning and performance of support services to the main activity of the company. In this way, the organization will also be able to adapt easily and quickly to changes. As shown in Figure 11, FM presents a set of features (Manola, 2018), which are based on specific aspects such as:

- The strategic aspect concerning the operational methods of management and distribution of resources to support the objectives to be followed.
- The analytical aspect related to the needs' knowledge, the control of the management results and the efficiency of the services provided, the analysis of possible new techniques and solutions that encourage the achievement of the company's goals.
- The management and operational aspect that concerns all services coordination, including procedures and implementation of delivery processes.

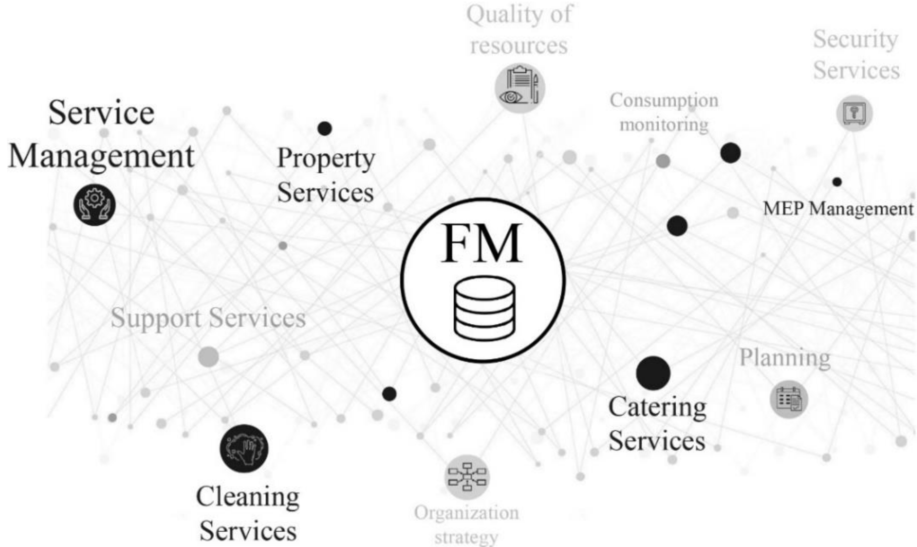

Figure 11 – Principal characteristic of Facility Management

Once the characteristics of FM have been established, it is also essential to define the figure of the **Facility Manager** who, for this sector, is one of the major players in the BIM process. This actor could be described as: "*Person responsible for the facility management organization who is the single point of contact for the client on the strategic level; leads the FM organization, ensures quality and continuous improvement and conducts strategic projects and tasks*" (UNI EN 15221 - 4, 2011). This figure is, therefore, characterised by a high level of managerial skills and, to perform this role, he needs to know the company's strategies in depth. This need is essential in order to be able to design services and workspaces useful to facilitate change and contribute to the achievement of company objectives[5]. During the research activity, one of the first steps carried out regards the identification of the **FM needs** of the case study, thanks to a comparison with the Facility Manager of the stadium and its office (Table 1). These requirements, as illustrated in detail in the Data Organization chapter, has been analysed and transposed in the BIM database.

Table 1 – Principal information of Facility Management for the case study

Building Services	Space Services	People Services
As-built documentation	Space registry	Capacity and space occupancy index
Material schedules	Definition of spaces' use and related information	Types of space surfaces
Maintenance manuals and plans	Workstation surveying	Administrative asset management and acquisition orders
Assets registry	Survey of the room's lock	Documents archive
Maintenance History	…	….

Analysing the state of the art of the traditional method, it is possible to highlight how a peak of **data loss** characterizes the end of each phase during the building lifecycle. In detail, for FM, this situation occurs at the end of the construction stage due to the incorrect way of storing information, often carried out manually or on paper. In many cases these data have to be reported by the FM staff within the used Computerized Maintenance Management System (CMMS) platforms, generating a considerable waste of time and a substantial increase in the possibility of error. Besides, there is the difficulty in keeping the information up to date during the useful building life, and the traditional method does not allow to avoid duplication and fragmentation of information. For correct management of the buildings, nowadays it is often necessary to carry out new data collection surveys that generate additional costs associated with management activities. FM is based on a strong relationship between data needed for its development, and this information should interface with different relational database reading systems. The management

[5] Definition of Facility Manager taken from the website of the International Facility Management Association: http://www.ifma.it/index.php?pagina=articolo.php&id_articolo=26&var_id_menu=70 &nodata (last consultation on the 05th of September, 2020).

aspect also becomes an essential element for the correct conservation of a building, and the operative workflow should not be based on a traditional approach that aims to investigate the problem by considering the graphic information separately from the descriptive, performance and maintenance ones (Lo Turco, 2015).

On the other side, with the application of the BIM methodology based on an integrated and unique database, information is not duplicated, avoiding the information loss or their lack during updating activities. In this way, all the actors involved extract data from the same content, highlighting the relational features of geometric and alphanumeric information. The key to achieving the potential of this application lies in the **objectives' identification** during the database structuring phase. In this way, it is possible to maintain the database unique during the entire building life, regardless of when it is created. Connected to this aspect, the **data accuracy** and their **accessibility** are other important aspects which allow an optimisation of the whole process (De Palma, 2018). The BIM methodology can, therefore, be applied on a building in any phase of its life cycle, with different impacts on the way the database is structured, as mentioned in this research work for the existing ones.

Taking into account the whole construction process, it is possible to point out how one of the significant challenges of BIM applied to FM is the definition of its information content, identifying the responsible actor and the time for their integration inside models (Ugliotti, 2017). In this way, everything is based on the Know-how, which is strictly linked to the management and maintenance phase (

Figure 12).

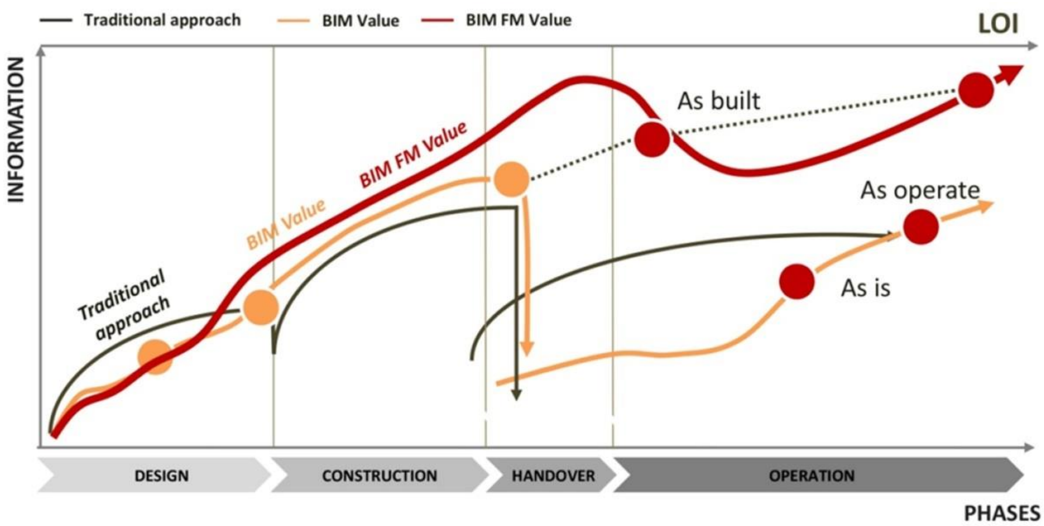

Figure 12 – Building process correctly involving Facility Management (Ugliotti, 2017)

The presented research activity is placed in the Operation phase since the case study is an existing building managed with the traditional method. For this reason, it was necessary to understand how to structure an **As-is model for FM**, starting from an existing As-built and As-is database composed by 2D drawings and technical datasheets. Since these documentations, effected by a series of data loss during the lifecycle, retrieved with specific survey activities, it has been possible to increase the information level indicated by the BIM FM Value.

After this step, the operative part of the research activity has been developed through the definition of uses and objectives that will be achieved with FM activities, defining a proper methodological standardization. It allowed the modelling of the PIM aimed at FM thanks to the modelling activities of the stadium suppliers, each for its specific discipline. This activity has been carried out through the application of specific BIM guidelines for FM. These documents reproduce the structure and contents of the BIM procurement documents enriched with a series of operational requirements deriving from the identified standardization. The activity carried out is, therefore, part of the challenge related to the application of BIM for FM, which aims to define an operational methodology able to achieve the **Integrated Project Delivery** (IPD).

Starting from these considerations and the achieved results in this thesis, the proposed methodology can contribute to the continuous research field of the BIM methodology aimed at a collaborative and interoperable use of data (Barbero, Del Giudice, Ugliotti, & Osello, 2020). If these considerations are compared to the definitions contained in the latest international regulation's updates (UNI EN ISO 19650-1, 2019), analysing what is defined within the Italian disposition (UNI 11337-1, 2017) related to the digital maturity of the construction process, it is possible to enrich a stage of maturity two, which is identified as "BIM according to the ISO series" (UNI EN ISO 19650-1, 2019).

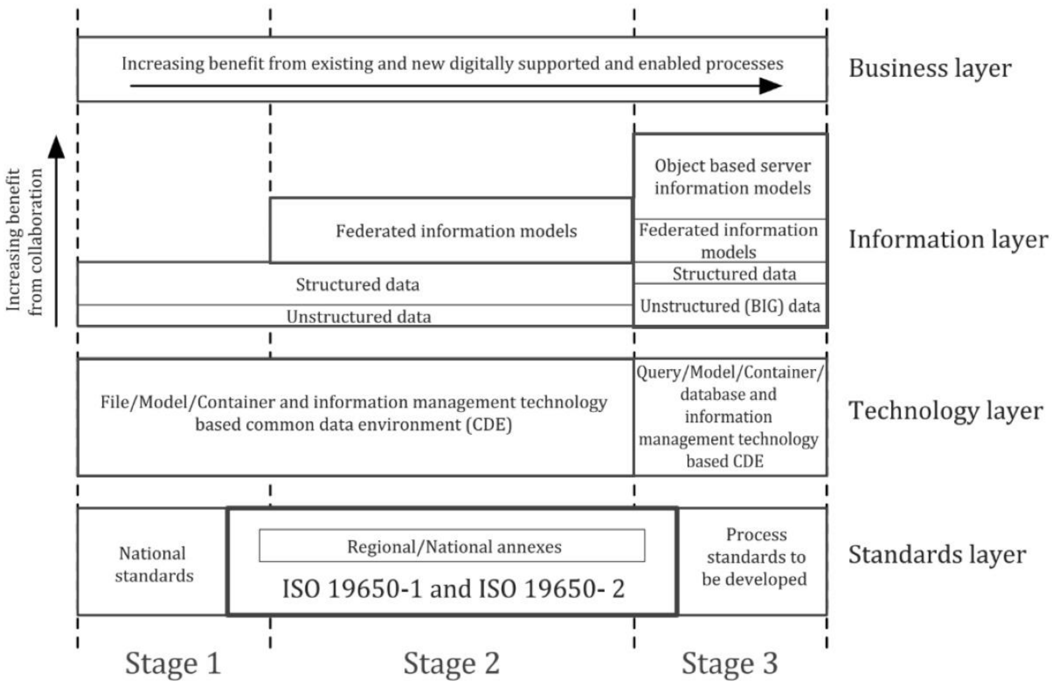

Figure 13 – A perspective on stages of BIM maturity of analogue and digital information management (UNI EN ISO 19650-1, 2019)

Figure 13 shows the information management as a sequence of maturity stages shown as Stage 1, 2 and 3. It also indicates that legislation development, technological advances and the most sophisticated forms of information management are all factors that, combined, offer benefits to ever-increasing organizations. Stage 2 is where a combination of manual and automated information management processes is used to generate a federated or aggregated information model. This information model includes all the information packages provided by the teams in charge concerning a real estate asset or a contract.

2.2 The case study

The case study of the research activity is represented by the **Allianz Stadium**, a football arena owned by Juventus Football Club (Figure 14). It was built in the districts of Vallette and Lucento placed in the North-West part of the city of Turin, near the Continassa's area. Realized in the same area of the existing and demolished Delle Alpi Stadium, which reuses part of the structures, the Allianz Stadium hosts team matches from the 2011-2012 season, and it can contain 41,507 spectators. It also belongs to the UEFA fourth category, which is the highest ones for technology development. The Allianz Stadium is a very complex building, with a great urban transformation impact and the numbers below allow understanding this definition:

- 140450 square meters of the internal stadium area
- 430 square meters of the photographers and journalists' room
- 221 workstations in the press area;
- 30 cafes;
- 12 cafes inside the hospitalities;
- 11 points of sale for commercial activities

The Allianz Stadium was the result of the wishes of Juventus since 1994, which only reached an agreement with the City of Turin in 2002 and it was the first stadium owned at its inauguration in Italy. The project was assigned to architects Hernando Suarez and Gino Zavanella and engineers Francesco Ossola and Massimo Majowiecki, with a total investment of about 150 million euros. It was only in 2008 that the Juventus Directors' Boards officially approved the construction of the new stadium which, as mentioned above, began with the demolition of the Delle Alpi in November 2008 and ended with the inauguration on the 8^{th} of September 2011. The new construction represents an important example in the field of football stadiums, thanks to the high standards achieved in terms of sustainability, visitor comfort and safety. The stadium is part of a widespread project aim at the requalification of the urban environment in which it is located. Together with this building, the Juventus Museum, J-Medical, J-Village and Area 12 have been built during the last years, creating an integrated set of interconnected structures[6].

[6] Information related to these implementation in "Torino, arriva l'eco-stadio reciclato dal Delle Alpi" di Crosetti Maurizio, 2008. Website for its consultation: http://www.repubblica.it/2008/12/sezioni/ambiente/torino-ecostadio/torino-ecostadio/torino-ecostadio.html (last consultation on the 07^{th} of September, 2020).

Figure 14 – The case study of the research activity: the Allianz Stadium
Images source: https//: www.Juventus.com and Google Maps

The structure of the stadium, which develops on different **elevations**, has an external part outside the height of the lot, and an internal one, below it. The access is provided through eight entrances in different points of the stadium, which sometimes use broad access ramps that follow the development of the green hills, creating at the same time the outer ring that circumscribes the stadium itself. These are based on the only existing part of the old Delle Alpi stadium that has not been demolished but rebuilt, allowing the passage from an altitude of +12.00 m to a height of +18.00 m. Starting from this level, the entrance to the playground's stands is made through 16 distribution walkways that allow to reach the different sectors, totally free of architectural barriers. The composition of the bowl shows the coexistence of reinforced concrete and steelworks, with step-holding beams and prefabricated structure. Analysing a typical section of this part of the stadium (Figure 15), it is possible to see the different structural typologies made up of: i) the structural element cast in place, which represents the foundations and the elevation elements of the areas below the tribune; ii) the 1st and 2nd level floor stalls, made up of beams and prefabricated structure; iii) the tribune, made up of steel beams on which the prefabricated stands are located. The structure of the bowl has been designed to obtain an "English stadium" where fans are involved in the events carried out, with excellent visibility from each seat.

At the same time, the building is composed of a whole series of spaces and environments surrounding the bowl itself, which are organized on seven different altimetric levels. As will be explained later in the operative section, the presence of this double and different structuring has generated several repercussions in particular for the analysis of the interaction with the IWMS platform which is based on level definition.

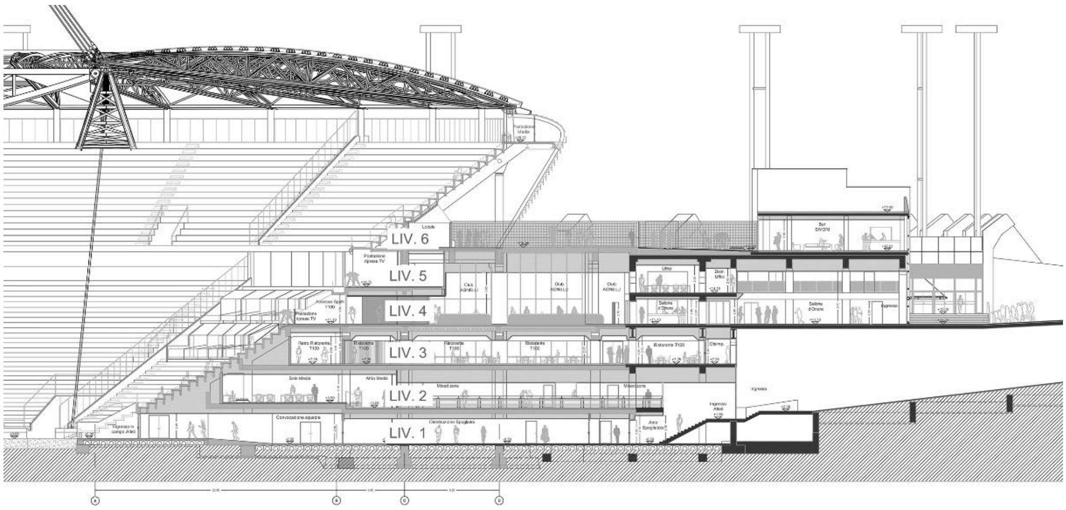

Figure 15 – Cross-section of the Allianz Stadium, extracted from the As-built project documentation

As visible, the stadium is closed by the very particular roof system, which represents the symbol of the stadium itself. It is composed of four main reticular beams placed along the perimeter of the playing field, suspended at the tops of the court by tie-rods, which are connected to two inverted V-shaped supports called "Pennoni" (Majowiecki, Ossola, & Pinardi, 2010). These are then connected to specific weights in the ground using anchoring cables appropriately stabilized against the wind action. The principal beams represent the support for secondary cover beams which also have a reticular structure of smaller dimensions than the major ones. The second support of these structural elements is represented by steel columns placed along the external perimeter of the tribune. A PVC covering completes the roofing structure, enabling the spectator protection from the atmospheric conditions (Barbero, 2016). Complementing the lateral envelope, the external façade is characterized by the presence of 7000 differently coloured aluminium panels that make up the pattern of a moving flag, projected by designer Fabrizio Giugiaro. At the top of the stadium, the panels take on green, white and red colours to create a ring representing the Italian flag (Filippi & Vallinotto, 2011).

Starting from this illustration of the case study, it is easy to understand the definition of a stadium as a "**complex building**" characterized by a high amount of elements and data that must be managed and maintained over time. As defined in the literature, a complex building could be described as "*a whole structure, as a building, made up of interconnected or related structure*"[7]. For these kinds of entities like hospitals, laboratories, manufacturing, stadiums, the construction phase is most challenging, the risk is typically most significant, and the need for improvements is critical. Therefore the BIM methodology is very useful to improve outcomes in following stages of the life cycle (Report SmartMarket, 2015), starting from the central role of information.

[7] Definition of "complex building" taken from the website: https://www.thefreedictionary.com/building+complex#:~:text=building%20complex%20%2D%20a%20whole%20structure,of%20higher%20education%20is%20housed (last consultation on the 09th of October, 2020)

At the same time, the **entity** stadium should be defined as "*a fixed facility for outdoor sports events, consisting of a series of stands developed along the perimeter of the space in which the events take place where spectators take their seats*"[8]. Analysing this definition, it is possible to define it as a point of aggregation at a social level. This aspect highlights the strong link with the urban context that needs to be taken into account when a building of this type is designed (UEFA, 2011). This kind of building can also be a requalification instrument of urban texture with a popular and industrial vocation in the process of degradation typical of a suburban area. In this way, it is possible to benefit from the social role that football plays in today's society, creating an innovative sports facility that lives 365 days a year (Filippi & Vallinotto, 2011). The connection between the stadium and the surrounding urban network is also highlighted by the history of its construction, by the analyses carried out within the Integrated Intervention Programme (PR.IN) as a variant of the General Regulatory Plan jointly with the Municipality of Turin and the Municipality of Venaria and by the care used during the designed phase for the context interaction (Filippi & Vallinotto, 2011). The stadium as a place is also significantly linked to technological implementations and represents, in the collective imagination, a symbol of sharing experiences and **social inclusion**. In this context, digitalization becomes the pulsating heart of the innovative process that allows the development of new services based on the knowledge of the structure and therefore on greater availability of information (Osello & Ugliotti, 2017). Through the setting of an information database based on BIM methodology, the stadium is enriched with a whole series of geometric and alphanumeric information. Through these data, using current technologies, it is possible to bring users nearer to the football environment by making them live immersive experiences, establishing a link with the client through an interactive, dynamic and user-friendly application. The transition from CAD to BIM, beyond the methodological and design steps, change the vision of the stadium. The essential difference between CAD data and CAD objects compared to parametric building modelling is the real-time and self-coordination of the information in every view (Vanlande, Nicolle, & Cruz, 2008). Starting from this point, a new vision of an interactive stadium that interfaces as a front-end tool was born, that is dynamically and continuously evolving. The incremental use of the BIM methodology can lead to the construction of an "**archive of the future**" contributing to the definition of Stadium 2.0, illustrated in the introductory chapter, which actively engages all the actors involved in the entire life cycle of the opera. In this way, the BIM methodology plays a key role for football structures not only in carrying out FM activities but also through the presentation of an innovative image based on the sharing of information (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019).

Following the illustration of the case study and the considerations presented, Figure 16 illustrates the operational process defined jointly with the owner and developed during the PhD program.

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[8] Definition of entity taken from the website of the Google Dictionary website: https://www.google.com/ (last consultation on the 08th of September, 2020).

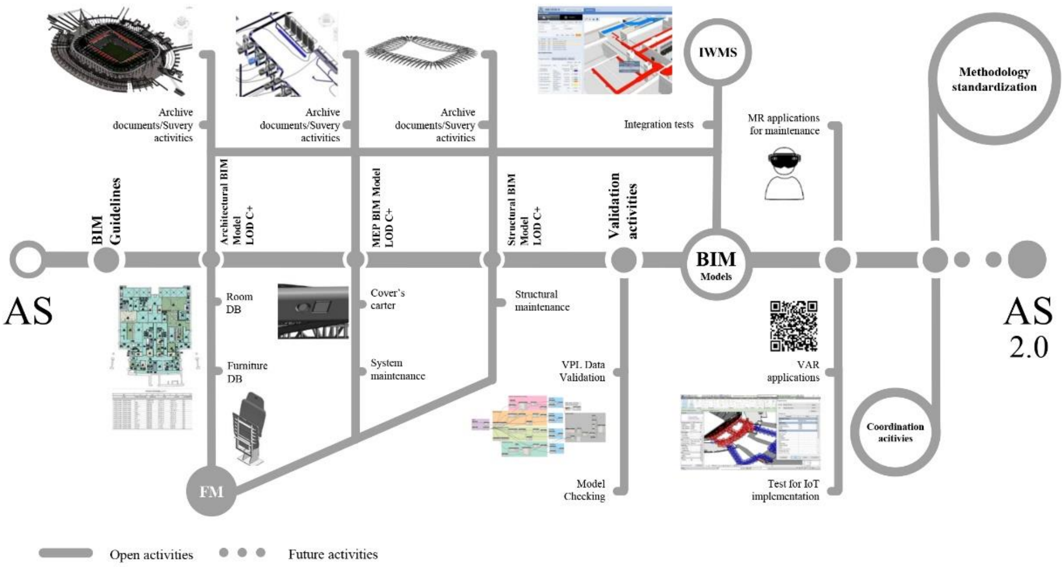
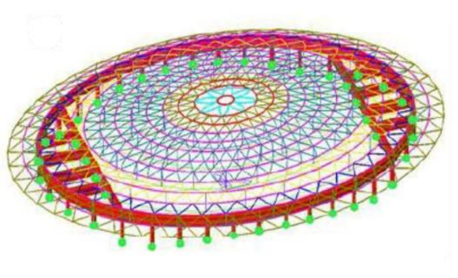


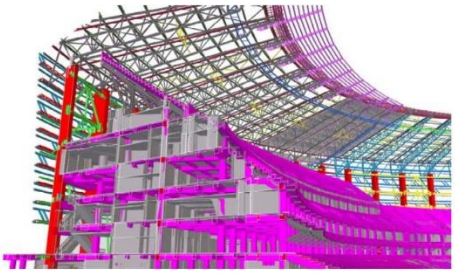
Figure 16 – Research operational activities related to the case study and the PhD program

2.2.1 BIM adoption for stadiums

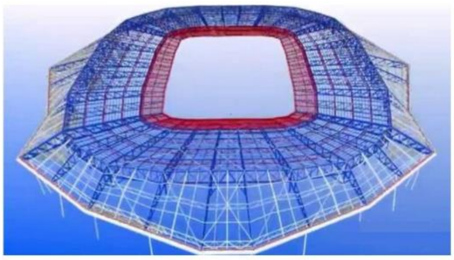
After the illustration of the case study characteristics and the associated definitions the analysis of other possible cases concerning the application of the BIM methodology to this type of buildings was carried out during the research activity. Starting from state of the art, the application of this methodology was investigated for a series of case studies that do not represent the totality of the existing examples but enable to highlight the innovative characteristics of the research activity carried out.

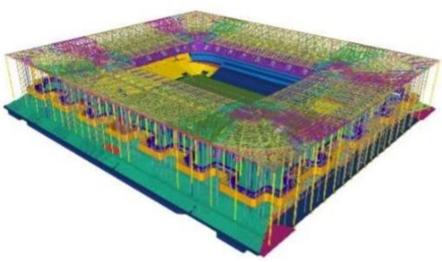
Table 2 – Some examples of BIM adoption for stadium in international literature

The Houjie Stadium - China	
Reference: Zhang, Liu, & Gong	
Year: --	
BIM methodology application:	
Parametric modelling of steel structure for their analysis, constructability of the stadium, and material quantity take-off, and construction progress simulation.	

Baku Olympic Stadium - Azerbaijan	
Reference: Theodorou, Kapatsina, Gkougkoulina, & Dagklis, 2014	
Year: 2014	
BIM methodology application:	
Analysis of roof installation and animation, FEM analysis of steel structure joints, creation of the entire model for the real-time of data during the construction activities.	

CSKA Stadium – Russia (Moscow)	
Reference: https://bexelconsulting.com/projects/cska-stadium/ (last consultation on the 08th of September, 2020)	
Year: 2016	
BIM methodology application:	
Management of the design documents, coordination of architectural, structural, and MEP disciplines, data extrapolations for quantity take off.	

Stade de Lumieres – France (Lione)	
Reference: https://www.infobuild.it/2016/07/bim-tekla-structures-tre-stadi-francesi-campionati-calcio-2016/ (last consultation on the 08th of September, 2020) and Dettori, 2019	
Year: 2016	
BIM methodology application:	
Development of the steel structure of the stadium for dynamic simulation.	

Matmut Atlantique – France (Bordeaux)	
Reference: https://www.lavoripubblici.it/news/2016/07/ARCHITETTURA/17145/Europei-di-Calcio-2016-il-BIM-per-la-progettazione-e-costruzione-di-3-stadi (last consultation on the 08th of September, 2020) and Dettori, 2019	
Year: 2016	
BIM methodology application:	
Development of the steel structure of the stadium for the analysis of its complexity in order to evaluate also the architectural impact with the environment	

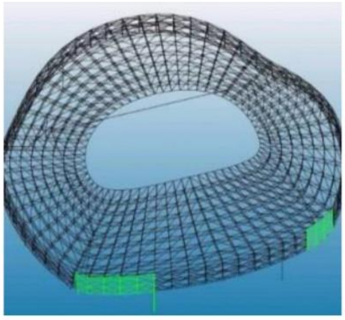
Stade Velodrome – France (Marsiglia)

Reference: https://www.bimportale.com/bim-euro-2016/ (last consultation on the 08th of September, 2020) and Dettori, 2019

Year: 2016

BIM methodology application:

Analysis of the particular shape of the structural roof of the stadium for its global analysis and employment of the BIM model for time management during the construction phase.



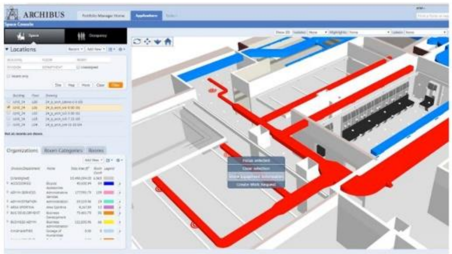
Allianz Stadium – Italy (Torino)

Reference: this thesis elaborated by the author during the research activity

Year: 2017 - 2020

BIM methodology application:

Definition of the BIM data content for Facility Management, integration with an IWMS platform, and VAR application for maintenance purposes.



Goias Arena - Brazil

Reference: https://graphisoft.com/es/case-studies/archicad-implementation-at-the-right-moment-goias-arena (last consultation on the 08th of September, 2020)

Year: 2018

BIM methodology application:

Development of the stadium project, based on the collaboration between all the actors involved, use of the BIM model for quantities extrapolation.

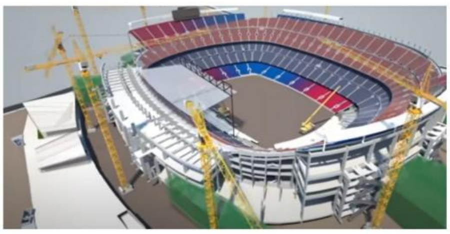
Camp Nou – Spain (Barcelona)

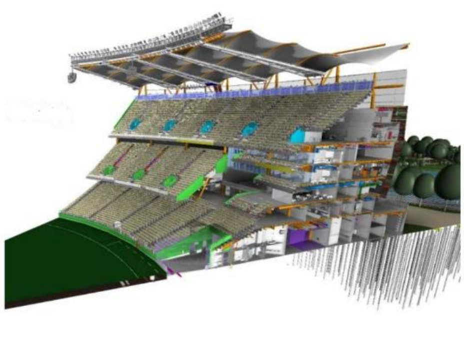
Reference: http://biblus.accasoftware.com/en/bim-for-renovation-projects-designing-camp-nou-with-bim-technology/ (last consultation on the 08th of September, 2020)

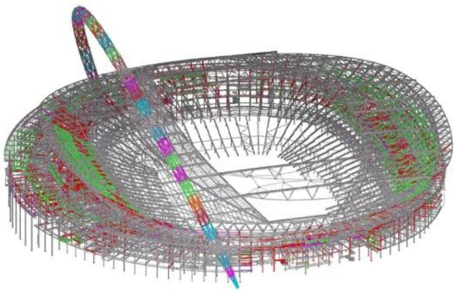
Year: 2018

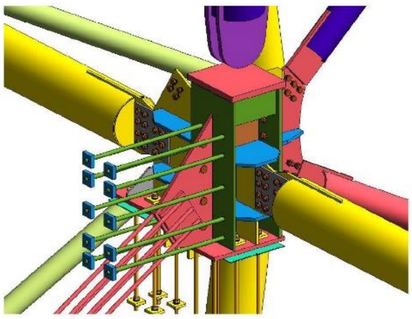
BIM methodology application:

BIM model for the analysis of the suitability of the project, 4D modeling, and simulation for interferences with football matches.

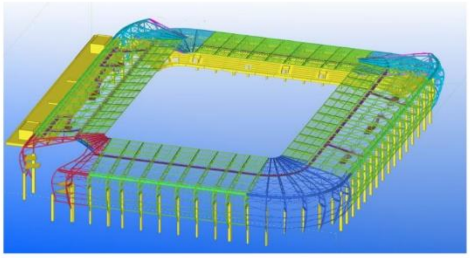


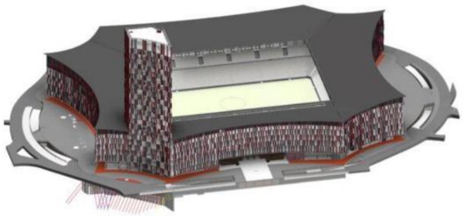
Perth Stadium - Australia	
Reference: https://bim.natspec.org/images/StrategicOutcomeswithBIM/NATSPEC_BIM_170803_Melanie_Binks_MPX.pdf (last consultation on the 08th of September, 2020) and Hurst, 2015	
Year: 2018	
BIM methodology application:	
Design process of the stadium with weekly coordination, Data management and virtual reports, 4D simulation, and analysis of the facilities management application, based on 51 federated models with LOD 500	

Wembley Stadium – England (London)	
Reference: https://www.tekla.com/references/wembley-stadium (last consultation on the 08th of September, 2020) and Dettori, 2019	
Year: 2019	
BIM methodology application:	
Development of the structural BIM model for the design phase, for data extrapolation and quantity take-off and for scheduling activities during the construction phase.	

Gewiss Stadium – Italy (Bergamo)	
Reference: https://www.bimportale.com/restyling-dello-stadio-bergamo/ (last consultation on the 08th of September, 2020)	
Year: 2019	
BIM methodology application:	
Integrated application for the management of all the implementation activities of the stadium, starting from the coordination to the global and local structural analyses.	

Dall'Ara Stadium – Italy (Bologna)	
Reference: http://bim.acca.it/il-nuovo-stadio-di-bologna-sara-realizzato-con-il-bim/ (last consultation on the 08th of September, 2020)	
Year: 2019	
BIM methodology application:	
Development of the BIM model for the management of the renovation and redevelopment of the stadium, with possible applications for the maintenance phase.	

The National Football Stadium - Slovenia	
Reference: https://construsoftbimawards.com/slovak-national-soccer-stadium/ (last consultation on the 08th of September, 2020)	
Year: 2020	
BIM methodology application:	
Development of the cantilevers BIM model for structural analyses and simulations.	

The New National Stadium – Albania (Tirana)	
Reference: https://www.bimportale.com/stadio-nazionale-dellalbania/ (last consultation on the 08th of September, 2020)	
Year: 2020	
BIM methodology application:	
Creation of the BIM model for the project phase, aim for the coordination between all the disciplines involved, analysis, and development of the external facade.	

Stadium Project - Qatar	
Reference: https://www.bimcommunity.com/experiences/load/224/stadium-project-qatar (last consultation on the 08th of September, 2020)	
Year: 2020	
BIM methodology application:	
Development of the BIM model for coordinated MEP services with other disciplines of the project.	

The examples analysed show also for this kind of building what has been highlighted in the section related to state of the art: the application of the BIM methodology is consolidated for the architectural and structural design phases, the redevelopment and renovation, but it should be explored for the management and maintenance phases in order to show its potentials.

2.3 BIM uses for Facility Management

As defined by the Italian regulation (UNI 11337-4, 2017), for each step of the graph concerning the building information process (Figure 2), the definition of the objectives related to each phase is necessary for the proper application of the BIM methodology. The model, the objects and the documents developed during a specific step of the process are tools and support for the objectives' achievement mentioned above. Achieving a defined goal allows the employment of the BIM model for a particular use: this one, together with the information evolution of models, defines the necessary LOD for each object. This value is preparatory for the definition of the quantity and quality of the information needed. At the same time, this model content should be at least the necessary value and enough to ensure the achievement of the objective related to a specific process phase.

For this reason, the owner inside the BIM procurement dispositions should define the aim of the specific process phase (UNI 11337-1, 2017) (UNI 11337-4, 2017) (UNI 11337-5, 2017), from which the objectives of the model and their related uses should be defined. As mentioned in part in the introduction, the relation between **model uses** and **objectives** of the process could be illustrated in Figure 17. Both of them are defined in function of the specific aim of the process phase, and the achievement of model uses could be reached through the development of specific objectives. At the same time, these have particular features and workflows in relation to the uses to be pursued, thus allowing their development.

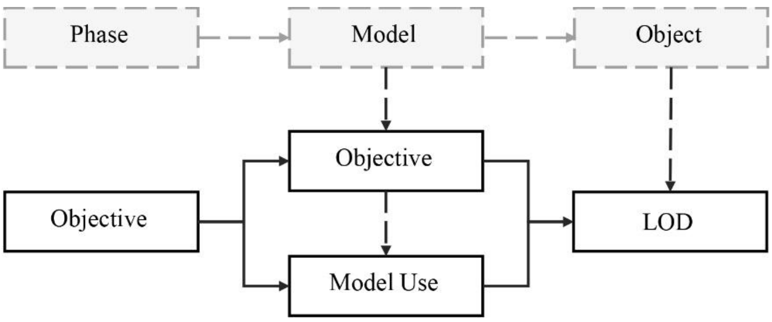


Figure 17 – Phase and model objective and use (UNI 11337-4, 2017)

Besides, the Italian regulation (UNI 11337-4, 2017) defines in the prospect B.1 an example of a matrix that could be integrated into the BIM procurement documents. It allows the definition of the aims of the phase, the objectives of the model and its uses. Related to this table, a series of sheets are also identified to propose a hypothetical geometric and alphanumeric information content of reference for the technical and economic planning, final design and executive design phases, relating to public contracts. The absence of specifications for the management phase of the lifecycle highlights the existing gap illustrated at the beginning of the thesis.

To better understand what has been developed, it is therefore essential to attribute the proper meaning to the terms used, which are the object of analysis and implementation, to highlight the potentialities of BIM methodology application. In detail, the term "**BIM methodology objective**" refers to "specific results that when accomplished, move the organization toward their BIM goals". At the same time, starting from the literature review, the "**BIM model uses**" term assumes different definition like:

- "*The BIM model uses is defined as the aim for which the model and the information goal are defined in BIM procurement documents. The model uses contribute to precisely defining the LOD needed for each object to achieve the information goals required by the model*" (UNI 11337-4, 2017). At international level, the employment of the model for the analysis of geometric interferences (Clash Detection), graphic virtualization (Design Authoring), quantity take-off (Quantity take-off) is consolidated as BIM model uses. However, further model uses could include the analysis of inconsistencies (Code Checking), energy efficiency, and the ones identify for this research activity.
- "*A model use represents the interactions between a User and a Modelling system to generate Model-based Deliverables. Model use is also the intended or expected Project Deliverables from generating, collaborating-on and linking models to external databases. There are tens of Model Uses including Clash Detection, Cost Estimation and Space Management*"[9]. Starting from the interpretation of this definition, it is, therefore, possible to understand that Model Uses represent the user's objectives aimed at creating a specific output. Model-based Deliverables are consequently the outputs of a correct implementation of model use, while Project Deliverables are the results of design and construction activities (Dettori, 2019).
- "*A BIM Use is defined as a method of applying Building Information Modeling during a facility's lifecycle to achieve one or more specific objectives*" (Kreider & Messner, 2013). In this reference, it is illustrated how BIM Uses derives from the combination of two essential aspects: the BIM Use Purposes and the BIM Use Characteristics. These are treated in appropriate tables by the authors of the reference, who analyse and deepen their respective characteristics. The BIM Use Purpose communicates the primary objective of implementing the BIM Use, and it is divided into five categories: gather, generate, analyse, communicate, and realize (Kreider & Messner, 2013). It represents the specific objective to be achieved through the application of the BIM methodology during the building lifecycle.

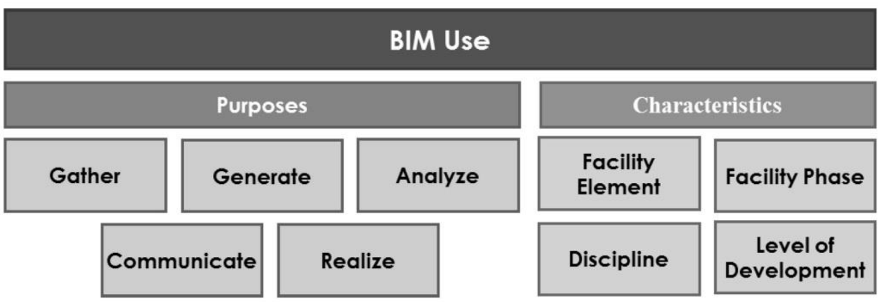


Figure 18 – The components of a BIM Use (Kreider & Messner, 2013)

9 Definition of model uses extracted from the BIM dictionary website: https://bimdictionary.com/terms/search (last consultation on the 11th of September, 2020).

- "*A BIM Use is a task, outcome or deliverable that a BIM model is used for. A particular BIM Use must have a useful real-world outcome. It should only be listed as a BIM Use for a project if there is a specific reason to do it; a specific party who will do it; a specific party who will receive the results; a specific outcome that aids the design, building or operation of the project facility*" (Practical BIM, s.d.).
- "*Model Uses identify and collocate the Information Requirements that need to be delivered as 3D digital models. As a knowledge block, Model Uses form part of a large modular language that connects information requirements with System Units, Defined Roles, and Competency Items*" (BIMe Initiative, 2020). Model uses are also classified as one type of Information Uses which also includes document and data uses and they are generally based on granularity metrics at a component level like Level of Definition, Level of Development and Granularity Level.

Within this scenario, our research activity has been carried out, following the characteristics illustrated in Figure 19:

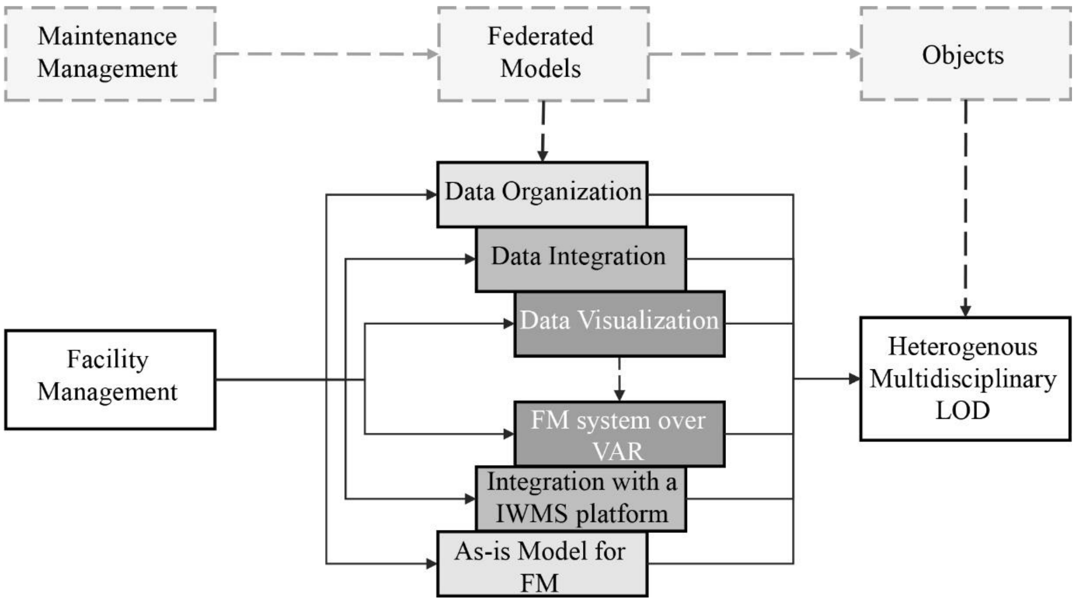


Figure 19 – Phase and model objectives and uses of the case study

The uses and objectives' framework of the research activity reflects what has been indicated and defined in the international literature. Since the case study is a complex building, with an articulated and sophisticated requirements scenario, the identified uses are wide-ranging, and they may include more uses than, for example, those classified within the definition provided by some references (BIMe Initiative, 2020). Moreover, as can be seen through the thematization of the table concerning the methodology standardization and in the Data Visualization chapter, the use "FM system over VAR" has been analyzed from a general point of view, highlighting its potential for future implementations and detailed analysis.

2.3.1 As-is model for FM

This BIM model use is aimed at setting out how the database is structured and implemented in order to allow it to be used for the FM purposes illustrated in the previous chapters. The definition of this use for the present case study and the complexity of the FM discipline includes several single uses provided by some of the classifications analysed during the research activity (BIMe Initiative, 2020). In detail, the "**As-is model for FM**" use involves space management, the construction of the registry required for maintenance activities, the government of building systems and the management of a different geometric detail based on the type of object analysed (Figure 20). As mentioned in the introduction, particular attention has been reserved for O&M activities which, for the present case study, represent one of the most significant aspects of FM.

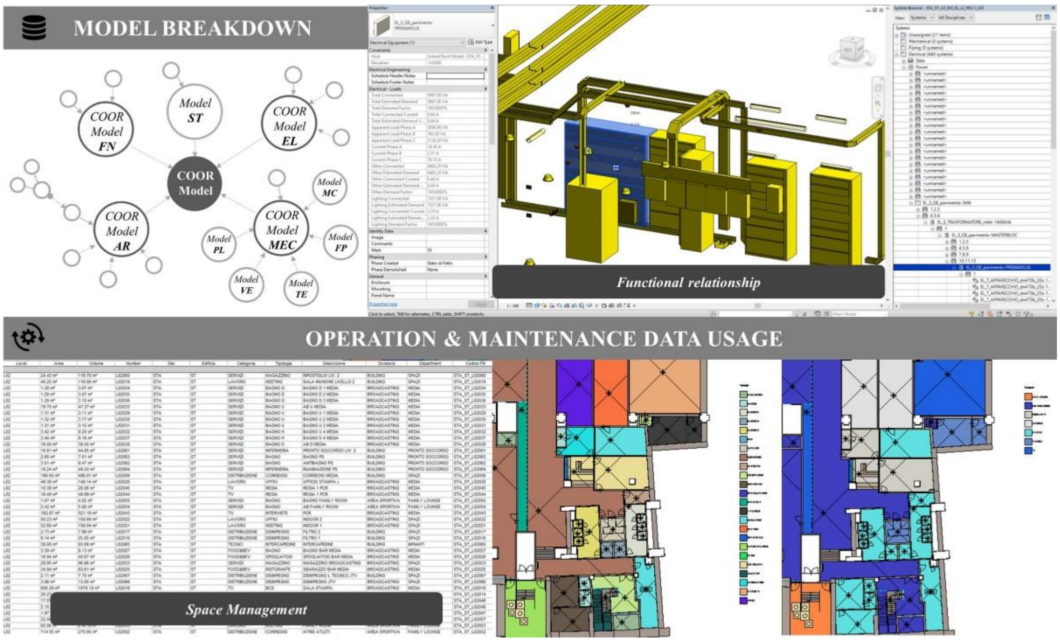


Figure 20 – Uses of an As-is model for FM (Barbero, Del Giudice, Ugliotti, & Osello, 2020).

In order to make the BIM model suitable for the defined objectives and useful for Facility Managers, it is not sufficient to develop the parametric database alone, but it is necessary to organize the information in a helpful way for the different activities. The model is not only a three-dimensional representation of the building but also a multidimensional tool for the analysis and control of the entity itself (Osello & Ugliotti, 2017). The database could be interrogated and extracted by all the actors of the building process. This aspect allows extending the definition of BIM to its meaning of management methodology. For this reason, the structure of the information content should be implemented through the development of coding, classification, decomposition and georeferencing systems for elements that facilitate their precise identification and management (Barbero, Del Giudice, Ugliotti, & Osello, 2020). At the same time, it is also necessary to set up the correct ways for data consultation: the BIM model represents the base for the data integration with an IWMS platform, but it can be used directly for data querying and extrapolation as a stand-alone database. Therefore, the analysis and definition of the building Work Breakdown Structure (WBS) become essential, and they allow to define the subdivision of models. On the other side, the use of a data schedule enables the spaces' identification that should be managed as well as the assets' analysis that should be maintained.

Given the importance of the rooms for management activities, enriching the BIM model with a whole series of information allows to map and control them in terms of use, occupation and maintenance. Improving the database with a punctual knowledge of these entities provides Facility Managers to control services in an increasing thoroughness and to obtain FM and key performance indicators (KPIs) useful for evaluating cost chargebacks, the utilization rate as well as a performance measurement of the maintenance activities (Osello & Ugliotti, 2017). Thanks to this consideration, through the employment of different plug-in able to manage and enrich specific kind of information, an accurate quantity take-off of the model can be achieved. The finish area of architectural elements, as well as material quantities of constructive building parts, provide valuable quantitative indications for cleaning and maintenance activities. Connected to this, the data about system component and single equipment is also essential and, thanks to the parametric nature of BIM models, it is possible to manage the functional relations between all the elements (Barbero, Del Giudice, Ugliotti, & Osello, 2020). Since in the case of an existing building is very difficult to get a reliable scheme and technical drawings, the central aspect for a correct model structure lies in establishing the functional and spatial relationships among the elements. In this way, the focus is on the functional connection between objects, which allow to manage maintenance activities and not on the detail of the graphical representation.

When the objectives to be pursued have been identified, it is necessary to define the meaning of As-is model for FM. Starting from the analysis of the international literature, there is no unique definition of a BIM model for FM but, according to the needs to be pursued, the following solutions may have been identified (Ugliotti, 2017):

- An **As-built** model, which is complete and detailed both on a geometric and alphanumeric point of view and can only be obtained if FM is included in the design and construction phases. This model presents some criticalities linked to the difficulty of managing information due to its high degree of complexity.
- An **As-operate** model, which is presented with an advanced but not detailed geometric representation with all the alphanumeric parameters necessary for FM. This type of model is suitable for monitoring functional relations, the connection between objects and spaces and its structuring is based on maintenance principles, overcoming those types of design activities.
- An **As-is** model, which is represented by a simplification of the geometric representation of the building's real configuration. If compared with the As-operate model, it is suitable for the management of a real estate portfolio, based on a reduced amount of data common to all the buildings analysed. In

this case, the objects, are reliable from number, size and qualitative location within the spaces.

Starting from this background, the As-is models developed for the FM during the research activity could be defined as a simplified representation of the state of the art of the existing building aimed at creating a digital graphic model able to acquire the geometric and alphanumeric contents of the building. From a **geometrical point of view**, the FM objective concerns the realization of the volumetric footprint of each object, the spatial placement at a qualitative level and the respect of the elements' number, to which are added for some typologies the increase in detail aimed at visualization activities. From the **alphanumeric viewpoint**, the aim is to perform the compilation of all the information deriving from the consultation of the As-built documentation and the maintenance schedules, currently used as a reference for the performance of management activities. Since it is an existing building, the documentation used as the starting point for the implementation of models has been verified on site thanks to appropriate survey activities that allow filling the existing updating gap, checking the compliance with the real configuration. This deficit is frequently linked to the application of the traditional method because it is not based on a unified and integrated database. Based on these considerations, the concept of **heterogeneous LOD** has been defined and applied to the whole case study as a starting requirement for FM activities. It is based on the definition of the Level of Geometry (LOG) and Level of Information (LOI) proper for an FM model, starting from the primary reference standard (UNI 11337-6, 2017) and (AIA Document G202, 2015). The achieved result is the definition of the LOD 200+ of the BIM model, where the added value of "+" consists of describing the model element with geometrical characteristics (LOG C) and alphanumerical attributes that usually belong to LOI F and G, as defined by the owner's needs (Barbero, Ugliotti, & Del Giudice, 2019). These considerations are related to an **existing building** for which it is not essential to achieve a high level of graphic detail, but it is necessary to link the elements to technical details and maintenance procedures. The model definition developed during the research activity, therefore, could be classified in the middle between the meaning of the As-operated and the As-is model provided by the analysed literature. From an alphanumeric point of view, the FM model is more like the first case, since it is a complex building in which the alphanumeric component and the one of correct spatial location dominate. On the other hand, the stadium is part of a private real estate, and it is therefore based on criteria of information collection that must also be used for the other buildings. Besides, the As-built documentation used has been subjected to specific survey activities able to increase reliability and correspondence to the real configuration of the BIM model. Starting from these considerations and the possible future developments concerning other owner's buildings, it is possible to talk of As-is model for FM developed during the research activity.

Defined the use to be pursued in detail, it is easy to understand how its achievement is linked to the objective of a proper Data Organization. This aim has also an impact on other uses, as can be seen in detail subsequently. The information organization, which can be declined in a series of operational activities typical of the proposed methodological standardization, varies in its declinations depending on whether the digitized entity is a new or existing building. The passage of the model from the design/construction phase to the management stage could generates different solutions in terms of structuring compared to those illustrated in this thesis, following an existing database that must be implemented at an alphanumeric level and simplified at a geometric level. Since it is a database that must be suitable and implementable throughout the entire life cycle of the building, it is, therefore, necessary to schedule the workflow, the information and how to enter it. In particular, it is essential to define whether the data can be obtained directly from the implementation of the model or whether it must be included from outside sources.

2.3.2 Integration with an IWMS platform

In order to investigate the potential offered by the BIM methodology in the FM field, the BIM database should be linked with management services based on the latest technologies. To fulfil the requirements of SIGeM, the research activity carried out focused on the analysis of the BIM database **integration with an IWMS platform**. For the case study, it is represented by Archibus©, which allows the management of a large amount of data and a broad overview in facilities' management of a building and real estate portfolio. Archibus© is composed of a series of modules that may be implemented individually, allowing a whole series of activities through the management of tables, reports and charts. These modules are: Asset Management, Space Management and Planning, Real Estate Portfolio Management, Capital Projects Management, Risk and Environment Management, Removals and Movements Management, Building Operations, Workplace Services, Technology Extensions[10]. It is, therefore, possible to access geometrical and alphanumerical information through the consultation of plans, 3D visualizations, space inventories and equipment schedules. This database may also be interrogated and implemented by all the stakeholders of the process. Operating in this way, the challenge of Facility 4.0 is accepted by developing an operating method that makes it possible to structure and classify documentation, manage the activities to be carried out and the timetable based on a single centralised archive of all material.

The innovative feature of the connection between the BIM model and an IWMS platform, compared to the traditional methodology based on CAD plans, is represented by a database-database interaction, creating a unified environment for asset management. A primary key connects the two databases, and there is a bidirectional connection between the platforms thanks to the verification of the field

[10] Definition of different Archibus© modules takes from the website: https://www.ediltecnico.it/68068/gestione-immobiliare-con-bim/ (last consultation on the 15th of September, 2020).

and table correspondence (Osello & Ugliotti, 2017). Since the correlation between these databases, it is necessary to establish the correct hierarchical structure that identifies the building at a spatial level in the IWMS database. In this way, the different assets could be traced back to the building levels as within BIM models. The structure has to be defined by the identification of the site, building, and floors to which different rooms correspond. In this way, it is possible to bring all the entities of the models to the different levels they belong to. For the present case study, the integration process is based on the transfer of the database extracted in ODBC format into the IWMS platform and it is carried out level by level. This process is schematically illustrated in Figure 21. Starting from the 3D visualization, it is possible to query all the alphanumeric information associated to every single element of the building. These are implemented through a suitable mapping of the BIM model parameters with those explicitly created in the Archibus© environment, with the same typology of the original ones. As can be seen afterwards, shared parameters have been used to carry out this interaction for the case study, which resulted particularly suitable for the aims to be pursued.

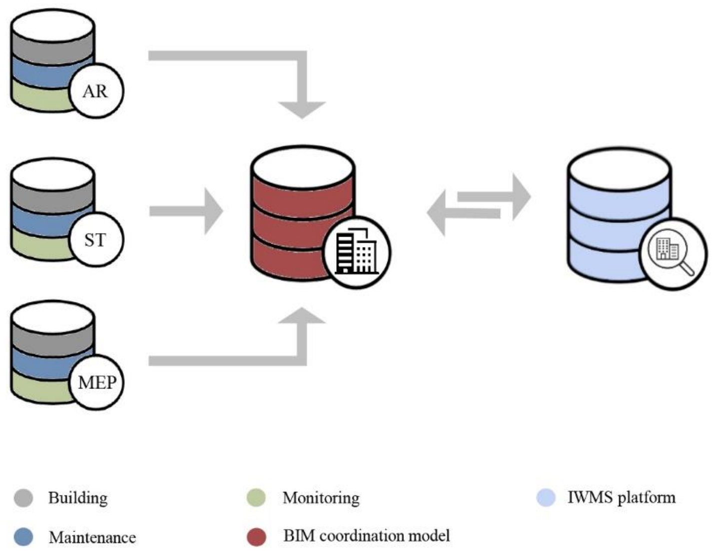


Figure 21 – Methodological workflow for the integration with an IWMS platform

Subsequently, it is possible to update the information directly from the management platform interface where it is easier and simpler to perform, reconnecting with the BIM database in the case of substantial changes. The possibility of visualising the entire building model, with all its geometric characteristics, in addition to the alphanumeric information, allows the creation of an integrated connection. For this reason, the current case study focuses on the use of "Integration with an IWMS platform". The term integration means precisely the operation that allows connecting two different databases: the BIM and FM ones.

The illustration of the characteristics of the present model use makes it clear how its achievement moves through the objective of Data Integration, which consists in the application of technical and operational standards. These should be considered the starting point of the goal definition to be pursued as they generate different impacts, in particular on the structure of the alphanumeric content and the way it is populated. Precisely the need to verify the correctness of these aspects for a proper database integration has brought to an important investigation during the research activity that enriched the concept definition of **Data Validation**. Due to the close correlation between the BIM database and the FM one, based on the data uniqueness, it is essential to populate data correctly from a formal point of view, thanks to the application of specific population rules defined within the BIM procurement dispositions. As illustrated in the Introduction, this concept is part of the BMC, which is expected to be one of the major contributions of the BIM methodology in the AECO industry (McGraw-Hill, 2014). BMC is based on the employment of geometric and alphanumeric information for the development of different types of checking. These are based on BIM model and algorithms for processing data against a set of rules defined in BIM procurement documents (Vergari, et al.). About the definition of the BMC environment, in the literature, there are different concepts classified by Hjelseth following an ontology-based analytical approach (Hjelseth, 2010) (Hjelseth, 2015) (Hjelseth, 2016). According to it, the BMC concepts identified could be divided in Compliance checking solutions, separated into Validation checking and Content Checking, and Design solution checking divided into Smart object checking and Design option checking (Hjelseth, 2016). In the literature, the most used meaning for BIM is the Validation checking (Hjelseth, 2016), composed by Clash Detection and Code Checking. With this concept, it is possible to verify the compliance of BIM model against a set of rules based on different sources, such as norms, codes, external standards, contracts, or other requirements. The validation checking process is based on processing predefined criteria where the outcome can be: “pass”, “fail”, or “not checked” and the output is generally a report of the detected errors (Vergari, et al.). In this way, it is possible to employ only external and common rules, expected for a different kind of project, allowing the definition of the Horizontal BMC. For this reason, during the research activity, a lack of Data Validation concerning internal standards defined in the BIM procurement dispositions and BIM guidelines has been pointed out. This concept allows to enrich the Vertical BMC related to the specific disposition for the building and model uses and to develop a methodology to check the alphanumeric content of the parametric database. The results of this implementation allow implementing the definition of BMC as the sum of Clash Detection, Code Checking and Data Validation (Vergari, et al.).

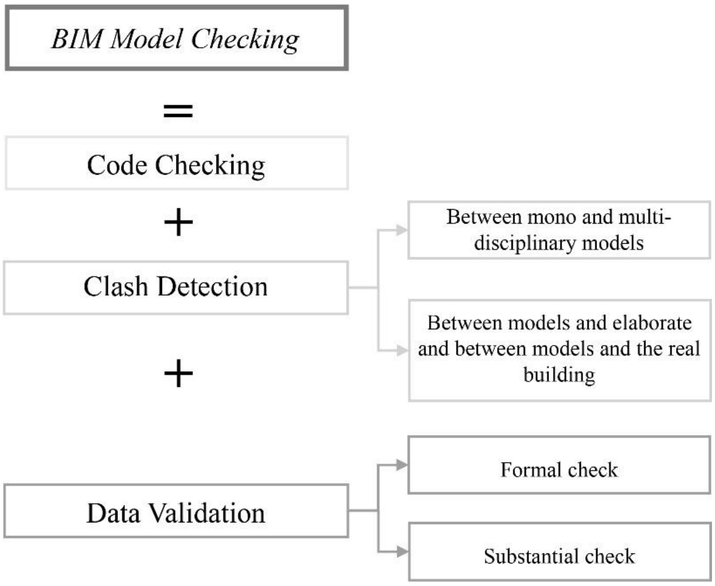


Figure 22 – Definition of Data Validation in BMC

These results have been achieved due to an analysis of the state of the art that deal with BMC on a deontological level, signed with relevance 1 (Eastman, Lee, Lee, & Jeong, 2009) (Pauwels, et al., 2011) (Zhong, et al., 2012) (Hjelseth, 2016) (Hjelseth, 2010) (Hjelseth, 2015) (Dimyadi & Amor, 2013) (Solihin & Eastman, 2015) (Ciribini, Ventura, & Bolpagni, 2015) (Donato, Lo Turco, & Bocconcino, 2018) (Sydora & Stroulia, 2019) (Nawari, 2019) (Eastman, Solihin, & Lee, 2019). In these contributions, authors highlight the importance of the automated rule checking for the employment of BIM models, showing different approaches and the best practices on this topic (Vergari, et al.). On the other side, references with relevance 2 are focused on the tool used during the research activity, discussing the application of VPL in the BMC environment for the checking activities of BIM models against a defined set of rulesets (Preidel & Borrmann, 2015) (Preidel & Borrmann, Towards code compliance checking on the basis of a visual programming language, 2016) (Preidel, Borrmann, & Daum, 2017) (Reinhardt & Mathews, 2017) (Ghannad, Lee, Dimyadi, & Solihin, 2019) (Kim, Lee, Shin, & Choi, 2019).

Table 3 – Classification and analysis of BMC references for the research activity (Vergari, et al.)

Author	Title	Year	Relevance	
			1	2
Eastman, Lee, Jeong, Lee	Automatic rule-based checking of building designs	2009		
P. Pauwels, D. Van Deursen, R. Verstraeten, J. De Roo, R. De Meyer, R. Van de Walle, J. Van Campenhout	A semantic rule checking environment for building performance checking	2011		
B.T. Zhong, L.Y. Ding, H.B. Luo, Y. Zhou, Y.Z. Hu, H.M. Hu	Ontology-based semantic modeling of regulation constraint for automated construction quality compliance checking	2012		
J. Dimyadi, R. Amor	Automated Building Code Compliance Checking - Where is it at?	2013		
W. Solihin, C. Eastman	Classification of rules for automated BIM rule checking development	2015		
M. Preidel, A. Borrmann	Automated Code Compliance Checking Based on a Visual Language and Building Information Modelling	2015		
M. Preidel, A. Borrmann	Towards code compliance checking on the basis of a visual programming language	2016		
A. Ciribini, Ventura, M. Bolpagni	Informative content validation is the key to success in a BIM-based project	2016		
E. Hjelseth	Classification of BIM-based model checking concepts	2016		
M. Preidel, Daum, A. Borrmann	Data retrieval from building information models based on visual programming	2017		
V. Donato , M. Lo Turco, M. Bocconcino	BIM-QA/QC in the architectural design process	2017		
J. Reinhardt, M. Matthews	The Automation of BIM for Compliance Checking: A Visual Programming Approach	2017		
Ghannad, Lee, Dimyadi, Solihin	Automated BIM data validation integrating open-standard schema with visual programming language	2019		
Sydora, Stroulia	Towards Rule-Based Model Checking of Building Information Models	2019		
Kim, Lee, Shin, Choi	Visual language approach to representing KBimCode-based Korea building code sentences for automated rule checking	2019		
Nawari O. Nawari	A Generalized Adaptive Framework (GAF) for Automating Code Compliance Checking	2019		
Y.C. Lee, C. M. Eastman, W. Solihin	The Mechanism and Challenges of Validating a Building Information Model regarding data exchange standards	2019		

The overview of the BMC set out above allows satisfying the requirements for coordination and verification under the disposition of the Italian regulation (UNI 11337-5, 2017). The introduction of the Data Validation declination enables the verification of the information content of BIM models. Starting from graphical model coordination, BMC activities should be done between the visual models, between the graphical models and outputs, and between models and regulations or constraints through (UNI 11337-5, 2017): i) Clash detection as the analysis of physical and information interference; ii) Model and Code checking as the analysis and control of information inconsistencies; iii) Resolution of clashes and inconsistencies. Inside a BIM workflow, the Italian regulation (UNI 11337-5, 2017) defines three different coordination level:

- **CL1** = "*coordination of model data and information within a single graphical model*".
- **CL2** = "*coordination of data, information and information content between models*".
- **CL3** = "*coordination of data, information and information content between information models and outputs and between outputs*".

On the other side, considering the alphanumeric content, data and information should be verified on information models of the work as an overall or single one, for each stage of the building process. Within the digital representation, three primary verification levels of information are identified (UNI 11337-5, 2017):

- **VL1** = "*internal verification of the data, information and information content at a formal level*".
- **VL2** = "*internal verification of the data, information and information content at a substantial level*".
- **VL3** = "*independent check of the data, information and information content and data rooms at a substantial level*".

The general workflow defined in the Italian regulation (UNI 11337-4, 2017) for checking and validation activities is summarized in the chart below (Figure 23):

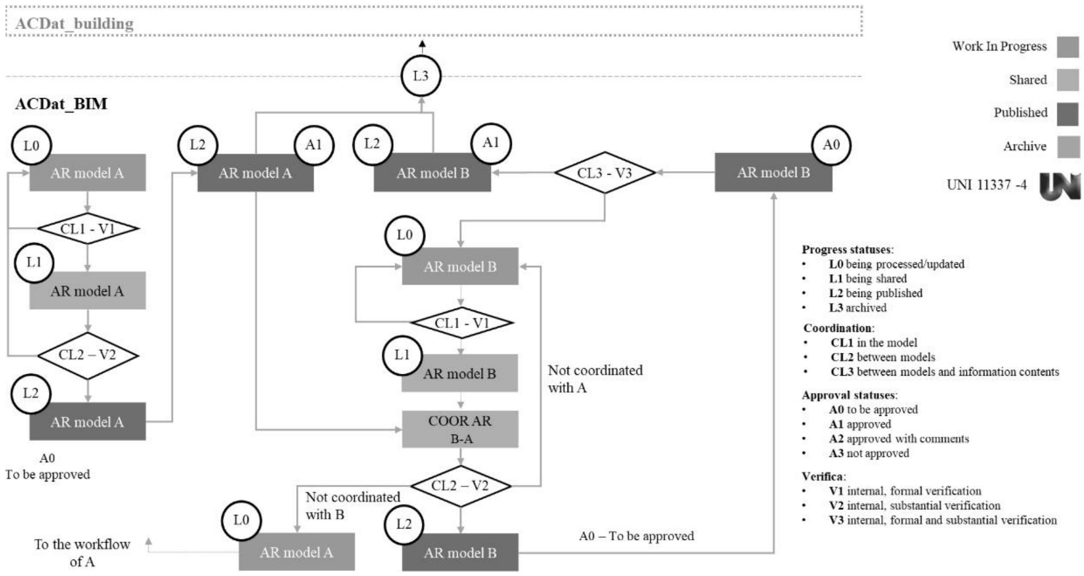


Figure 23 – Workflow of the validation process (UNI 11337-4, 2017).

Starting from the literature review and the consideration developed during the research activity, it is possible to identify and analyse different model checking software of the BMC environment, as ones summarized in Table 4. Some of them are often considered "**black-boxes**" in the literature due to the lack of transparency of rules used for the creation of validation reports (Preidel & Borrmann, 2015) (Vergari, et al.). For this reason, some research has been focused on the employment of VPL for BMC: it represents a code-based language that allows the manipulation of the graphical and alphanumeric elements (Amoruso, 2016). As visible in the Data Integration chapter, the employment of VPL enable to develop a tool for automated BMC classified as a **white box**, that satisfies a wide audience as well as to obtain an effective easy-to-use and "one-size-fits-all" approach that covers all the project requirements. In this way, it also possible to change and update the validation rules, in function of the project and the process phase (Vergari, et al.).

Table 4 – Comparison between some tools for the BMC process

Software / Activity	Solibri Office	Autodesk Navisworks	Autodesk Dynamo	Interference Check for Revit	BCF Manager	MR/AR applications	....
Clash detection							
Code Checking		-		-	-	-	
Data Validation		-		-	-	-	
Interoperability	Open	Open	Close	Close	Open	Open	
Activity schedule	YES	YES	YES	YES	YES	NO	
Costs	By license	By license	Free	Free	Free	By license	
Type of output	Black box	Black box	White box	Black box	White box	-	
....							

Clash Detection between mono and multi-disciplinary models.
Clash Detection between models and existing documentations and between models and real configuration.
Code checking.
Data Validation

2.3.3 FM system over VAR

This model use is based on the interrogation of BIM model content as a visual resource of information aimed at disseminating and sharing data. The VAR tools allow implementing applications that find many uses in **Data Visualization** but mainly in object querying. At the state of the art, the interoperability process is often not able to transfer the alphanumeric database, and for this reason, a subsequent programming activity is necessary. At the moment, only the requirements related to the graphic component of objects can be identified (Barbero, Del Giudice, Ugliotti, & Osello, 2020).

As defined in the introduction section, this model use has been principally investigated and structured to provide an overview of its potential. The applications explored concerned:

- The employment of an application in **Mixed Reality** (MR) (Milgram & Kishino, 1994) for the overlapping of the digital model with reality, to verify its correspondence during the validation activity. In order to achieve this aim, the application has been developed for Microsoft HoloLens which allow the geometric model check through the overlapping of the virtual model into real one according to a real scale environment (Viale, 2019), as visible in Figure 24.
- The development of an application in **Virtual Reality** (VR) (Wang X. , 2015) that allows immersive navigation of the model. This tool, on one hand, enables the design of a possible virtual tour of the stadium, on the

other hand, it allows the visualization of some usually hidden portions of the building during the performance of FM activities. In this case, the model is used as a visual resource, navigable through HTC Vive viewers. For this goal, it is crucial to develop the objects geometric content not only increasing the Level of Detail but also in terms of graphic performance. As visible in Figure 24, the geometric detail should be high and set for appearance, material and colours in order to make the visualization realistic. In this way for furnishing elements, this implementation becomes a fundamental element for the management of internal configuration, according to different scenarios (Barbero, Del Giudice, Ugliotti, & Osello, 2020). In addition, the visualization of an object should be managed to allow the visibility, for example, of the Heating, Ventilation and Air Conditioning (HVAC) conduit behind ceilings, useful for maintenance training.

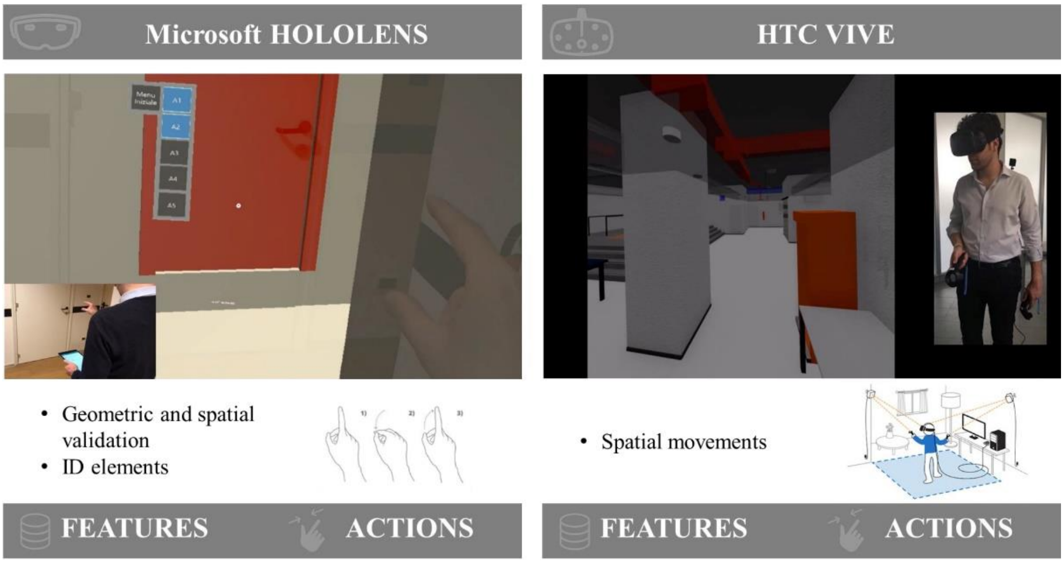


Figure 24 – FM system over VAR for geometric validation and maintenance support (Barbero, Del Giudice, Ugliotti, & Osello, 2020).

- As illustrated within the definition of Stadium 2.0, the BIM database of the individual building may represent the first step in the purpose of the **digital archive** into which several domains may converge. Within the new idea of a stadium based on an integrated database, it is possible to interrogate and implement this content thanks to the activities of all the actors involved during the building life cycle. The chapter on Data Visualization will illustrate several examples developed that provide, for example, the use of the BIM-based information content by the owner and the management of event configurations useful to the organisational operator (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019). The combined vision of this methodological and operational approach, as visible in Figure 25, could generate a social impact on the whole community.

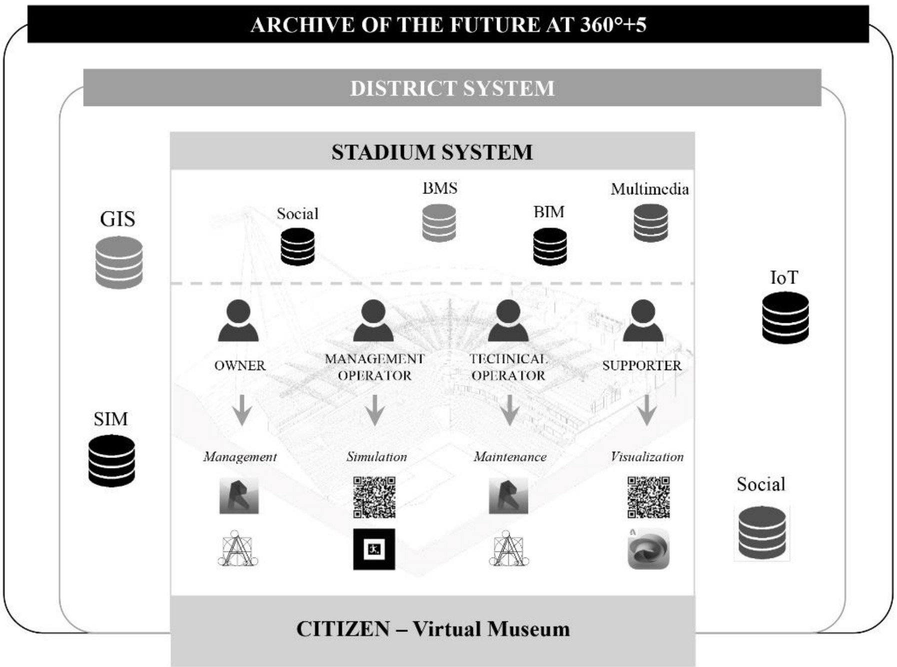


Figure 25 – Methodological workflow for the concept of the digital future archive (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019)

From the illustration of the operating results of this use, it is therefore clear how the archive of the future is achieved through the identification of the objective of Data Visualization starting from the definition of the BIM procurement documents. The implementation of this objective will represent an innovative way to communicate information in order to reach users and meet new important needs.

Chapter 3

Methodology standardization

The introduction of state of the art related to the definition of the BIM methodology and its application in the FM environment allow understanding the aim of the research activity. As illustrated, it is represented by the evaluation of a **BIM methodology standardization**, based on the model uses and objectives of the case study, which enable to fill in the actual gap inside BIM procurement disposition, making the process operating with an integrated strategic vision. This methodology standardization is composed of a series of activities necessary to start a digitization process, enriched with a series of operational requirements. These protocols, based on a series of **technical standards**, allow creating specific **BIM guidelines for FM**.

In detail, these documents allow the owner to provide the correct dispositions that have to be pursued by suppliers to achieve the established uses (Kensek, 2015). They represent the starting point on which the planning of the implementation activities is carried out. Since this topic is closely linked to the information content of the BIM model, the first propaedeutic activity to achieve the desired methodological standardization concerned the analysis and study of **BIM procurement documents**. These contain the basis for the definition of the graphic and informative content for the organization of a model during the service procurement, and they represent the starting point for the BIM guidelines definition. Currently, there are two main documents required to develop a model (Barbero, Del Giudice, Ugliotti, & Osello, 2020):

- "*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*"[11];

- "*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*"[12].

For the management of information during modelling activities, the literature provides various reference standards and norms for the correct structuring of the documentation necessary for the definition of the requirements established by the owner (Succar, 2009). In this case, the term standard could be defined as "*Detailed set of product/service descriptions (prescriptive or performance-based) acting as a reference to be measured. Standards typically denote a set of Specifications which are authoritative and test-proven*"[13]. The different times of development and diffusion of BIM methodology in the countries of the European Union and the rest of the world have generated the creation of numerous standards and reference procedures for the documentation structuring. For this reason, the state of the art of international literature on this topic is widespread, and the following regulation examples are the two most significant ones which allow the definition of the **Capitolato Informativo** (CI), as defined by Italian legislation. The guidelines developed during the research activity are based precisely on the structure of this document, as visible in the results section, since they should illustrate the objectives that the owner wants to achieve through the implementation of the BIM methodology.

The first release of a document that contains the objectives and characteristics expressed by the owner for the structuring of a BIM model is represented by the BIM Project Execution Planning guide (BIM planning guide for facility owners - Version 2.0, 2013). This guide identifies the activities necessary for the correct development and management of the BIM methodology, and it consists of three essential parts related to strategic planning, implementation planning and procurement planning. After that, during the last years, one of the most internationally recognized standards has been developed inside the English technical specification (PAS 1192 - 2, 2013). This second one contains the definition of the documentation that must be produced for the proper development of the information content of a building model during its entire life cycle. The reference document required is the EIR which collects the requirements expressed by the owner for the information modelling activities. This document contains three sections: the information management, the commercial management and the

[11] Definition of Employer Information Requirement (EIR) extracted from the BIM dictionary website: https://bimdictionary.com/en/employers-information-requirement/1 (last consultation on the 18th of September, 2020).

[12] Definition of Building Information Modeling Execution Plan (BEP) extracted from the BIM dictionary website: https://bimdictionary.com/en/bim-execution-plan/1 (last consultation on the 18th of September, 2020).

[13] Definition of Standard extracted from the BIM dictionary website: https://bimdictionary.com/terms/search (last consultation on the 19th of September, 2020).

competence assessment. In this way, it is important to highlight how this technical specification is based on the **information workflow** of the building and, starting from its analysis, the corresponding one for the present case study has been defined. It summarises the future steps that the owner will have to perform for the appropriate management of the BIM database, once the implementation and research phase of this thesis has been completed. During the project implementation, the implementation of the PIM has been carried out by each maintenance supplier who has created the models, following the dispositions contained in the BIM guidelines. As visible in the information workflow, the process is completed when the setting of the Asset Information Model (AIM) for FM is completed, achieving the identified set of objectives. Once these have been enriched, a new cycle linked to FM will begin, which will be based on maintaining the previously identified uses and on the possible enrichment of the database through the definition of new BIM uses and objectives of the model.

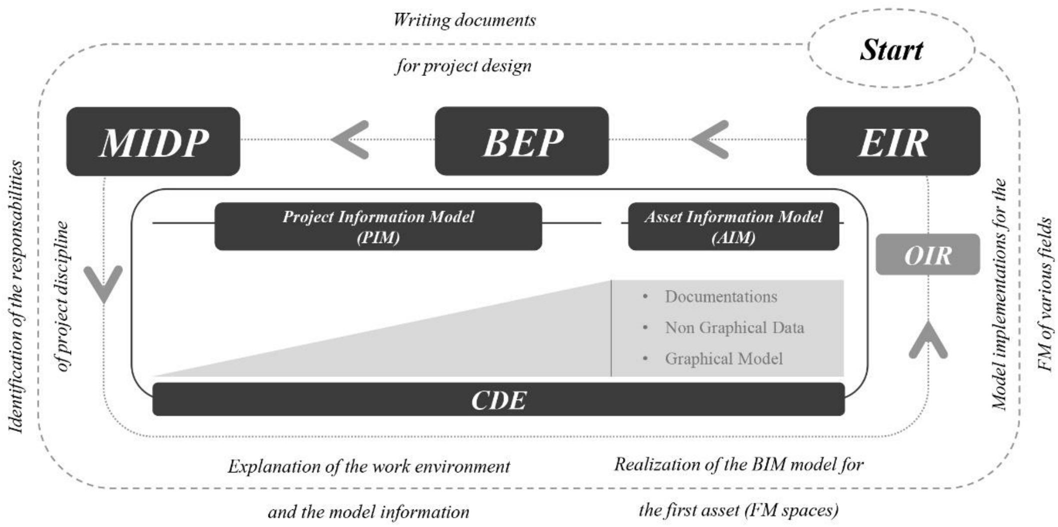


Figure 26 – Information workflow for the entire Data Management of the process[14]

Starting from the definitions structured by the English specification, the Italian regulation (UNI 11337-6, 2017) defines the CI as a document having the same aims as the EIR and composed of three main sections. The main contents of its parts are:

[14] Master Information Delivery Plan (MIDP) represents "*a plan listing all the information deliverables of a project including models, drawings, specifications, equipment, schedules and Room Data Sheets. A Master Information Delivery Plan (MIDP) identifies when project information is to be prepared, by whom, and using what protocols and procedures*". Definition extracted from the BIM dictionary website: https://bimdictionary.com/terms/search (last consultation on the 19th of September, 2020).

Organizational Information Requirement (OIR) is defined as "*the data and information necessary for an organization to satisfy its requirements and meet its objectives. In an Asset Management context, OIR are translated into Asset Information Requirements*". Definition extracted from the BIM dictionary website: https://bimdictionary.com/terms/search (last consultation on the 19th of September, 2020).

- The introduction, where the main characteristics of the CI object are illustrated;
- The technical section, which contains information on the hardware and software infrastructure, data formats to be used, classification systems and reference systems;
- The management section defines uses and objectives of models, the levels of development to be adopted, the roles and responsibilities of the actors involved, the characteristics of the models, the verification and validation procedures and the analysis of interferences and inconsistencies.

Starting from the analysis of the indications of the Italian regulation, for a suitable approach to advanced methodological standardization, some examples of CI/EIR have been analysed, focusing in particular on the relevant reference standards (Employer's Information Requirements - Versione 07, 2013) (Medaway Council, 2015) (BIM planning guide for facility owners - Version 2.0, 2013) (NATSPEC National BIM Guide, 2016).

These considerations are the primary step for the guidelines definition. They satisfy the set objectives through the analysis and application of **standards** and **technical specifications** that allow providing an operational character to this document. In this case, concerning the specific content of a document, the standard meaning is not a specification related to entire document structure, but a reference for the delineation of particular aspects of its information content. In that case, its definition as "*A level of quality or attainment*" is pursued through the application of national and international legislation[15] related to information content of BIM database. The standard could also be defined as "*a technical document designed to be used as a rule, guideline or definition. It is a consensus-built, repeatable way of doing something*"[16]. At the same time, it is possible to affirm that a standard represents "*a formula that describes the best way of doing something*"[17]. Based on these considerations, for the guidelines' definition for this research activity, a series of preliminary standards have been taken into consideration to achieve the results necessary to reach the objectives set out in the following chapters. These are related to:

- **Data exchange formats**, which allow sharing information throughout the entire life cycle of the building. As indicated, since the case study is connected to a private owner and not to a public one (Decreto legislativo 18 aprile 2016, n° 50, 2020), the desired and shared proprietary formats have been entered directly based on the project needs and software used. As a

[15] Definition of standard extracted from the bsi website: https://www.bsigroup.com/en-GB/standards/Information-about-standards/what-is-a-standard/ (last consultation on the 19th of September, 2020).

[16] Definition of standard extracted from the cen website: https://www.cen.eu/work/ENdev/whatisEN/Pages/default.aspx (last consultation on the 19th of September, 2020).

[17] Definition of standard extracted from the ISO website: https://www.iso.org/standards.html (last consultation on the 19th of September, 2020).

future development, it will be of absolute relevance to investigate the open exchange methods using the IFC format (UNI EN ISO 16739 - 1, 2020).

- The **classification** and the levels of decomposition of the building **system**, core of the information process. These allow integrated management of BIM model thanks to the element control for management and maintenance activities. For the current case study, given the fragmentation of the numerous alternatives offered for this kind of breakdown, it was decided to refer only to the standards of the Italian regulation. It divides the building system into three levels: class of technological unit, technological unit and class of technical element (UNI 8290, 1987). This decomposition needs to be combined with an additional classification system capable of identifying individual components and sub-components (Erba, Osello, Semeraro, & Ugliotti, 2015). For this purpose, it was decided to use the MasterFormat classification system (MasterFormat Numbers & Titles, 2016). It lists titles and section numbers for organizing data about construction requirements, products, and activities. An additional classification system used during the research activity regards the **management** of **spaces** for their proper maintenance and querying on the reporting stage. Towards this goal, these have been broken down based on the specificities of the case study, starting from the logics defined in the reference standard (ANSI/BOMA Z65.1 - 2010: Office Buildings: Standard Methods of Measurement, 2010). Their adoption provides, at the hierarchical level, the population of the following parameters: Division, Department, Category and Typology. At the same time, the Archibus© software supports the BOMA classification.
- The definition of the information content carried out through the investigation of the different meanings, interpretations, and enrichment of the **Level of Development** inside the **FM step**. Table 5 shows the state of the art analysed and the initial benchmark to guide the implementation activities. It represents the starting point for further development necessary to make the definition more usable and operative during the research activity, through the concept of heterogeneous LOD.

Table 5 – List of international standards and specifications analysed for the case study (Barbero, Del Giudice, Ugliotti, & Osello, 2020).

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 degree 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.

- The identification of the roles of the actors involved in the process, through the structuring of the **Responsible, Accountable, Consulted, Informed** (RACI) **matrix**. A simplified version of this matrix can be represented by a table that summarises the actors involved, with their respective roles and responsibilities within the project workflow. One possible standard has been implemented by the Italian regulation, allowing the classification of **roles** and figures related to BIM activities (UNI 11337-7, 2018). It also defines the competences of these four different roles indicated in Figure 27. These can be compared with the requirements of the English specification (PAS 1192 - 2, 2013), to which the Italian standard refers.

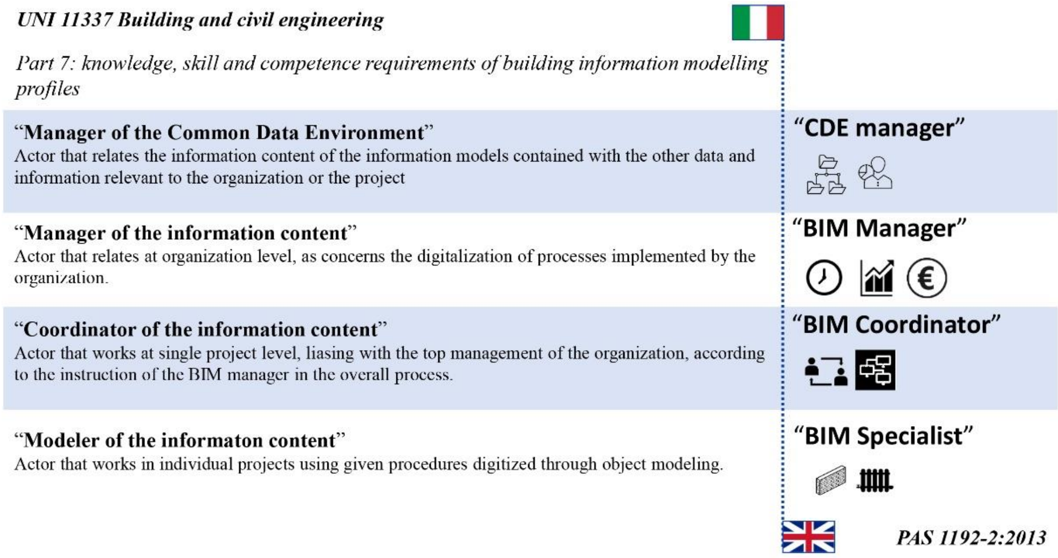


Figure 27 – Definition of BIM roles.

- The definition of the structuring activity for the alphanumeric database, essential to achieve correct data integration. Based on the above considerations regarding the COBie exchange format, the operating standard concerning the structuring of **shared parameters** has been defined. This kind of parameters could be used in different families, models and templates, allowing their replication in separated databases (Barbero, 2019). Their use has been investigated to optimise the implementation of the different models, improving at the same time the integration with the IWMS management software (Ugliotti, 2017). Shared parameters are contained in a specific file in .txt format, which can be recalled in different families and projects and allows structuring in specific typological groups.
- The definition of **collaborative workflow** between all the actors involved in the process. Related to this aspect, one of the significant difficulties in the building process is the management of a large number of design files where information is often stored and represented in different ways. The implementation of a consolidated BIM model allows generating a unique database, avoiding difficulties in documentation alignment due to single and independent revision's file. As can be seen in the following chapters, for the case study two different ways to manage models have been investigated: i) **integrated model**; ii) **federated model**, focusing on data and worksharing between maintenance's suppliers (Barbero, Del Giudice, & Manzone, 2018). The adoption of one of these two structuring methods implies a different data use, based in the first case on a single multi-discipline model where information is aggregated together. On the other side, the second case is founded on a shared area where several mono-discipline models are coordinated and linked together (Di Giuda, Villa, Teicholz, Sacks, & Liston, 2016). In both cases, all the actors involved in the BIM implementation work on the model, which represents the only instrument for information exchange. For this reasons, it is essential to define the correct collaboration

workflow for the modelling implementation, using specific standards as a starting referee (PAS 1192 - 2, 2013) (BS 1192, 2007) (AEC (UK) BIM Technology Protocol, 2015)

- The structure definition of the **data sharing space**, with its operational rules that will be respected during its use. A common international standard (BS 1192, 2007) defines the Common Data Environment (CDE) useful structure during the entire lifecycles. The CDE is defined as "*A single source of information which collects, manages and disseminates relevant, approved project documents for multidisciplinary teams in a managed process. A CDE is typically served by a Document Management System that facilitates the sharing of data/information among Project Participants. Information within it need to carry one of four labels (or reside within one of four areas): Work In Progress (WIP) Area, Shared Area, Published Area, and Archive Area*"[18]. Italian regulation has also adopted this structure for the definition of the Ambiente di Condivisione Dati (ACDat) (UNI 11337-5, 2017).

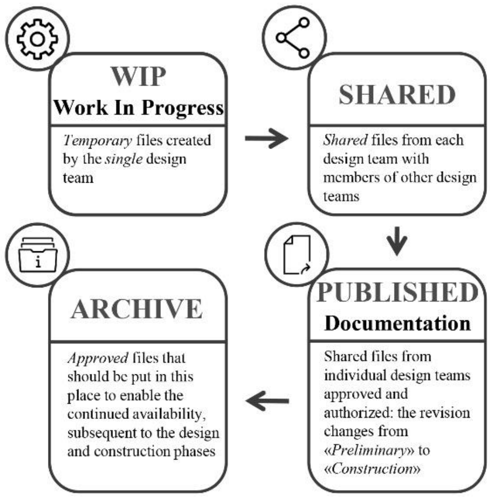


Figure 28 – The normative structure of the ACDat

- The definition of the **denomination rules** of the file's nomenclatures that are developed during the internal life cycle of the work. The term file is related to all the documentation connected to the implemented database to which also the developed guidelines and related annexes belong. In this way, it is clear how the project documentation is not only represented by the BIM models. For this activity, taking into account the specificities of the case study, the standard defined by the English specification has been used and developed as reference (BS 1192, 2007).

Together with these standards, specific **technical specifications** have been analysed and implemented for the definition of the guidelines. These operating dispositions can be defined as the result of an **operational activity/choice**, sometimes related to preliminary standards, that must be carried out to allow the

[18] Definition of Common Data Environment from the BIM dictionary website: https://bimdictionary.com/terms/search (last consultation on the 20th of September, 2020).

correct achievement of the established objectives. Working in this way, it is possible to decline standard in an operational form, enriching the set of rules identified by BIM procurement. From this definition, it is clear to understand how the technical standards vary with the set objectives and consequently, how the **guidelines** are a **tailor-made solution**, able to optimize and make the process operational.

Starting from these considerations, it is possible to define the proposed methodological standardization as the set of activities necessary for the correct implementation of the digitisation process aimed at achieving the objectives of the FM field. In this way, it is also possible to meet the increased complexity of BIM systems by analysing specific uses at the beginning of their life cycle. What has been developed is based on the meaning of the standardization term defined as: "*process of implementing and developing technical standards to guide the creation of something during a process, maximizing results and compatibility*"[19]. The set of activities identified during the research activity (Table 6), and their combination with each different objective of the model, results:

Table 6 – Activities of the BIM methodology standardization for FM

	Activities	Data Organization	Data Integration	Data Visualization
Objectives definition				
1	Statement of purpose	X	X	X
Documentation analysis				
2	As-built documentation analysis	X		
3	FM service procurement analysis	X		
4	Survey activities	X		
Regulation adoption				
5	National regulation adoption	X	X	
6	Classification systems	X	X	
Worksharing				
7	Collaborative BIM working	X	X	
8	Coordination steps	X		
Data Sharing				
9	Graphical and Information Data delivery	X		X
10	ACDat structure and sharing rules	X		
11	Model files codification	X		
Geometric content definition				
12	Model breakdown structure	X		
13	Model accuracy/reliability	X		
14	Modelling rules and graphical convention	X	X	X

[19] General definition of Standardization from Wikipedia website: https://en.wikipedia.org/wiki/Standardization (last consultation on the 20th of September, 2020).

15	Schedule and view definition	X		
16	Views visualization ranges		X	
17	Geometrical data update		X	X
Alphanumeric content definition				
18	Parameter definition	X	X	X
19	Element naming codification and population rules	X	X	
20	System hierarchy definition	X	X	
21	Import/Export data transfer		X	
22	Database integration with other datasets		X	
BIM Model Checking				
23	Clash Detection	X		X
24	Code Checking	X		
25	Data Validation	X	X	

Once identified, these activities have been grouped into macro-activities as a result of the relative relationship, allowing a simplified analysis in the following chapters.

- **Objectives of definition**
  - *Statement of purpose*: definition and analysis of the BIM implementation aim.
- **Documentation analysis**
  - *As-built documentation analysis*: activity carried out to identify all the features necessary for the FM activities, analysing the issues related to the traditional process. This activity also includes the identification of the operating procedures for structuring and querying the database.
  - *FM service procurement analysis*: analysis of the existing documentation concerning the management of maintenance activities that have been essential for the correct definition of the concept of component and sub-component. The first one is defined as a 3D parametric element with geometric and alphanumeric characteristics created in the BIM modelling environment and identified in the IWMS management platform. The second one could be defined as an item with only alphanumeric features, created directly in the IWMS software environment or massively loaded inside it from an external database. This kind of element is not present in the BIM models, and it is connected to the component through an alphanumeric parameter.
  - *Survey activities*: refer to specific actions carried out by the maintenance supplier in order to verify the reliability of the As-built documentation. In this way, the information could be validated for the As-is database.

- **Regulation adoption**
  - *National regulation adoption:* it refers to the operational application of common standards defined in the normative documentation, previously mentioned and tailored to the specific features of the case study.
  - *Classification system*: this activity regards the definition of a series of parameters necessary for the classification of elements, depending on specific standards and also to supplier's denomination rules. This activity is strictly related to the Model Breakdown structure, which concerns the decomposition of the building system in order to define its operational organization.
- **Worksharing** defined as the collaboration method that allows multiple team members to work on the same model at the same time. Generally, on many projects, team members are assigned to a specific area, and they work only on it[20].
  - *Collaborative BIM working*: it refers to the operation way adopted for the worksharing. As defined by international standard, there are two main ways for collaborative working in the BIM environment: i) the implementation of an integrated, central model which works like a server where all team members could work simultaneously on a local copy, synchronizing their work; ii) the setting of a federated model which is composed by different, single models linked together. In this case, the development of a shared area is necessary to share all files between the actors involved, allowing the execution of coordination activities through the implementation of coordination models with different models linked together. The method used to structure the worksharing also has an impact on the integration with the IWMS platform identified, particularly in terms of geometric information content.
  - *Coordination step*: refers to the activities necessary for the actors' coordination thanks to the definition of operational meetings, advancement reports, and shared tools for the resolution of possible issues.
- **Data Sharing** defined as the activity based on sharing platforms and information to make data accessible by all the actors involved in the building lifecycle.
  - *Graphical and Information Data delivery*: this activity is related to the identification of a data exchange format. It allows the identification of data format for the documentation elaborated by the owner as well as by the supplier, based on the specific project step.
  - *ACDat structure and sharing*: the activity that concerns the creation of the ACDat environment and the definition of the loading rules to be

[20] Definition of Worksharing from Autodesk website: https://knowledge.autodesk.com/ support/ revit-products/learn-explore/caas/CloudHelp/cloudhelp/2018/ENU/Revit-Collaborate (last consultation on the 20th of September, 2020).

followed. These are defined based on the expected progress steps and operational coordination methods.
This activity also includes the definition of the authorizations and access policy to consult and upload the material for the individual suppliers of the process, in order to safeguard the ownership of the data itself, which is a very sensitive issue for complex building.

- *Model files codification*: it regards the definition of the files' codification rules, starting from the application of the international standards and references.

- **Geometric content definition**
  - *Model Breakdown Structure*: the activity that allows the definition of the breakdown structure of the work through the identification of all the project activities (Bocconcino, Del Giudice, & Manzone, 2016). Starting from the WBS, it is necessary to define the Work Breakdown Elements (WBE) which allows a progressive articulation in increasingly smaller elements, identifying all the related features. This activity is strictly connected to the documentation analysis of the existing building. This operation, and consequently the database that could be extracted, is an essential factor to be considered carefully at the beginning of the modelling phase because future changes could be very complex and a loss of information could be generated (Barbero, Del Giudice, Ugliotti, & Osello, 2020).
  - *Model accuracy/reliability*: this operation essentially regards existing buildings since it concerns the definition of the reliability degree of a model element and the relative associated data. This activity is very important because it allows having an overview of the entire BIM database, reducing the actual waste of time and money in information searching. Furthermore, for a building structure that continually evolves as the case study, an even higher level of reliability could be achieved at the end of the entire digitalization process. For the research activity, the definition of its operational compilation rules has been carried out through a general, common rule with a series of specifications for defined types of elements.
  - *Modelling rules and graphical convention*: this activity allows the definition of the modelling and structuring rules of individual objects both from a geometric and alphanumeric point of view. In this way, it is possible to define the information content of each parametric element, establishing at the same time the technical standards for the correct structuring of 2D symbology.
  - *Schedule and view definition*: this operation regards the creation of the model template that will be shared between all the actors involved in the process. In this way, it is possible to share the same general settings and implementation rules which include all the parameters required and the category schedule structure. These activities allow the creation of the project browser, defined on the specific objectives of the BIM model,

with the specification of the coordination levels. These are the levels connected to the Archibus© ones that enable the effective integration between the two software as established in the modelling rules.

- *View visualization ranges*: the definition of this characteristic is closely linked with the expected results of the 2D visualization. Their definition allows managing and changing the visualization of an object inside the single plant view in the BIM model and the respective view in Archibus©. It is also necessary to consider for their setting the drawing's representative conventions, due to the possibility of its extrapolation from the BIM model.
- *Geometrical data update*: it is connected to the concept of "upgrade" introduced for the case study in order to identify some objects inside BIM models for which an implementation of geometric detail will be required. This activity will be necessary for Data Visualization where, for some specific uses, the visual appearance of the object is important but also for Data Integration. In this case, sometimes the upgrade is necessary for the proper development of FM activities. Thanks to the application of these considerations, BIM guidelines will include the technical standard's identification required for the achievement and the management of this aim. This aspect has been mapped inside BIM models through the compilation of a proper alphanumeric parameter.

- **Alphanumeric content definition**
  - *Parameter definition*: refers to the identification of all parameters identified for the project and the association to each category in order to set the proper template structure. Starting from the analysis of the As-built documentation and the FM objectives, the definition of the meaning of each parameter has been necessary to allow an integrated structure of the BIM database. This activity is also related to the definition of the kind and typology of the alphanumeric information. Concerning this list, all the created and used parameters belong to five main clusters: objects naming, classification and coding, geometrical features, specific characteristics, and hierarchy.
  - *Element naming codification and population rules*: this operation is connected to the identification of technical standards, based on the legislation ones, for the definition of the objects name and the population rules of parameters. These allow, on one hand, an integrated approach of the methodology for all BIM models during the entire lifecycle. On the other hand, these rules ensure compliance with the syntactic formal restriction for the correct integration of the database.
  - *System hierarchy definition:* it refers to the description of the operational activity for a correct hierarchy definition, depending on the specific consultation need. During the research activity, the hierarchy definition within the modelling software has been planned with the system browser, and it has been replicated and implemented with a proper alphanumeric parameter. This last aspect has been necessary for its

extrapolation from the modelling software, allowing its consultation in the IWMS platform. At the same time, this solution overcomes the limitations in the number of hierarchical levels imposed by the modelling software and the subdivision of the BIM databases following the adoption of the federated models, allowing a unique hierarchy system.

  - *Import/Export data transfer*: this activity is related to different tests carried out to analyse the kind and typology of a parameter for a correct extrapolation in the ODBC exchange format, identified for the integration with the IWMS platform. Knowing the real extrapolation of the information from the 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 (Barbero, Del Giudice, Ugliotti, & Osello, 2020).
  - *Database integration with other datasets*: this activity regards all the protocol and operating standards necessary for correct integration of the BIM database inside another platform. This operation is based on the need to update data from the As-is model to the FM platform, implementing them according to the specific aim of the project. This integration is founded on one of the significant strengths of the BIM methodology: the uniqueness of data which is essential during the entire building lifecycle (Barbero, Del Giudice, Ugliotti, & Osello, 2020). In this way, it becomes essential to standardize also the management of the database, knowing the updating workflow.
- **BIM Model Checking** as the process of checking the BIM database as illustrated in Chapter 2, starting from the international background, defining specific steps.
  - *Clash Detection*: refers to the activity of checking the geometric configuration of the BIM objects created by suppliers, with the implementation of a specific operating step that allows a substantial control with the real configuration of the building.
  - *Code Checking*: refers to the verification of the model compliance with external specific disposition established by regulations. For the research activity, due to the models' aim and the existing feature of the building, this activity regards the substantial control of classification rules.
  - *Data Validation*: this activity is connected to the formal and substantial control of the alphanumeric BIM model content of the BIM model to verify the correctness of information for the integration step through the employment of a VPL tool.

Illustrated all the activities identified for the proposed methodological standardization, it is clear how BIM guidelines for FM 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 (Barbero, Del Giudice, Ugliotti, & Osello, 2020).

Chapter 4

Data Organization

In the context of existing buildings, the definition and the structure of data is the first step of the digitization process. The importance of this objective lies in the essential role of data within the building process and how it is used, with a considerable influence on the database definition. With the **traditional** management **method**, one of the main problems of the **Data Organization** is the lack of a unified database, the duplication of data, the different versions of the archived files that make the process complicated and with possible high data loss. For this reason, the creation of an **integrated** and **unique database** based on the parametric model represents an essential innovation in the application of the BIM methodology in this field.

Compared to the traditional method, the BIM As-is model for FM is a digital representation of the effective state of the building, based on the uniqueness of the data that needs to be continuously updated by the responsible actors. As highlighted in Chapter 2, this model should be structured appropriately based on operational needs and correctly populated. In the case of existing buildings, the data to be transferred derives from the collection and analysis of existing documentation and information acquired through survey activities or other acquisition techniques. In this way, it is possible to overcome the data loss that occurred during the management with the traditional method due to all the problems illustrated. For this reason, the concept of data reliability is particularly important. Its definition becomes essential to achieve the objectives for which the model is created.

For the development of first considerations concerning the identify project objectives, a **prototype model** has been developed (Figure 29). It regards a particularly significant portion of the stadium represented by the locker room of the first team. In this way, it has been possible to test several operational protocols defined and included in the BIM guidelines, and then to improve them thanks to the constant comparison with the suppliers during the implementation activities of the models themselves.

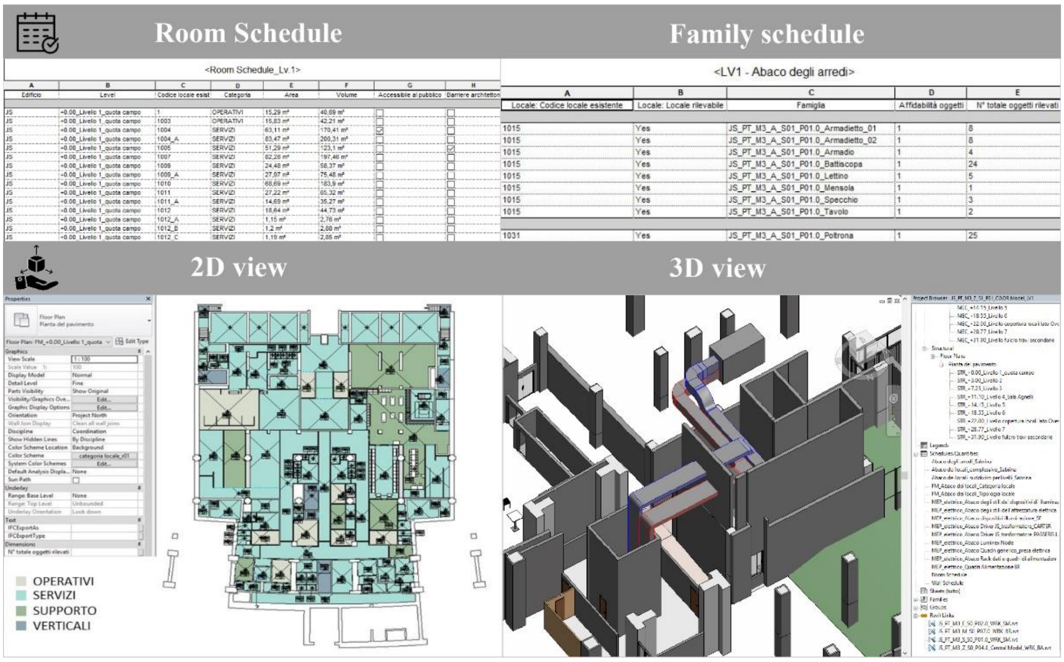


Figure 29 – Prototype models develop for Data Organization, Data Integration and Data Visualization tests during the research activity

4.1 Objectives definition

Functionally as defined in the literature (Ugliotti, 2017), Data Organization is based on the logical and functional breakdown of the model and the employment of shared parameters and templates. In this way, it is possible to **structure a BIM database** which could be interrogated in a shared way. At the same time, it is based on the analysis of data necessary for the FM activities and the definition of the database structure. This analysis should be done for each parametric model, defining its level of information need, but also from a general point of view related to the entire discipline models. In this way, it is possible to obtain BIM models that are enabled to respond to the typical **FM daily questions**. The information inside models is continuously updated and, thanks to their extrapolation, allows to share and manage heterogeneous data: from material quantities to the characteristics of the envelope, from the rooms' volumes to the list of electronic devices, with the ability to implement the type of data processed. This process can therefore lead to a quicker response in organizational needs by increasing the quality of the service offered (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019).

With the application of the BIM method to the FM field, a sustainable activity is done, and, for this reasons, several researchers in the literature started to speak about Suitable Facility Management (Erba, Osello, Semeraro, & Ugliotti, 2015). It represents the population of Computer Maintenance Management System (CMMS) application with the information related and contained in a 3D parametric model (Teicholz, 2013). At the same time, the BIM models are navigable on different smart devices that, however, display the same information content, preserved through the rule of data uniqueness (Barbero, 2016). The different applications also provide services of consultation of individual objects that allow the user to perform activities of verification and approval of previously uploaded data, assuming a real control procedure aimed at optimizing the project (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019).

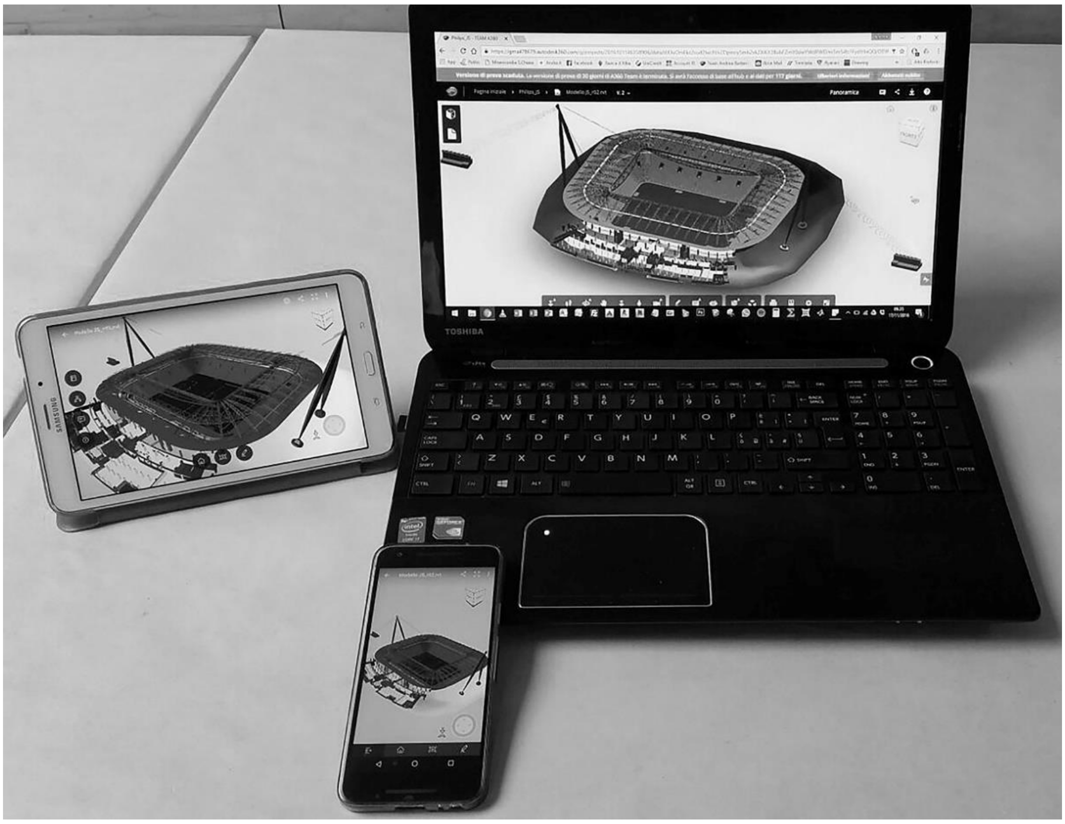


Figure 30 – Different smart devices for the consultation of BIM models (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019)

4.2 Documentation analysis

The analysis of the **existing documentation** is an essential, primary activity for the correct organization of the database since, being an existing building, it represents the starting point for the implementation of BIM models. For this purpose, a collection of all current documentation has been conducted, analysed and reorganized based on the contents and the respective update version. These documents were mainly composed of 2D As-built/As-is documents developed with the traditional method, technical sheets, system certifications. A section of the project ACDat has been therefore reserved to the archiving of this kind of elaborate. As shown in chapter 4.5, for available documentation, a folder has been prepared for individual suppliers to upload documentation in their possession. In this way, it is, therefore, possible to take advantage of the implementation of the BIM models also to collect all the existing information, which perhaps the owner did not have access to, certifying the content before using it.

The operating mode of the existing As-is documentation use illustrated below represents a possible operating mode, investigated during the research activity for the definition of an operational workflow. It has been applied for the implementation of Architectural (AR) models of level 1 and level 2 and the different AR and Mechanical, Electrical and Plumbing (MEP) disciplines of the prototype models, through some thesis work of students that collaborated on this research project. Subsequently, each supplier followed and defined their operational workflow for the implementation of the various disciplinary models, taking into account the dispositions contained in the BIM guidelines regarding the objectives to be pursued and the precision required for the modelling activities.

Starting from these considerations, as an operational proposal, "**As-is CAD Model**" have been developed including the various existing As-built/As-is 2D drawings divided according to the updated version, loaded as files linked to their belonging levels (Figure 31). Working in this way, as can be seen in the structuring of the worksharing, it is possible to have all the necessary documentation for the implementation of the models without increasing the model weight.

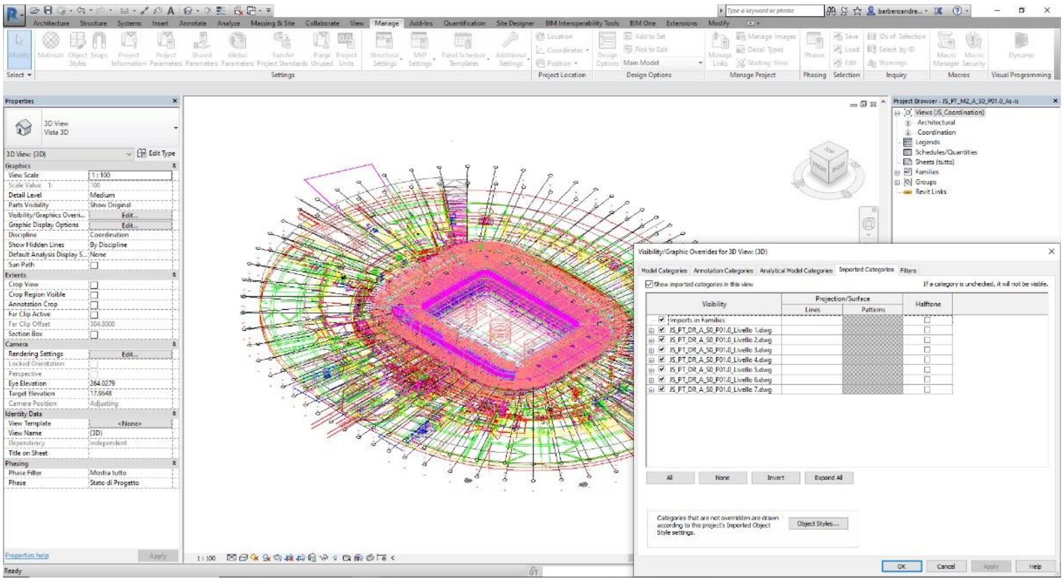


Figure 31 – As-is CAD model for the development of BIM models

These same models have been used for the realization of the respective BIM models which subsequently needed to be checked against the real configuration (Step 1 - Figure 32). Often the existing documentation is incomplete or outdated, thus requiring specific control and verification activities. Therefore, it has been decided to use the same BIM model to carry out the survey activities, consulting it through the Autodesk BIM 360 application (Figure 33). This **Augmented Reality** (AR*) **tool** enables the consultation of the BIM model and other project files by tablet or other smart devices to obtain, for example, the room existing code directly from As-is project during the survey activities. The developed BIM model could be used for the extrapolation of 2D planimetric view that can be used during the geometrical survey activity, especially when, for example, there is a team of two people with only one tablet available.

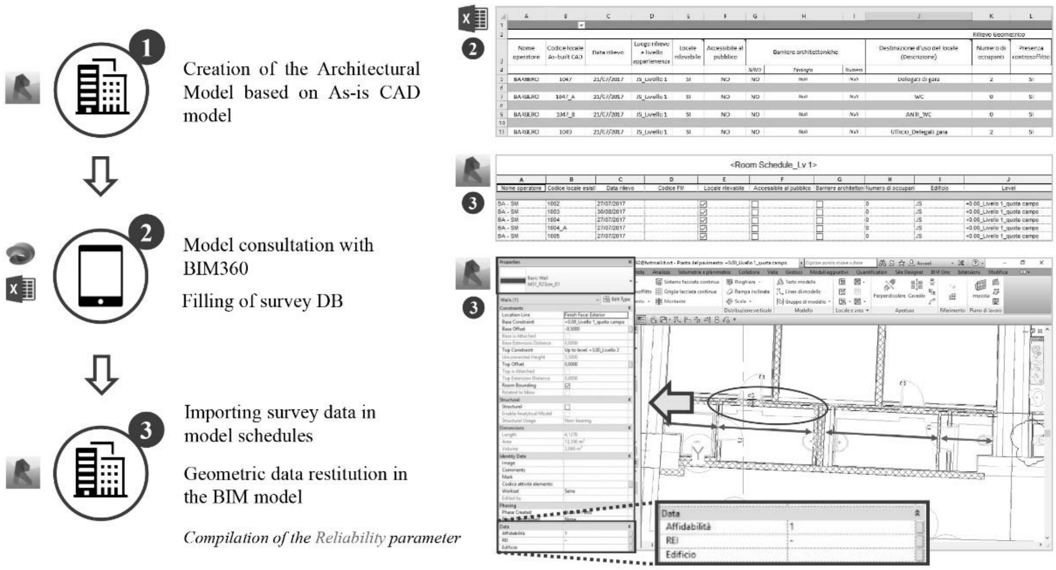


Figure 32 – Step of the survey activity for the Architectural model

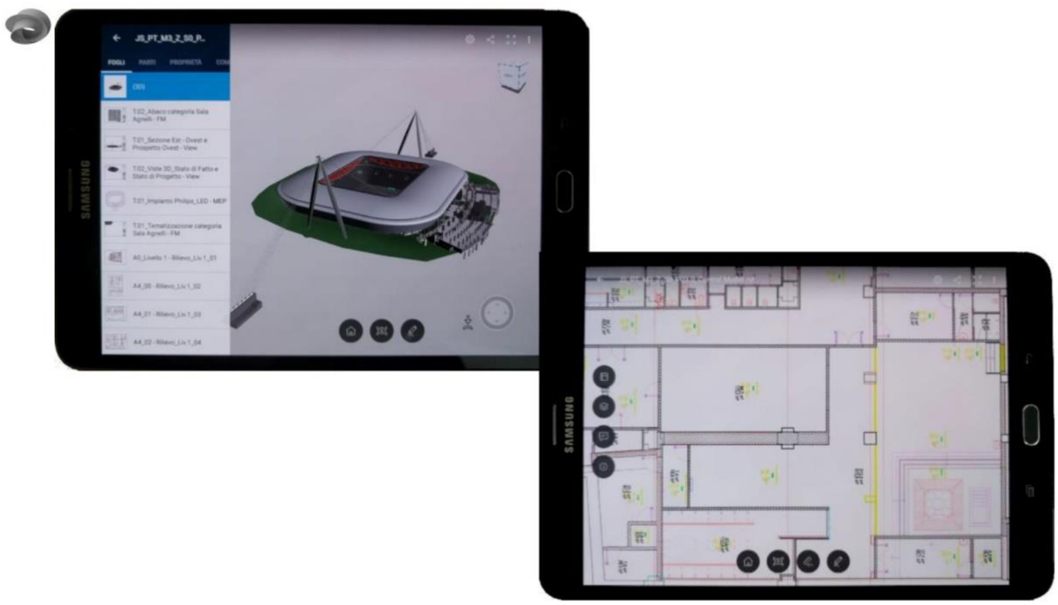


Figure 33 – Adoption of Autodesk BIM 360 application for the survey activities

On the other hand, concerning the system components, their checking takes place starting from formal verification of the spatial placement and number of objects using, in this case, the existing As-is documentation (Figure 34). After this step, the implementation inside BIM models has been carried out. This operational approach derives from the strict correlation with the architectural discipline and the verification of possible reference schemes for their insertion, such as the structure of the ceilings.

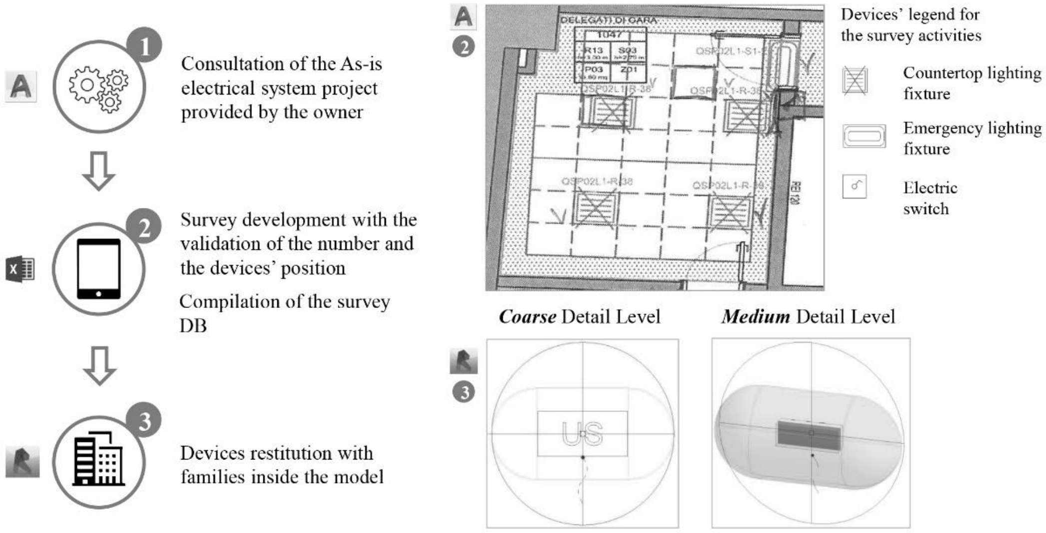


Figure 34 – Step of the survey activity for the MEP models

For the aim of the project, the **geometrical survey** activity concerned the verification of the general dimensions of the spaces, with planimetric and volumetric checks, and the collection of information about the rooms defined in a specific Excel sheet. (Step 2 – Figure 32). This database contains a whole series of parameters identified together with the owner, which results associated with each room and requested in the effective configuration of the alphanumeric content (Table 7). This activity has also been combined with a general photographic survey of the premises with 360° panoramic views and detailed photos, organised following the identification codes of the individual areas.

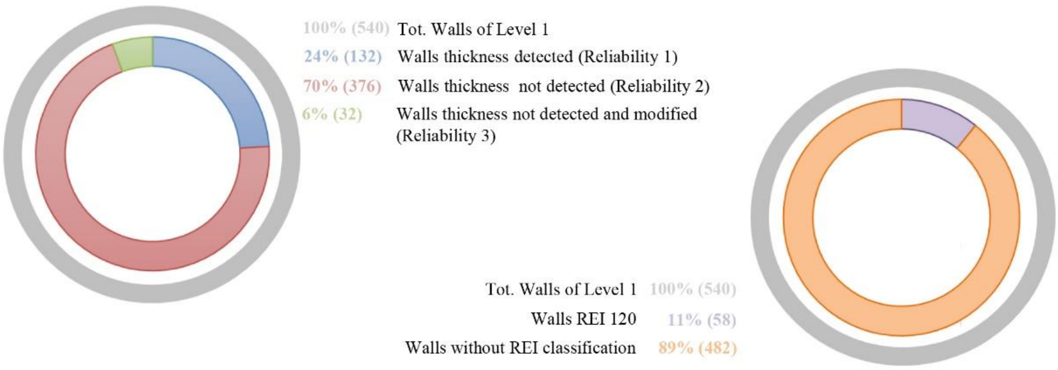
Table 7 – Example of parameters defined for the survey activities

Geometric Survey																					
Operator name	As-built CAD Room code	Survey Date	Survery Place and Level	Detectable Room	Accessible to the public	Architectural barriers			Room Description	Number of occupants	Presence of suspended ceiling	Room Height	Floating floor	Internal finishing			Windows			Furniture	
						YES/NO	*Typology*	*Number*						*Floor*	*Walls*	*Ceilings*	*YES/NO*	*Typology*	*Number*	*Typology*	*Number*
BA - SM	1031	26/07/2017	JS_Livello 1	SI	NO	NO	*Null*	*Null*	Spogliatoio_JV	25	SI	2,4/2,70	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	Armadio cambio giocatori	25
BA - SM	1031	26/07/2017	JS_Livello 1	SI	NO	NO	*Null*	*Null*	Spogliatoio_JV	0	SI	2,4/2,70	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	NO	*Null*
BA - SM	1015	26/07/2017	JS_Livello 1	SI	NO	SI	Scale di uscita	1	Area relax JV	1	SI	2,4/2,9	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	Lavandino	1
BA - SM	1015	26/07/2017	JS_Livello 1	SI	NO	SI	Scale di uscita	1	Area relax JV	0	SI	2,4/2,9	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	Lettino	5
BA - SM	1015	26/07/2017	JS_Livello 1	SI	NO	SI	Scale di uscita	1	Area relax JV	0	SI	2,4/2,9	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	NO	*Null*
BA - SM	1015	26/07/2017	JS_Livello 1	SI	NO	SI	Scale di uscita	1	Area relax JV	0	SI	2,4/2,9	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	NO	*Null*
BA - SM	1015	26/07/2017	JS_Livello 1	SI	NO	SI	Scale di uscita	1	Area relax JV	0	SI	2,4/2,9	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	NO	*Null*
BA - SM	1015A	26/07/2017	JS_Livello 1	SI	NO	SI	Scale di accesso (ad angolo)	1	Docce_Area relax JV	0	SI	2,6	NO	Piastrelle/legno	Intonaco	Intonaco	NO	*Null*	*Null*	Vasca da bagno	2
BA - SM	1033	26/07/2017	JS_Livello 1	SI	NO	NO	*Null*	*Null*	Sala da pranzo	16	SI	2,4/2,7	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	NO	*Null*
BA - SM	1033	26/07/2017	JS_Livello 1	SI	NO	NO	*Null*	*Null*	Sala da pranzo	0	SI	2,4/2,7	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	NO	*Null*
BA - SM	1032	26/07/2017	JS_Livello 1	SI	NO	NO	*Null*	*Null*	Docce_Atleti	14	SI	2,4	NO	Piastrelle	Piastrelle	Controsoffitto a quadrati grigliati	NO	*Null*	*Null*	Doccia	14
BA - SM	1098	26/07/2017	JS_Livello 1	SI	NO	NO	*Null*	*Null*	Spogliatoio_Fisioterapisti	3	SI	2,7	NO	Gomma	Intonaco	Intonaco	NO	*Null*	*Null*	Armadio cambio fisioterapisti	3

Electrical System					Fire protection system															
Intrusion detection device		Digital clock/timer			Smoke detectors			System activation light			Fire extinguisher					Wall hydrant				Note
YES/NO	*Number*	*YES/NO*	*Typology*	*Number*	*YES/NO*	*Typolgy/Codification*	*Number*	*YES/NO*	*Typolgy/ Codification*	*Number*	*YES/NO*	*Typology*	*Code*	*FM/As-is Code*	*Number*	*YES/NO*	*Typology*	*Code*	*Number*	
NO	*Null*	SI	Digitale - 51x20 cm	1	SI	A-L1-LP1-S25	1	NO	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*
NO	*Null*	SI	Digitale - 51x20 cm	1	SI	A-L1-LP1-S26	1	NO	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*
SI	1	SI	Digitale - 51x20 cm	1	SI	A-L1-LP1-S27	1	SI	32x13	1	SI	6 litri idrico (schiuma)	1107	L1E015	1	NO	*Null*	*Null*	*Null*	*Null*
SI	1	SI	Digitale - 51x20 cm	1	SI	A-L1-LP1-S29	1	SI	32x13	1	SI	6 litri idrico (schiuma)	1050	L1E014	1	NO	*Null*	*Null*	*Null*	*Null*
SI	1	SI	Digitale - 51x20 cm	1	SI	A-L1-LP1-S30	1	SI	32x13	1	SI	6 litri idrico (schiuma)	677	L1E016	1	NO	*Null*	*Null*	*Null*	*Null*
SI	1	SI	Digitale - 51x20 cm	1	SI	A-L1-LP1-S34	1	NO	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*
SI	1	SI	Digitale - 51x20 cm	1	SI	A-L1-LP1-S36	1	NO	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*
NO	*Null*	NO	*Null*	*Null*	SI	A-L1-LP1-S33	1	NO	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*
NO	*Null*	NO	*Null*	*Null*	SI	A-L1-LP1-S28	1	NO	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*
NO	*Null*	NO	*Null*	*Null*	SI	A-L1-LP1-S24	1	NO	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*
NO	*Null*	NO	*Null*	*Null*	NO	*Null*	*Null*	NO	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*
NO	*Null*	NO	*Null*	*Null*	SI	A-L1-LP1-S23	1	NO	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*	NO	*Null*	*Null*	*Null*	*Null*

Regarding the geometrical survey, the parameters identified in Table 7 allow: i) the identification of the person who carried out the relief operation; ii) the room concerned by the survey activity and the corresponding level; iii) the date of the activity; iv) information specific to the space such as the presence of architectural barriers, number of occupants, the destination of the room, the height of the room; v) the presence of a floating floor; vi) the types of internal finishes; vii) the existence of windows; viii) the availability of furniture. About the MEP part, the parameters selected allow: i) the identification of the number of terminals to be surveyed; ii) the classification of their type; iii) the mapping of their naming code, currently used for their classification.

After the survey operation, the information collected within the BIM models has been implemented in order to increase the knowledge level (Step 3 – Figure 32). This aspect has been converted into the definition of the alphanumeric parameter **Reliability**, associated with each model element. As an example, for wall objects, an analysis of the results obtained after the survey activities mentioned above concerning the AR model of level 01 has been carried out, highlighting the achieved increase in the knowledge level. As visible in Figure 35, it is possible to see the improvement equal to 18%. Throughout the entire life cycle of the building, thanks to the execution of future maintenance activities, a reliability level of 100% will be reached.

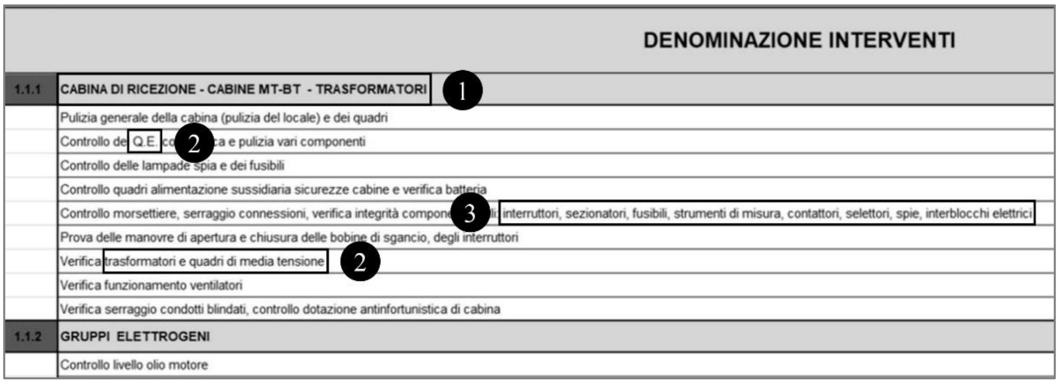


<Wall Schedule_Lv.1>

A	B	C	D	F	G	H	I	J
Classi di unità tecn	Unità tecnologiche	Classi di elementi t	Type	Width	Area	Edificio	REI	Affidabilità
3	3.1	3.1.1	M02_R42cm_00	0,42	17,89 m²	JS	-	2
3	3.1	3.1.1	M02_R52cm_00	0,52	13,29 m²	JS	120	2
3	3.1	3.1.1	M02_30cm_00	0,3	57,75 m²	JS	-	2
3	3.1	3.1.1	M02_R32cm_00	0,32	59,34 m²	JS	-	2
3	3.1	3.1.1	M02_R52cm_00	0,52	12,28 m²	JS	-	2

Figure 35 – Results of the survey activities of Architectural Level 1

The knowledge survey conducted, as identified in similar studies (Osello & Ugliotti, 2017) aims at achieving the data collection necessary for the correct setting of the BIM model for FM. The objective is, therefore, to know not only the work geometry but also the spatial location of the objects that constitute the building systems (Erba, Osello, Semeraro, & Ugliotti, 2015). To this information content, it is then necessary to associate all the alphanumeric data required to populate the maintenance content. For this reason, an analysis of the existing documentation based on specific maintenance schedules, structured by discipline, has been conducted, establishing the object and time for the performance of individual activities (Figure 36). This documentation has been very useful also for a detailed examination of the definition of the various **components** (Point 2 - Figure 36) and **sub-components** (Point 3 - Figure 36) that represent the entire set of objects maintained inside the stadium. This analysis is also linked to the various maintenance procedures (Point 1 - Figure 36) that are carried out on the components and sub-components of the stadium. The link relating to the application of the BIM methodology to the FM field is connected to the organisation of maintenance procedures which should also be reviewed from the structure of the families and types contained in the BIM model.



	DENOMINAZIONE INTERVENTI
1.1.1	CABINA DI RICEZIONE - CABINE MT-BT - TRASFORMATORI
	Pulizia generale della cabina (pulizia del locale) e dei quadri
	Controllo de[illegible] Q.E. co[illegible]ca e pulizia vari componenti
	Controllo delle lampade spia e dei fusibili
	Controllo quadri alimentazione sussidiaria sicurezze cabine e verifica batteria
	Controllo morsettiere, serraggio connessioni, verifica integrità compone[illegible] interruttori, sezionatori, fusibili, strumenti di misura, contattori, selettori, spie, interblocchi elettrici
	Prova delle manovre di apertura e chiusura delle bobine di sgancio, degli interruttori
	Verifica trasformatori e quadri di media tensione
	Verifica funzionamento ventilatori
	Verifica serraggio condotti blindati, controllo dotazione antinfortunistica di cabina
1.1.2	GRUPPI ELETTROGENI
	Controllo livello olio motore

Figure 36 – Extrapolation of maintenance documentation

4.3 Regulation adoption

Starting from the particular use of the building analysed the adoption of a **classification system** for the building and spaces had been defined, starting from national regulations and classification systems.

The first one is represented, as illustrated, by the Italian regulation (UNI 8290, 1987), implemented and detailed by the MasterFormat system that allows reaching the level of the component, as visible in Figure 37. This information has been inserted for each type of element by populating the respective shared type parameters (Figure 38). The parameters associated with the individual components and the population rules have been indicated respectively in Annex 02 and 02.1 of the BIM guidelines. Considering that some elements were not included in the classification provided by the regulation, the creation of a shared document inside the ACDat has been necessary to allow the implementation of this codification, during the setting of BIM models, operating in a coordinated and shared manner between the different disciplines.

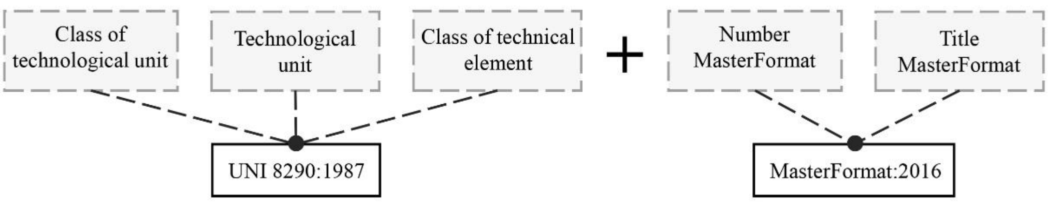


Figure 37 – The classification system adopted for the case study

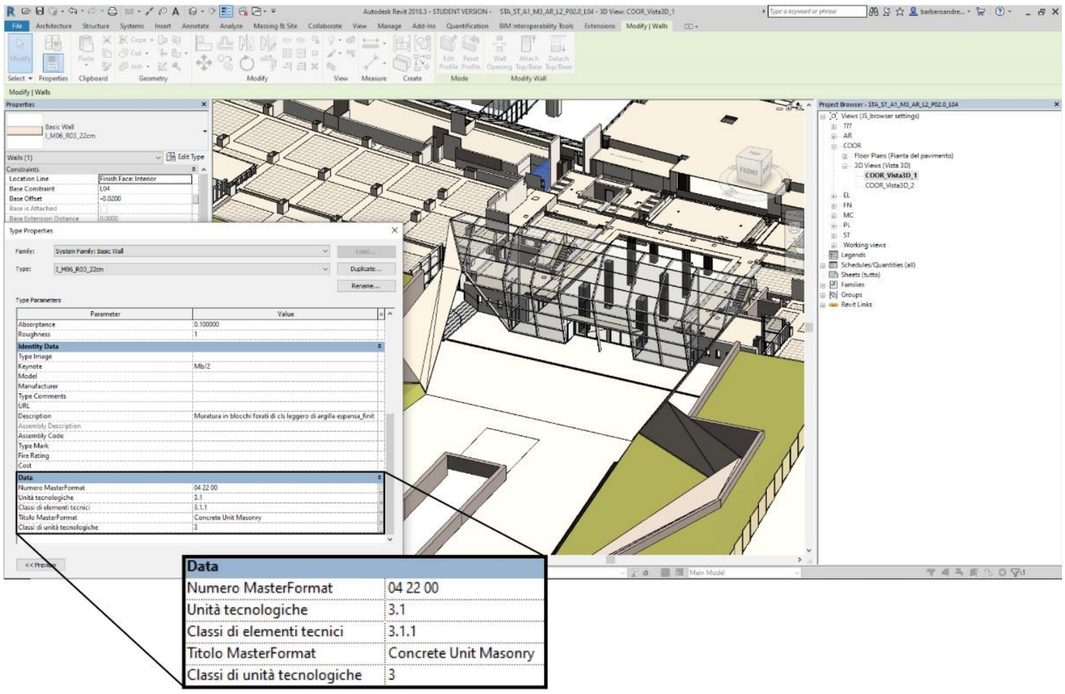


Figure 38 – Example of the classification population for a wall

The second classification system, linked to **spaces**, has been provided based on the reference standard that defines the relative organisation logics (ANSI/BOMA Z65.1 - 2010: Office Buildings: Standard Methods of Measurement, 2010). For this purpose, the owner has defined within the Annex 02 how to compile these parameters for each environment, following its intended use (Figure 40). Since this information is punctual and the association to the single room is univocally traced through the corresponding identification code, this information has been massively loaded within each AR model using Autodesk Dynamo. In this case, the application of specific shared instance parameters associated with the spaces allowed their implementation within the models. The obtained classification is a useful tool for the management of rooms as it provides their graphic thematization and consultation inside the relative schedule, as shown in Figure 29.

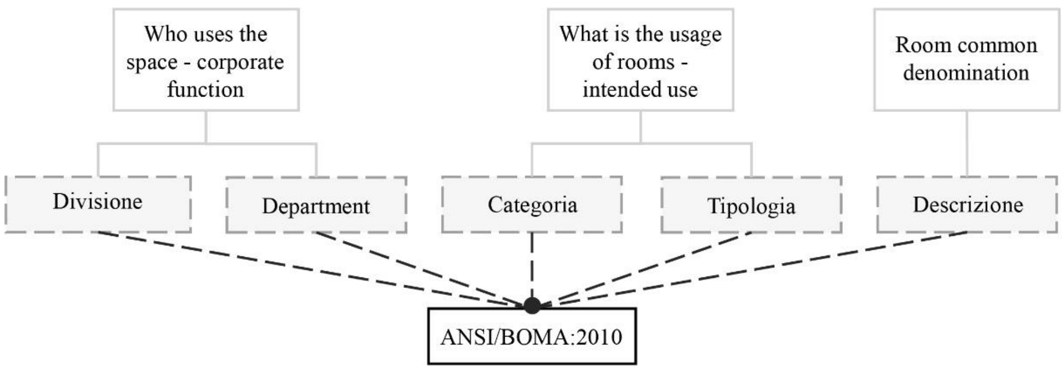


Figure 39 – The classification system adopted for rooms.

CODICE FM	DIVISIONE	DEPARTMENT	CATEGORIA	TIPOLOGIA	DESCRIZIONE
STA_ST_L03001	HOSPITALITY	T100	SOMMINISTRAZIONE	RISTORANTE	RISTORANTE T100
STA_ST_L03002	HOSPITALITY	T100	SOMMINISTRAZIONE	SBARAZZO	SBARAZZO T100
STA_ST_L03003	BUILDING	SPAZI	DISTRIBUZIONE	CORRIDOIO	CORRIDOIO T100
STA_ST_L03004	BUILDING	IMPIANTI	TECNICI	CAVEDIO	CAVEDIO NORD-OVEST
STA_ST_L03005	BUILDING	IMPIANTI	TECNICI	CAVEDIO	CAVEDIO SUD-OVEST
STA_ST_L03006	BUILDING	BABYPARK	SERVIZI	INTRATTENIMENTO	BABYPARK 1 OVEST
STA_ST_L03007	BUILDING	BABYPARK	SERVIZI	INTRATTENIMENTO	BABYPARK 2 OVEST
STA_ST_L03008	BUILDING	BABYPARK	SERVIZI	MAGAZZINO	RIPOSTIGLIO BP 1
STA_ST_L03009	BUILDING	BABYPARK	SERVIZI	BAGNO	ANTIBAGNO BP 1
STA_ST_L03010	BUILDING	BABYPARK	SERVIZI	BAGNO	BAGNO 1 BP 1
STA_ST_L03011	BUILDING	BABYPARK	SERVIZI	BAGNO	BAGNO 2 BP 1
STA_ST_L03012	BUILDING	SPAZI	DISTRIBUZIONE	DISIMPEGNO	DISIMPEGNO ASC. SUD-OVEST
STA_ST_L03013	BUILDING	SPAZI	DISTRIBUZIONE	ASCENSORE	ASC. SUD-OVEST
STA_ST_L03014	BUILDING	SPAZI	DISTRIBUZIONE	SCALA INTERNA	SCALE SUD-OVEST
STA_ST_L03015	BUILDING	SPAZI	DISTRIBUZIONE	DISIMPEGNO	DISIMPEGNO ASC. NORD-OVEST
STA_ST_L03016	BUILDING	SPAZI	DISTRIBUZIONE	ASCENSORE	ASC. NORD-OVEST
STA_ST_L03017	BUILDING	SPAZI	DISTRIBUZIONE	SCALA INTERNA	SCALE NORD-OVEST
STA_ST_L03018	BUILDING	IMPIANTI	TECNICI	LOCALE TECNICO	LOCALE TECNICO 1 SU CORRIDOIO T100
STA_ST_L03019	BUILDING	SPAZI	SERVIZI	ARCHIVIO	ARCHIVIO DOCUMENTALE STADIO
STA_ST_L03020	HOSPITALITY	SKYBOXLOUNGE SUD	CATINO SKYBOXLOUNGE SUD	SKYBOX	SUITE 1
STA_ST_L03021	TRIBUNE	SUD-OVEST LIV. 1	CATINO SKYBOXLOUNGE SUD	SETTORE	SUITE 1
STA_ST_L03022	HOSPITALITY	SKYBOXLOUNGE SUD	CATINO SKYBOXLOUNGE SUD	SKYBOX	SUITE 2
STA_ST_L03023	TRIBUNE	SUD-OVEST LIV. 1	CATINO SKYBOXLOUNGE SUD	SETTORE	SUITE 2

Figure 40 – Extrapolation of Annex 02 of the BIM guidelines with the rooms' classification

4.4 Worksharing

The worksharing issue represents one of the fundamental characteristics of the BIM methodology because it allows several actors, each one for their own discipline and area of competence, to work on the same project in a coordinated and integrated mode. Only in this way it is possible to achieve the set objectives, based on the data uniqueness. For this reason, it has been necessary to study and define the structure of the **BIM workflow**, according to the different actors involved in the project (Figure 41).

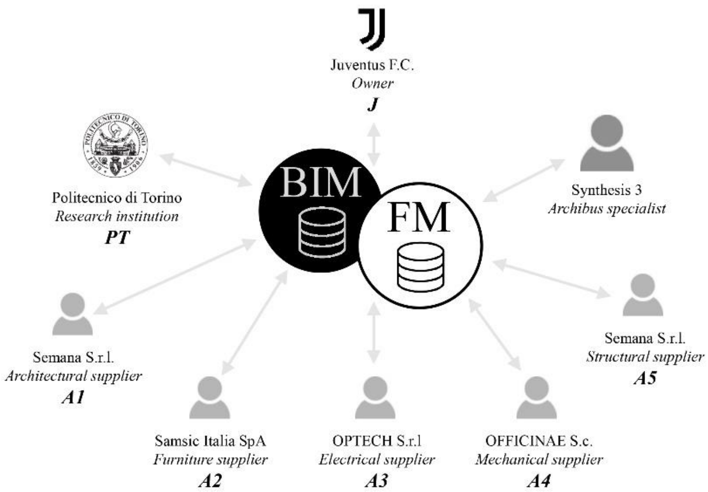


Figure 41 – Actors involved in the research project

As defined in the literature, the availability of data represents the essential starting point for the implementation of 3D parametric models. With this methodology, information should be displayed three-dimensionally and modified in a simplified mode compared to the traditional workflow. Starting from the specific step of the building process analysed, the BIM model could be approached and developed in different ways (Barbero, Del Giudice, & Manzone, 2018). For these reasons, it is essential to analyse the workflow and rules necessary for the proper realization of multidisciplinary BIM database. In this way, an operational update of drawings, time and cost estimation can be made from the information in the 3D building geometry (Thomassen, 2011), allowing to make information accessible and retractable continuously.

As discussed in the methodology standardization chapter, the definition of the best worksharing workflow is based on the principal factors that influence the modelling approach, and, during the research activities, two different ways have been investigated. **Integrated** and **federated model** present different characteristics concerning the modelling activities and the choice between these two different solutions affects the availability of data accessible by the actors involved (Barbero, Del Giudice, & Manzone, 2018). In this scenario, the first strategy is based on a unique database managed with worksets tool, as visible in Figure 42. The second one, instead, is based on different single models which could be linked in a unique coordination model, joining all the different disciplines (Figure 43). For the illustrated analysis, during the research activity, a specific study has been done, implementing both strategies in order to develop the proper consolidated model through visualization and simulation tools, checking the planning of maintenance activities. So, both approaches have been selected to explore and study collaborative workflows and interexchange between stakeholders. These activities have been carried out with several tests on some different BIM models related to a portion of the stadium connected to the lighting systems, which represent a significant part of every single discipline involved in the project.

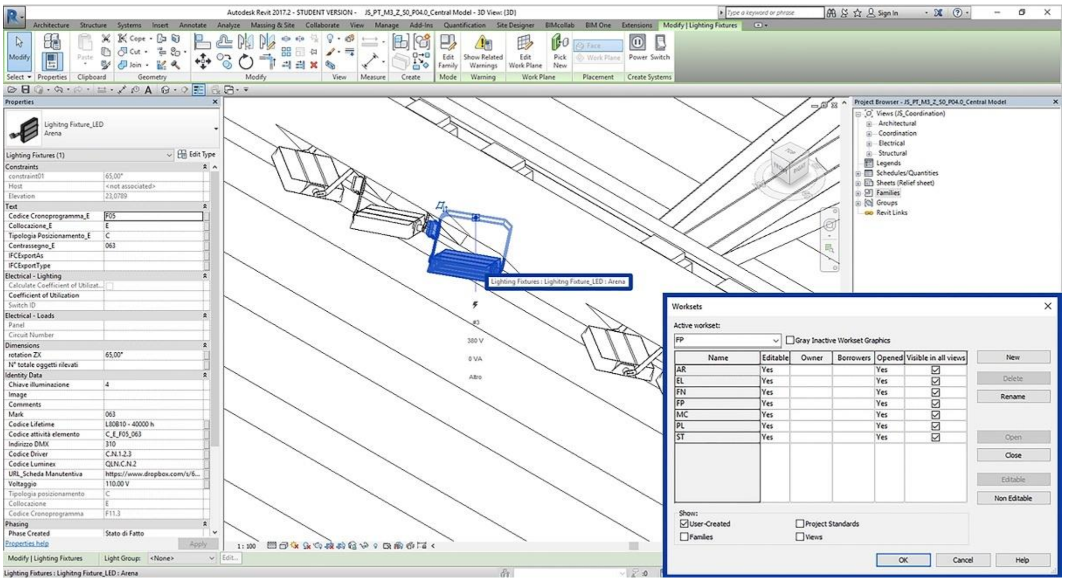


Figure 42 – Axonometric view of the Integrated model tested (Barbero, Del Giudice, & Manzone, 2018)

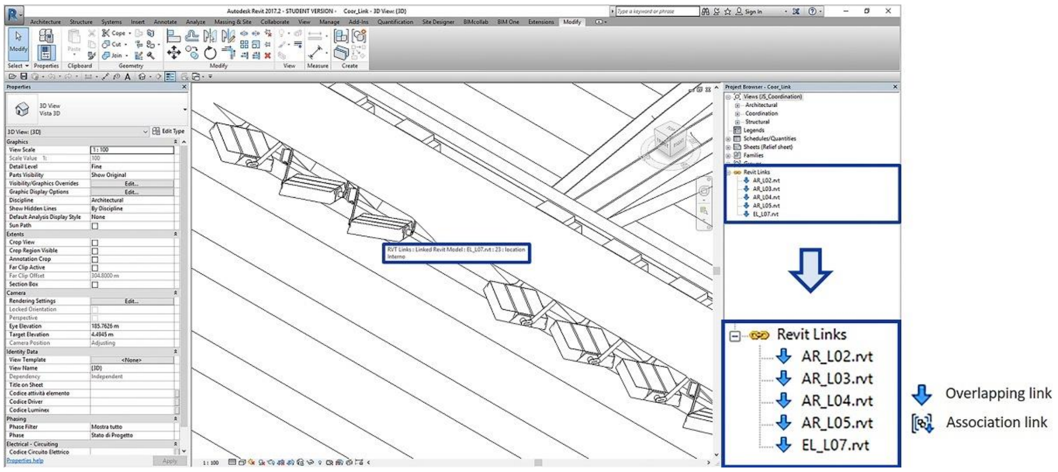


Figure 43 – Axonometric view of the Federated model tested (Barbero, Del Giudice, & Manzone, 2018)

Table 8 summarizes and explains the identified **features for the assessment** of these two strategies. Their flexibility has been analysed considering activities like model implementation, viewing, reporting and system administration. In order to compare the integrated and federated approach, a score has been assigned to each feature (1 = coarse, 2 = medium, 3 = high), developing a synthetic matrix able to be used as a BIM method tool for the identification of the better solution in function of the owner goals. Each factor has been evaluated considering the effort on geometry generation, connected to worksharing, and the data employment during the operational step related to the data sharing topic. Concluded this activity, an evaluation rank has been implemented to obtain a hierarchy based on each level of importance, in function of the modelling techniques (Barbero, Del Giudice, & Manzone, 2018). First of all, each characteristic has been evaluated investigating its usage in both integrated and federated models assigning a Yes/No value, considering the operating application during the modelling activities. In this way, comparing only the total amount of Yes value with the No one, the decision should be oriented on the integrated model, but it may be wrong if compared with the model's goals and the corresponding value. For this reason, the evaluation carried out has been developed with an adding level of importance connected to this aspect (Barbero, Del Giudice, & Manzone, 2018).

Table 8 - List of project features with Yes/No assigned values and List of assigned effort value (Barbero, Del Giudice, & Manzone, 2018)

n.	Features	Integrated Model	Value	Federated Model	Value
1	Objects	YES	1	YES	1
2	Object interaction	YES	2	NO	1
3	Embedded schedules	YES	3	NO	2
4	Reference level	YES	1	YES	1
5	Object editing	YES	2	YES	1
6	Plant systems	YES	3	YES	2
7	Host	YES	3	YES	1
8	Schedule	YES	1	YES	1
9	Reliability	YES	1	YES	1
10	Clash (Revit)	YES	2	NO	1
11	Clash (NWD)	YES	1	YES	3
12	Small File size	NO	1	YES	3
13	Inter-exchange response	YES	1	YES	3
14	FM synchronization	YES	2	YES	1
15	Database upgrade	YES	3	YES	2
16	File number (>1)	NO	2	YES	1
17	Shared model number (>1)	NO	2	YES	1
18	Use of model (by supplier)	NO	1	YES	3
19	Facility with VR	YES	2	NO	1
20	nD application	YES	1	YES	1

So, the identified features have been implemented assigning a percentage value able to enhance their characteristics, considering two different phases of the building process: the operation step which regards the BIM model implementation and the consolidated one, related to their management (Table 9).

Table 9 – List of assigned parameters value related to creation and operation steps (Barbero, Del Giudice, & Manzone, 2018)

n.	Features	Value creation %	Value operation %
1	Objects	0,25	0
2	Object interaction	0,5	0,5
3	Embedded schedules	0,25	0,5
4	Reference level	0	0,25
5	Object editing	0,5	0,25
6	Plant systems	0,25	0,75
7	Host	0,5	0,25
8	Schedule	0,25	0,5
9	Reliability	0,25	0,75
10	Clash (Revit)	0,5	0,25
11	Clash (NWD)	0,25	0,5
12	Small File size	0,5	1
13	Inter-exchange response	0,5	1
14	FM synchronization	0,25	1
15	Database upgrade	0,5	1
16	File number (>1)	0,75	0,75
17	Shared model number (>1)	0,25	0,25
18	Use of model (by supplier)	0,75	1
19	Facility with VR	0,25	0,5
20	nD application	0,25	0,5

For example, the characteristic n. 18 highlights how the adoption of the federated model enables the simultaneous use of models without synchronization issues, considering the CDE workflow. However, this difference is mitigated by the assigned score related to both creation and operation steps, according to the project usage. It is essential to highlight how assigned scores take into account the goodness of each modelling way, highlighting their characteristic and weaknesses. The achievement of model flexibility purposes could change in function of the chosen tools and the project's aims (Barbero, Del Giudice, & Manzone, 2018).

The comparative matrix illustrated in Table 8 could be considered the first result achieved. It provides different outputs concerning the importance of each feature which could modify their value depending on the project objectives, as shown in Table 9. Connected to these considerations, the two spider charts in Figure 44 highlight the main differences between these two model strategies, showing the characteristics with the highest score. Their comparison shows how some features of the operation step, as characteristics number 18, 15, 13, 12, achieve the highest evaluation score, while in the creation step the highest score is 2,25. The study carried out highlights that the implementation step is influenced mainly by the use of a proper BIM workflow (Barbero, Del Giudice, & Manzone, 2018).

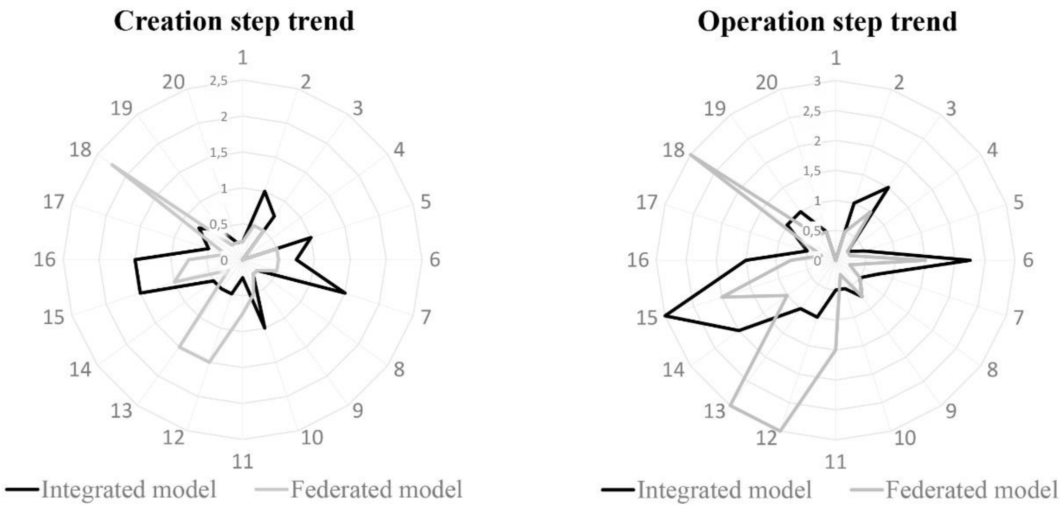


Figure 44 - Spider chart of the creation step (left) and Spider chart of the operation step (right) (Barbero, Del Giudice, & Manzone, 2018)

In these terms, considering the relevance of feature 18 as one of the main factors of the research activity, the best solution provided by the tests carried out is the federated strategy. While the integrated model allows a simpler data update, the federated one is more powerful with operative actors. In this way, they could work in a different way using various models maintaining the small size of files (feature 12) and, also for these reasons, this kind of worksharing has been developed for the research project (Barbero, Del Giudice, & Manzone, 2018). The implementation of this kind of model for maintenance step implies the adoption of the same inter-exchange model strategy also in the creation phase, considering the possible issues illustrated in Table 8. The overall score assigned to these strategies is quite similar, showing that the analytical area is the same, while the graphical databases achieved several specific peaks. Moreover, the federated approach enables the employment of particular discipline models that belong to different tools, generating a replicable methodological approach through open BIM languages (Barbero, Del Giudice, & Manzone, 2018). In conclusion, the testing activities carried out allow to illustrate how worksharing and data management represent one of the most important challenges of the AEC industry that is going to innovate itself using the BIM approach as an Information and Communication Technology (ICT) methodology.

Connected to this topic, the **model framework** and the corresponding ways to extract its data are an essential feature for the proper implementation of a BIM project and its use in the FM field. So, the main point lies in the definition of the better mode to breakdown the work and the models. This choice should be taken carefully before starting the modelling activities because subsequent variations may be difficult and could generate some data loss. The developed structure should be considered not only for the implementation phase but also for the management and updating steps to be effective. Regarding this matter, there are no codified rules and, for this reason, it is possible to implement several strategies, according to the complexity of the structure analysed and the corresponding objectives (Barbero, Ugliotti, & Del Giudice, 2019). For the case study, the federated model workflow has been chosen and structured with two or three different **hierarchical levels** in function of the specific discipline or sub-discipline. This difference is based on the way the discipline is developed: as can be seen concerning the WBS, if it has mainly horizontal development, a model has been developed for each level/floor. On the other side, for disciplines with a mostly vertical trend, it has been decided to proceed with a unique multi-level model. Figure 45 shows a general view of the operative federated BIM workflow develops for the research activity. In detail, the discipline and sub-discipline involved with the operation and coordination models are: Architectural (AR), Structural (ST), Furniture (FN), Electrical (EL), Plumbing (PL), Ventilation (VE), Thermal (TE), Fire Protection (FP), Mechanical (MC) as the model of system sources. So, it could be essential to investigate the disaggregation of the project activities defined by the WBS and the WBE, explaining the aims of every single discipline and relative information, to establish roles and competences during the creation step of the BIM models (Barbero, Ugliotti, & Del Giudice, 2019).

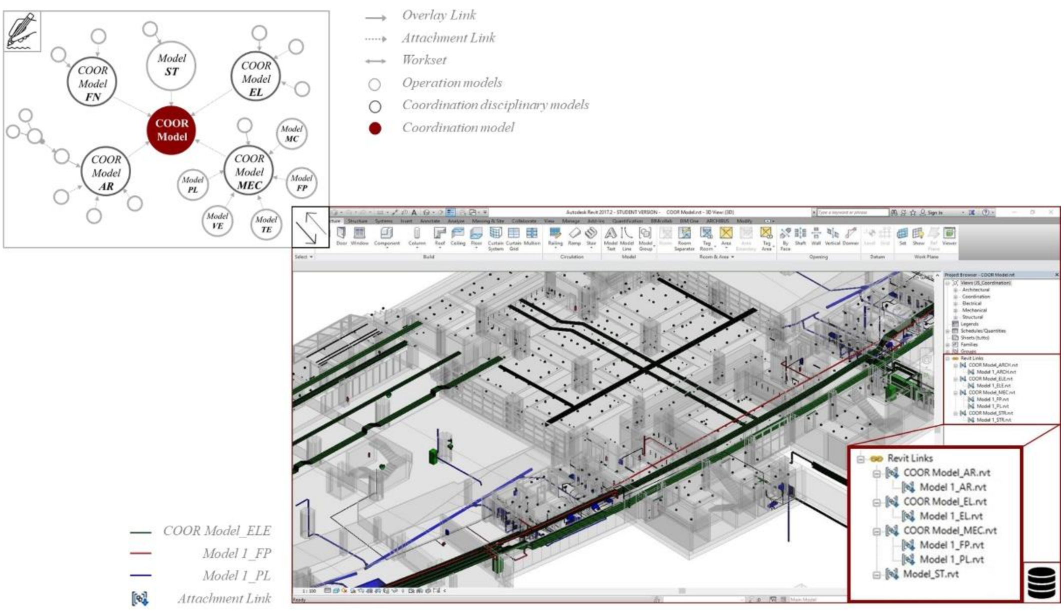


Figure 45 – Example of the federated BIM workflow of the case study (Barbero, Ugliotti, & Del Giudice, 2019)

Associated to the worksharing methods illustrated for the modelling step, it has been necessary to establish a series of preparatory activities required to manage the **coordination of** the various **actors** involved. This aspect has been translated into weekly coordination meetings aimed at jointly evaluating the progress of activities and the resolution of any multidisciplinary aspects. Operatively, as illustrated in the modelling rules, AR and ST models represent the starting point for the spaces' definition, necessary for the correct implementation of MEP models. These meetings also facilitated the communication about operating procedures and the confrontation on the different dispositions contained in the BIM guidelines. The topics discussed at each meeting have been summarised in operational reports shared between all the actors.

For the management of geometric and alphanumeric aspects strictly related to monodisciplinary features, the cloud tool named Trello has been used, allowing the creation of shared notice boards. Within each of them, subdivided by discipline, the different notes divided by level and type of application have been inserted. For each note, through specific labels, questions and the following steps for receiving and closing the issue (Figure 46) could be managed.

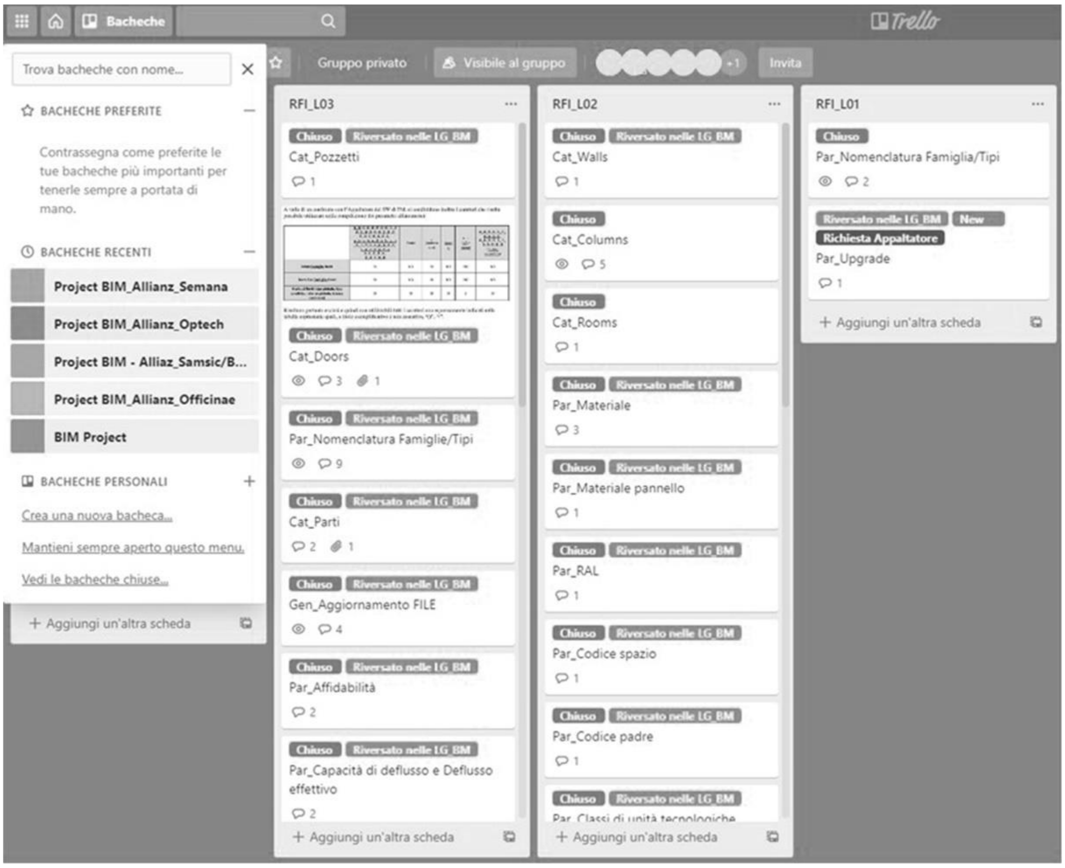


Figure 46 – Example of the cloud tool Trello for the operative coordination of each discipline

On the other side, in order to facilitate the management of link models for each discipline, a shared coordination matrix has been developed and completed overtime by each actor during the realization phase, thanks to its sharing in the

Trello tool. In this way, it has been always possible to view the interaction between the different disciplines, implementing the effectiveness of the coordination itself (Table 10).

Table 10 – Coordination matrix of link models for the case study

Models \ Link models	AR L01	AR L02	AR L03	AR L04	AR L05	AR L06	AR L07	AR LCT	EL L01	EL L02	EL L03	EL L04	EL L05	EL L06	EL L07	EL L08	EL Catino	ST	FN1	FN2	FN3	FN4	FN5	FN6	FP	VE	TE	MC	PL
AR L01																		■	■										
AR L02																		■		■									
AR L03																		■			■								
AR L04																		■				■							
AR L05																		■					■						
AR L06																		■						■					
AR L07																		■											
AR LCT																		■											
EL L01	■							■										■											
EL L02		■																■											
EL L03			■	■														■											
EL L04				■				■										■											
EL L05					■			■										■											
EL L06						■												■											
EL L07							■											■											
EL L08																		■											
EL Catino								■										■											
ST																		■											
FN1	■																	■											
FN2		■																■											
FN3			■															■											
FN4				■														■											
FN5					■													■											
FN6						■												■											
FP	■	■	■	■	■	■	■											■											
VE	■	■	■	■	■	■	■											■											
TE	■	■	■	■	■	■	■											■											
MC			■	■														■											
PL	■	■	■	■	■	■												■											

4.5 Data Sharing

As illustrated in the methodological section, the concept of Data Sharing is based on the creation of a **common environment** for sharing building documentation, structured and named taking into account the Italian regulation's disposition (UNI 11337-5, 2017) and the international references to which it refers (BS 1192, 2007). This tool should be accessible to all actors in the process, allowing the sharing of the required file formats within BIM procurement documentation. Starting from the indications given on the structure of the CI, the BIM guidelines developed during the research activity contain a section on data exchange formats. It is divided between the data supply formats delivered by the owner and the data formats produced by the individual supplier. Table 11 illustrates, for example, what is required for this research activity concerning the data formats delivered by the owner.

Table 11 – Example of the exchange data format insert in the developed BIM guidelines

Exchange data format		
Document	**Exchange format**	**Note**
As-built documentation	.dwg / .pdf / .docx / .xlsx	The supplier should verify the most updated version, which will be subject to the owner validation.
BIM models	.rvt	-
BIM guidelines	.pdf	-

Annexes of guidelines	.xlsx / .docx / .ppt	-
Shared parameters	.txt	-
Template file	.rte	-
Material's libraries	.adsklib	-
Families libraries	.rfa	-

For the research activity, an ACDat environment has been structured with its specific folder, defined on needs to be pursued. As shown in Table 12, the access rules and actions allowed for each actor have been described for each folder. In detail, the structure carried out includes:

- **Work In Progress (L0)**: folder used by the various authorised actors to carry out the operational activities related to the project implementation. It is stored in their own local spaces and therefore does not appear within the structure defined for the ACDat.
- **Shared (L1)**: folder with this specific articulation:
  - sub-folder "J": As-built project documentation delivered by the owner to the suppliers;
  - sub-folder "PT": containing the existing architectural BIM models shared to provide a basis for their modelling activities of suppliers;
  - sub-folder "A1–A5": containing the BIM models and the files delivered by the suppliers for the update steps to the actor responsible of the verification and coordination activities, as well as any As-built documentation shared and made available by the supplier;
  - sub-folder "Modelli_COND": structured with a folder for each supplier, in which BIM models are uploaded for the interdisciplinary coordination and shared with the other actors involved, starting from their request.
- **Published (L2)**: folder with this specific articulation:
  - sub-folder "Modelli_VER": containing the BIM models uploaded by each supplier, completed for the specific progress step considered and suitable for verification and coordination activities by the responsible actor. It also contains the folder of geometric and alphanumeric validation results shared by the responsible actors. This folder also includes the uploading of the BIM models submitted as the archive version, after the validation activities have been implemented;
  - sub-folder "Capitolati": BIM Guidelines, Annexes to the Guidelines and other useful documents for the model implementation;
  - sub-folder "As-built": As-built documentation verified by the supplier and submitted to the owner as the most updated and reliable version.
- **Archive (L3)**: folder whose content is the archive version and it corresponds to the documents which will be connected to the IWMS platform. In detail, this folder contains:

- sub-folder “Modelli_VER”: BIM models verified by the responsible actor and validated by the owner;
- sub-folder “Capitolati”: is a copy of the same name folder contained in the L2 section, validated by the owner;
- sub-folder “As-built”: As-Built documentation validated by the owner.

Table 12 – ACDat structure of the research project

ACDat structure				
Folder	Sub-folder 1	Sub-folder 2	Sub-folder 3	Access
L1	J	As-Built	DB	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download)* A2 *(read/download)* A3 *(read/download)* A4 *(read/download)* A5 *(read/download)*
			Disegni	
		Immagini	-	
		Modelli	-	
	PT	Modelli_AR	-	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download)* A2 *(read/download)* A3 *(read/download)* A4 *(read/download)* A5 *(read/download)*
		Modelli_EL	-	
		Modelli_MC	-	
	A1	Modelli	Folders for each single level	J *(read/download and write)* A1 *(read/download and write)* PT *(read/download and write)*
		As-Built	DB	
			Disegni	
	A2	Modelli	Folders for each single level	J *(read/download and write)* A2 *(read/download and write)* PT *(read/download and write)*
		As-Built	DB	
			Disegni	
	A3	Modelli	Folders for each single level	J *(read/download and write)* A3 *(read/download and write)* PT *(read/download and write)*
		As-Built	DB	
			Disegni	
	A4	Modelli	Folders for single sub-discipline and single level	J *(read/download and write)* A4 *(read/download and write)* PT *(read/download and write)*
		As-Built	DB	
			Disegni	
	A5	Modelli	Folders for each single level	J *(read/download and write)* A5 *(read/download and write)* PT *(read/download and write)*
		As-Built	DB	
			Disegni	

	Modelli_ COND	A1	Folders for each single level	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download and write)* A2 *(read/download)* A3 *(read/download)* A4 *(read/download)* A5 *(read/download)*
		A2	Folders for each single level	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download)* A2 *(read/download and write)* A3 *(read/download)* A4 *(read/download)* A5 *(read/download)*
		A3	Folders for each single level	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download)* A2 *(read/download)* A3 *(read/download and write)* A4 *(read/download)* A5 *(read/download)*
		A4	Folders for single sub-discipline and single level: FP – Fire Protection MC – Sources PL – Plumbing TE – Thermal VE – Ventilation	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download)* A2 *(read/download)* A3 *(read/download)* A4 *(read/download and write)* A5 *(read/download)*
		A5	-	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download)* A2 *(read/download)* A3 *(read/download)* A4 *(read/download)* A5 *(read/download and write)*
L2	Modelli_ VER	A1	Folders for each level and validations folder	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download and write)*
		A2	Folders for each level and validations folder	J *(read/download and write)* PT *(read/download and write)*

				A2 *(read/download and write)*
		A3	Folders for each level and validations folder	J *(read/download and write)* PT *(read/download and write)* A3 *(read/download and write)*
		A4	Folders for single sub-discipline and single level: FP – Fire Protection MC – Sources PL – Plumbing TE – Thermal VE – Ventilation and validation folder	J *(read/download and write)* PT *(read/download and write)* A4 *(read/download and write)*
		A5	Folders for each level and validations folder	J *(read/download and write)* PT *(read/download and write)* A5 *(read/download and write)*
	Capitolati	Linee_Guida	-	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download)* A2 *(read/download)* A3 *(read/download)* A4 *(read/download)* A5 *(read/download)*
		Allegati	Folders for each shared version of the documentation	
	As-Built	DB	-	J *(read/download and write)* PT *(read/download and write)* A1 *(read/download and write)* A2 *(read/download and write)* A3 *(read/download and write)* A4 *(read/download and write)* A5 *(read/download and write)*
		Disegni	-	
L3	Modelli_ VER	A1	Folders for each single level	J *(read/download and write)*
		A2	Folders for each single level	
		A3	Folders for each single level	
		A4	Folders for single sub-discipline and single level: FP – Fire Protection MC – Sources PL – Plumbing TE – Thermal VE – Ventilation	
		A5	Folders for each single level	
		FEDERATO	Folders for each single level	

	As-Built	DB	-	J *(read/download and write)*
		Disegni		
	Capitolati	Linee_Guida	-	J *(read/download and write)*
		Allegati	-	

After a critical analysis of the tool used during the research activity, it is necessary to point out that the structured sharing environment did not allow actors, except for the owner, to perform actions directly in the cloud environment, but only to upload and download files. Moreover, this tool did not allow the management of operational annotations directly in shared modality or of the different versions of the models developed by the single actors in the cloud, enabling only file storage. One of the future improvements of the whole process is, therefore, the employment of a BIM oriented tool that allows the structuring of an ACDat able to maximize the benefits of data sharing.

For this reason, it was necessary to manage and coordinate the weekly sharing uploads of the different disciplinary models through specific and detailed file naming rules. The **denomination rules** developed for the research project have been based, as mentioned above, on the international reference standard (BS 1192, 2007), implemented with specific aspects related to the peculiarities of the case study (Table 13) and the owner portfolio. The fields identified are not mandatory for all files, given the wide range of the document type to be named, but it is necessary to use them when suitable for the analysed element, such as the REV field for BIM models. In detail, for the denomination of this type of file, it is necessary to insert the reference to the single advancement step, in order to manage the implementation of multidisciplinary geometric and alphanumeric observations, through the uploading into the ACDat. The identified advancement steps carried out for the case study are:

- **P01** = Step 1 aimed at geometrical validation, formal alphanumerical validation Step 1 related to the essential parameters for integration with the IWMS platform and multidisciplinary geometric validation activities.
- **P02** = Step 2 aimed at formal alphanumeric validation Step 2, substantial alphanumeric and multidisciplinary alphanumeric validation.

Table 13 – File denomination rules of the case study

Acronym	Description
SITE	Identifier of the site name (for the complete list of sites' nomenclatures refer to Annex 02). **STA**: Allianz Stadium **MUS**: Museo **MGS**: Megastore **JHQ**: JHQ **JTC**: Juventus Training Center
BUILDING	Identifier of the building name (for the complete list of sites' nomenclatures refer to Annex 02). **ST**: Stadio **AR**: Autorimessa P7-P9 **AE**: Aree Esterne **VF**: Villaggio Fornitori

	…
ORIG	The acronym of the file author. **J**: Owner of the project **PT**: Politecnico di Torino **A1**: Supplier 1 - Architectural **A2**: Supplier 2 - Furniture **A3**: Supplier 3 - Electrical **A4**: Supplier 4 - Mechanical **A5:** Supplier 5 - Structural
TYPE	The type and kind of information contained in the file. **DR**: Drawing **M2**: Two-dimensional model **M3**: Three-dimensional model **VS**: Visualization **SC**: Schedule or table **SP**: Specification **CO:** Coordination **IT**: Interoperability
DISCIPLINE	The information discipline contained in the file **AR:** Architectural **EL:** Electrical **FN:** Furniture **FP:** Fire Protection **GN:** Generic **MC:** Mechanical (as the model of system sources) **PL:** Plumbing **VE:** Ventilation **TE:** Thermal **ST:** Structural
CLASSIF	The file classification inside the ACDat **L0**: Work In Progress **L1**: Shared **L2**: Published **L3**: Archive
REV	It represents the revision of the file corresponding to the progress step of the model implementation (reference to Annex 05). **P01**: Step 1 **P02**: Step 2
SEQU	It is a progressive that represents the number of controls carried out by the responsible actor, always belonging to the same step. **.0** **.1** **.2** **.3** …
DESCRIP	It contains detailed identification of the file contents (maximum 10 characters). In the case of models organised by level: **L01** = Level 1 **L02** = Level 2 **L03** = Level 3 **…** Example: "STA_ST_PT_M3_AR_L1_P01.0_L01" represent the denomination of the 3D architectural model of level 1 of the stadium, elaborated by Politecnico di Torino.

4.6 Geometric content definition

Once defined the objective to be pursued, the use of the As-is model for FM and the data sharing and worksharing methods to be adopted, the proposed methodological standardization focuses on the actual **information content** of the models. Starting from the existing documentation analysis, the first step for their proper setting is represented by the definition of the WBS. It allows identifying the structure of each parametric model according to the discipline analysed.

The first example of **WBS** used for the analysis carried out with the owner is shown in Figure 47: the aim is to identify the levels of structuring required for each discipline and the aspects necessary for a correct organization. These last ones, as visible in the graph below, belong to the proposed standardization.

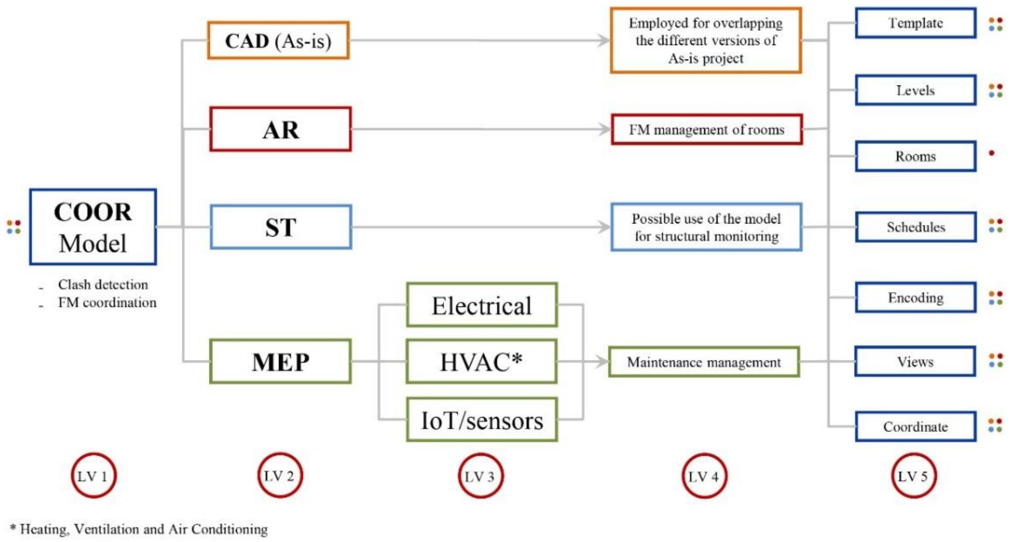


Figure 47 – The WBS definition of the research project.

In the detail, for the case study, the federated structure investigated is based on the integration of different disciplines that enable the definition of the building digitalization and the work breakdown established by the various players involved. The core of this structure is the **coordination model** which collect all discipline models (Figure 48). The five discipline of every single supplier, as illustrated in Figure 41 and Figure 45, represent the first level of breakdown, characterised by specific coordination disciplinary models or single discipline model like the structural one. This last one contains all the structural elements of the stadium, including all the roof beams and the "Pennoni". Subsequently, the second hierarchical level is represented by **operational models** where files are further divided to ensure greater manageability of use and to control the size in function of the specific needs of each actor. The main logic is a subdivision by plan where possible, like for example the architectural, furniture and electrical one. Besides, linked to the AR coordination model, there is also the model related to the stadium bowl, with all the relative seats that belong to it. For AR and ST models, the logic of subdivision of the elements by level must take place based on the rooms, as building space, to which they belong and which they therefore delineate. For their realization, the horizontal elements that represent an additional discriminating factor for their subdivision should also be examined. Some exceptions to this logic are the AR and ST columns, the T walls against the ground, the sub-gradation walls that delimit the basin and the relative partitions for which level modelling is planned in order to guarantee a contextualisation of the rooms once the models have been imported into the IWMS platform. In the case of Mechanical System (MEC), the discipline has been divided into different sub-disciplines, one for each main kind of system, allowing the implementation of single multi-level models. In this way, due to the main vertical trend of elements, it is possible to avoid several kinds of problems. The identified sub-discipline results: PL, VE, TE, FP and MC, which contains, in detail, all the system sources of the stadium. In detail, these are: heating and cooling power station, north-west and south-west sub-central, heat exchangers, waterpower station and fire-fighting centre. In the proposed workflow, a specific As-is CAD model has been associated with each coordination model, to verify the development of the model.

The file connection could be created through the set of two different kinds of link: **Attachment** or **Overlay**[21]. In this way, it is possible to make data of other different models available to all the actors involved without their replication in the parametric modelling environments, increasing software and hardware performance at the same time. The federated structure also enables the coordination of all the disciplinary models and their management during the development activities and the implementation of the verification's and coordination's process. Nevertheless, the proposed structure has some limitations like the lack of a unique object identification for elements that belong to different models and the hierarchy definition of systems divided into several models. These issues, for the research project, have been overcome by introducing alphanumeric parameters, as visible in the section related to Data Integration (Barbero, Ugliotti, & Del Giudice, 2019).

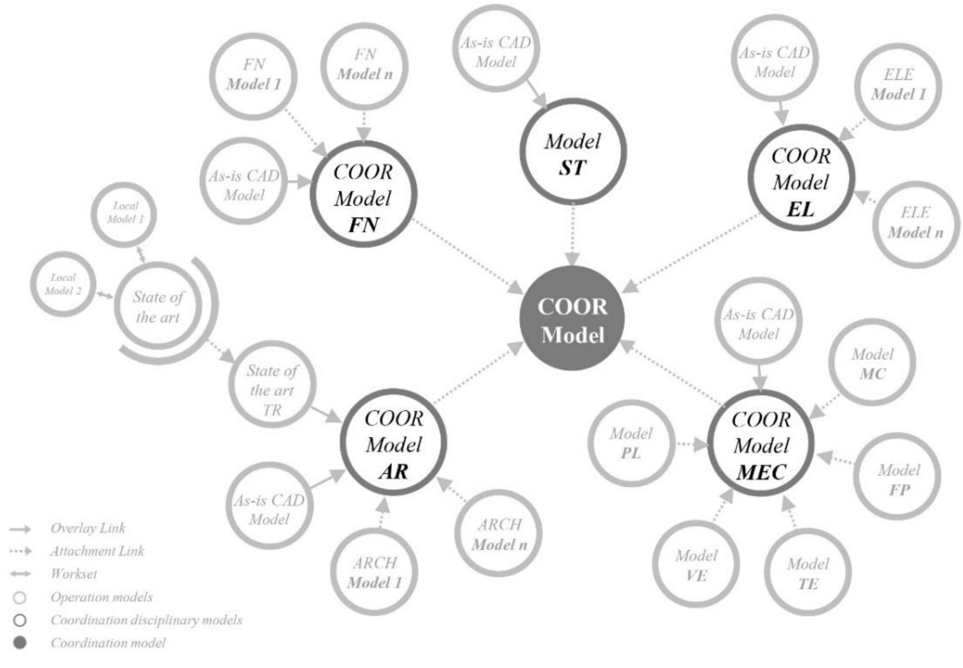


Figure 48 – Project BIM workflow: federated model

[21] The definition of the link type allow to manage the nested link. "*The link become nested when a model, that contains other linked models, is linked*". For this activity, the type Overlay "*does not load nested models into the host model, so they do not display in the project*" while the Attachement one "*loads nested linked models in the host model and displays them in the project*". Definitions extracted from from the Autodesk Knowledge Network website: https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/CloudHelp/cloudhelp/2016/ENU/Revit-Collaborate/files/GUID-F8929030-3D77-4F7B-A01F-3C88C600466E-htm.html (last consultation on the 19th of November, 2020).

Once the general building breakdown has been defined, for each discipline, it is necessary to proceed with the definition of the **WBE**. This allows the objects' identification that should be included in a model, with a specific **LOG** and **LOI** value assigned to them. Figure 49 shows, for example, an extract from the WBE developed for the AR discipline. As illustrated in the previous chapter, the definition of the LOD value for the entire model is not exhaustive. For this reason, the identification of detail characteristic for every single object is needed to control the reliability, granularity and use of the information associated to them. Their definition should be done taking into account the objectives, documentation and professional and economic resources available (Barbero, Ugliotti, & Del Giudice, 2019). This consideration is closely connected to the concept of **Level of Information Need** (UNI EN ISO 19650-1, 2019). In this way, the definition of standards and rules necessary for the implementation of BIM models and objects could be integrated into the BIM guidelines, from an operational point of view (Barbero, Ugliotti, & Del Giudice, 2019).

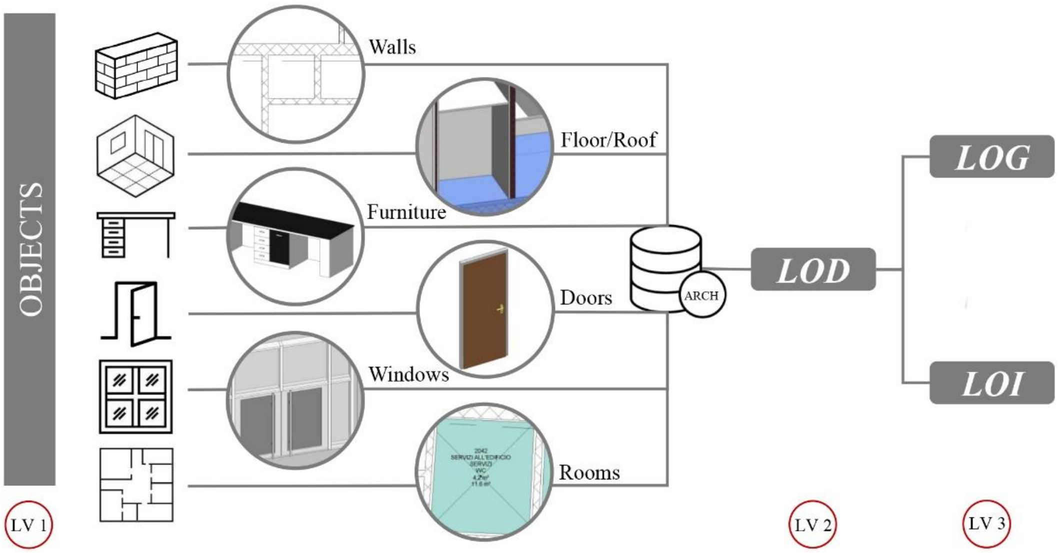


Figure 49 – The WBE definition for the architectural discipline of the case study

The definition of the LOG and LOI value starting from the analysis of the existing international standards, as summarized in Table 5. For FM objectives, the description of LOG and LOI has been implemented separately for each object, allowing possible future implementations linked to new goals. For this reason, each model element should be discussed and described before the modelling step, to allow its proper implementation by each actor of the process. The innovative definition of the meaning of LOD related to the model element developed for the case study is based on the American Institute of Architects (AIA) (AIA Document G202, 2015) protocol and the Italian regulation (UNI 11337-6, 2017) reference definition. While 200 rates defined by AIA explains each model element represented by generic graphical contents, with alphanumerical data as optional value, C rate proposed by UNI integrates this definition illustrating every object as "defined element" with proper alphanumerical information useful for the project aims. Anyway, C rate regards new buildings, while the case study is an existing one. For this reason, the number of attributes which define the LOI value of model objects in the research case study is greater than the geometric contents proposed by the two regulations, prescribed with LOG definition. In this context, the added value of "+" allows the description of model elements with geometrical characteristics typical of a LOG C suitable for the project aims and alphanumerical attributes that usually belong to LOI F and G, as defined by the owner's needs (Barbero, Ugliotti, & Del Giudice, 2019). For example, wall elements are represented graphically in a simplified way, taking into account the specific material finishes, while information contents deep in detail explicating several characteristics through alphanumeric code as visible in Figure 50 (i.e. building classification system, wall typology, material codes and the value of reliability) (Barbero, Ugliotti, & Del Giudice, 2019). At the same time, as another example, lighting fixtures are represented with only the geometry that allows the spatial size to be identified. About the alphanumeric content, it is enriched with different parameters which enable the identification of all technical and maintenance features of the elements (Figure 51).

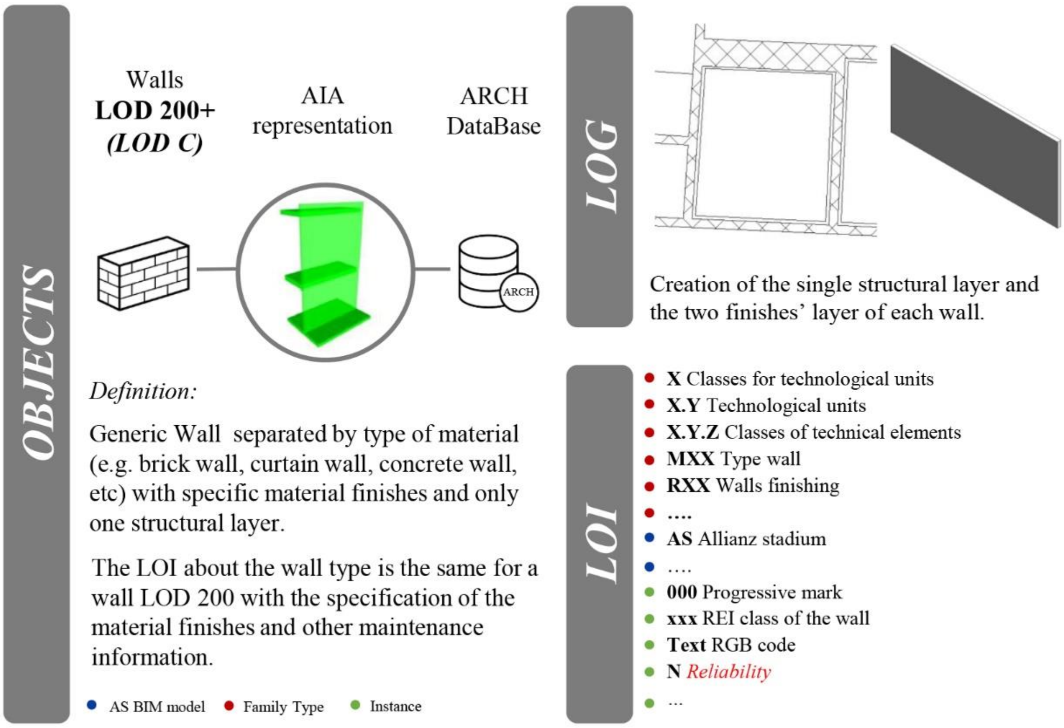


Figure 50 – The definition of LOD 200+ for Walls (Barbero, Ugliotti, & Del Giudice, 2019)

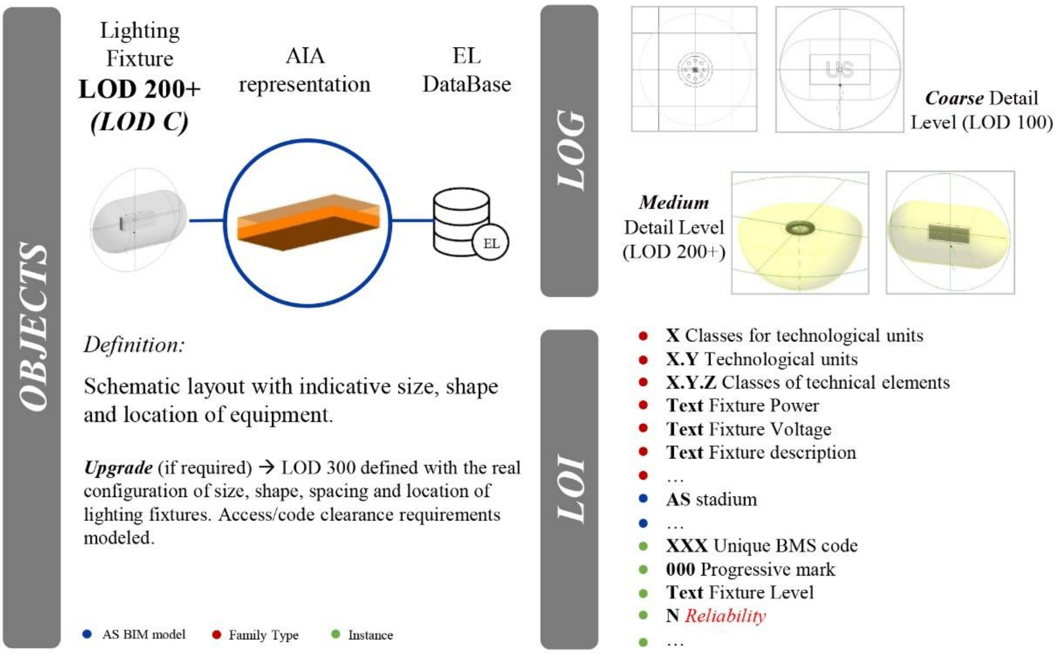


Figure 51 – The definition of LOD 200+ for Lighting Fixtures

As shown in the images above, the concept of the information **reliability** related to an existing element is particularly important and it has been illustrated in the chapter on the survey activities carried out from the analysis of As-built documentation. The meaning of this parameter varies depending on the type of category and component analysed, as summarised in Table 14.

Table 14 – Definition of the parameter Reliability for different kind of components, defined in the BIM guidelines

Parameter group	Parameter	Note	Description
GN	Reliability	Definition for all kind of components, unless otherwise specified	*1 = Element detected in the field and/or belonging to recognizable typological/modular schemes.* *2 = NOT detected, not belonging to a typological/modular pattern modelled according to the As-built* *3 = Assumed on the basis of documents other than design As-built, not detected and not belonging to one of the previous cases.*
		Room definition	*1 = Detected* *2 = NOT detected*
		Walls definition	*1 = Wall thickness detected* *2 = Wall thickness NOT detected (defined on the basis of As-built)* *3 = Wall thickness NOT detected and modified to respect the geometric dimensions of the rooms*
		Manhole definition	*1 = Objects verified at the level of type, spatial location, depth and dimensions* *2 = Objects for which the spatial location is fixed by As-built documents, the depth has been detected or standardised while the size of the manhole cover has been verified.* *3 = Objects not included in the two previous cases*
		Parts definition	*These objects maintain the definition of the parameter Reliability of the original wall object*

The concept of LOD 200+, considered as a **heterogeneous LOD**, has been applied to the whole case study. Figure 52 underlines the complexity of the developed model and the resulting evaluation of the proper LOD+ for each object such as wall, lighting fixtures and seats. Besides, within this definition, the LOG of each parametric element could be upgraded developing new project objectives like, for example, some application concerning Data Visualization (Barbero, Ugliotti, & Del Giudice, 2019). For this reason, as shown in Figure 52, three different levels of geometric detail for each object have been defined: i) the low one, represented by 2D symbology when possible; ii) the medium one, consisting of simplified geometries that allow the definition of the spatial envelope of the object; iii) the high value, which presents the geometries with a detailed level of geometry, as illustrated about the "upgrade" parameter. This topic will be discussed in more detail in the Data Visualization section. Therefore, heterogeneous LOD definition is considered a result applicable to the entire model.

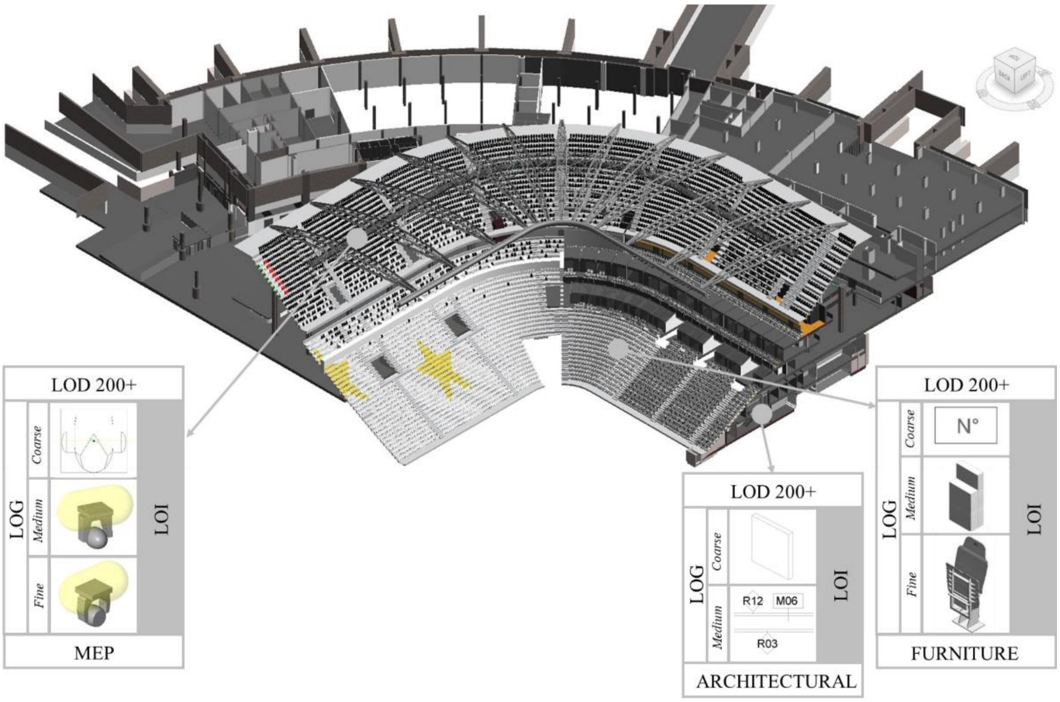


Figure 52 – The heterogeneous LOD for the federated BIM model (Barbero, Ugliotti, & Del Giudice, 2019)

This disposition has been summarised in specific disciplinary sheets contained in Annex 03 of the BIM guidelines in order to allow its correct implementation by the several actors involved in the process, and they are recapitulated in Appendix B of this thesis. As an example of the work carried out, the sheets relating to the AR, EL and PL disciplines are reported. Inside these sheets are also summarized the adopted graphic conventions for the representation of 2D symbology and alphanumeric parameters to be associated with every single created component. The definition of these aspects within the elaborated guidelines is essential in order to allow individual suppliers the opportunity to properly organise their activities for the implementation of families and models.

In addition to the graphical convention, specific **modelling rules** should be defined: they are elaborated from the considerations carried out during the research activity and, at the same time, allow to make the defined activities operational. In detail, together with the owner, it has been decided to include the multidisciplinary rules within the BIM guidelines, while the individual disciplinary dispositions, which are more precise, have been summarised in Annex 04. The first ones have an impact on the management aspects of model coordination and structuring activities and belong to the definition of methodological standardization. The second ones, on the other hand, concern more detailed operational choices that may be carried out in different ways. Nevertheless, these have been reported in the documentation developed as essential to ensure uniform and standardized methodological applications on future other buildings of the owner. The modelling rules included in the guidelines are:

- All elements have to be created in the "Status of fact" phase and should be associated only with a **coordination level**, adequately defined within the template file. For this purpose, to correctly determine the level to which an object belongs, it is necessary to follow this rule: an object is linked to the level from which it is operationally accessed to perform the related maintenance activities.
- The modelling of the wall entities should be carried out using the corresponding system category, with **parts objects** activated within the specific 3D view of the common coordination discipline.
- The parametric families (.rfa) should be created as "**surface-based**" for all categories for which the modelling software allows it and which do not have a specific host for their placement preparatory for correct use. Their insertion should be done to have a proper population of the host parameter. The reference surface of the family should be identified during the modelling phase, since its impact on the corresponding structure, allowing the correct movement of objects during their insertion. An exception to this logic is represented by AR and ST families, used for the setting of the models acting as hosting, adequately linked in the elaborated model, according to the modalities illustrated in Figure 48. The models linked as reference surfaces for the placement of system objects should not be removed to preserve the correct population of the host field, but, in the case of shared updates, simply reloaded.

  During the research activities, the choice to model with host-based families has created some problems related to anomalies of the modelling software during the reloading of some AR models when the number of objects contained within them has increased significantly. Moreover, this choice has implied the coordination need to be always in advance with the AR and ST discipline respect to the others, for at least one level of the building. Indeed, another problem is related to the ID value of AR and ST objects: if it changes after the modelling connection of a system element, this one lost the correct population of the host field. For these reasons, system modelling should start as soon as the construction of the host objects is completed to keep their IDs unchanged, minimizing critical issues.
- Throughout the modelling of each family (.rfa) it is necessary to activate the "**Room calculation point**" if the category adopted supports this field. This point should be oriented in the modelling space to ensure that the object can be correctly recognized inside the room to which it belongs.
- In the case of components for which it is necessary to have the respective

dimensional parameters within the IWMS platform, these should be created from the corresponding **shared parameters** ensuring correct information integration. This requirement has been indicated in Annex 02.

- The attribution of the **material characteristic** should take place starting from the definition of its specific fields in Annex 02.1. The creation of the single material has to occur through the predisposition of the specific material library file (.adsklib), allowing its adoption within each model. Besides, the assignment of specific RGB value for all materials belonging to each element category has been defined, allowing a first organization and graphic subdivision of what has been developed.
- The modelling of the system objects should be carried out through the modelling of **MEP objects** equipped with a specific **connector** that allows system hierarchy. The discipline of each object is defined based on the breakdown indicated in the WBE. It also allows, together with Annex 02, the identification of the modelled components.

Strictly linked to the modelling rules, the definition of the **template file** for the integrated and standardized implementation of the different models by single suppliers is essential. This aspect, together with the implementation of the shared parameters file and the materials library, allows the adoption of a shared and standardised language. As illustrated by the Autodesk Knowledge Network, the creation of the Template file is essential for project performance. Consequently, one of the main objectives of the template is the definition of the Project Browser, composed of the project and schedule views necessary for querying and extrapolating information according to the established uses and objectives. As an example, for the research activity, a multidisciplinary template for the model set has been developed, following for its structure the federated organization shown in Figure 48. In detail, in the template file have been set:

- The **shared coordinates** of the project, which are necessary for the correct link activities of the different models during the monodisciplinary and multidisciplinary coordination activities.
- The set-up of the measurement reference **unit** for the models' implementation.
- The definition of project **levels**, necessary for integration with the IWMS platform (Table 15): as indicated in the modelling rules, this is an essential point because objects should be necessarily linked only to one of the coordination levels available. In this way, it is possible to keep the ID of individual levels unchanged and ready to a correct integration activity. Together with these, other operational levels have been created, in the same amount, with different heights that reflect the characteristic elevation of the existing CAD documents, from which operational plants have been generated.

Table 15 – Identification of the coordination level of the project

Floor views		
Discipline	**View name and level**	**Note**
Coordination	**L01** (ID: 133650) **LCT** (ID: 132424) **L02** (ID: 133973) **L03** (ID: 134154) **L04** (ID: 134429) **L05** (ID: 134659) **L06** (ID: 134846) **L07** (ID: 135245) **L08** (ID: 132425)	All objects' categories, in Show Parts view, and Rooms are visible. The corresponding altimetric heights of levels are: L01 = +0.00 LCT = +0.76 L02 = +3.50 L03 = +8.10 L04 = +12.10 L05 = +14.75 L06 = +18.55 L07 = +22.00 L08 = +31.90

- The **views** definition has been conducted through the identification of several plan views, disciplinary and coordination 3D views, disciplinary elevation views and two main section views, necessary for the research project. Each one has also been associated with a specific visualization range, essential for a correct geometry integration of the 2D representation inside the IWMS tool.
- The definition of the **schedule views** that contain, for each category and each discipline, the alphanumeric parameters that it is necessary to fill in. This views' denomination contains the discipline and the acronym of each category to which it belongs, as visible in Figure 53. The separation by discipline has been necessary due to the design choice to proceed with the creation of a single multidisciplinary template and the belonging of several categories to different disciplinary domains. This aspect is also essential for the definition of the information population rules. In fact, for the alphanumeric population of each component, the following rules have been prepared:
  - Compilation of the parameters contained in the disciplinary schedule with the effective value includes in operational documents or with "ND" as "Not Applicable/Not Associable" or "NA" as "Not Available/Not Findable".
  - Compilation of the model parameters identified as "Built-in" typology in Annex 02.
  - Non – compilation of the shared parameters associated with the category that do not appear in the category disciplinary schedule analysed because it means that the characteristic is not connected with discipline considered.

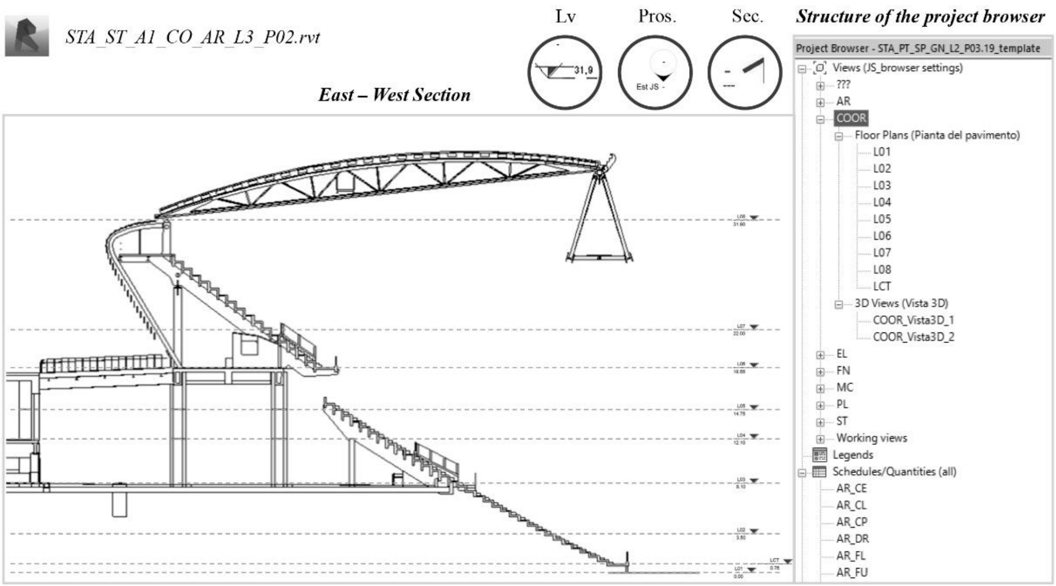


Figure 53 – Structure of the project Template (.rfa)

As a future project development, at the end of the multidisciplinary modelling activities, the template file could be implemented through the uploading of all the different system and loadable families created, to make them available for future implementations.

Starting from the application of the proposed methodological standardization, contained within the BIM guidelines and integrated by the technical expertise of each actor involved, the **results** of the project connected to the **geometric content** definition have been obtained. These are then summarized in figure and graphs below, with the indication of categories and objects number, used in every single discipline. In detail, Figure 54 and Table 16 summarise the values inherent to the content of the individual operating models and the coordination model of the AR. The graph illustrated in Figure 55 represents the same values listed in Table 16, displayed on a logarithmic scale.

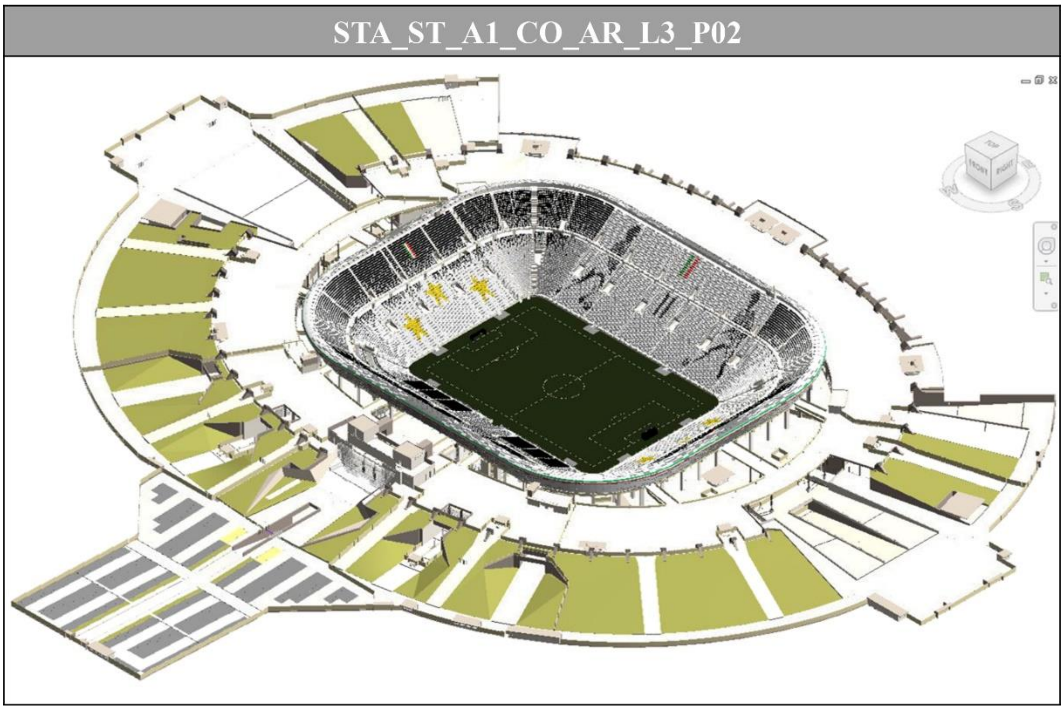


Figure 54 – Architectural coordination model of the case study

Table 16 – Elements table of each category of the Architectural discipline

	STA_ST_A1_M3_AR_L3_P02_L01	STA_ST_A1_M3_AR_L3_P02_L02	STA_ST_A1_M3_AR_L3_P02_L03	STA_ST_A1_M3_AR_L3_P02_L04	STA_ST_A1_M3_AR_L3_P02_L05	STA_ST_A1_M3_AR_L3_P02_L06	STA_ST_A1_M3_AR_L3_P02_L07	STA_ST_A1_M3_AR_L3_P02_LCT	STA_ST_A1_CO_AR_L3_P02
Ceilings	215	128	484	398	198	99	4	0	1526
Columns	66	71	904	1064	969	411	82	0	3567
Curtain Panels	0	18	148	838	82	54	0	0	1140
Doors	123	68	461	344	155	262	13	0	1426
Floors	165	76	561	379	155	287	21	220	1864
Furniture	0	3	37	0	0	6480	1	41447	47968
Parts	2000	1173	7440	5215	2177	3317	257	203	21782
Railings	12	24	608	158	50	249	10	300	1411
Ramp	0	0	0	4	0	0	0	0	4
Roofs	0	7	36	59	11	73	9	0	195
Room	133	64	477	277	120	252	16	116	1455
Site	84	14	1116	1233	0	617	4	13	3081
Slab Edges	3	4	27	28	0	0	0	0	62
Stairs	16	5	28	47	20	4	2	4	126
Structural Fraiming	0	0	26	80	0	24	213	69	412
Windows	0	4	21	45	8	26	4	0	108
								TOT:	**86127**

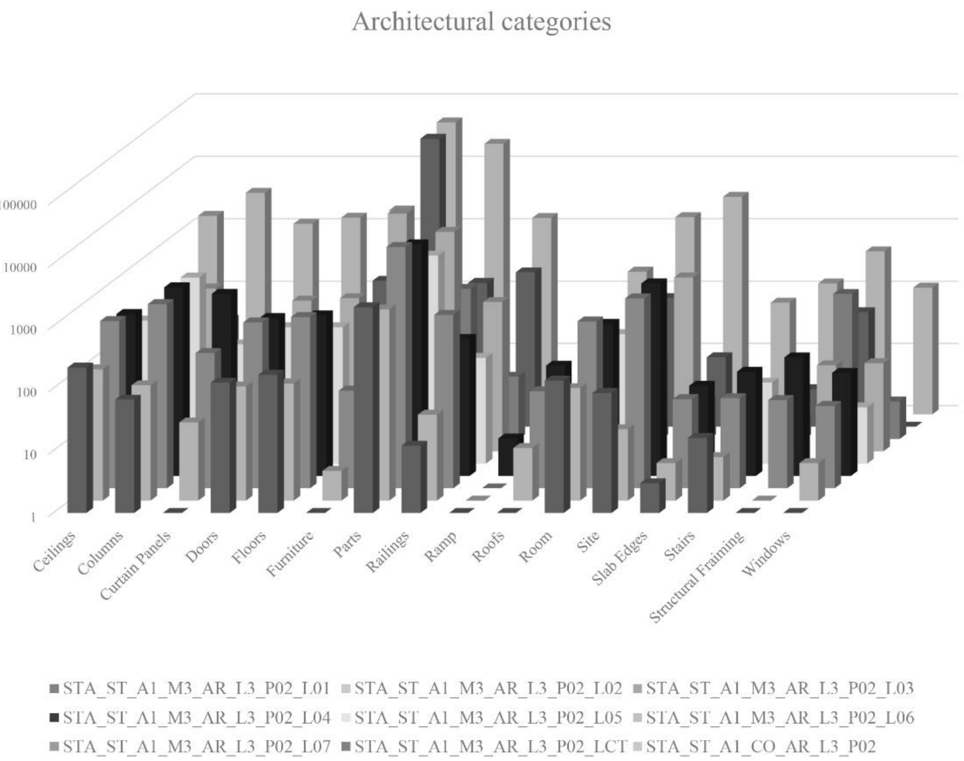


Figure 55 – Elements graph of each category of the Architectural discipline

This recap should be carried out for each disciplinary coordination model, obtaining the summary Table 17 illustrated in the following representation. These allow us to understand the complexity of the building analysed, the large number of elements contained and the amount of data involved when compared with the summary Table 20 of the alphanumeric content illustrated in chapter 4.7.

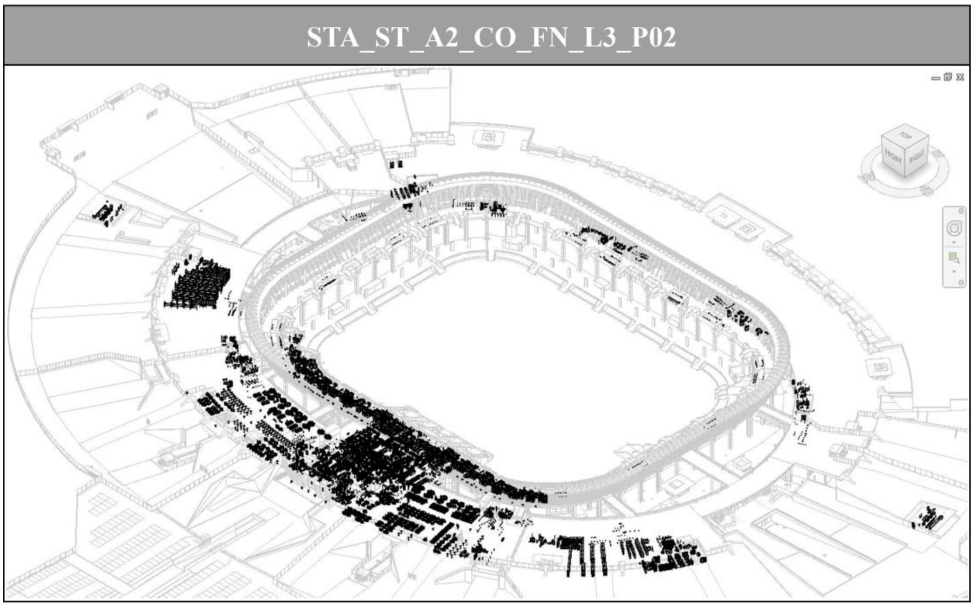


Figure 56 – Furniture coordination model of the case study

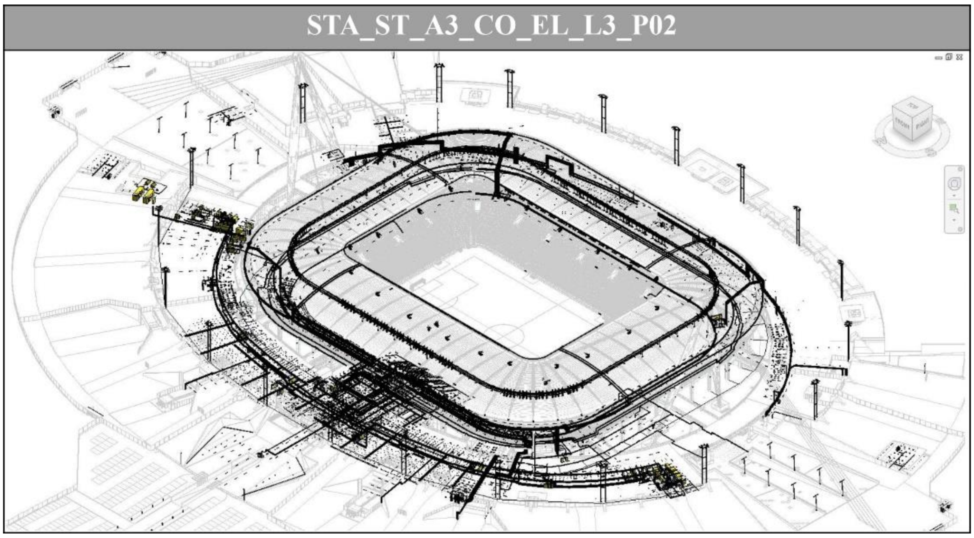


Figure 57 – Electrical coordination model of the case study

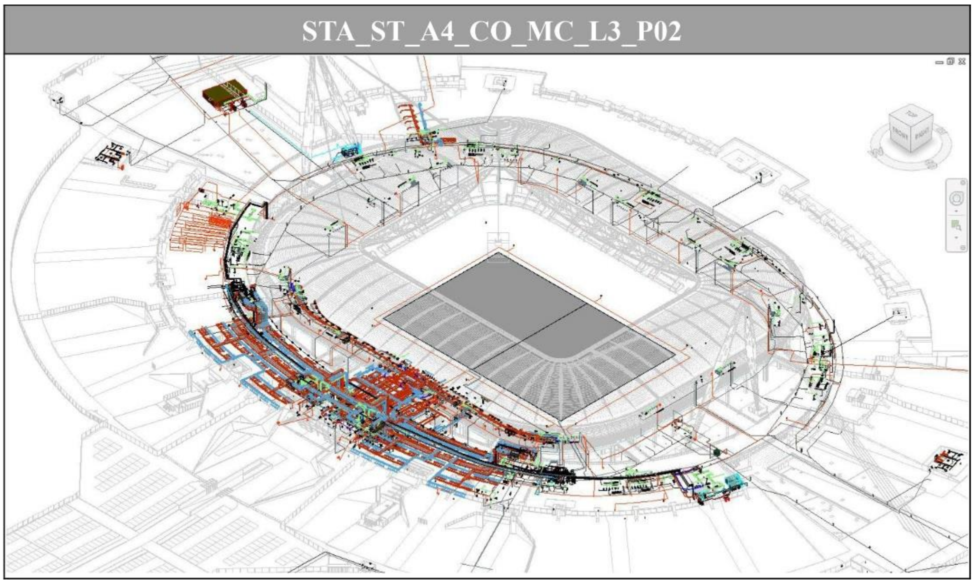


Figure 58 – Mechanical coordination model of the case study

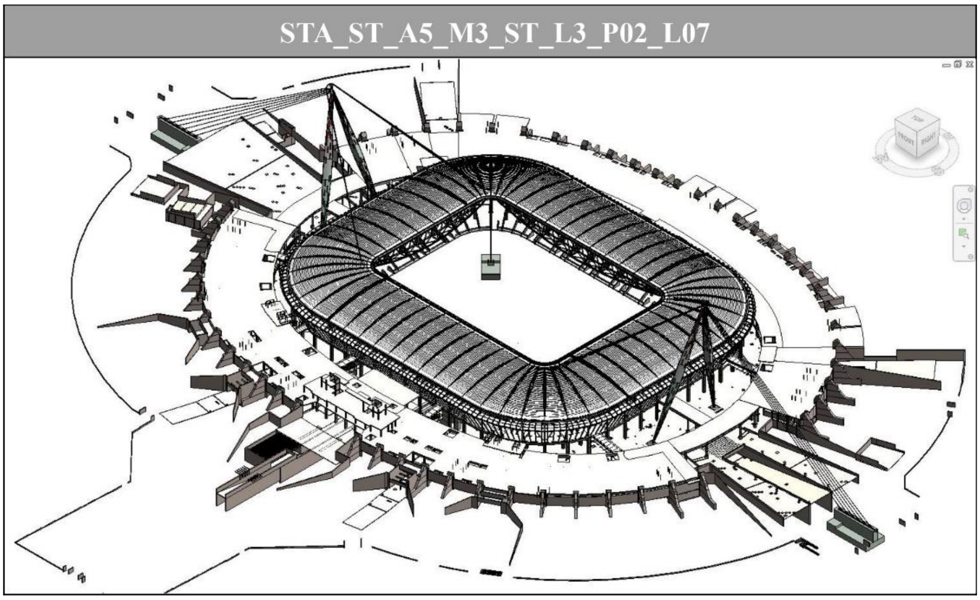


Figure 59 – Structural model of the case study

Table 17 – Elements table of each category of the multidisciplinary coordination model

	STA_ST_A1_CO_AR_L3_P02 (8 operational models)	STA_ST_A2_CO_FN_L3_P02 (6 operational models)	STA_ST_A3_CO_EL_L3_P02 (9 operational models)	STA_ST_A4_CO_MC_L3_P02 (5 operational models)	STA_ST_A5_M3_ST_L3_P02_L07 (1 operational model)	STA_ST_J_CO_GN_L3_P02 (29 operational models)
Air Terminals	0	0	0	1840	0	1840
Cable Trays	0	0	7543	0	0	7543
Cable Trays Fittings	0	0	6199	0	0	6199
Ceilings	1526	0	0	0	0	1526
Columns	3567	0	0	0	0	3567
Communication Devices	0	0	1285	0	0	1285
Conduits	0	0	110	0	0	110
Conduit Fittings	0	0	52	0	0	52
Curtain Panels	1140	0	0	0	0	1140
Doors	1426	0	0	0	0	1426
Ducts	0	0	0	3681	0	3681
Duct Accessories	0	0	0	43	0	43
Duct Fittings	0	0	0	4434	0	4434
Electrical Equipment	0	316	919	0	0	1235
Electrical Fixtures	0	0	3183	0	0	3183
Fire Alarm devices	0	0	2081	0	0	2081
Flex Ducts	0	0	0	1612	0	1612
Flex Pipes	0	0	0	40	0	40
Floors	1864	0	0	0	390	2254
Furniture	47968	8759	2	0	0	56729
Lighting Fixtures	0	0	8914	0	0	8914
Mechanical Equipment	0	0	0	671	0	671
Parts	21782	0	0	0	0	21782
Pipes	0	0	0	12624	0	12624
Pipe Accessories	0	0	0	832	0	832
Pipe Fittings	0	0	0	11457	0	11457
Plumbing Fixtures	0	0	0	2809	0	2809
Railings	1411	0	0	0	992	2403
Ramp	4	0	0	0	0	4
Roofs	195	0	0	0	6	201
Room	1455	0	0	0	0	1455
Site	3081	0	0	0	0	3081
Slab Edges	62	0	0	0	0	62
Sprinklers	0	0	0	588	0	588
Stairs	126	0	0	0	0	126
Structural Columns	0	0	0	0	3694	3694
Structural Connections	0	0	0	0	22	22
Structural Framing	412	0	347	0	3599	4358
Walls	0	0	0	0	2179	2179
Windows	108	0	0	0	0	108
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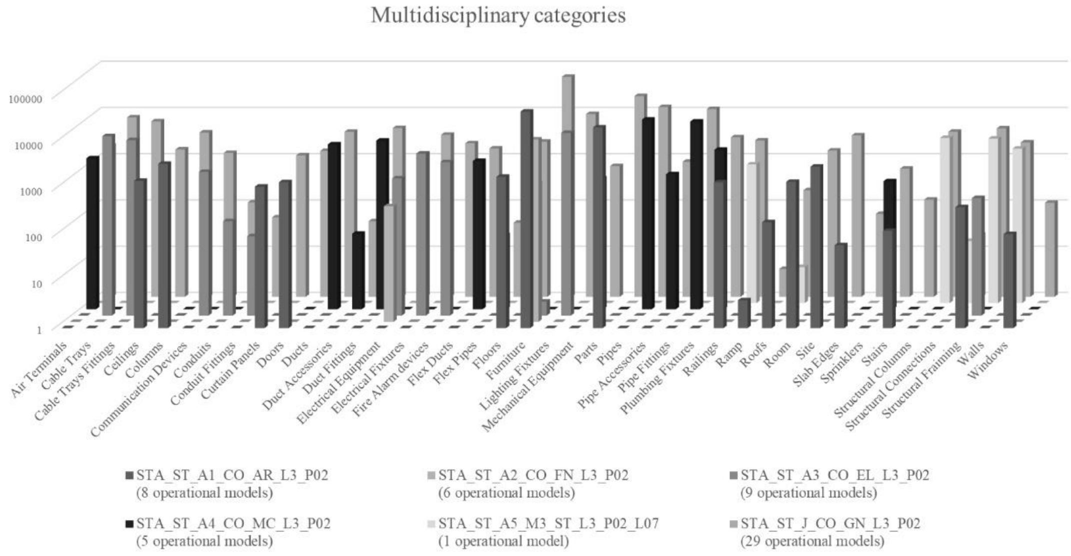


Figure 60 – Elements graph of each category of the multidisciplinary models

4.7 Alphanumeric content definition

Inside the proposed methodological standardization, the **alphanumeric content definition** is based on the identification and creation of the parameters to be compiled by the suppliers responsible for the individual BIM models. Starting from the requirements framework defined from the FM and the existing As-built documentation, the content of the BIM guidelines' Annex 02 has been determined through a collaboration with the owner. This document contains the association of the different parameters required for each discipline component. At the same time, for each parameter, its typology and format have been defined. About the different type of parameters of the research project, two separate cases have been identified within the research project: i) **Built-in parameters** defined as "*those that already exist in a file for elements when you start modelling, both in a project file or in a family file. They are always available because they represent the basic properties of objects and they can be scheduled out of the box*"[22] and ii) **shared parameters** defined as parameter store in a specific and independent file, used for the creation of project parameter. They can be used for the creation of project or family parameters in multiple families and projects, thanks to their addition inside the elaborated file (Barbero, 2019). In detail, therefore, the Built-in parameters are the pre-existing ones within the file, and they should be populated according to the dispositions contained in the proposed standardization. On the other side, the shared ones represent all the additional parameters identified as necessary to achieve the

[22] Definition of Built-in typology parameter from Autodesk website: https: https://knowledge.autodesk.com/support/revit-products/learn-explore/caas/simplecontent/content/shared-vs-project-parameter-use-revit.html?st=built-in%20parameter%20in%20revit (last consultation on the 07th of October, 2020).

set objectives in the methodological standardization. To simplify the alphanumeric population activity, all shared project parameters in the template file have been grouped under the typological group “Data”. As concerns the **format**, the following types have been used: Text, Area, Length, Volume, Material, Electric Load, Electric power, Number, Yes/No. The combination of type and format characteristic of the identified parameters for the case study is summarized in Table 18.

Table 18 – Parameter Typology and parameter Format of the case study

		Parameter Typology	
		Built – in Parameter	**Shared Parameter**
Parameter format	**Text**	X	X
	Area	X	
	Length	X	X
	Volume	X	
	Material	X	X
	Electric load		X
	Electric power		X
	Number		X
	Yes/No	X	X

The creation of the shared project parameters has been necessary both to facilitate Data Integration and to allow the creation of the different parameters in the individual disciplinary operating models. The integrated management of the alphanumeric database structure of the different models is supported by this type of parameters thanks to their belonging to a **.txt file** that can be shared between all the suppliers involved. As visible in Figure 61 about the case study, these parameters have been divided into groups, following their affiliation to one or more disciplines, or according to their specific function. This kind of parameters could also be recalled directly inside the schedule created in the Template file and, if they are created and compiled within a family, the subsequent populating in the project file is automatic.

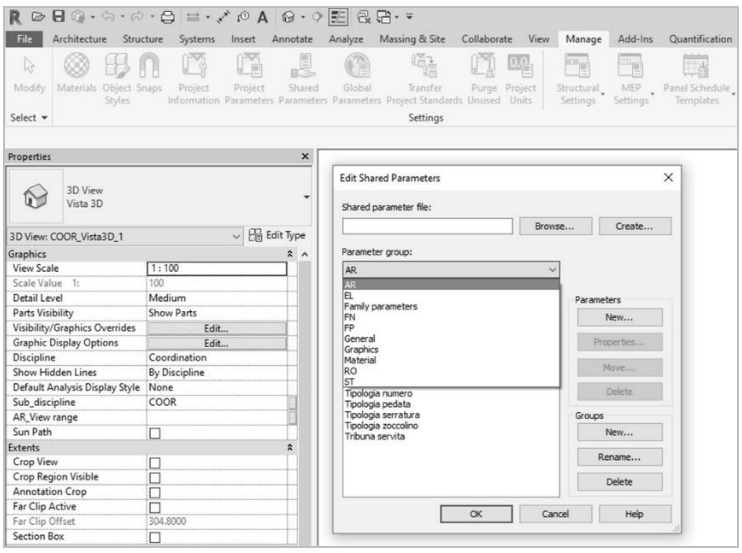


Figure 61 – Structure of the Shared parameters file (.txt)

In BIM guidelines' Annex 02, as visible in Table 19, the belonging category of each component has been associated together with the supplier, in order to obtain the **association of each parameter to the individual category**. The same content for objects identified as a disciplinary example has been reported in the section of the LOI contained in the sheets of Appendix B. This association is essential for the proper implementation of this type of parameters within the Template file, to provide a suitable tool to accommodate all the information that must be entered into the BIM models during the implementation phase. Annex 02 also identifies, for each component that should be modelled, the corresponding sub-components and related parameters, for which the IWMS platform represents the data master. In addition, a series of parameters in light grey have also been associated with the components, representing their documents. These ones correspond to the documental repository that will be implemented directly inside Archibus©.

Table 19 – Extract of Annex 02 of the Electrical discipline

Object			Parameters	Parameter Typology	Parameter Format	Data master		
Category	Component	Sub-component				Revit		Archibus
						Type	Instance	
Lighting Fixtures	Apparecchi illuminanti		Schedule Level	Built-in parameters Annex 02.1	Text		X	
			Family		Text	X		
			Type		Text	X		
			Description		Text	X		
			Altezza_std	Shared parameters - Annex 02.1	Length	X		
			Larghezza_std		Length	X		
			Lunghezza_std		Length	X		
			Diametro_std		Length	X		
			Classi di unità tecnologiche		Text	X		
			Unità tecnologiche		Text	X		
			Classi di elementi tecnici		Text	X		
			Numero MasterFormat		Text	X		
			Titolo MasterFormat		Text	X		
			Asset Code		Text		X	
			Codice As Built		Text		X	
			Affidabilità		Text		X	
			Sito		Text		X	
			Edificio		Text		X	
			Codice piano		Text		X	
			Codice padre AR		Text		X	
			Codice padre ST		Text		X	
			Codice padre FN		Text		X	
			Codice padre EL		Text		X	
			Codice padre BMS		Text		X	
			Codice padre SP		Text		X	
			Codice padre UPS		Text		X	
			Codice padre SCS		Text		X	
			Codice padre MC_HOT		Text		X	
			Codice padre MC_COLD		Text		X	
			Codice padre FP		Text		X	
			Modello		Text		X	
			Produttore		Text		X	

			Voltaggio		Electric load	X		
			Potenza nominale		Electric power	X		
			Codice impianto EL		Text		X	
			Codice impianto SP		Text		X	
			Linea di alimentazione		Text		X	
			Tipologia cavo EL		Text		X	
			Tipologia cavo SP		Text		X	
			Tipologia cavo BMS		Text		X	
			Materiale		Material	X		
			Gruppo impianto		Text		X	
			Manutenzione da normativa		Yes/No		X	
			Libreria		Text	X		
			Autonomia		Text	X		
			Accensione		Text		X	
			Cavetto di sicurezza		Yes/No		X	
			Schede tecniche		-			X
			Certificazioni		-			X
			Schemi As Built		-			X
		Plafoniera	Asset Code		Text			X
			Tipologia		-			X
			Schede tecniche		-			X
		Lampada	Asset Code		Text			X
			Tipologia		-			X
			Schede tecniche		-			X
		Elementi di fissaggio ed appensioni	Asset Code		Text			X
			Tipologia		-			X
			Schede tecniche		-			X
		Cavetto di sicurezza	Asset Code		Text			X
			Tipologia		-			X
			Schede tecniche		-			X
		Alimentatori	Asset Code		Text			X
			Tipologia		-			X
			Schede tecniche		-			X

Once the parameters' implementation for each discipline has been completed, a summary table of the **alphanumeric content** required in BIM guidelines has been carried out, as shown in Table 20.

Table 20 – Project parameters with relative features

Parameters	Parameter Format	Parameter Typology	Kind of parameter		AR	ST	FN	EL	MEC
			Type	Instance					
Family Name	Text	Built-in	X		X	X	X	X	X
Type Name	Text	Built-in	X		X	X	X	X	X
Asset Code	Text	Shared		X	X	X	X	X	X
Categoria	Text	Shared		X	X				
CDC	Text	Shared		X	X				
Classi di elementi tecnici	Text	Shared	X		X	X	X	X	X
Classi di unità tecnologiche	Text	Shared	X		X	X	X	X	X
Codice As Built	Text	Shared		X	X	X	X	X	X
Codice FM	Text	Shared		X	X				
Department	Text	Built-in		X	X				
Descrizione	Text	Shared		X	X				
Divisione	Text	Shared		X	X				
Edificio	Text	Shared		X	X	X	X	X	X

Number	Text	Built-in		X	X					
Numero MasterFormat	Text	Shared	X		X	X	X	X	X
Reparto	Text	Shared		X	X					
Settore	Text	Shared		X	X					
Sito	Text	Shared		X	X	X	X	X	X
Titolo MasterFormat	Text	Shared	X		X	X	X	X	X
Unità tecnologiche	Text	Shared	X		X	X	X	X	X
Affidabilità	Text	Shared		X	X	X	X	X	X
Altezza	Length	Shared		X	X			X	
Altezza totale parapetto	Text	Shared		X	X				
Altezza_std	Length	Shared	X		X	X		X	
Area	Area	Built-in		X	X	X			
Base constraint	Text	Built-in		X	X	X			
Base Level	Text	Built-in		X	X	X			
Capacità	Number	Shared	X						X
Codice piano	Text	Shared		X	X	X	X	X	X
Codice spazio	Text	Shared		X	X	X			
Diametro_std	Length	Shared	X		X	X		X	
Larghezza	Length	Shared		X				X	
Larghezza_cm	Length	Shared		X	X				
Larghezza_std	Length	Shared	X		X	X		X	
Level	Text	Built-in		X	X	X		X	X
Lunghezza	Length	Shared		X	X	X		X	
Lunghezza_std	Length	Shared	X		X	X		X	
Materiale	Material	Shared	X		X		X	X	X
Materiale pannello	Material	Shared	X		X				
Materiale telaio	Material	Shared	X		X				
Perimeter	Length	Built-in		X	X	X			
Reference Level	Text	Built-in		X	X			X	X
Rivestimento	Yes/No	Shared		X		X		X	X
Schedule Level	Text	Built-in		X			X	X	X
Spazio netto_cm	Length	Shared		X	X				
Structural material	Material	Built-in		X	X	X			
Thickness	Length	Built-in	X		X	X			
Volume	Volume	Built-in		X	X	X			
Width	Length	Built-in		X	X	X		X	
Accensione	Text	Shared		X				X	
Accessibilità al pubblico	Yes/No	Shared		X	X				
Accessibilità disabile	Yes/No	Shared		X	X				
Accessibilità operativa	Text	Shared	X					X	X
Accessibilità operatori/materiale	Text	Shared	X						X
Assegnatario	Text	Shared		X	X				
Autonomia	Text	Shared	X					X	
Azionamento	Text	Shared	X						X
Batterie	Text	Shared		X				X	
Blocco prese	Yes/No	Shared		X			X		
Capacità deflusso	Text	Shared		X	X				
Capienza max	Number	Shared		X	X				
Capienza max Match Day	Text	Shared		X	X				
Caratteristiche resistenza al fuoco	Text	Shared		X	X	X			X
Caratterizzazione grafica	Yes/No	Shared		X	X				
Cavetto di sicurezza	Yes/No	Shared		X				X	
Cavi scaldanti	Yes/No	Shared		X					X
Cespite	Text	Shared		X			X		
Classe di reazione al fuoco	Text	Shared		X	X		X		
Codice impianto EL	Text	Shared		X	X			X	X
Codice impianto FP	Text	Shared		X				X	X
Codice impianto MC	Text	Shared		X					X

Codice impianto SP	Text	Shared		X				X	
Data ultimo rilievo	Text	Shared		X	X		X		
Deflusso effettivo	Text	Shared		X	X				
Description	Text	Built-in	X		X	X	X	X	X
Elemento a vista	Yes/No	Shared		X		X			
Fragilità	Yes/No	Shared		X			X		
Gate	Text	Shared		X	X				
Gruppo impianto	Text	Shared		X	X			X	X
ID elemento	Text	Shared		X	X				
Impilabilità	Yes/No	Shared		X			X		
Libreria	Text	Shared	X					X	X
Linea di alimentazione	Text	Shared		X	X			X	X
Locali compartimentati	Text	Shared		X					X
Manutenzione da normativa	Yes/No	Shared		X				X	X
Modello	Text	Shared		X	X		X	X	X
N addetti movimentazione	Number	Shared		X			X		
Nome giocatore	Text	Shared		X	X				
Numero	Text	Shared		X	X				
Numero di occupanti	Number	Shared		X	X				
Numero parcheggio	Text	Shared		X	X				
Percentuale di occupazione	Number	Shared		X				X	
Peso_kg	Number	Shared	X				X		X
Potenza nominale	Electric power	Shared	X		X		X	X	X
Produttore	Text	Shared		X	X		X	X	X
Quantità CEE 2PT 16A 230V	Number	Shared		X				X	
Quantità CEE 2PT 32A 230V	Number	Shared		X				X	
Quantità CEE 2PT 63A 230V	Number	Shared		X				X	
Quantità CEE 3PNT 125A 400V	Number	Shared		X				X	
Quantità CEE 3PNT 16A 400V	Number	Shared		X				X	
Quantità CEE 3PNT 32A 400V	Number	Shared		X				X	
Quantità CEE 3PNT 63A 400V	Number	Shared		X				X	
Quantità CEE 3PT 125A 400V	Number	Shared		X				X	
Quantità CEE 3PT 16A 400V	Number	Shared		X				X	
Quantità CEE 3PT 32A 400V	Number	Shared		X				X	
Quantità CEE 3PT 63A 400V	Number	Shared		X				X	
Quantità frutti dati	Number	Shared		X				X	
Quantità interruttore MT	Number	Shared		X				X	
Quantità interruttore MTD	Number	Shared		X				X	
Quantità prese poli in linea	Number	Shared		X				X	
Quantità prese schuko	Number	Shared		X				X	
Quantità tappi	Number	Shared		X				X	
RAL	Text	Shared		X	X	X	X		X
Rivestimento scale	Text	Shared		X	X				
Separatori	Text	Shared		X				X	
Settore servito dx	Text	Shared		X	X				
Settore servito sx	Text	Shared		X	X				
Tipo movimentazione	Text	Shared		X			X		
Tipologia cavo BMS	Text	Shared		X				X	X
Tipologia cavo EL	Text	Shared		X				X	
Tipologia cavo SP	Text	Shared		X				X	
Tipologia numero	Text	Shared	X		X				
Tipologia pedata	Text	Shared		X	X				
Tipologia serratura	Text	Shared		X	X				
Tipologia zoccolino	Text	Shared		X	X				
Tornello A	Text	Shared		X	X				
Tornello B	Text	Shared		X	X				
Tribuna servita	Text	Shared		X	X				

Ubicazione	Text	Shared		X					X
Upgrade	Yes/No	Shared		X	X				
Voltaggio	Electric load	Shared	X		X		X	X	X
Vomitorio dx	Text	Shared		X	X				
Vomitorio sx	Text	Shared		X	X				
Codice padre AR	Text	Shared		X	X	X	X	X	X
Codice padre BMS	Text	Shared		X	X	X	X	X	X
Codice padre EL	Text	Shared		X	X	X	X	X	X
Codice padre FN	Text	Shared		X	X	X	X	X	X
Codice padre FP	Text	Shared		X	X	X	X	X	X
Codice padre MC_COLD	Text	Shared		X	X	X	X	X	X
Codice padre MC_HOT	Text	Shared		X	X	X	X	X	X
Codice padre SCS	Text	Shared		X	X	X	X	X	X
Codice padre SP	Text	Shared		X	X	X	X	X	X
Codice padre ST	Text	Shared		X	X	X	X	X	X
Codice padre UPS	Text	Shared		X	X	X	X	X	X
Total parameters: 144					**95**	**44**	**41**	**76**	**52**

As mentioned in the illustrative paragraph of the methodological standardization, this large quantity of parameters could be grouped in 5 main clusters:

- **Object Naming** contains the parameters concerning the object denomination like the family and the type name of the analysed component.
- **Classification and coding** contains the parameters defined for the objects and rooms classification (as illustrated in chapter 4.3) and for the unique identification of components in the database. In detail, these last ones allow a unique and transversal object codification represented by the Asset Code for the objects and the Number for the rooms, the insertion of any pre-existing identification codes and the identification of the level, building and site to which the element belongs. Their creation has been carried out to ensure the correct data integration process as illustrated later in the corresponding chapter 5.5, in addition to the need for consultation and extrapolation of multi-model and multi-site data.
- **Geometrical features** contains all the geometric parameters used for the implementation of dimensional information. This group includes the reliability parameter and all the different Built-in parameters concerning the level of objects insertion.
- **Specific characteristics** is the largest parameter cluster as it contains all the parameters used to enter detailed information necessary to carry out maintenance activities. Among these, the model and manufacturer parameters play an important role. In detail, unlike what is visible in the literature, for the case study these fields have been created by instance since it is expected to update this data for different components directly from the IWMS platform since, for the defined LOG, there are no impacts at the graphic level.
- **Hierarchy** contains the alphanumeric parameters necessary to create the different complete multidisciplinary hierarchies. In fact, given the use of a

federated model, in the System browser of the modelling software it is not possible to have an overall multidisciplinary hierarchical view of the entire building. For this reason, eleven parameters have been defined for each object allowing the mapping of the functional relations between the components, called "Codice padre XX". These are representative of each desired hierarchical system, and their population rules are defined as follows:

- For each afferent discipline, the compilation should be done through the Asset Code of the corresponding "Padre/Sorgente" element of the system configuration.
- For each afferent discipline, if they do not have a "Padre" of reference in the system structure, the compilation should be done through their Asset Code. On that assumption, therefore, there will not be objects that have all eleven "Codice padre XX" parameters filled in with NA. As an example, all objects belonging to the AR, ST and FN disciplines are included in this case, since they do not fall within real hierarchical systems.
- For each discipline for which the component performs the source system function, the compilation should be done through its specific Asset Code.
- If the element is not related to a specific discipline, the parameter should be populated with the term NA.

These parameters have been also essential for the proper hierarchy development in the IWMS platform, as illustrated in chapter 5.5.

Once the alphanumeric parameters necessary for the model structuring has been defined, the proposed methodological standardization also concerned the definition of the **populating logic** of these parameters starting from their description. For this purpose, during the research activity, the Annex 02.1 has been developed within the BIM guidelines in order to perform this function. This document has been implemented with the support of the project suppliers who provided the technical knowledge for the definition of essential rules necessary for the database integrity. Particular attention has been paid to the **standards of the naming** of families and types, structured according to precise criteria illustrated in Annex 01 and Annex 01.1. The first document contains, for each discipline, the list of families and types created for each category with the corresponding description. This last parameter is particularly important since it contains the illustration of the acronyms used for the denominations. Due to the looped implementation need during the development of modelling activities by suppliers, this document has been operationally shared within Trello. Once the stadium building has been completed, Annex 01 will be used as a complete list of all the system and loadable families representing the owner's BIM library. At the same time, the reference standards for the denomination rules contained in Annex 01 have been illustrated and summarized in Annex 01.1. This document includes the logic to be followed for families and types naming defined for each discipline, in addition to the formal rules necessary for correct data integration as shown in chapter 5.5. For example, Table 21 and Table 22 show the shared logics for the MEP elements, regarding the EL discipline, These standardization has been carried out starting from the references identified in the literature (BIM Essential Guide for MEP consultants, 2103), (European MEPcontent Standard - Version 3.0). For the case study, the **Family denomination** standard adopted has this structure: *Sub-discipline_Category_Sub-category_Description*

Table 21 – Family naming denomination for Electrical discipline of the case study

<table>
<tr><th>Acronym</th><th colspan="3">Description</th></tr>
<tr><td>SUB-DISCIPLINE</td><td colspan="3">Identifier of the discipline or sub-discipline to which the MEP object refers (max. 3 characters including the "_").
EL: Electrical</td></tr>
<tr><td>CATEGORY</td><td colspan="3">Description of the functional category to which the analysed MEP object belongs (max. 2 characters including the "_"), combining both the category related to the modelling activity and the category related to the maintenance function of the object.

S: Source (element representing the power supply of a system portion).

C: Network (element constituting the horizontal and/or vertical system distribution).

T: Terminal (terminal element of the system).

E: Equipment (network support element that does not perform the function of a source).

A: Accessory (element representing a node of the network).</td></tr>
<tr><td rowspan="11">SUB-CATEGORY</td><td colspan="3">Description of the functional subcategory to which the analysed MEP object belongs. These are subdivided by category, with the relative Description aimed at the correct object identification.</td></tr>
<tr><td>Category</td><td>Sub-category</td><td>Note</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td rowspan="2">S</td><td>QE</td><td>Quadro Elettrico</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td rowspan="2">C</td><td>RACCORDO</td><td>Raccordo canalizzazione</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td rowspan="2">T</td><td>APPARECCHIO</td><td>Dispositivo di illuminazione</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td rowspan="2">E</td><td>ATTREZZATURA</td><td>Attrezzatura elettrica</td></tr>
<tr><td>…</td><td>…</td></tr>
<tr><td>DESCRIPTION</td><td colspan="3">Identification code of the object type detected within the existing As-Built documentation, the related maintenance data sheets or the classification currently used.</td></tr>
</table>

Concerning the **Type denomination** standard (Table 22), the identified structure is: *Parameter Kind 1_Parameter Kind 2_Parameter Kind_...* selected by the supplier in the function of the operational needs related to the object named.

Table 22 – Type naming denomination of the case study

Acronym	Description
PARAMETER KIND 1	The parameter that identifies the geometrical dimensions of the object and allows its differentiation, obtained from the As-built elaborations provided by the owner and the survey activities, reported in mm. For example: 500x400 (width x height)
PARAMETER KIND 2	The parameter used to identify the material constituting the analysed object, whose denomination is reported extensively.
PARAMETER KIND 3	The parameter that identifies the electrical power of the object analysed, to be considered as a characteristic associated with the electrical connector within the BIM family. This value is also useful for the correct system hierarchy. For example: 120W
PARAMETER KIND 4	…
PARAMETER KIND 5	Identification code of the model or manufacturer of the object type analysed. This field can be used only for components subject to Upgrade, based on shared rules in BIM guidelines.

4.8 BIM Model Checking

Starting from the contents illustrated in chapter 2 on **BMC**, the process of checking the information content of the BIM models developed during the research activity is based on **Clash Detection**, **Code Checking** and **Data Validation** activities, as identified in the summary scheme in Figure 22. All these activities allow meeting the verification and coordination requirements set out in the Italian regulation (UNI 11337-5, 2017) according to the workflow summarised in Figure 23. Starting from this last one, during the research activity, specific operating methods have been defined allowing the achievement of the objectives set at the verification and coordination level, involving all the actors of the process. These methods are:

- **Formal geometric control and substantial geometric control,** which are part of the Clash Detection activity, aimed at verifying the correctness of the geometric BIM content. In particular, the formal control activity has been carried out by the owner through the performance of monodisciplinary and multidisciplinary, single-level and multi-level clash detection supported by the Autodesk Navisworks software. In this way has been possible to perform the activities required by the CL1 and CL2 coordination steps and the VL1 and VL2 verification steps (UNI 11337-5, 2017). On the other hand, the substantial geometric check has been structured to ensure that the BIM model corresponds to the real configuration, through a random check. In this way, it has been possible to carry out the activities planned in step CL3 of coordination.
- **Substantial alphanumeric control**, which could be considered as a part of the Code Checking activity, since it verifies the correctness of the alphanumeric content included in the BIM model. This control also involves the verification of correctness of the parameters compiled in function of the

pre-existing As-built documentation. In detail, for the present case study, a random check aimed at this type of control has been planned, assigning a weight to each parameter checked, in order to create a summary illustration of the model reliability for the owner (Figure 67). Through the mentioned activity, it is possible to satisfy the VL2 and VL3 verification steps and the CL2 and CL3 coordination steps (UNI 11337-5, 2017).

- **Formal alphanumeric control**, which requires the verification of the correct application of operating protocols provided in the BIM guidelines and related to the alphanumeric population activity. This check is part of the Data Validation process and it is based on the definition of a series of rules established with the owner and the Archibus © specialist, starting from the implemented guidelines essential for the integration with the IWMS platform.

The illustration of the operating BMC methods adopted is confirmed by the definition of the progress steps (Step 1 and Step 2) defined together with the documentation denomination rules. Based on the illustrated definitions, the first two types of control are analysed below, concerning the Data Organization objective.

Regarding the **formal geometrical control activities**, aimed at identifying and resolving spatial interferences, the owner has defined how the controls should be carried out. Interference control activities between Object/Object and Model/Models have been carried out in a specific mode following a pre-established set of rules, including the relative tolerance. For this research activity, it has been established that the Object/Object interference control is the responsibility of every single supplier. As an example, Figure 62 shows the result of the Clash Detection between the AR and EL disciplines, concerning only Level 04. It is one of the outputs delivered to individual supplier, together with the observations in .html format containing the IDs of the objects involved in the control and the indication of the actor to which the issue is assigned.

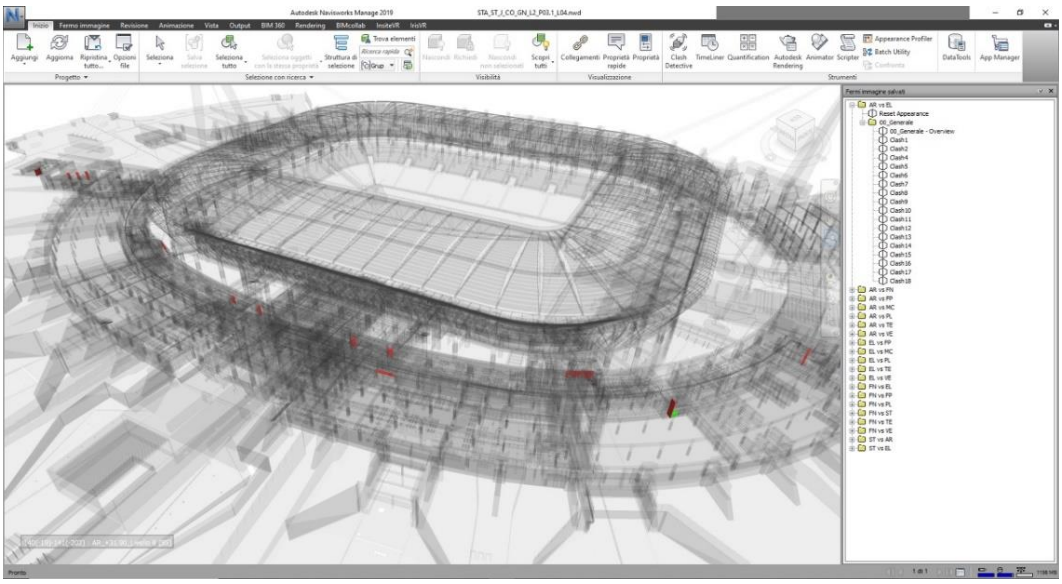


Figure 62 – Example of Clash Detection AR vs EL, carried out by the owner

The **substantial geometric validation activity** has been carried out by conducting random measurements of the real building configuration, in order to compare the information detected with the values contained in the BIM models. Operationally, the same workflow of survey activities has been used starting from the visualization of the model on a mobile device through the Autodesk BIM 360 application. Any differences found have been collected within specific notes on the application and subsequently reported in a **BIM Collaboration Format file**[23](.bcf).

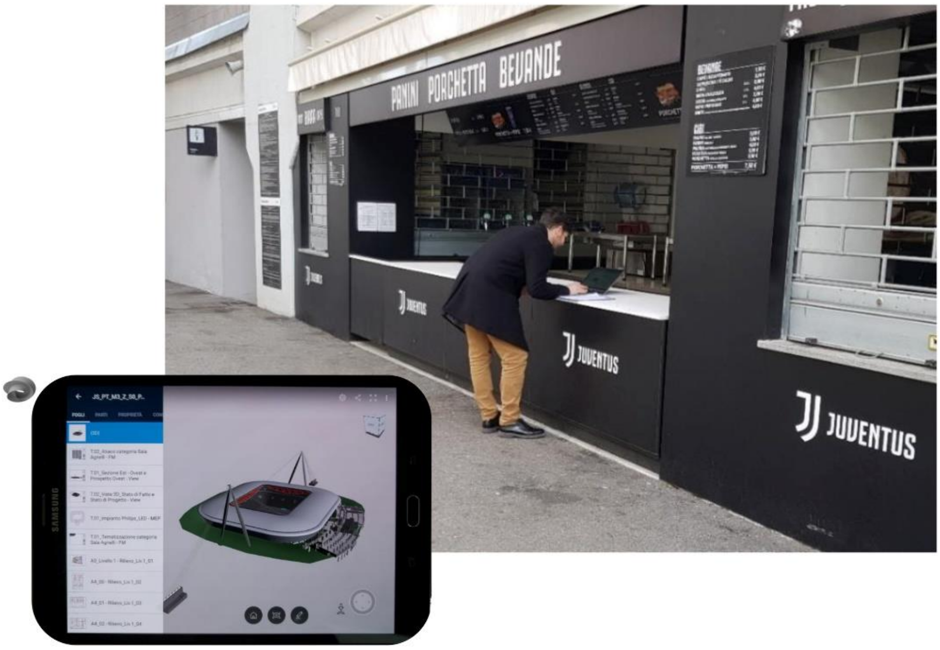


Figure 63 – Survey activities for geometric-substantial validation

The .bcf file format is an OpenBIM format that allows the exchange of observations and operational notes related to specific points of a model between the various actors involved in the process. This format could also be used for the implementation of the observations identified during the formal geometric check. Moreover, through the "resolution state" of individual comments, this tool allows the monitoring of the progress condition regarding the implementation of the indications delivered by the validation coordinator (Figure 64 and Figure 65). The .bcf format, inside the platform of BIM collab, also allows the analysis and the graphitization of the revisions trend and the relative evaluation in function of the affiliation discipline (Figure 66). It is, therefore, possible to understand the dual functionality of the .bcf format both as a coordination and validation tool.

[23] Definition of BCF and its characteristic and application are defined in the buildingSMART website: https://www.buildingsmartitalia.org/standard/standard-bs/bim-collaboration-format-bcf/ (last consultation on the 08th of October, 2020).

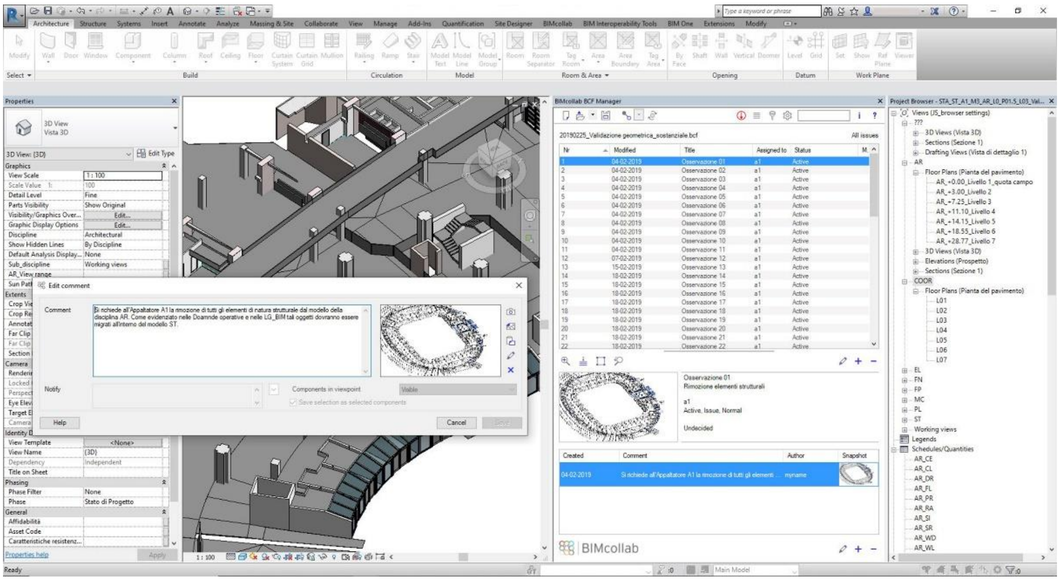


Figure 64 – Management of the .bcf file for geometric substantial validation

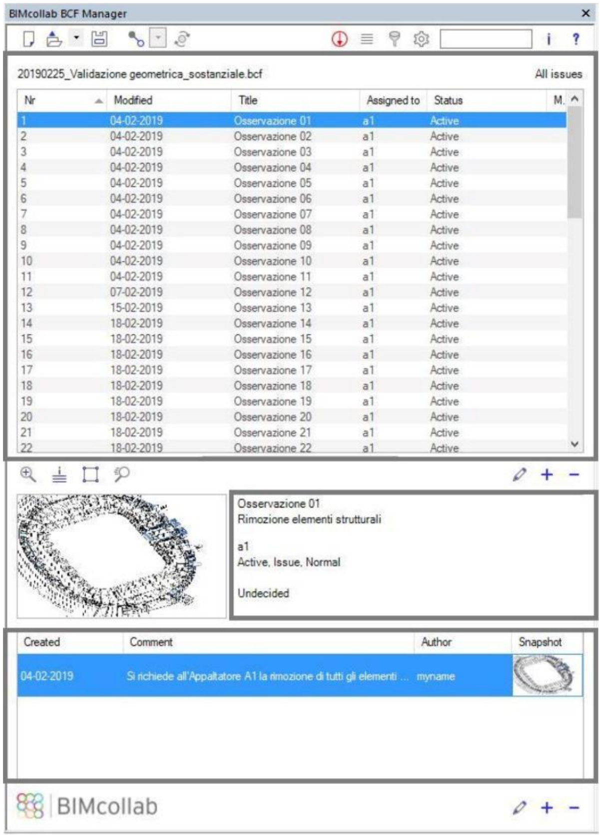


Figure 65 – Structure of the .bcf schedule

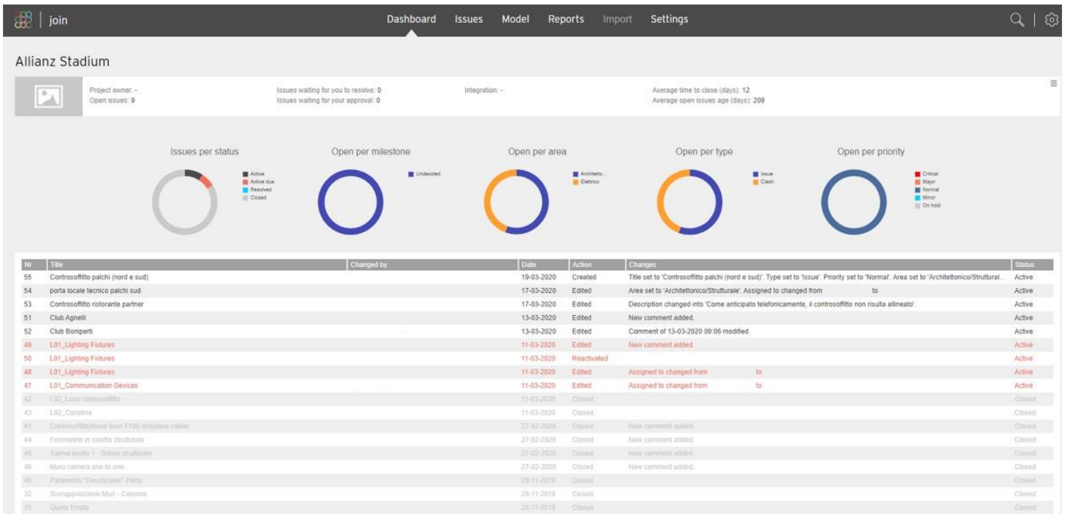


Figure 66 – BIM Collab dashboard for the project monitoring

Concerning the **substantial alphanumeric control**, an Excel tool has been implemented with the owner indicating the respective content to be checked for each discipline (Figure 67). In detail, the first part of the schedule shows the general information of the model. The second one reports one object for each category with the details of all the relative parameters, to carry out the established random check. For each one, a weight value representative of the parameter's importance has been assigned: in this way it has been possible to award a result in % value of the validation activity for each category and the analysed model. This value has allowed obtaining a positive or negative result of the validation activity carried out, thanks to the comparison with the acceptance limit set by the owner.

Allianz Stadium

ELECTRICAL MODEL
VALIDATION LEVEL 2

Validation Documentation delivered on 27/01/2020

Weight	Characteristic/Parameter	Formal Validation	Data	Substantial Validation	Validation	Score	Note
	File: STA_ST_A3_M3_EL_L2_P02.0_L02						
1,00	Nomenclatura file		STA_ST_A3_M3_EL_L2_P02.0_L02		1	1	
1,00	Utilizzo di Revit 2017 - ENU		--		1	1	
1,00	Sistema di coordinate condivise		--		1	1	
1,00	Inserimento oggetti		--		1	1	
1,00	Viste modelli		--		1	1	
1,00	Intervallo di visualizzazione		--		1	1	
1,00	Compilazione abachi categorie		--		1	1	
1,00	Dimensione file (<250 MB)		--		1	1	
TOT 8,00							

TOT	8,00
% Validazione essenziale	100%
% Validazione	100%
% Juventus	100%
Risultato	Validato

Weight	Characteristic/Parameter	Formal Validation	Data	Substantial Validation	Validation	Score	Note
	Object: Electrical Equipment (ID: 251221)						
1,00	Level		L02		1	1	
1,00	Family		EL_S_RACK_dati		1	1	
1,00	Type		800x800x1200		1	1	
0,25	Categoria oggetto		Electrical Equipment		1	0,25	
0,50	Fase: Stato di fatto		Stato di fatto		1	0,5	
0,50	Altezza		0		1	0,5	
0,50	Lunghezza		0		1	0,5	
0,50	Larghezza		0		1	0,5	
0,50	Altezza_std		1.20		1	0,5	
0,50	Lunghezza_std		0.80		1	0,5	
0,50	Larghezza_std		0.80		1	0,5	
0,75	Description		Armadio rack dati		1	0,75	
0,50	Classi di unità tecnologiche		5		1	0,5	
0,50	Unità tecnologiche		5.8		1	0,5	
0,50	Classi di elementi tecnici		5.8.2		1	0,5	

PARAMETRO ESSENZIALE --> peso = 1
Parametro necessario per una corretta interazione Revit - Archibus e parametro importante per la struttura del progetto

PARAMETRO NON ESSENZIALE --> peso < 1
Peso del parametro tarato infunzione della sua importanza in relazione alle attività manutentive connesse

LEGENDA VALORI PESI	
1,00	Valore essenziale per il funzionamento del progetto
0,75	Valore importante
0,50	Valore di media importanza
0,25	Valore di bassa importanza

Figure 67 – Report of the alphanumeric substantial validation activity

Chapter 5

Data Integration

The Data Integration objective is strictly connected to the employment of an IWMS platform like the software Archibus©, adopted for the case study. It allows having an overview of a Real Estate portfolio, obtaining detail information about a given asset in terms of typology, occupancy and maintenance procedures (Ugliotti, 2017). As illustrated in the previous chapters, the integration between BIM models and a management platform enables to overcome the issues related to the separate management of drawings and alphanumeric data that represent an inadequate duplication of information and effort, typical of the traditional method. One of the main objectives of using an IWMS platform is the possibility of consulting all the data entered after integration through a simplified web portal, available to the various players involved during maintenance activities. (Ugliotti, 2017). Due to these considerations, as indicated previously, the objective of Data Integration has been operationally addressed together with the Archibus © expert supplier. For this reason, in this chapter of the thesis, the operational standards necessary for the correct structuring of BIM models have been discussed in order to guarantee that the Data Integration process implies the lowest possible number of data loss. The results achieved during the integration of the BIM database with the IWMS platform have been also reported since it has been one of the main topics of the presented activity. On the other hand, no detailed discussion has been carried out about the operating and software solutions proposed by the actor responsible for the IWMS platform because these are not strictly related to the research activity carried out.

Operationally, the **Data Integration** objective is linked to the data master definition which is represented by the platform where the information is inserted and to the information transfer's direction. For the presented research study, only the information flow that involves the passage from the BIM database to the Archibus© one has been investigated. This operational choice derives from the workflow defined by the owner. He decided to proceed with the structuring of the geometric and alphanumeric content within the modelling software while the subsequent updating of specific alphanumeric data related to maintenance activities will be done directly within the IWMS platform. This operating workflow should be declared during the integration procedure, defining what the data origin of each parameter is. As indicated in specific operative instructions (ARCHIBUS Inc.), however, it is possible to implement and investigate the **bidirectional information workflow** of the Data Integration. This aspect indeed represents a potential future development, which can be analysed based on the owner's operational needs during the performance of the maintenance activities.

5.1 Objectives definition

The expected result of achieving this objective is the **integration** between the **BIM database** developed in the modelling software and the **management one**. The concept of Data Integration could be defined as: "*the process to be implemented on data coming from different information sources, necessary to provide to the user a unified view of the information*"[24]. At state of the art, there are still some relational issues between the software involved, which require a series of operational standardizations, related to information structure, to allow a correct integration as explained in chapter 2.1. These fall within the proposed standardisation since they could be replicated independently of the case study, based on the same objective to be pursued.

The word **integration**, therefore, requires the transfer/synchronisation of the geometric and alphanumeric information from one software to another. For this reason, it is necessary to prepare the contents of the BIM model adequately and ready for the connection with the final structure of the IWMS database (Barbero, Del Giudice, Ugliotti, & Osello, 2020). The topic of data integration, therefore, deals with two different databases that are linked together. To achieve this aim, it is important to point out that the database contained in the IWMS platform is entirely independent of the BIM models, which are the starting point for its population and subsequent implementation during maintenance operations. In practice, it is essential to proceed with the analysis and identification of existing issues to identify the impacts on the structure of the database and to be able to anticipate them within the BIM guidelines, through operational dispositions. These are standards which should be necessary to adopt in order to avoid data loss, according to what has been investigated during the research activity.

At the same time, the defined integration activity could be part of the broad field of **interoperability**. It could be defined as: "*the ability of two or more systems to exchange information. It is one of the pillars of BIM because the information contained in a BIM model needs to be exchanged to be useful*" (Santos, 2010). Another possible definition of this concept is: "*The ability of two or more systems, applications or components to exchange information with each other and then be able to use them*". (Erba, Osello, Semeraro, & Ugliotti, 2015). This operation, in

[24] General definition of Data Integration from Wikipedia website: https://it.wikipedia.org/wiki/Data_integration (last consultation on the 15th of October, 2020).

the analysed literature, is illustrated and described as based on the use of an openBIM format, which allows the exportation of information from one software (as an output) into an exchange format that will be read by a second software (as an input). For this reason, the interoperability represents one of the key points of the digital transformation of the asset industry and one of the principles on which the OpenBIM concept is based. It is defined as: "*an approach that extends the benefits of BIM (Building Information Modeling) by improving the accessibility, usability, management and sustainability of digital data in the built asset industry. openBIM processes can be defined as sharable project information that supports seamless collaboration for all project participants. openBIM facilitates interoperability to benefit projects and assets throughout their lifecycle*"[25].

Thanks to these analyses, the process illustrated in this chapter could be defined as an **interoperable integration process**, since it involves the information transfer from one software to another, without the use of a specific data exchange format, but through direct interaction between the two platforms involved. In detail, for this case study, the integration process involves two different ways of data integration:

- The **publication activity**, defined as the process that allows having a 2D plan of each level and a 3D view from the setting one of the BIM model. This enables the integration of the geometric content within the IWMS platform by directly reading the native format, thanks to the use of the existing Smart Client Extension for Revit® plug-in.
- The **cataloguing activity** described as the process that allows an exchange of data from Autodesk Revit to Archibus© according to a grid of fields linked to each other during the interaction mapping operation. During the research activity, it has been decided by the software supplier to use the ODBC exchange format for the transposition of alphanumeric information.

From the achievement of this objective, it is possible to view and query the BIM database within the IWMS platform, proceeding to consult its data (Figure 68), subsequently associating the preparatory maintenance procedures and scheduling their execution (Figure 69).

[25] Definition of the openBIM approach taken from the BuildingSmart website: https://www.buildingsmart.org/about/openbim/openbim-definition/#:~:text=openBIM%20extends%20the%20benefits%20of,in%20the%20built%20asset%20industry.&text=openBIM%20processes%20can%20be%20defined,collaboration%20for%20all%20project%20participants (last consultation on the 15th of October, 2020).

Figure 68 – Prototype models inside the IWMS platform Archibus©

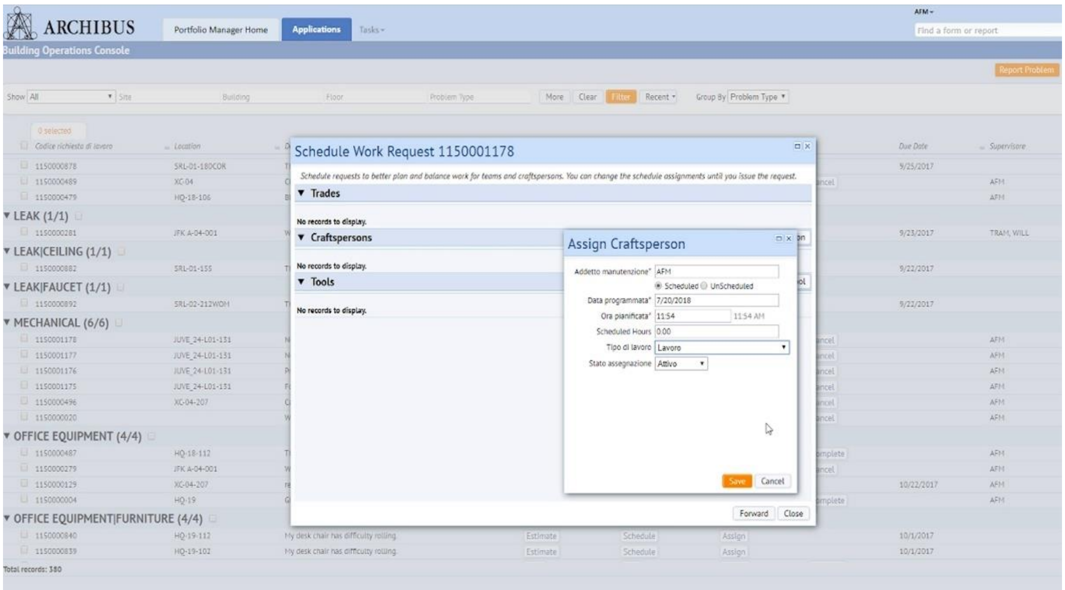


Figure 69 – Example of the creation of a work request in Archibus©

5.2 Regulation adoption

As visible in Figure 37 and Figure 39, the definition of some specific parameters within the modelling software allows to carry out a whole series of query and analysis activities of models during the management activities. In detail, concerning what has been illustrated in chapter 4.3, the parameters adopted for the object's classification could be consulted and used to carry out the above activities. These same parameters indicated in BIM guidelines starting from the existing standards (Figure 40) have been associated with the corresponding Archibus© parameters. This connection allows to carry out specific **system queries** based, for example, on the intended use and the type of room, automatically obtaining the amount of the corresponding squares. Therefore, the definition and the population of the mentioned parameters should be carried out considering this aspect.

5.3 Worksharing

The choice of how to structure the project **worksharing** had a significant impact on Data Integration. In detail, the implementation of a federated model affected the default way of executing the publication procedure. Actually, the software Archibus© allows for its operating logic based on the identification of the site, building and level declared during the connection activity between the software, the **publication** of a 2D view for each level of every single building and a 3D view for each building and level, if the starting model changes. For this reason, if the model is multi-level, the 3D publication is unique for all levels of the model. Working with a federated structure, several **publication tests** have been carried out to identify the correct workflow for connecting the different models starting from the implemented coordination one.

Concerning the **2D publication**, the coordination model has been structured using the AR model as a basis for each level, linking all the other disciplines inside it, allowing the achievement of the expected results as visible in Figure 70. It should be highlighted that this result is quite difficult to read given the complexity of the disciplines involved, the number of objects and the standard function of the "Space Console" view aimed at analysing and managing spaces and not objects. (ARCHIBUS Inc.).

Figure 70 – 2D multidisciplinary publication of the L03 of the case study inside Archibus©

About the **3D publication**, it has been carried out during the project implementation by setting the super-categories. These represent a set of BIM model categories properly selected, which allow improving the consultation usability of the model inside the Archibus© navigation panel. This structure makes possible to manage the graphical “switching on and off” of the assets that fall within the categories contained in the selected super-category (ARCHIBUS Inc.). These could be activated from the associated panel in the management platform through the connection with its corresponding button. During the integration tests, different publication procedures have been tested, starting from the previously structured coordination model, which highlighted a problem linked to this activity. In fact, the coordination model does not allow to complete the 3D publication procedure because the categories, contained within the models link in the AR one were not visible during the setting of the super-categories. For this reason, a customised solution inside the IWMS platform has been implemented by the software supplier, providing a panel with a link to each necessary 3D publication view (Figure 71). Due to the federated workflow, the operative models structured in levels have several links equals to the levels to be published (Figure 72). On the other side, concerning multilevel operating models, the publication link is unique for each model. In addition to these links, standard configuration functions have been implemented to allow the “switching on and off” of the project assets by Levels, regardless of their super-category. This operation, as detailed in chapter 5.5, is based on the shared parameter "Codice piano" which allows the overcoming of several criticalities connected to the variation of the reference parameter for every single category.

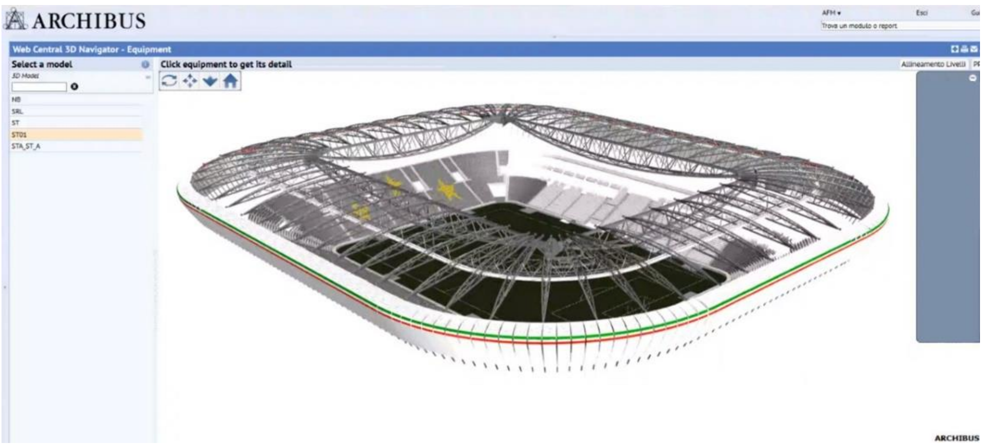


Figure 71 – 3D multidisciplinary publication of a portion of the case study inside Archibus©

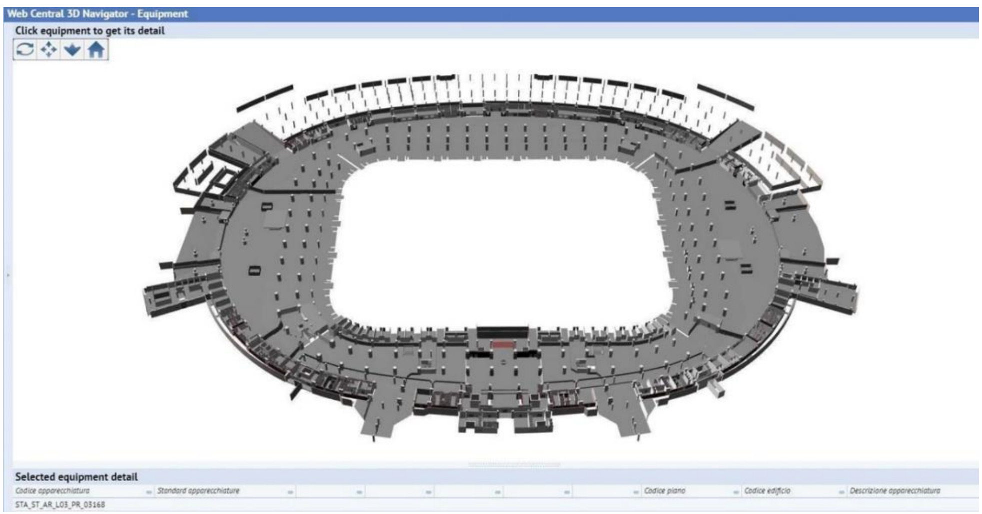


Figure 72 – 3D architectural publication of the L03 of the case study inside Archibus©

The developed category panel presents a customised structure for the present case study based on the articulation of the different disciplinary models, illustrated in Table 23. This structure, in addition to the illustrated federated structure and levels section, considers and allows the management of assets by discipline, through the definition of "Level Elements". During the implementation of these aspects, the other owner's sites and buildings have also been taken into consideration, highlighting the transversal aspect of the implemented FM management tool.

Table 23 – Structure of the custom Category Panel inside Archibus©

Discipline	Levels	Level Elements
Architectural S01	S01	Site
Architectural L00	L00	Architectural
Architectural L01	L01	Structural
Architectural L02	L02	Primary Sources
Architectural L03	L03	Ventilation and Air conditioning system
Architectural L04	L04	Heating system
Architectural L05	L05	Plumbing system
Architectural L06	L06	Fire protection
Architectural L07	L07	Electrical system
Architectural L08	L08	Furniture
Architectural LCT_01	LCT	
Architectural LCT_02		
Structural		
Primary Sources		
Ventilation and Air conditioning system		
Heating system		
Plumbing system		
Fire protection		
Electrical system S01		
Electrical system L00		
Electrical system L01		
Electrical system L02		
Electrical system L03		
Electrical system L04		
Electrical system L05		
Electrical system L06		
Electrical system L07		
Electrical system L08		
Furniture S01		
Furniture L00		
Furniture L01		
Furniture L02		
Furniture L03		
Furniture L04		
Furniture L05		
Furniture L06		
Furniture L07		

Based on the results obtained during the research activity and illustrated in this chapter, it seems possible to highlight how the impact of a federated model for the publication activity is independent of the number of levels defined within the modelling operational workflow. On the other side, regarding the **cataloguing procedure**, the use of a federated model has no particular impact compared to the adoption of an integrated one. The Archibus© database is unique and unbroken regardless of the number of models catalogued, as illustrated in Figure 48. The uniqueness of the final database that may be consulted during maintenance activities allows the execution of multi-building and multi-site research and analysis.

5.4 Geometric content definition

The achievement of a correct Data Integration has an impact on the definition of the **geometric content** of the BIM model, since, based on the analyses carried out during the research activity, it is necessary to follow the operational dispositions contained in the BIM guidelines. These derive, as explained in the previous chapter, from the application of specific modelling rules.

Among these, the first concerns the **2D symbology** for which it is necessary to use only the symbol lines, to ensure the correct integration. These should be modelled in order to be correctly positioned when the reference surface of the implemented family varies. As visible in Appendix B and Figure 52, this 2D symbology should be associated with the low level of geometric detail, and its definition has been made from the As-built documentation analysed in collaboration with the suppliers. Thanks to their visualization within the 2D views in the IWMS platform, suppliers will have more information available to them during the performance of maintenance activities. For this purpose, several tests have been carried out to analyse the results achieved at the maximum zoom level that of this tool concerning the Space Console inside Archibus©, as shown in Figure 73 with a general configuration and in detail in Figure 74.

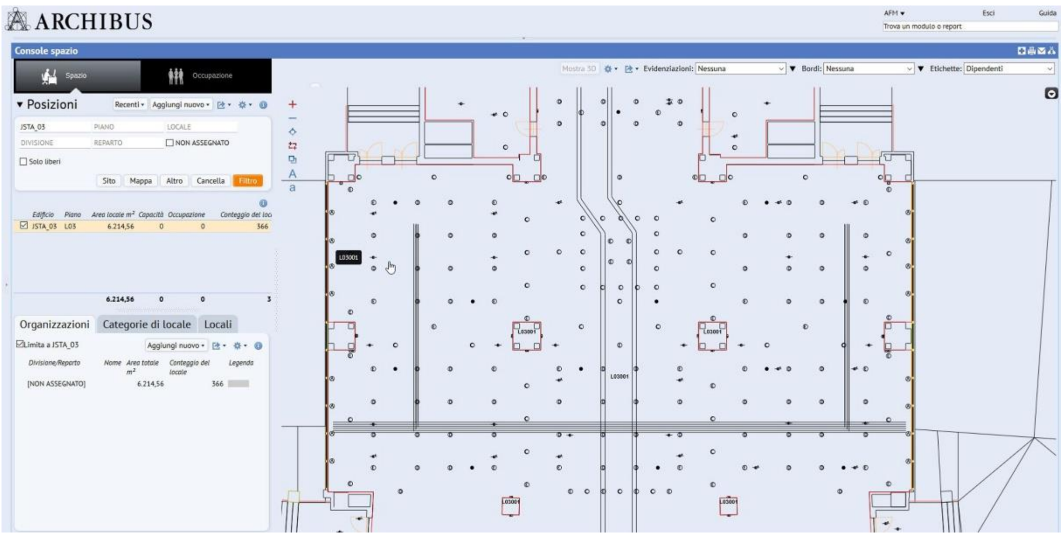


Figure 73 – General extrapolation of the Electrical symbology in the 2D representation in Archibus©

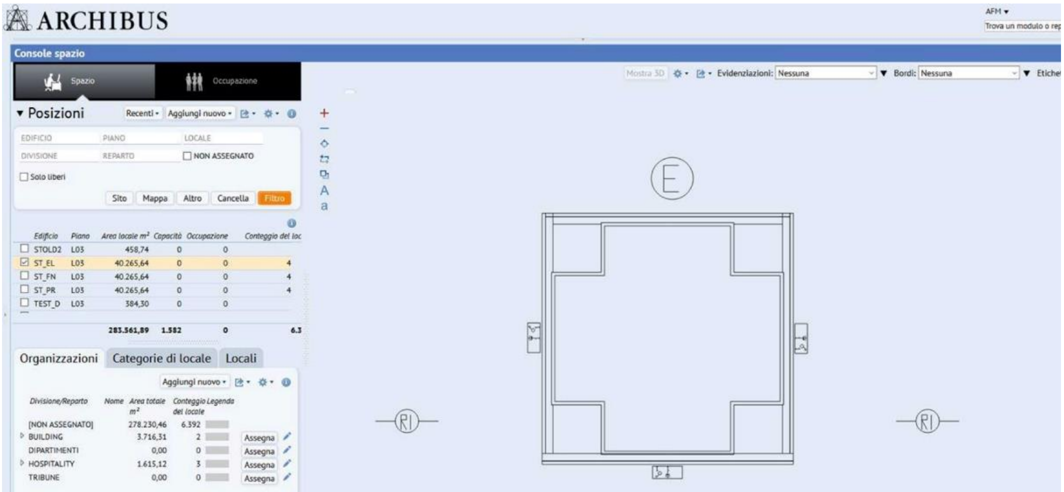


Figure 74 – Detailed extrapolation of the Electrical symbology in the 2D representation in Archibus©

Still connected to the topic of 2D visualization, one of the activities identified within the proposed methodological standardization concerns the correct setting of the **visualization range** of the different model views since it influences the result obtained in the IWMS platform. Respecting the standard rules of representation, the definition of the most suitable range allows managing the way objects are displayed and which of them are visible. The publication procedure of Archibus© generates, in general, a print of what is visible inside a view of the digital model. It is therefore clear that a correct analysis of these aspects is essential during the template structuring activity, to set the most suitable "View visualization ranges" involved in the publication process. Even at the 3D publication level, setting the level of detail of the views connected with the Archibus© software allows defining which level of geometric detail is visible during the maintenance activity. The definition of this information is strictly linked to the Data Visualization objective through the "Upgrade" parameter. The choice to use a high level of geometric detail within the IWMS platform should be defined according to the evaluation of the impacts between the increased weight due to the implementation of the information contained, the effective use of this data during the maintenance activity, and the possible effect of the platform slowing down. At the state of the art, there are no similar examples to the case study analysed that would allow a prediction of the impact of this type of choice on the management software.

As mentioned in Chapter 4.6, for a proper integration between the BIM model database and the Archibus© structured one, each object should be linked to a specific level. During the modelling phase, however, an impacting aspect has been highlighted thanks to specific tests: the field containing the **level information** changes depending on the object's category and the template used for its modelling. Besides, within the BIM guidelines implemented for the case study, two different types of the level's information have been identified:

- the **modelling positioning level** that is visible within the software used for model implementation;

- the **database positioning level** that is visible in the ODBC export of the database.

Regarding the first valorisation, the reference parameter varies according to the category considered and the reference template used for the family implementation, only in the case of loadable families. It has been observed that, for example, the adoption of a generic template for a surface-based family will involve the "Schedule Level" parameter in the created objects. On the other hand, concerning the export to ODBC for the second valorization, tests conducted jointly with the owner have highlighted that the populated field depends exclusively on the category analysed (as visible in Table 24 and Table 25). In fact, for families "from library" or "face-based generic model" the exported valorisation is the same.

Table 24 – ODBC export for the parameter "Level" – Loadable families

Loadable Family	From library	Face-based generic model (with category change)	Mechanical System	Electrical	Architectural
Cable Tray Fittings	No parameter	No parameter	-	No parameter	-
Electrical Equipment	Level	Level	-	Level	-
Electrical Fixtures	Level	Level	-	Level	-
Lighting Fixtures	Level	Level	-	Level	-
Fire Alarm Devices	Level	Level	-	Level	-
Communication Devices	Level	Level	-	Level	-
Conduit Fittings	No parameter	No parameter	-	No parameter	-
Structural Framing	Level/Reference Level	Level/Reference Level	-	Level/Reference Level	-
Pipe Fittings	No parameter	No parameter	No parameter	-	-
Pipe Accessories	No parameter	No parameter	No parameter	-	-
Plumbing Fixtures	Level	Level	Level	-	-
Mechanical Equipment	Level	Level	Level	-	-
Sprinklers	Level	Level	-	-	-
Duct Fittings	No parameter	No parameter	No parameter	-	-
Air terminals	No parameter	No parameter	No parameter	-	-
Duct Accessories	No parameter	No parameter	No parameter	-	-
Furniture	Level	Level	-	-	Level
Doors	Level	Level	-	-	Level
Windows	Level	Level	-	-	Level
Site	No parameter	No parameter	-	-	No parameter
Structural Stiffeners	No parameter	No parameter	-	-	-
Columns	Base Level	Base level	-	-	Base Level
Structural Columns	Base Level	Base level	-	-	Base Level

Table 25 – ODBC export for the parameter "Level" – System families

System Family	From library	Face-based generic model (with category change)	Mechanical System	Electrical	Architectural
Cable Tray	No parameter	-	-	No parameter	-
Conduit	No parameter	-	-	No parameter	-
Pipes	No parameter	-	No parameter	-	-
Flex Pipes	No parameter	-	No parameter	-	-
Ducts	No parameter	-	No parameter	-	-
Flex Ducts	No parameter	-	No parameter	-	-
Floors	Level	-	-	-	Level
Ceilings	Level	-	-	-	Level
Parts	Base level	-	-	-	Base Level
Ramps	Base level	-	-	-	Base level
Railings	Base level	-	-	-	Base level
Walls	Base constraint	-	-	-	Base Constraint
Slab Edges	No parameter	-	-	-	No parameter
Roof gutter	No parameter	-	-	-	No parameter
Rooms	Level	-	-	-	Level
Structural foundation	No parameter	-	-	-	No parameter
Roofs	Base level	-	-	-	Base level
Stairs	Base level	-	-	-	Base level

Based on these analyses, the following overview has been included in the implemented BIM guidelines of the case study, according to the implemented models (Table 26):

Table 26 – Specification of the project reference systems

Reference systems		
Autodesk Revit object category	Positioning level - modelling	Positioning level - database
Air Terminals	Schedule Level	None
Areas	-	-
Cable Tray Fittings	Level	None
Cable Trays	Reference Level	None
Ceilings	Level	Level
Columns	Base Level	Base Level
Communication Devices	Schedule Level	Level
Conduit Fittings	Level	None
Conduits	Reference Level	None
Curtain Panels	-	-
Curtain Wall Mullions	-	-
Data Devices	-	-
Doors	Level	Level
Duct Accessories	Level	None
Duct Fittings	Level	None
Ducts	Reference Level	None
Electrical Equipment	Schedule Level	Level
Electrical Fixtures	Schedule Level	Level
Fire Alarm Devices	Schedule Level	Level
Flex Ducts	Reference Level	None
Flex Pipes	Reference Level	None
Floors	Level	Level
Furniture	Level/Schedule Level	Level
Generic Model	-	-
Lighting Devices	-	-
Lighting Fixtures	Schedule Level	Level
Mass	-	-
Mechanical Equipment	Schedule Level	Level
MEP Fabrication Containment	-	-
MEP Fabrication Ductwork	-	-
MEP Fabrication Hangers	-	-
MEP Fabrication Pipework	-	-
Nurse Call Devices	-	-
Parking	-	-
Parts	Base Level	Base Level
Pipe Accessories	Level	None
Pipe Fittings	Level	None
Pipes	Reference Level	None

Plumbing Fixtures	Schedule Level	Level
Railings	Base Level	Base Level
Railings_Supports	-	-
Railings_Terminations	-	-
Ramps	Base Level	Base Level
Roofs	Base Level	Base Level
Roofs Gutter	None	None
Rooms	Level	Level
Security Devices	-	-
Shaft Openings	Base Constraint	-
Site	Level	None
Slabde Edges	None	None
Spaces	-	-
Specialty Equipment	-	-
Sprinklers	Schedule Level	Level
Stairs	Base Level	Base Level
Structural Columns	Base Level	Base Level
Structural Connections	-	-
Structural Foundations	Level	None
Structural Framing	Schedule Level/Reference Level	Level/Reference Level
Structural Stiffeners	Level	None
Structural Trusses	-	-
Telephone Devices	-	-
Topography	-	-
Walls	Base Constraint	Base Constraint
Windows	Level	Level

As discussed in detail in the next chapter, each **parameter** of the BIM model should be **mapped** within a specific field of the Archibus© platform. Starting from the tests carried out on the level parameter, it has also been possible to connect several parameters belonging to the BIM Database within a single field of the IWMS database. Concerning this field and its considerable importance for different aspects in the management platform, it has been decided to insert a shared instance parameter called "Codice piano". It has been filled in, for each parametric object present in the models, with the corresponding coordination level name to which the element is associated. This operative strategy allowed the use of this parameter, for example, for the correct functioning of the Levels buttons within the category panel previously described, proceeding to populate the "Codice Livello" field of Archibus©. The formal characteristics of the denomination used for levels should consider, already during the populating phase in the modelling software, the maximum number of characters allowed in the IWMS platform, equal to four. From a critical point of view, the defined operating mode is applied for the resolution of a software issue, generating a data duplication. For this reason, future implementations of the software involved will be able to overcome this criticality, keeping the concept of uniqueness of the data intact.

The Level parameter is also essential for the correct **cataloguing process** of **rooms**, which should all be linked to the only corresponding level of coordination they belong to. Taking into account this aspect during the modelling activity, the altimetric heights of the coordination levels have been defined with different value respect the As-built existing valorization, as summarized in Table 15. Moreover, following a specific modelling rule, it is not possible to create overlapping rooms belonging to the same level because this action could generate different issues in the maintenance platform.

This consideration is also essential for the proper definition of the room to which each object belongs. In fact, one of the main ways of managing maintenance activities could be by space and, for this reason, the association asset - room becomes essential, as can be seen in the maintenance activities window below (Figure 75). If the object, for its category, is not automatically linked to its space through the “Puntatore del locale”, an alphanumeric parameter called "Codice spazio", defined in Annex 02 allows the insertion of this information.

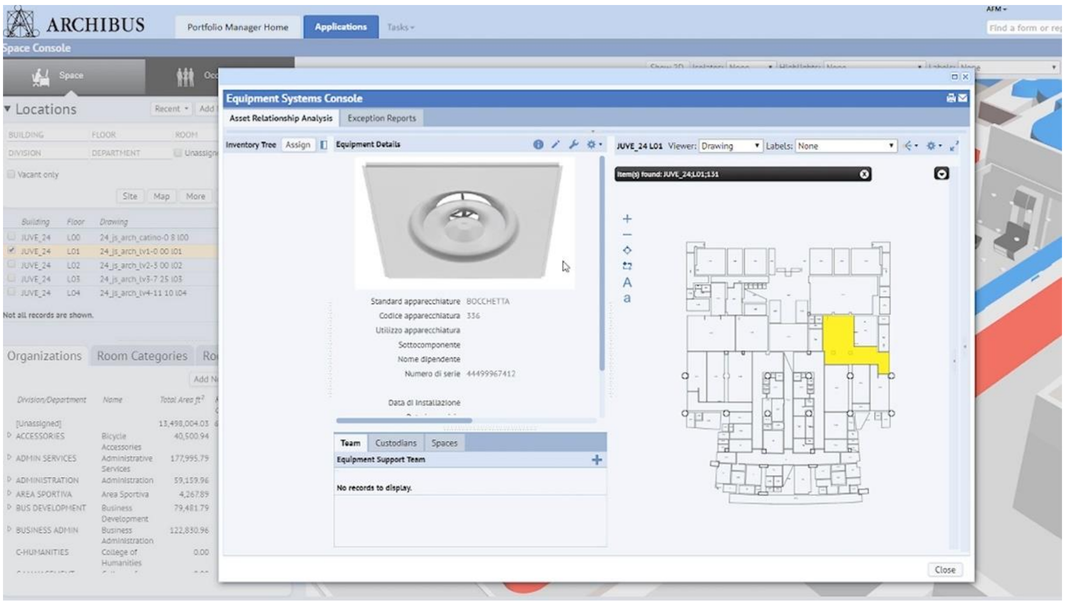


Figure 75 – Example of maintenance activity inside Archibus©, during the integration tests

The development of integration tests during the research activity also allowed the identification of some issues that had not yet been found in other projects present in literature, with a similar objective. For example, during the first 3D publishing operations, a problem has been found related to the loss of some columns geolocation, belonging to the AR discipline and the “Columns” category. The same has been found for the ST discipline and thus to the “Structural Columns” category (Figure 76). This aspect has been extensively analysed by all the actors involved for these project activities and directly by the Archibus© company which has then released an update of the plug-in used to carry out the publication activity that allows overcoming the problem mentioned above (Figure 77).

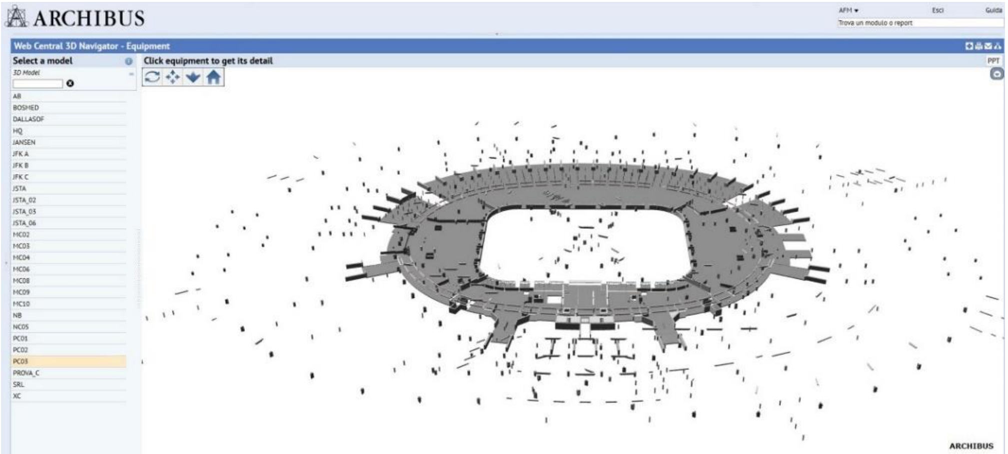


Figure 76 – 3D publication issue connected to the Structural Columns in Archibus©

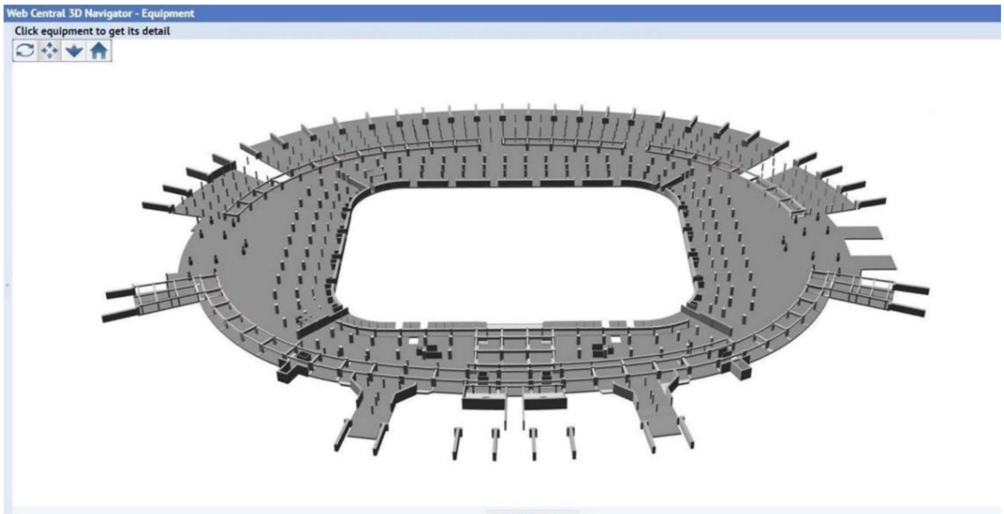


Figure 77 – Problem resolution through the plug-in release by the software house Archibus©

5.5 Alphanumeric content definition

For a BIM database, the Data Integration is also based, on the correct integration of the alphanumeric content since obtaining data in a usable format is part of the standard identification. The **database extrapolation** is the first step to manage BIM data in different external or integrated management platforms (Barbero, Del Giudice, Ugliotti, & Osello, 2020).

For these reasons, several tests have been carried out to monitoring and analyse the operational transition of information from the BIM database to the ODBC structure. Their execution allows to analyse the effective integration of different kinds of attribute: i) Built-in parameters; 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. Besides, also the "Type" or "Instance" nature of the parameter has been considered during the integration analysis. This aspect influences both the BIM database tables extracted in ODBC and the IWMS platform in which a parameter is located. The achieved results are visible in Table 27. For example, to enrich the correct transition of shared parameters, they should be created in the .rvt file as a shared project parameter even if they are contained within a family (.rfa) (Barbero, Del Giudice, Ugliotti, & Osello, 2020).

Table 27 – ODBC exchange tests (Barbero, Del Giudice, Ugliotti, & Osello, 2020)

	Built - in Parameters		Family Parameters	Project Parameters	Shared Parameters
System Family	✓		—	Type ✓ Istance ✓	(.rvt) Type ✓ Istance ✓
Loadable Family	It is possible to see the nature of the parameter	✓	Type ✗ Istance ✗	Type ✓ Istance ✓	(.rvt) Type ✓ Istance ✓ (.rfa) Type ✓ Istance ✓
	Associated to each single family inside the property panel	✗	—	—	—

The second step is then represented, as anticipated, by the **connection** of each extracted field with the respective one within the destination platform. For the present case study, this operation allowed obtaining, within the management environment, all the necessary information that have been grouped and subdivided according to the discipline to which they belong, as can be seen in Figure 78.

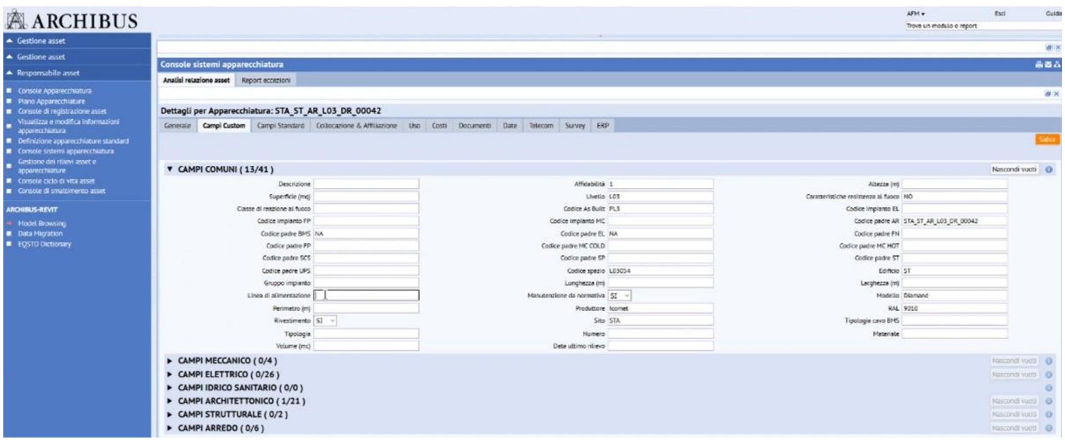


Figure 78 – Consultation of the alphanumeric parameters inside Archibus©

Also, according to the analysis highlighted during the research project, the distinction between type parameter and instance one affects the determination of the Archibus© **database table** in which data are placed at the end of the cataloguing process. Instance information is located within the equipment table and it is directly linked to the individual asset. On the other side, type parameters are located in the equipment standard table and are characterized by a specific identifier that represents the connection between the standard and the asset. In this way, it is possible to avoid the duplication of the standard information inside the database despite their association to several assets. At the same time, the concept of standards plays an important role since this information is used for the assignment of maintenance procedures. Therefore, the methods used for the identification of standards within Archibus© could have an impact at the modelling level. This consideration occurs if, as the example of the current case study, it is decided to employ the "type name" denomination of object as the required standard.

Always concerning the alphanumeric content definition, a series of technical operating standards are linked to the **naming rules** and the way the alphanumeric content is populated, which require the observance of specific formal rules, necessary for the proper data integration. Indeed, as shared during the implementation of the project by the software supplier, the use of special characters may generate problems in the integration step. Therefore, in the implemented guidelines, the dispositions summarized in Table 28 have been provided. These are defined for both the name of loadable families (.rfa) and types of loadable or system families.

Table 28 – Family and Type denomination rules for Archibus©

	A,B,C,D,E,F,G,H,I,J,K, L,M,N,O,P,Q,R,S,T,U,V, W,X,Y,Z, a,b,c,d,e,f,g,h,i,j,k,l,m,n, o,p,q,r,s,t,u,v,w,x,y,z 0,1,2,3,4, 5,6,7,8,9	Point	–	Space	+ -	à,á,è,é,ì,í,ò,ó,ù, ú, À,Á,È,É,Ì,Í,Ò, Ó,Ù,Ú,Ú
Autodesk Revit Family name	YES	NO	YES	NO	NO	NO
Autodesk Revit Type name	YES	NO	YES	NO	NO	NO

Concerning the maximum number of characters that can be used for the parameters compilation, the following limitations have been applied: i) Family nomenclature: maximum 32 characters; ii) Family types nomenclature: maximum 32 characters. The rules concerning the family's nomenclature regard only the loadable families, since for the system ones it is not possible to modify their denomination provided by the modelling software. On the other side, the type's nomenclature concern both loadable and system families.

Regarding the way to **populate the alphanumeric parameters**, specific operational provisions have been defined, as visible in Table 29.

Table 29 – Alphanumeric population rules for Archibus©

	A,B,C,D,E,F,G,H,I,J,K, L,M,N,O,P,Q,R,S,T,U,V, W,X,Y,Z, a,b,c,d,e,f,g,h,i,j,k,l,m,n, o,p,q,r,s,t,u,v,w,x,y,z 0,1,2,3,4, 5,6,7,8,9	Point	_	Space	+ -	à,á,è,é,ì,í,ò,ó, ù,ú, À,Á,È,É,Ì,Í,Ò ,Ó,Ù,Ú,Ú
Revit Parameters	YES	YES	YES	YES	YES	YES

All characters not expressly indicated in the table above are therefore excluded and not usable, such as, for example, "()", "/". The following limitations have been defined associated with the maximum number of characters that can be used to fill in the parameters: i) Numeric Fields (number, length): maximum 11 characters (including decimal numbers and relative separator); ii) Text Fields (text, material): maximum 250 characters. It is easy to understand how these aspects, especially for buildings with a large number of objects, may have a significant impact. The need to guarantee the achievement of the set objective, therefore, requires to verify the correct application of the illustrated dispositions, which represents the input for the development of the formal alphanumeric control linked to the Data Validation concept.

As previously anticipated, based on the considerations developed in this chapter and the particularities of the case study, it has been necessary to proceed with the definition of a series of essential parameters for the proper integration between the two databases. This need derives from the operational choice of using a tailor-made solution based on the ODBC format. In detail, these parameters are:

- **Sito**: instance parameter to be filled in with the acronym of the site indicated in Annex 02.
- **Edificio**: instance parameter to be filled in with the acronym of the building indicated in Annex 02.
- **Codice piano**: instance parameter to be filled in with the denomination of the coordination reference level, to which the object is connected.
- **Asset Code**: instance parameter that uniquely identifies an object within a single site and between different ones. Its structure is illustrated in Table 30.

Table 30 – Structure of the Asset Code parameter

STA	Acronym relative to the **site** to which the analysed object belongs: **STA:** Allianz Stadium **MUS:** Museo **MGS:** Megastore **JHQ:** JHQ **JTC:** Juventus Training Center …
ST	Acronym relative to the **building** to which the analysed object belongs: **ST:** Stadio

	AR: Autorimessa P7 – P9 **AE:** Aree Esterne **VF:** Villaggio Fornitori …
EL	Acronym relative to the **discipline** or **sub-discipline** to which the analysed object belongs: **AR:** Architectural **EL:** Electrical **FN:** Furniture **FP:** Fire Protection **GN:** Generic **MC:** Mechanical (as the model of system sources) **PL:** Plumbing **VE:** Ventilation **TE:** Thermal **ST:** Structural
L01	Acronym relative to the coordination **level** to which the analysed object belongs: **L01:** Level 1 **L02:** Level 2 **…**
EE	Acronym relative to the **category** to which the analysed object belongs. For Example: **EE:** Electrical Equipment
00801	**Unique** progressive **number** identification by category and level, composed of five numbers.

In detail, the parameters Site, Building and Floor Code have been necessary as the first step of the integration for the proper creation of the space inventory environment. After that, each asset connection has been defined through the employment of two key parameters: the Asset Code for model equipment and the **Number** for rooms. This last one is composed by six numbers: the first three are the acronym of the coordination level of belonging (i.e. L03), while the last three represent a progressive number of the room (i.e. 003). In this way, this data is unique only for a single building (i.e. L03003) and, for this reasons, the alphanumeric parameter "Codice FM" has been definite to contain also the indication of the site and the building, becoming unique for the entire IWMS database (i.e. STA_ST_L03003).

Always connected to the alphanumeric population issue, as indicated in chapter 4.7, a set of parameters belonging to the Hierarchy group have been defined. In detail, they allowed rebuilding the complex multidisciplinary hierarchy of the different building systems within Archibus©, recreating at the same time what has been developed within each single BIM model (Figure 79). Starting from the meaning of these parameters and the corresponding operational methods of implementation it is possible to obtain, within the management platform, the monodisciplinary and multidisciplinary hierarchy to which the object belongs, through the hierarchic visualization of the Asset Code parameters of the objects involved (Figure 80) as "terminale" or "padre" of the system.

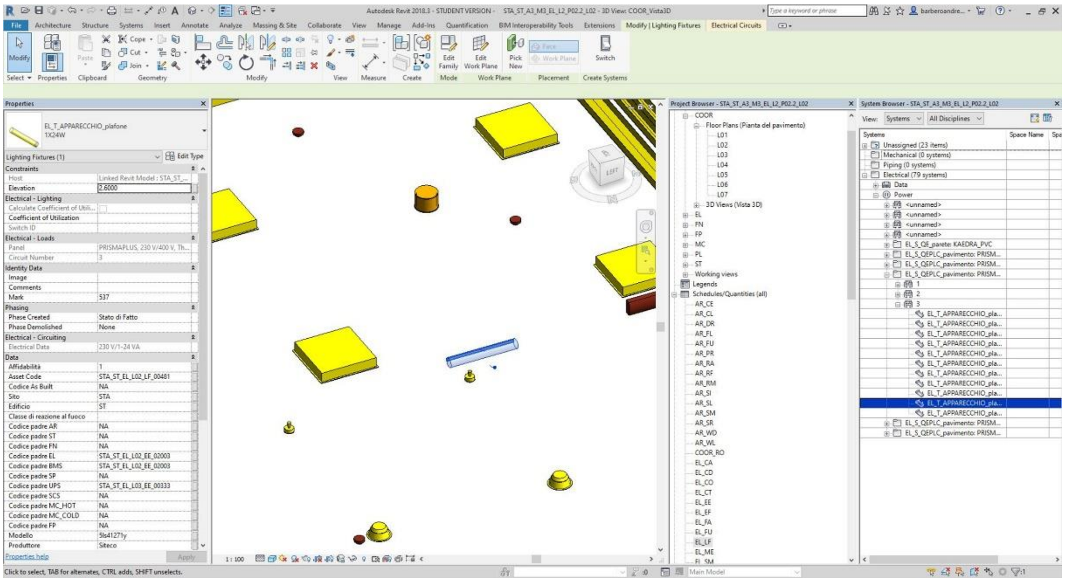


Figure 79 – Example of the Electrical system hierarchy implemented in Autodesk Revit

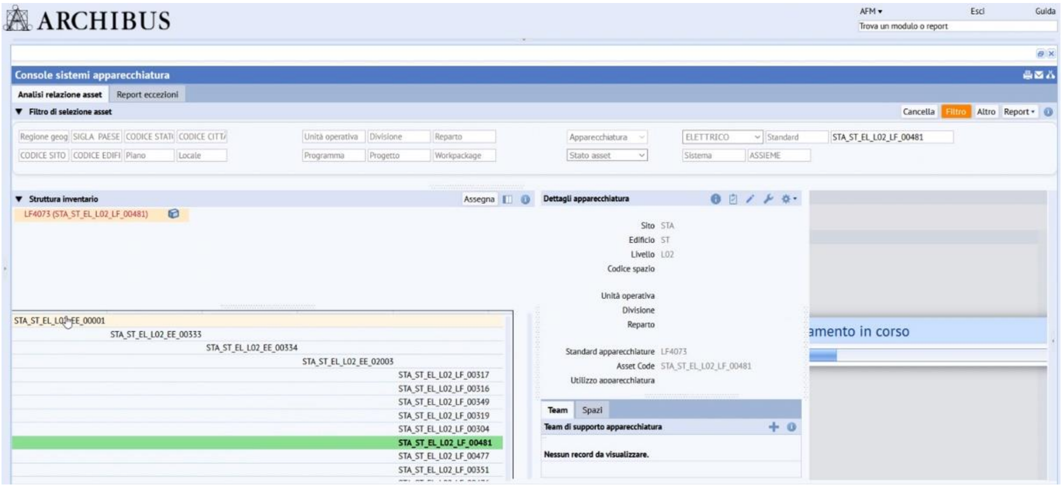


Figure 80 – Example of the Electrical system hierarchy implemented in Archibus©

Thanks to the illustration of the operating standards performed above, it has been described how to manage the objects present in the BIM models, defined as components, of the case study. On the other side, regarding the sub-component objects, it has been planned to insert them directly in the Archibus© database through massive uploading, starting from the population of an Excel sheet with a specific structure. Every single line of this document represents a sub-component under maintenance, as visible in the extract of Annex 02 shown in Table 31. The columns, on the other hand, constitute the parameters associated with each one, that will be compiled in function of the effective membership of the sub-component analysed. Since these objects present only alphanumeric and non-graphic information and they are under maintenance activities, once the uploading procedure has been completed, they will be included in the equipment table. Their connection to the reference asset to which they belong has been implemented through the sub-component Asset Code structure, which recalls the Asset Code value for the component with a progressive number, allowing them to be unique.

Table 31 – Example of the sub-component file for Archibus© uploading

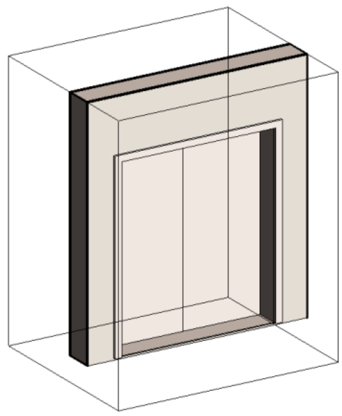
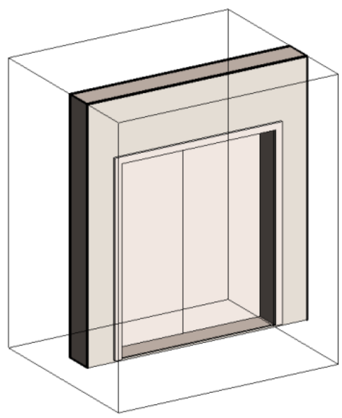
Asset Code	Parameter 1	Parameter 2	….	Parameter n
STA_ST_EL_L06_EE_00001_001				
STA_ST_EL_L06_EE_00001_002				
STA_ST_EL_L06_EE_00001_003				
STA_ST_EL_L06_EE_00001_004				
STA_ST_EL_L06_EE_00001_005				
STA_ST_EL_L06_EE_00002_001				
STA_ST_EL_L06_EE_00002_002				
STA_ST_EL_L06_EE_00002_003				
STA_ST_EL_L06_EE_00002_004				
STA_ST_EL_L06_EE_00002_005				

5.6 BIM Model Checking

As illustrated in the previous chapters, BMC is a topic of great importance in the research activities related to the construction sector. Indeed, its application allows the identification of **errors** and **criticalities** that could generate subsequent problems during the implementation of the process. In detail, regarding the objective of Data Integration, the implemented declination of **Data Validation** becomes particularly important as an integrated part of the **BMC** definition. The aim of the Data Validation process developed during the research activity is to implement a methodology for an automated BMC validation process of the alphanumeric content of a BIM model based on a **VPL** (Vergari, et al.), focused on the quality verification of information. At the same time, the proposed workflow enables meeting the growing need of owners to centralize their data ownership, augmenting its quality and reliability. In this way, the owner could check the considerable amount of data contained in BIM model, summarizing the results obtained in specific reports which could be shared with all the actors involved in the process (Vergari, et al.). Validation checking aims to verify the information quality in the BIM model within defined rules, based mainly on internal standards.

In order to obtain a correct integration of the BIM database, it is necessary to pursue a series of dispositions required by the IWMS database's structure during the implementation phase of the alphanumeric content, as illustrated in chapter 2.3 of the elaborated thesis. For this reason, the declaration of the **alphanumeric parameters under control** and **how the validation is implemented** become an integral part of the adopted guidelines and the proposed methodological standardization. The defined rulesets could be based on several sources, such as norms, codes, external standards, contracts, or on specific operational requirements like BIM guidelines (Vergari, et al.). For these reasons, the alphanumeric content checked for each advancement step of the research project has been summarised in Annex 05, showing the illustration of a significant object for every discipline. An extrapolation of this document concerning the AR discipline has been reported in Table 32. These schedules also contain the expected geometric content resulting from the analysed step. As visible, based on the needs expressed by the owner, almost all the parameters connected to the parametric objects have been subjected to the formal alphanumeric control. It has been carried out through the application of specific rules, illustrated subsequently, which change according to the parameter analysed. The only parameters indicated in Annex 02 that were not included in this activity are the Built-in parameters automatically compiled by the modelling software during the realization of the object itself and the dimensional parameters present for some families but not shared to the entire category analysed, to which they belong.

Table 32 – Schedule concerning the advancement steps expected for an object of the Architectural discipline

Component: Door			Loadable Family
	LOG	LOI	Output
STEP 1	Solido 3D che ne permette la definizione dell'ingombro spaziale	- Level - Phase - Thickness - Family - Type - Function - Affidabilità - Asset Code - Sito - Edificio - Codice piano	
STEP 2	Solido 3D che ne permette la definizione dell'ingombro spaziale	- Altezza_std - Larghezza_std - Classi di unità tecnologiche - Unità tecnologiche - Classi di elementi tecnici - Numero MasterFormat - Titolo MasterFormat - Codice As Built - Description - Codice padre AR - Codice padre ST - Codice padre FN - Codice padre EL - Codice padre BMS - Codice padre SP - Codice padre UPS - Codice padre SCS - Codice padre MC_HOT - Codice padre MC_COLD - Codice padre FP - RAL - Caratteristiche resistenza al fuoco - Modello - Produttore - Tipologia serratura - Materiale pannello - Materiale telaio	

Starting from the methodological scheme illustrated in Figure 6 extending to all disciplines of the project as described in Annex 05, the first steps of the validation process developed concerned the identification of the **meaningful information** that should be checked as illustrated before and the definition of the **checklist**. These are used to define what parameter should be checked within the modelling database for each category, in compliance with the disposition given by BIM guidelines for every discipline (Vergari, et al.). These aspects are visible in Figure 81, which show the total number of checked parameters for each single AR category with the indication of the parameter clusters' distribution and in the extract of Table 33. The entire checklist of the AR discipline is summarised in Appendix C, where is visible the association of every single parameter to the relative categories. This extrapolation regards the AR discipline (without Room category which has been analysed separately like a single discipline due to their specific checklist and rulesets) but, starting from data contains in Annex 02, the checklist' creation has been done for all the discipline and sub-discipline involved in the project with the adoption of the same logic, as visible in the chart represented in Figure 82. Another example of checklists, for the EL and TE disciplines of the case study, are summarised in Appendix C.

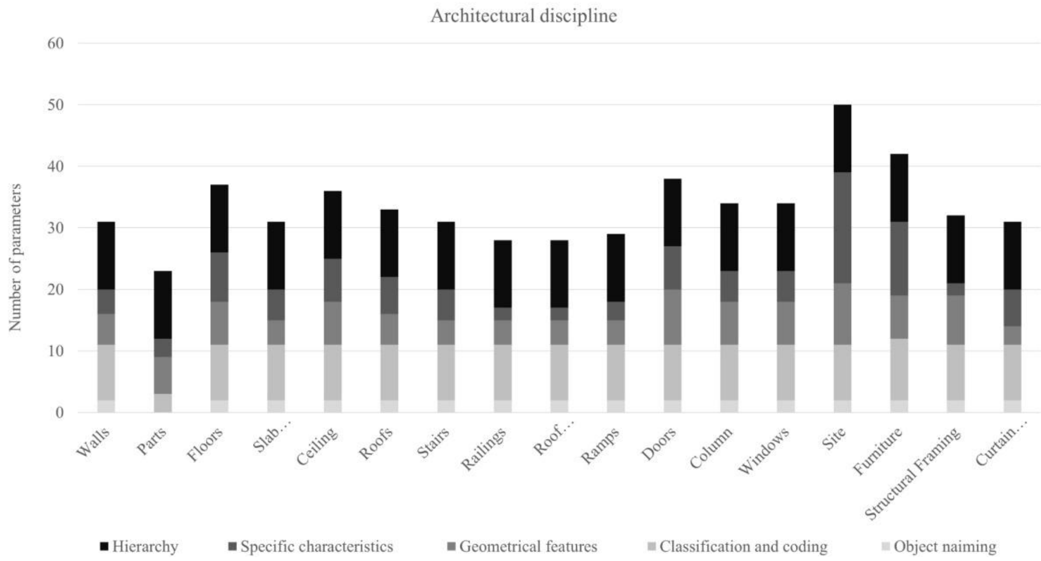


Figure 81 – Checklist of the Architecture discipline with the indication of each paramaters' cluster

Table 33 – Extract of a checklist of the Architectural discipline

CHECKLIST - ARCHITECTURAL DISCIPLINE																	
	Autodesk Revit categories																
	SYSTEM FAMILIES										LOADABLE FAMILIES						
Parameters	Walls	Parts	Floors	Slab Edges	Ceiling	Roofs	Stairs	Railings	Roof Gutter	Ramps	Doors	Column	Windows	Site	Furniture	Structural Framing	Curtain Panels
Phase																	
Level																	
Family																	
Type																	
……																	

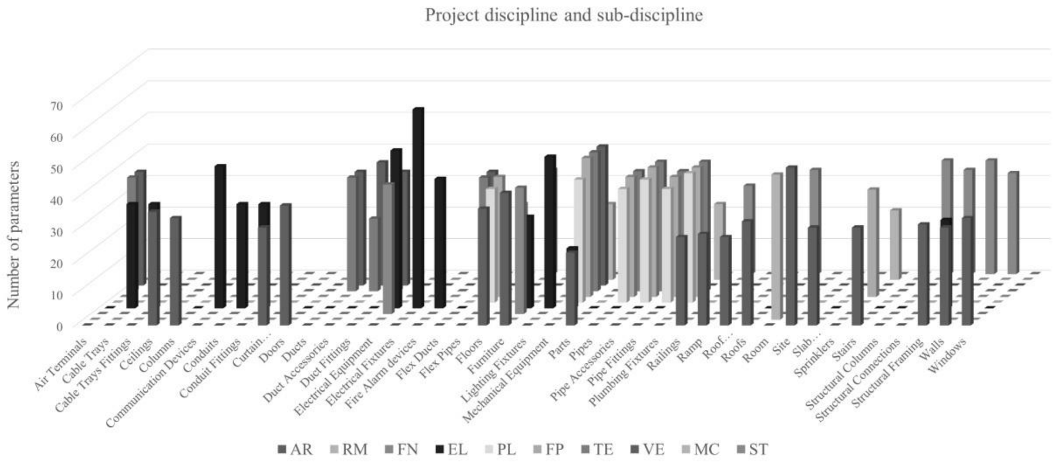


Figure 82 – Checklist of the project disciplines and sub-disciplines

Based on the checklist developed above, for each parameter, specific **rulesets** have been defined during the validation process definition, in order to verify specific aspects necessary for the Data Integration. The innovative aspect in the use of the VPL for this validation activities lies in the possibility of creating a flexible and visual control tool, which could be defined as a white box since it is possible to manage and implement every phase of the control. The implemented tool is based on Python[26], a specific programming language that allows the effective structuring of the different nodes which constitute the control process. Among these, based on the peculiarities of the control itself, specific nodes have been implemented, containing control rules called **Regular Expressions** (RegEx)[27] which are functions able to filter, compare or identify code strings, fulfilling the needs of the case study (Vergari, et al.). One of the major aspects of the proposed methodology concerns the definition, together with the owner, of the different control types to be adopted for each parameter, taking advantage of the great flexibility of VPL. The association of the checking rule to the single parameter for each discipline has been carried out considering the different needs required for the entire category. In this way, the population rules of each disciplinary schedules of Annex 02 illustrated in the chapter of Data Organization have been respected. This operational strategy, as explained below, affects how the control rules have been defined. Moreover, this definition has been done taking into account the importance of the project parameter analysed. For example, a significant role is played by the essential integration parameters, followed by those necessary for a correct structuring of the mechanical systems and so on. For these reasons, three main types of checking rules for the

[26] General definition of Python programming language from Wikipedia website: https://it.wikipedia.org/wiki/Python (last consultation on the 25th of October, 2020)

[27] Definition taken from the website of the "Guida alle espressioni regolari per webmaster" website: https://www.evemilano.com/come-funzionano-le-espressioni-regolari-regex/ (last consultation on the 24th of October, 2020)

case study have been defined, switching from a general check to a more detailed one (Vergari, et al.):

- **Check** if the **parameter** has been **compiled or not** (e.g. the parameter "Codice As Built", as visible in Figure 83).

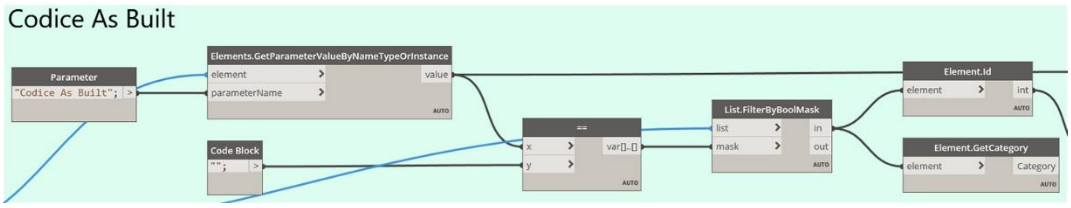


Figure 83 – Example of check if the parameter has been compiled or not in Autodesk Dynamo

- **Check** if the parameter has been compiled following the disposition of the BIM guidelines. This type of control has been classified for the research activity as a **formal** one. For this purpose, the specific RegEx should be defined by logical and/or mathematical constants and operators able to cover the different ways of populating alphanumeric content (Figure 84). For example, in this kind of check, there are Family Name and Type Name parameters which are generally populated manually and which should be developed in function of the logic defined in the Annex 01.1.

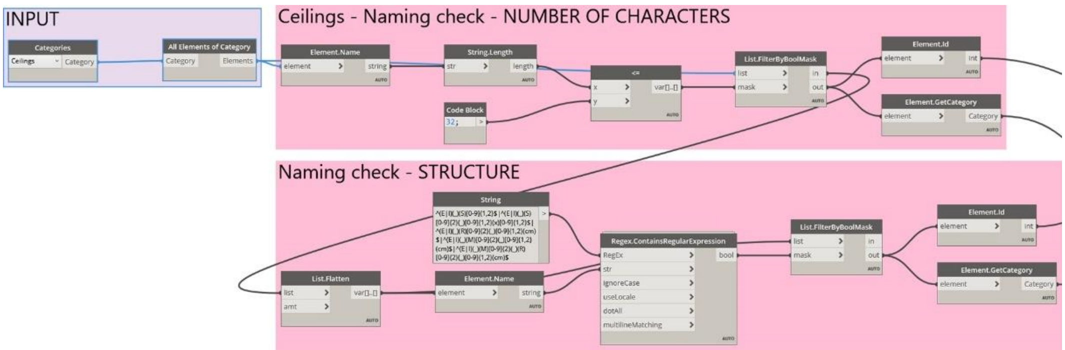


Figure 84 – Example of a formal check in Autodesk Dynamo

In detail, the RegEx checks that the structure used, in terms of letters, numbers and character sequences, corresponds to all the cases used and identified in Annex 01 and admitted by the rule itself (e.g. the "Type Name" parameter for the ceilings category: ^(E|I)(_)(S)[0-9]{1,2}$|^(E|I)(_)(S)[0-9]{2}(_)[0-9]{1,2}(x)[0-9]{1,2}$|^(E|I)(_)(R)[0-9]{2}(_)[0-9]{1,2}(cm)$|^(E|I)(_)(M)[0-9]{2}(_)[0-9]{1,2}(cm)$|^(E|I)(_)(M)[0-9]{2}(_)(R)[0-9]{2}(_)[0-9]{1,2}(cm)$)

- **Check** if the parameter has been compiled accordingly to the specific nomenclature defined in the BIM guidelines. The checking rule allows for the population of the parameter only the effective denomination determined in the BIM guidelines. This type of check for the research activity could be defined as a **substantial** check and it depends on the structure of the check itself, as visible in Figure 85. In detail, the RegEx checks the effective structure of the parameter that should be compiled with the specific characters foreseen in the BIM guidelines dispositions (e.g. the “Asset Code” parameter: *^(STA)(_)(ST)(_)(AR)(_)(L)[0-9]{2}(_)[A-Z]{2}(_)[0-9]{5}*). The only two values capable of variation and therefore controlled from a formal point of view are linked to the level and category information, enabling the use of the script on large numbers of data without the variation of individual RegEx. About the progressive number, the substantial control has been implemented with the check of its uniqueness.

Figure 85 – Example of a substantial check in Autodesk Dynamo

Illustrated the general characteristics of the implemented rules, the developed VPL control tool has been associated to a formal alphanumeric control, as previously defined, since it often does not consider the correctness of the content concerning the analysed object and its technical documentation. Table 34 shows an extract of the individual rulesets implemented for the AR discipline and consequently for all the different disciplines. The completed table is summarized in Appendix C where are also visible the rulesets developed for EL and TE disciplines.

Table 34 – Extract of rulesets of the Architectural discipline

Parameters	Step 1	Step 2	LF	SF	Type of check	Rulesets
Denominazione Family						Famiglie di sistema nessun controllo, per le famiglie caricabili regola strutturata in accordo ad Allegato 01 LG BIM (controllo formale). Massimo 32 caratteri, solo A-Z, 0-9 e "_" ammessi.
Denominazione Type						Massimo 32 caratteri solo A-Z, 0-9 e "_" ammessi. Strutturazione della regola in accordo ad allegato 01 LG BIM
Phase						Controllare che la fase di tutti gli elementi sia in "Stato di Fatto"
Level						Level (Floors, Ceilings, Doors, Windows, Site, Furniture)
						Reference Level (Structural Framing)
						Base Level (Parts, Roofs, Stairs, Railings, Ramps, Column)
						Base Constraint (Walls)
Thickness						Parametro di tipo - controllare che sia compilato
Structural material						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^(WL)(_)[A-Z]{2,3}$\|^(WL)(_)[A-Z]{1}[0-9]{2}$|^(WL)(_)[A-Z]{2,3}(_)[A-Z]{1,3}$\|^(WL)(_)[A-Z]{2,3}(_)[A-Z]{2,3}(_)[A-Z]{2,3}$|^(CE)(_)[A-Z]{2,3}$\|^(SM)(_)[A-Z]{2,3}$)

<table>
<tr><td>Material</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[A-Z]{2}(_)[A-Z]{2,3}$|^[A-Z]{2}(_)[A-Z]{1}[0-9]{2}$|^[A-Z]{2}(_)[A-Z]{2,3}( )[A-Z]{1,3}$|^[A-Z]{2}( )[A-Z]{2,3}( )[A-Z]{2,3}( )[A-Z]{2,3}$)</td></tr>
<tr><td>Structure (Structure)</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^(CE)(_)[A-Z]{3}$|^(CE)(_)[A-Z]{3}(_)[A-Z]{3}$|^(CE)(_)[A-Z]{3}(_)[A-Z]{3}( )[A-Z]{3}$)</td></tr>
<tr><td>Structure (Finish)</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^(FL)(_)[A-Z]{3}$|^(FL)(_)[A-Z]{3}(_)[A-Z]{3}$)</td></tr>
<tr><td>Structure (Substrate)</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^(RF)( )[A-Z]{1}[0-9]{2}$)</td></tr>
<tr><td>……</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

- Check if the parameter has been compiled or not.
- Check if the parameter has been compiled following the disposition of the BIM guidelines.
- Check if the parameter has been compiled accordingly to the specific nomenclature defined in the BIM guidelines.

The defined checklist and rulesets represent the input of the implemented validation tool which is based on the project federated organisation with a breakdown by discipline and sub-discipline, according to the category analysed and the type of parameters. The **metadata** of the implemented **algorithms**, therefore, follows the definition of the process's inputs (Vergari, 2019), as visible in Figure 86. The employment of a pattern enables to customize the check carried out, sharing at the same time its repeatability of the same in the setting of more complex scripts (Vergari, et al.).

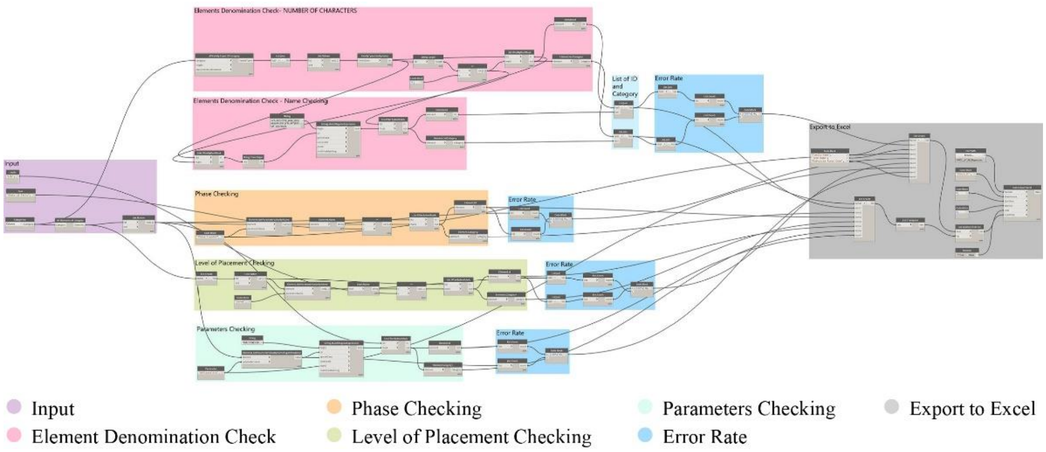


Figure 86 – Pattern of the algorithm developed in Autodesk Dynamo for Data Validation process (Vergari, 2019)

In the detail of the case study, for each discipline, Autodesk Dynamo scripts have been divided according to the two steps of advancement required by the BIM guidelines (Vergari, 2019). On one hand, **Step 1** has been operationally divided into two different scripts, one for loadable families and one for system families as the parameters checked and consequently, the implementation methods change. On the other hand, **Step 2** has been divided into several individual scripts to limit the size of the file and, therefore, the respective response times giving the possibility to verify specific groups of parameters independently. Another significant factor for the structuring of the check has been the single-level or multi-level nature of the discipline models analysed. Starting from the organization of the worksharing, all the scripts based on multi-level models have been structured in order to have, in input, the belonging level of the objects to be verified. This aspect has been essential to enable the **itinerary use** of scripts, allowing the validation of closed level within "Work in Progress" integrated models. All the controls have been structured to check only the objects linked to a single coordination level, to which all the instances not associated to a specific coordination level are added. In this way, all objects have been checked at the end of the validation of all coordination levels. On the other hand, regarding the disciplines composed of a single model for each level, the level's information has been used exclusively as a control for the detection of possible errors.

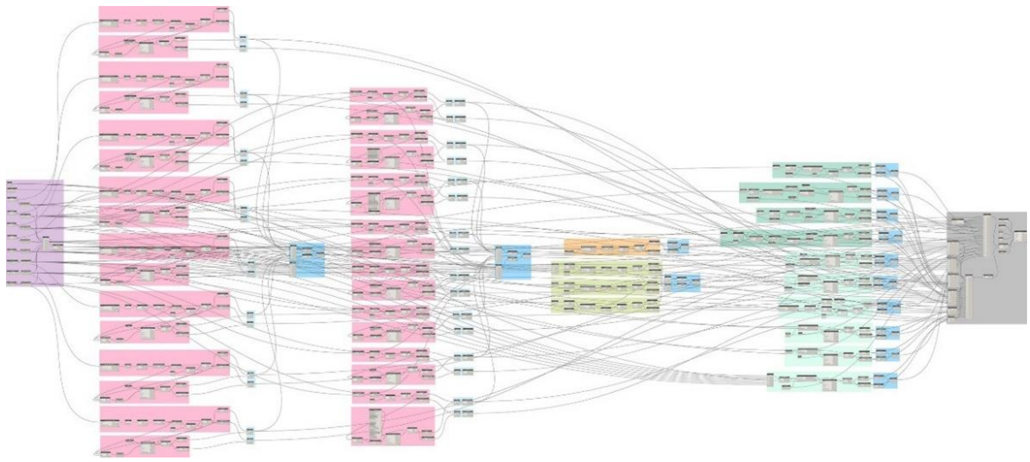


Figure 87 – Example of the Autodesk Dynamo script developed for the Step1_Loadable Families check of the Architectural discipline

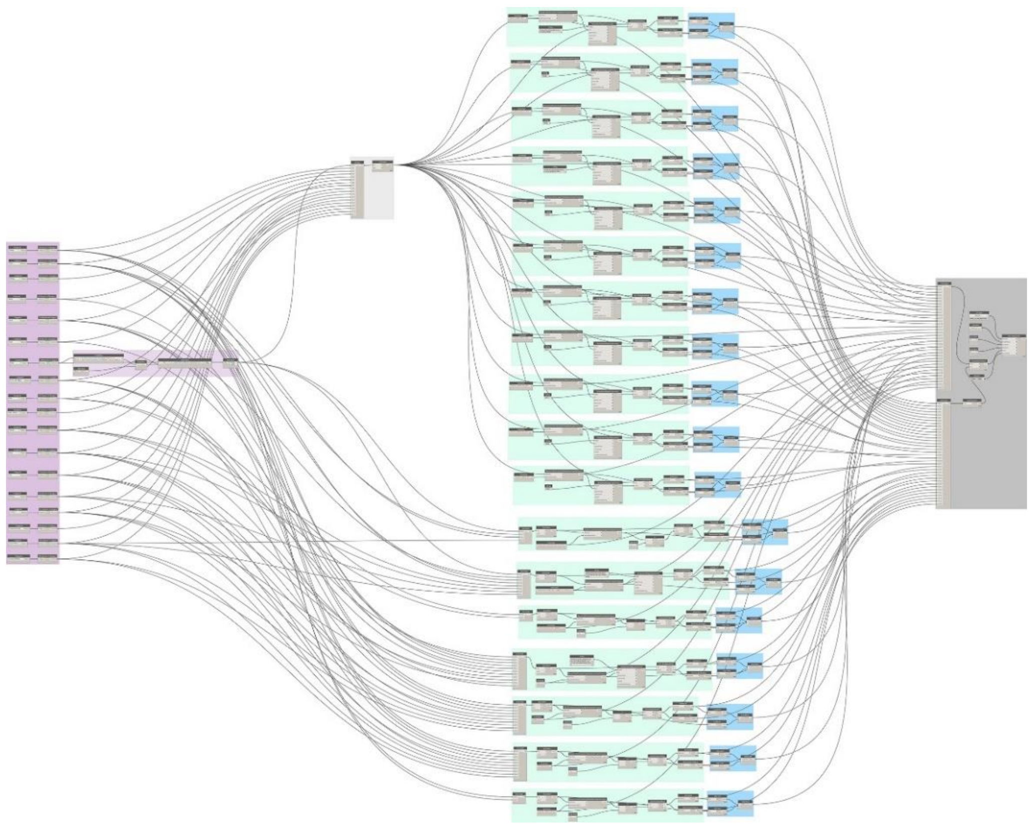


Figure 88 – Example of the Autodesk Dynamo script developed for the Step2 (part B) check of the Architectural discipline

The "Export to Excel" section of the implemented validation workflow allows the extrapolation of a report related to all the errors found, structured within a specific Excel sheet, subdivided in function to the script of the advancement step analysed, as visible in Figure 89 for the Step1_System Families check for the AR discipline.

Allianz Stadium

ARCHITECTURAL MODEL
VALIDATION LEVEL 1

Validation Documentation delivered on 15/05/2020

Parameter		Parameter		Parameter		Parameter		Parameter		Parameter		Parameter	
Type Name		**Phase Created**		**Level**		**Affidabilità**		**Asset Code**		**Univocità Asset Code**		**Codice piano**	
Error rate		Error rate		Error rate		Error rate		Error rate		Error rate		Error rate	
0,08		0,00		0,33		0,00		0,00		0,82		0,00	
Category	Object ID	Category	Object ID	Category	Object ID	Category	Object ID	Category	Object ID	Category	Object ID	Category	Object ID
Walls	437968			Railing	682436					STA_ST_AR_L01_PR_00036	822764		
				Railing	683329					STA_ST_AR_L01_PR_00086	822816		
				Railing	683929					STA_ST_AR_L01_PR_00088	822818		
				Railing	713707					STA_ST_AR_L01_PR_00151	822884		
				Railing	839036					STA_ST_AR_L01_PR_00210	822950		
				Railing	839054					STA_ST_AR_L01_PR_00218	822960		
				Railing	839064					STA_ST_AR_L01_PR_00220	822962		
				Railing	856243					STA_ST_AR_L01_PR_00262	823006		
				Railing	856913					STA_ST_AR_L01_PR_00263	823007		
				Railing	857519					STA_ST_AR_L01_PR_00498	823244		
				Railing	858425					STA_ST_AR_L01_PR_00639	823390		
										STA_ST_AR_L01_PR_00700	823457		
										STA_ST_AR_L01_PR_00777	823540		
										STA_ST_AR_L01_PR_00790	823555		
										STA_ST_AR_L01_PR_00796	823562		
										STA_ST_AR_L01_PR_00798	823564		
										STA_ST_AR_L01_PR_00813	823579		
										STA_ST_AR_L01_PR_00837	823604		
										STA_ST_AR_L01_PR_00986	823759		
										STA_ST_AR_L01_PR_01231	824013		
										STA_ST_AR_L01_PR_01489	824272		
										STA_ST_AR_L01_PR_01704	824509		
										STA_ST_AR_L01_PR_01707	824512		
										STA_ST_AR_L01_PR_01791	824598		
										STA_ST_AR_L01_PR_00151	902860		
										STA_ST_AR_L01_WL_00705	946506		
										STA_ST_AR_L01_WL_00705	946838		

Figure 89 – Extrapolation of the error rate report created through the validation activity for the Architectural discipline

To recap, the Data Validation process implemented for the research activity is driven by **compliance with operational dispositions** highlighted in the methodological standardization. This approach enables an investigation strictly related to the analysed project, compared to the cross-cutting nature of Code Checking based on external standards (Vergari, et al.). The implemented process has been used to validate all the BIM models developed during the research project, as visible in Figure 90 for the AR discipline. This graph shows, globally, the percentage of error of each parameter analysed for the different models constituting the AR discipline. In detail, starting from Level 04 to Level 06 the Data Validation activity regards only Step 1 and Step 2_B connected to the Hierarchy cluster for operational project reasons.

Figure 90 – Example of the error rate for the Architectural discipline

The illustrated **reports** and **graphs** represent one of the possible ways to structure the results obtained at the end of the validation process. According to the error rate of each parameter for every single discipline, it is possible to make multidisciplinary analyses. Moreover, from the output file, it is possible to identify for every single parameter the ID of each wrong object and its category. By manipulating the data, it is also possible to define the error percentages associated with each category for a given parameter. In this way, it could be easier to analyse the information in more detail, perhaps identifying problems linked to specific categories, which are otherwise unidentifiable if referred to the total number of objects in the model analysed.

The percentages thus obtained enable a series of analyses to be carried out on the reliability of data entered by suppliers during the modelling activities, regarding all categories as in the case of the graph visible in Figure 90. In the case of an error rate of 100%, this means that the parameter analysed has not been compiled or has been filled in incorrectly compared to the BIM guidelines' dispositions. On the other hand, a value equal to 0% indicates that the parameter has been compiled following what has been set up by the methodological standardization (Vergari, et al.). Analysing the achieved results, it can be highlighted that the adoption of guidelines allows reducing errors, despite the significant number of elements and data present in complex models such as the case study. Through this iterative control mode, it is easier to detect systematic compilation errors and forgetfulness (Vergari, et al.). Finally, it is important to highlight how the proposed workflow could be considered a methodological approach **replicable** for all kind of building: the only tailor-made aspects are related to the single parameters and rulesets.

Chapter 6

Data Visualization

6.1 Objectives definition

The implementation of a **new generation of stadiums**, based on the new concepts carried out from the major European football club experience, made football the core of a more complex service of cultural, commercial and leisure activities. Thanks to the digital transformation, it is possible to improve the architectural and functional characteristics of the stadium, making it an open and accessible space free of physical and conceptual barriers. In this scenario, this kind of building acquires importance in the collective imagination becoming a symbol of sharing experiences, also about social inclusion (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019).

For these reasons, inside the **digitalization process** based on the BIM methodology, this objective has been focused on the visualization of geometric and alphanumeric information with predefined **VAR tools**. For the research activity, some possible applications have been tested to highlight their use during maintenance activity, operational training of maintenance workers or immersive navigation and environment's virtualization (Talamo & Bonanomi, 2015). In this way, the integrated database could be visualised differently by several actors and for various purposes, developing a new concept of stadium, and in a more general way of building, that will become more "user-friendly" and "innovative". These applications also allow developing a possible future implementation of this model use like the creation of a virtual tour of the stadium, always based on the BIM database.

Starting from the methodological workflow illustrated in Figure 25, the methodology standardization connected to the "FM system over VAR" model use has been only developed in a general way, to illustrate possible future development and detailed analysis able to highlight all its features. For this reason, the results of the tests carried out and illustrated in this section will be analysed without going into operational detail like, for example, the interoperability between the software used or the reasons of the adopted workflow, in contrast with previous uses. The achieved results are based on the consideration carried out in chapter 2.3 and they are focused on the interrogation of the BIM data content as a visual resource of information. Thanks to VR, VAR and MR possible application have been examined, emphasizing their potential and developing the starting point for a new generation of 360° oriented stadiums in the virtual world accessible to its users 365 days a year (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019).

6.2 Data Sharing

The declination of technical activities related to Data Sharing for this kind of model use is based on the identification of the **information exchange format**, in particular concerning the extrapolation methods of the database created in the modelling software and how it is imported as input by the software used for the development of these tools. At the state of the art, the literature analysis highlights several interoperability issues in alphanumeric data transfer, with a subsequent and necessary programming activity for their implementation. For this reason, the actual requirements on this model use are principally connected to the graphic characteristics, that avoid the reintegration of data loss. The proposed methodological standardization, summarized in the BIM guidelines considers the results achieved from different interoperability test aims to identify the implementation workflow of the desired applications. Their definition is essential also for the identification of the existing **interoperability issues**. Starting from the results achieved on this research topic by two students that collaborate on this project during the development of their Master Thesis (Viale, 2019) and (Dettori, 2019), an example of the workflow developed for Data Visualization and the BIM Model Checking through a MR tool has been defined (Figure 91).

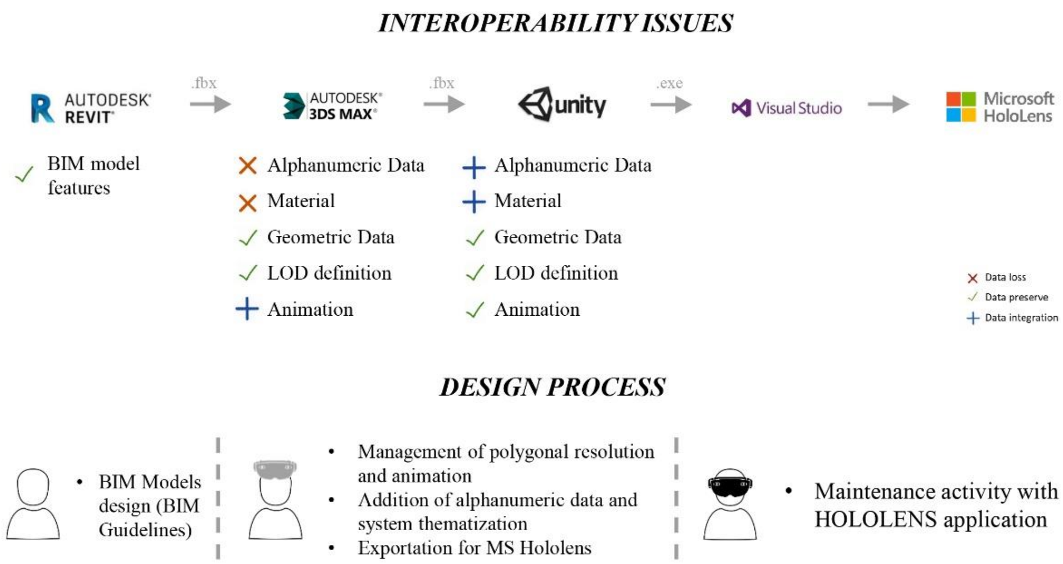


Figure 91 – Interoperability issues of MR applications

6.3 Geometrical content definition

The technical activities proposed by the methodological standardization concern the modelling rules to be adopted and the **improvement of the geometric content** of each object. The definition of these aspects allows the development of BIM models compliance also with the software used for the creation of the VAR application, respecting the requirements of the case study. As illustrated similarly in the previous chapters, it is necessary to know in advance the operating methods for the geometric information implementation, like for example the assignment of material in order to reduce the data loss within the software used for the implementation of the application. Moreover, also the possible implementation of an object visualization detail should be identified among the initial requirements included in the BIM guidelines, to define the operational procedures necessary for the creation of this additional information, as done for the present case study. Concerning this purpose, an alphanumeric parameter called "**Upgrade**" has been operationally inserted associated with the individual building rooms. It is defined as illustrated in Table 35.

Table 35 – Definition of the parameter Upgrade in the BIM guidelines

Parameter group	Parameter	Note	Description
AR/RO	Upgrade	Room definition	Yes/No parameter to be filled in for rooms that are subject to Upgrade, as defined within the implemented BIM guidelines. This parameter should be assigned in function of the dispositions provided by the owner and this assignment allow to identify all the spaces that should be upgraded from a geometrical point of view. The compilation with the Yes value results in an increment in the LOG of all the objects that belong to the identified room.

In order to manage the implementation of the geometric content of objects belonging to spaces subject to "Upgrade" during the tests conducted the different families have been created with an increasingly detailed LOG, combining the corresponding geometries to the different levels of detail available (low, medium and high values), as illustrated in Figure 52. In this way, creating different views of the model and varying their detail level it has been possible to change the geometric detail displayed in function of the needs to be pursued. This solution allows achieving the concept of heterogeneous LOD applied on the entire BIM model and it could be reached according to the objectives and uses to be achieved.

The tests carried out during the research activity allowed the development of the first example of spaces subject to "Upgrade", corresponding to the locker rooms of the first team that constitutes the prototype model implemented, identifying possible implementations of this use. In this case, the objective has been the implementation of the degree of geometric detail in order to achieve a realistic representation of the real environment configuration. The implementation of this activity connected to VAR tool for different interior scenarios enables actors to try the space virtually, anticipating the real experience and offering to the space manager a dynamic solution for the desired visualization. When the implementation of the prototype BIM models regarding the spaces and the relative furniture has been completed, a 360-degree render has been generated to obtain an immersive **VR tool**, navigable using simple **Google Cardboard**. This gives an immersive experience to the user inside the virtual environment, viewing the created environment real scale. The implemented tool is easy to use, thanks to the scanning of specific QRCodes with a smart device's webcam (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019), as the proposed solution represented in Figure 92 (Serra, 2017):

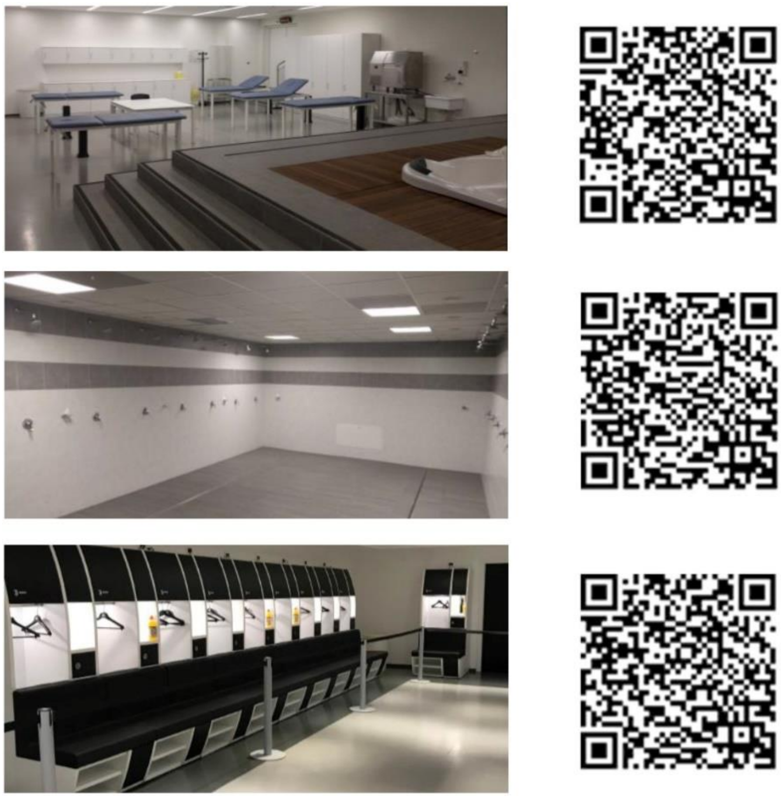


Figure 92 – VR application for the visualization of a room's configuration (Serra, 2017)

Another example of a VR application that allows the user to immerse himself in the created BIM models is the application developed for the **HTC Vive viewer** tool. In this case, it is possible to move directly inside the model and view the desired environments thanks to the use of controllers. In detail, for the research activity, the model has been set before being inserted into the software used for the application in order to be ready for maintenance activities. As illustrated in chapter 2.3, the definition of specific geometric features (e.g. the transparency of ceiling objects) could be used for the enrichment of maintenance purposes, allowing the visualization of the HVAC system during the immersive navigation of the BIM model, which is not visible in the real configuration (Figure 93). In this way, it could be possible to **plan maintenance activities** in an **innovative way**, reducing survey activities, thanks to the data reliability of the implemented models. Therefore, this VR application allows a greater degree of knowledge of the state of the art during the planning of maintenance activities.

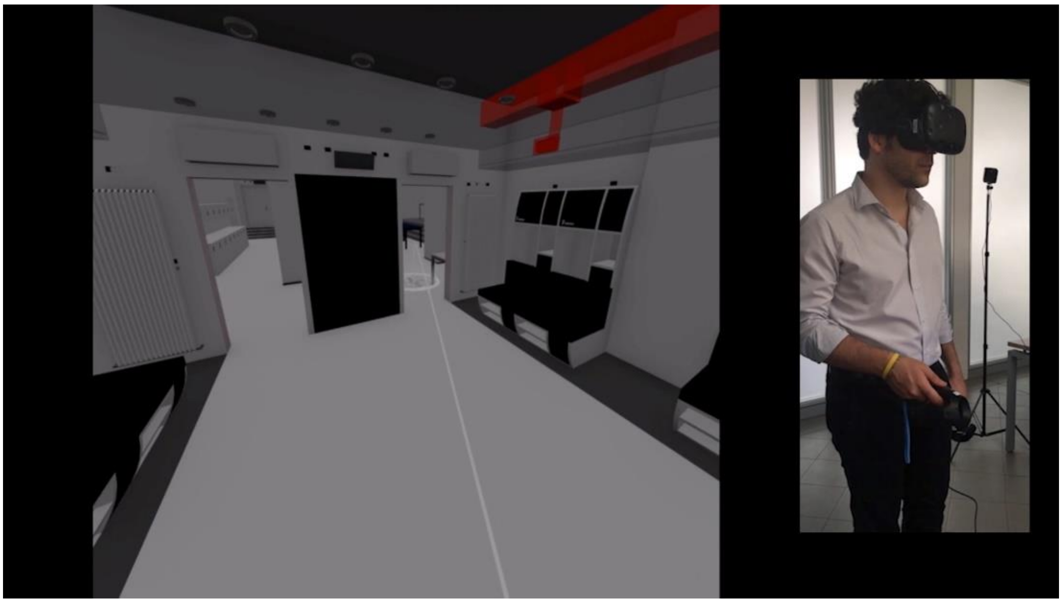


Figure 93 – VR tool for maintenance activities

Always connected to the operational activities based on the geometric content of BIM models, an example of **MR application** has been implemented as well. This technology allows to overlap the BIM model to the existing environment during its usage, thanks to a specific instrument: **Microsoft HoloLens** (Figure 94). In detail, the investigated tool enables to manage the spatial location of BIM objects and their geometric dimensions, allowing their spatial reorganization in the real environment configuration (Viale, 2019), as visible in Figure 95.

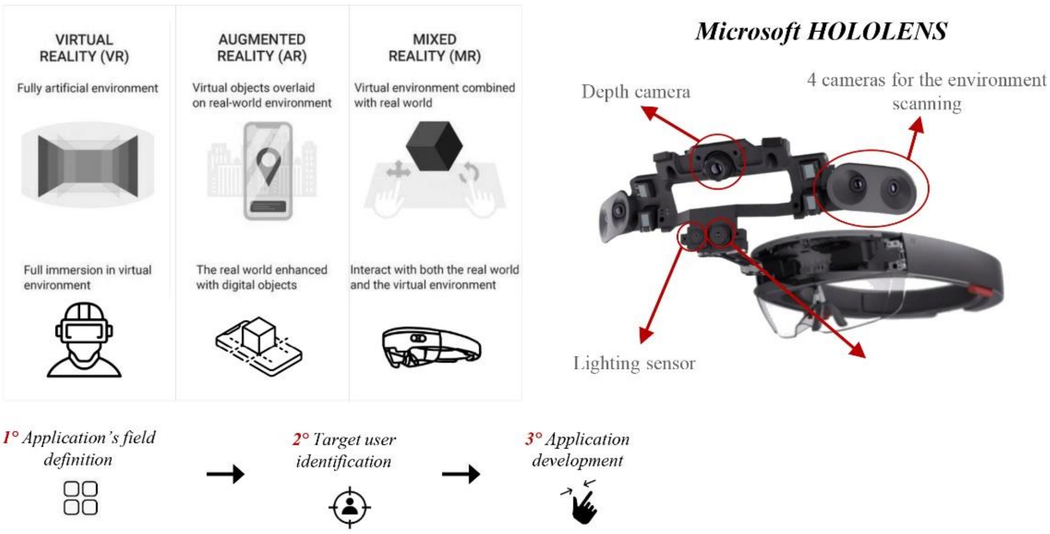


Figure 94 – Definition of MR and Microsoft HoloLens' components

Figure 95 – MR tool for room layout management (Viale, 2019)

6.4 Alphanumeric content definition

Connected to the definition of the alphanumeric content for this specific model use, the proposed methodological standardization regards the **type** definition of the **alphanumeric parameters**. This has been indicated from a methodological point of view since it is an aspect of considerable importance. In fact, the tests carried out during the research activity highlighted the **loss** of this **information** and the necessary subsequent reintegration directly in the software used for the VAR application. This consideration varies of course according to the software identified for the implementation of the application.

The identification of alphanumeric parameters also concerns the definition of the **information that needs to be displayed** during the adoption of the implemented application, in function of the results to be pursued. For the presented case study, the information considered most significant for the correct performance of maintenance activities regarded specific system's information. For this reason, MR could be an excellent support tool for the operational performance of maintenance activities: it is possible to query individual objects and the relative alphanumeric information as visible in Figure 96 (Viale, 2019) and Figure 97 (Dettori, 2019).

Another possible application is the use of MR for **training activities** of maintenance suppliers: for example, by querying an electrical panel created in a BIM model, the maintenance technician could be able to view and consequently to know all the data necessary for the intervention, directly in the real building environment. Through the development of a specific application for Microsoft HoloLens, during the tests carried out has been possible to analyse and implement in MR the operational steps that a maintenance technician should follow to carry out a specific activity. This additional information is displayed by the suppliers directly wearing the MR devices in superposition to the real object on which he is operating (Viale, 2019).

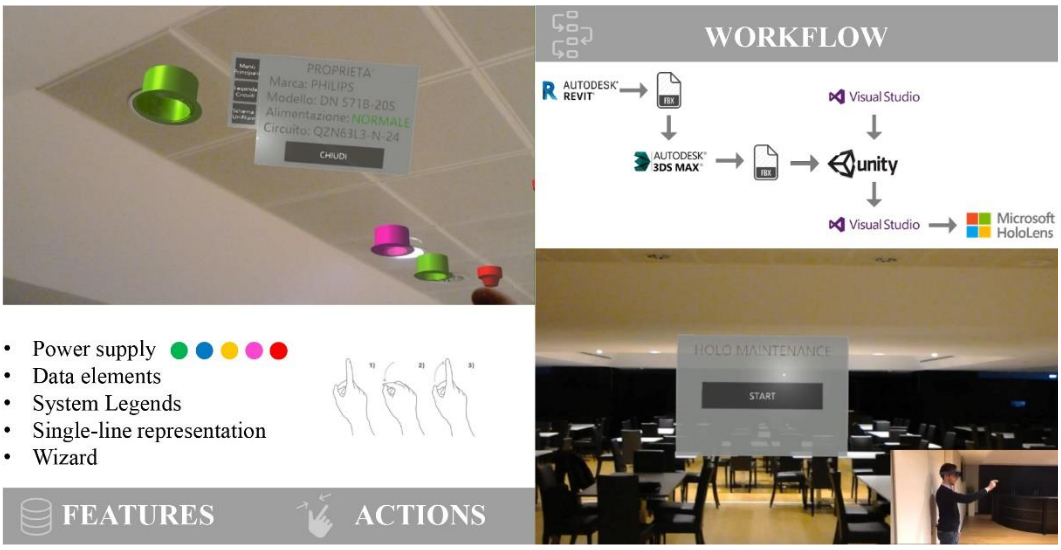


Figure 96 – MR tool for alphanumeric data consultation (Viale, 2019)

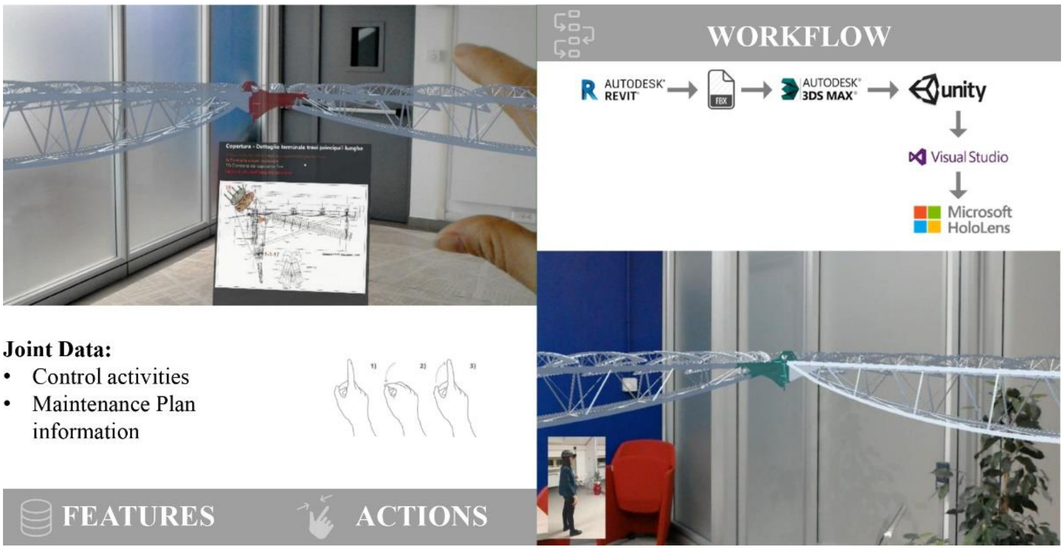


Figure 97 – MR tool for alphanumeric data visualization (Dettori, 2019)

6.5 BIM Model Checking

Starting from the same logic illustrated and implemented in the previous point, MR applications could also be used as a tool for carrying out **geometric validation activities**, by overlapping the digital model with the real environment. In this way, this technology allows visualising the correspondence of several digital models of different discipline to reality, through iterative navigation on a real scale in the real environment (Figure 98). The adoption of this kind of application associated with a way of recording any differences through the direct reading of the element ID could represent a very useful tool during the geometric validation activities (Viale, 2019), as shown in Figure 24.

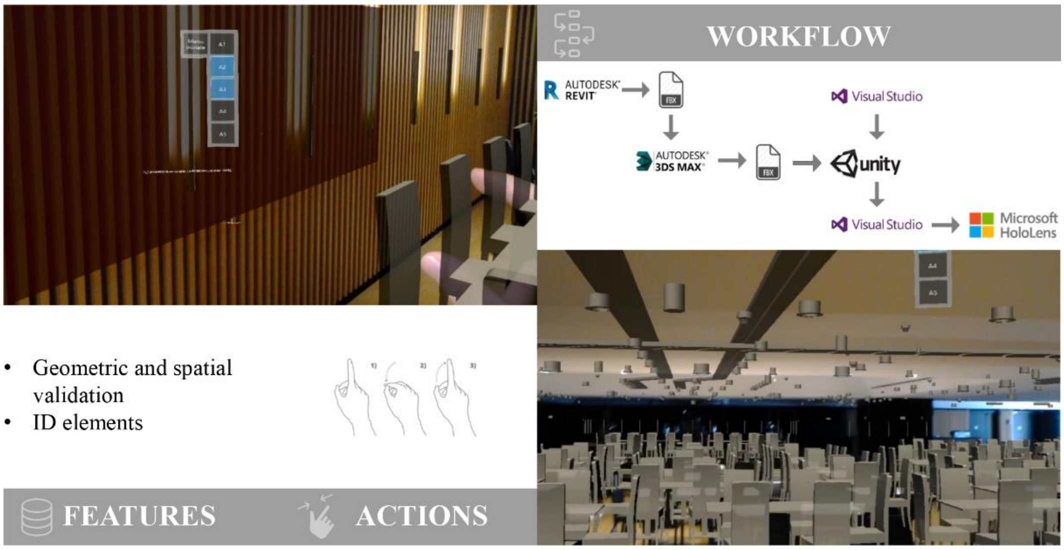


Figure 98 – MR tool for BMC (Viale, 2019)

Chapter 7

Results

The major challenge of this research study regards the definition of a **methodological standardization** composed of **operational protocols** that enrich BIM procurement documentation through the development of specific **BIM guidelines** for FM. This investigation process allowed the achievement of the model uses defining the specific requirements of each one by the analysis of the protocol and its corresponding activities. As illustrated in the thesis, a progressive increase of the BIM system complexity has been obtained, starting from the definition of the As-is model for FM, to the integration with an IWMS platform and the development of possible FM system over VAR (Barbero, Del Giudice, Ugliotti, & Osello, 2020).

In order to achieve the defined uses, during the research activity, it has been necessary to analyse in detail the respective objectives related to the FM phase of the building process, investigating a possible answer to the aims and questions illustrated at the beginning of the thesis. Concerning the topic of the Data Organization, it has been therefore possible to define a feasible **geometric** and **alphanumeric content** of the **As-is model aimed at FM**, reaching the operational definition of a BIM 6D model for FM. This model dimension, as defined by the Italian regulation (UNI 11337-1, 2017) is "*A simulation of the work or its elements based on use, management, maintenance and possible decommissioning, in addition to space*". Since the information content proposed by the research activity is based on these aspects, it is possible to associate the results achieved with the classification required by the regulation. All the considerations presented are connected to the case study analysed, represented by an existing building with a high degree of complexity. For these reasons, the operating results presented might change in the case of new buildings with different uses and maintenance requirements and also with a more detailed information content. In this case, thanks to a greater knowledge of the built environment, new research questions will arise like: i) how to manage the information content when switching from an As-built model to an As-is one during the building process; ii) how to manage the reduction of the geometric content for the management phase; iii) establish if the model developed for the design and construction phase is the same of the maintenance step, maintaining a single, integrated BIM model for the entire building process, or if two separated models are necessary.

The analysis carried out also highlights the **impacts** that the definition of the BIM **model uses** has on the structure of the database itself. This aspect has been highlighted in particular for the objective topic of **Data Integration** with an **IWMS platform**, which requires a detailed activity of planning and enrichment of the BIM procurement dispositions. This aspect is also linked to the third objective of the proposed standardization which illustrates the potential of using **VAR applications** for the management of some FM activities.

The combination and the management of these objectives have therefore led to the content definition of specific BIM guidelines for FM. The guidelines developed for this case study represent the documentation of the project "**Allianz Stadium 2.0**" to which the illustrated research activity belongs (Figure 99). All the documents of these guidelines have been implemented cyclically during the project development, following the confrontation with the suppliers on different operational aspects, included in the proposed methodological standardization.

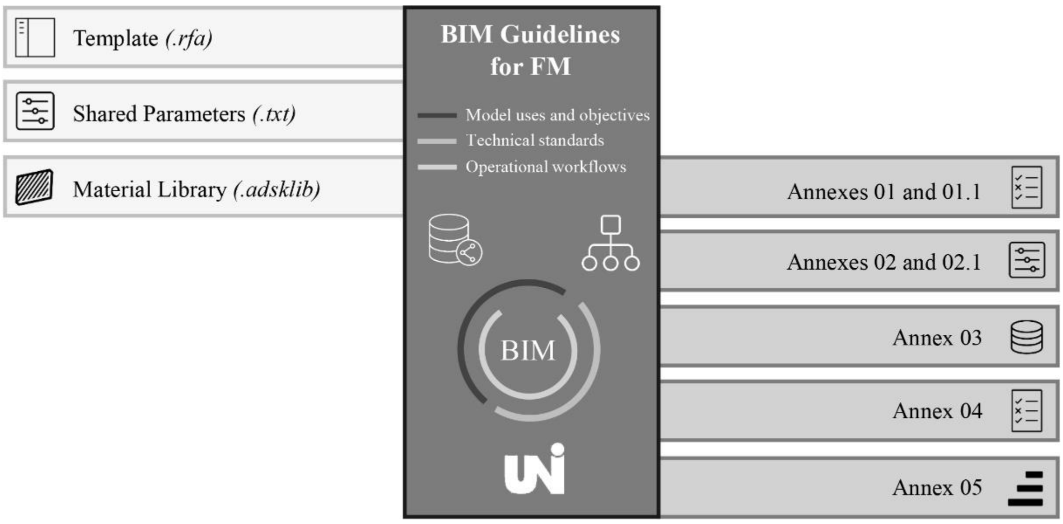


Figure 99 – Structure of BIM Guidelines for FM, implemented during the research activity

The developed guidelines are written in Italian for project needs and they are composed by the following documents shared with all the actors of the process within the project ACDat:

- **BIM Guidelines**: document delivered to each supplier and destined to the actor called "Information Coordinator" that deals with the coordination activities aimed at the realization of the project.
- **Glossary**: list of all acronyms used within the documents, to clarify their meaning and interpretation.

- **Annexes**: documents delivered to each supplier and assigned to the actors carrying out the operational implementing activities on BIM models.
  - *Annex 01: Object name table.* This document contains the nomenclatures of families and type and the description used at the state of the art for the realization of the project, subdivided by discipline.
  - *Annex 01.1: Rules for naming objects.* This document contains the denomination logics adopted during the implementation of Annex 01, to be used in case of future implementations.
  - *Annex 02: BIM object parameters table.* This document reports the association of the different parameters to each type of object inside the disciplinary models, to be used as a reference for the alphanumeric population of the model.
  - *Annex 02.1: Rules for parameters population.* This document contains the population logics of each parameter indicated in Annex 02.
  - *Annex 03: Example LOG and LOI.* This document illustrates the information associated with the objects belonging to the FM model. This analysis is detailed for a representative object of each discipline and sub-discipline.
  - *Annex 04: Modelling rules.* This document illustrates the modelling rules that need to be adopted for the development of FM models, with the relative geometric and alphanumeric content.
  - *Annex 05: Progress step.* This document illustrates the structure of the expected geometric and alphanumeric content for each advancement step planned for the project development.
- **Template**: multidisciplinary file .rte delivered to each supplier containing the structure of the project browser, the common spatial coordinates of BIM models and the alphanumeric parameters provided for each category.
- **Shared Parameters**: file .txt containing all the shared parameters, divided by discipline that have been recreated as project parameters within the template.
- **Materials Library**: file .adsklib representing the set of materials associated with different types of elements in each model, with the corresponding pre-denomination nomenclature.

In addition to these documents, the "Domande Operative" have also been developed as project documentation to support the implemented Worksharing and the exchange of observation through .bcf files. It is a group of files, one for each discipline, used weekly for the exchange of information on specific operational aspects of the project. This documentation has been developed to allow the maintenance of the historical data sharing of the different questions and answers and it has been fully implemented in the several updates of the BIM guidelines.

The structure of the proposed BIM guidelines provides the union of BIM procurement documents with a series of technical and operating standards connected to the specific uses and objectives of the BIM models. As illustrated, for the research activity the CI has been taken as a reference since it started from the analysis of the owner's demanding framework which has been subsequently transferred to the individual suppliers involved in the process for the implementation activity. If the phase considered concerning a supplier that meets the needs of an owner, the reference BIM procurement document changes. On the other side, the existing connection between the BIM guidelines and the objectives is impacting and is highlighted in the literature since there is no unique standard available at the state of the art. For this reason, the developed BIM guidelines are a tailor-made solution, but the proposed methodological process is independent of the case study which affects the geometric and alphanumeric contents deriving from the application of the technical required dispositions. So, the technical protocols are replicable for another kind of building with the same model uses and objectives and only if these last ones change, the technical and operating standards will necessarily vary, keeping unchanged the general methodology workflow.

Another important result achieved during the research activity regards the implementation of a possible **Data Validation** approach, based on VPL, that enables to perform a formal control of the alphanumeric model content to ensure the correct Data Integration, checking the different values entered and their reliability. The use of the VPL allows the development of a flexible and replicable operational workflow, able to analyse a large amount of meaningful data, structured in a complex way, based on specific inputs (checklist and rulesets) that could be changed in function of the specific case study and the corresponding Level of information need. The proposed process also gives the possibility to control each validation step, the customization of the control algorithm structure according to the specificities of the project and its application both for integrated and federated models (Vergari, et al.).

The last important results achieved during the research activity concerns the **adoption of the BIM methodology by the owner**, as the time liner shows in Figure 100.

Figure 100 – Timeline of the owner BIM adoption

This evolution enables the development of an innovative project that provides the application of the BIM methodology for FM of a stadium for the first time. Considering the literature analysis illustrated in chapter 2.3.1, the work carried out could be considered as the first existing application of this kind of methodology with these purposes for a stadium.

Chapter 8

Conclusion

The research activity carried out highlights the strengths linked to the application of **BIM for FM**, showing how this phase of the building process is one of those where the adoption of the BIM methodology is more complex. In general, the problems identified are also linked to the operating behaviour of the actors responsible for the management and maintenance phase, which are difficult to change. For these reasons, the application of BIM for FM is an important area for research. Besides, thanks to the results achieved, it is also possible to understand several **advantages** that the BIM methodology could provide compared to the traditional management method in term of reducing time and costs for information research and maintenance activities since it is based on a database that can be integrated with an IWMS platform,

The analyses performed during this research activity, therefore, represent the basis for the **overcoming** of the **existing gap** within the building process between the construction phase and the building management one, which should be based on the same integrated database, as illustrated in Figure 2. The development of a BIM model with a geometric and alphanumeric content suitable for these objectives should be recognized as an integral part of the infrastructure development process. Furthermore, this aspect requires the anticipation of many needs and problems from the management phase to the design and structuring of the database one, reducing the subsequent data loss. Operating in this way, the geometrical and alphanumeric content necessary for the FM phase should therefore be clearly defined through the evaluation of the project **Level of information need**. Linked to this aspect, it is necessary to define the **uses** and **objectives** for which a BIM model is structured, taking into account their impact on the database structure. Many researchers, in literature, are investigating the proper information content of BIM models for these types of FM applications. It is also of primary importance the definition of how to manage the **Data Sharing** and **Worksharing** which represent, at the state of the art, one of the main challenges of the construction industry. Indeed, several workflows could be followed to achieve the objectives of a project based on BIM methodology that can be customized relating to specific needs, allowing building Industry to be renovated, enhancing the value of sharing information, and optimizing time and costs resources (Barbero, Del Giudice, & Manzone, 2018). For these reasons, all these aspects should be defined uniquely inside specific **project guidelines**, based on BIM procurement documentation. Technical examples as the one illustrated in this thesis may contribute to the creation of a background of operational examples that could help to make the method effective and practical.

As said in the results section, the developed BIM guidelines are tailored to the specific project uses and objectives and customised in function of the complexity of the BIM systems (Barbero, Del Giudice, Ugliotti, & Osello, 2020). At the same time, the proposed methodological approach is replicable and it enables **overcoming the actual lack of standardization** among BIM procurement disposition. It also enriches the second level of BIM maturity, finalized to the collaborative and integrated use of data, as illustrated in Figure 13. Due to the replicable characteristics of this methodology, it is important to highlight its **strengths** and **weaknesses** connected to each model uses and the modelling efforts necessary for a correct extrapolation of data (Barbero, Del Giudice, Ugliotti, & Osello, 2020). From a critical analysis of the proposed methodological standardization, as can be seen in Table 36, the main issues found operationally concern the management of the complexity related to the structuring of the BIM guidelines and the time taken by suppliers to implement the proposed dispositions in their activities which, in some cases, have been particularly long.

Table 36 – Strengths and weaknesses matrix of the proposed standardization (Barbero, Del Giudice, Ugliotti, & Osello, 2020)

Model Uses	Strengths	Weaknesses
As-is model for FM	Digital building registry; Data management optimization; Discipline model coordination; KPIs control;	High modelling effort; Employee BIM training; Tailored rulesets; Resistance of change;
Integration with an IWMS platform	Efficient data update; Data source integration; Bidirectionality data sharing; User-friendly interface;	Data exchange issues; 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; Lack of rules for enabling FM with VAR;

The results achieved during the research activity also highlight the potential of the BIM methodology for the management of a large number of elements and information, both in terms of structuring and validation. The setting of an **integrated database** guarantees the **data uniqueness** during the whole process and the close interaction with the owner has been essential during its definition for the project. He has greatly contributed to the identification of the maintenance needs and the information content definition. This uniqueness is also ensured within the management platform. At the same time, thanks to integration tests based on a large amount of data, it has been possible to identify and overcome a series of critical issues that arose between the modelling and management software. This aspect has been possible also thanks to the direct contribution of the Archibus© software house, which highlights the importance of the research activity carried out at international level. Connected to this purpose and given the **great importance** that **data** will be assuming in the management of the built heritage as well as in our society, one of the main questions of the next research activities should regard the analysis of the useful life cycle of BIM models and the relationship with technological innovation. All the above considerations represent the aspects that will have to be managed at the end of the digitalization process of the construction sector, which contribute to the definition of the concept of **stadium 2.0**. It is based on the re-definition of urban sports venues as a place where meetings, dialogue, integration and social inclusion take place (Angelucci, Cellucci, Di Sivo, & Ladiana, 2015). In this term, the BIM methodology represents the starting point for an innovative management process of infrastructures, where information plays a key role. The connection between the digital environment and the society should be based on sharing protocols of different data content, minimizing their loss (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019).

To recap, as visible in Figure 101, the starting point of the research activity carried out was the traditional concept of stadium, based on 2D representation and a fragmented database with a lot of data duplication issues. At the end of this research contribution, the new concept of stadium 2.0 is born and it is based on the BIM methodology and an integrated data content inside an IWMS platform. The results achieved represent only the beginning of a process connected to the definition of the **digital archive of the future**, where the building should be more "user-friendly" through spatial and technological solutions like VAR tool that evolve with the changing needs, functional abilities and skills of individuals (Barbero, Del Giudice, Ugliotti, Manzone, & Osello, 2019).

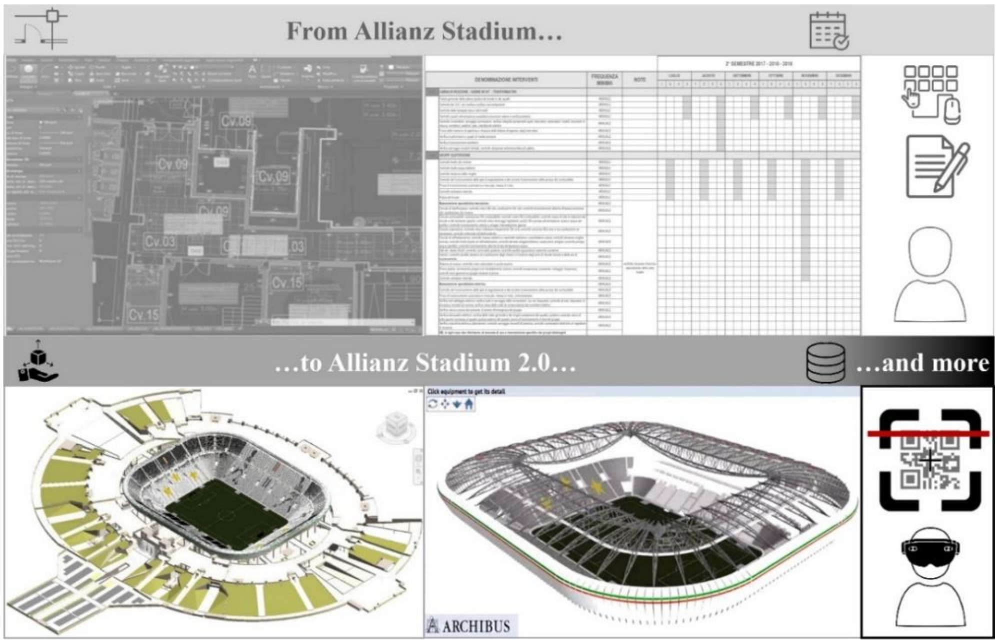


Figure 101 – Development of the new concept of stadium 2.0

8.1 Future Development

As a future development of this research activity, the **integration** between BIM models and **IoT devices** could be investigated, in order to evaluate the interaction between the parametric objects which create the digital environment and real-time data transmitted by this kind of devices. They could be, for example, position sensors of internal users (e.g. stewards) that enable their geolocalization inside the BIM environments. For this purpose, at the beginning, BIM models could be used for the identification of the spatial location of the different sensors as well as their range of action, exploiting parametric objects for the development of comparisons between different solutions (Masoni, 2019). Subsequently, models could be used as the starting point for the network's design and as a digital graphic base for real-time visualization of the different movements.

On the other side, another possible implementation regards the quantitative analysis of the benefits linked to the application of the BIM methodology in the FM field, to give a quantifiable value to this important innovation (Stowe, Zhang, Teizer, & Jaselskis, 2014). This investigation could be done through possible **ROI BIM analysis**, with an evaluation of the return on investment based on the management of the unified database, compared with the cost for the application of this methodology (Campanella, 2019). This idea will be based on the analysis of the cost/value of data, the weight of the adoption of this method on an existing building in terms of increased productivity, compared to a new one for which the methodology could already be applied during the design and the construction phase. In this case, as said in the results section, the definition of how to switch from an As-built to an As-is model will certainly represent another important field of research. To complete this possible analysis, there will also be the definition of the procedures for carrying out the maintenance of data, developing the concept of **information data maintenance**.

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Appendix A: List of publications

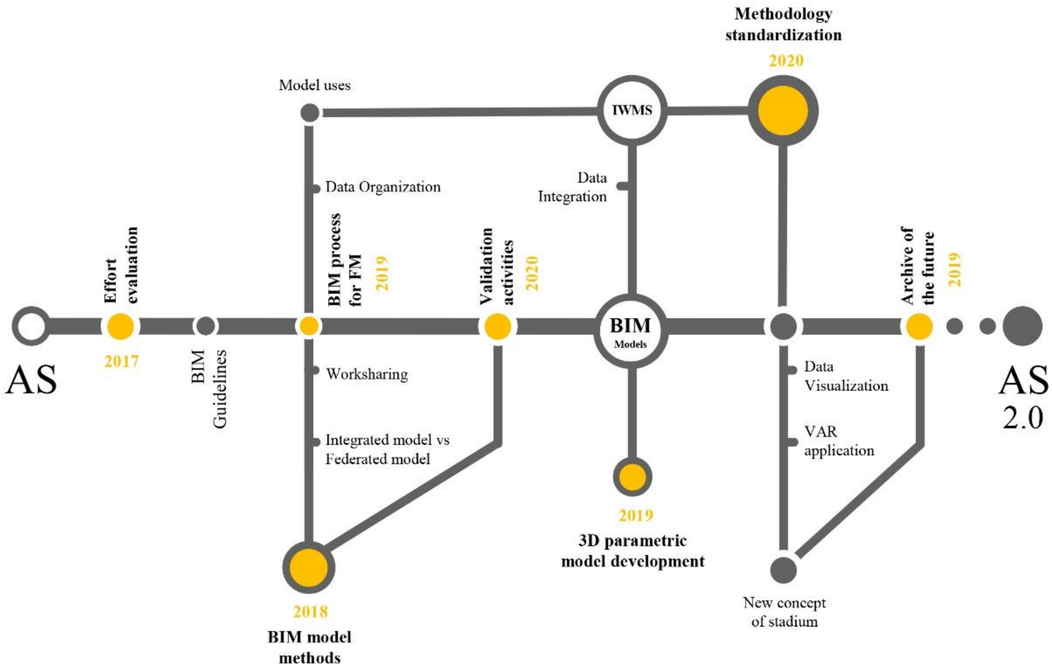


Figure 102 – Correlation between publications and topics analysed during the research activity

Barbero, A. (2018). Urban and Regional Development - Ph.D. Programme - ANNUAL REPORT 2018. *Urban and Regional Development - Ph.D. Programme - ANNUAL REPORT 2018*. Torino: DIST - Dipartimento interateneo di Scienze, Progetto e Politiche del Territorio dell'Università e del Politecnico di Torino.

Barbero, A. (2019). 3D parametric model development. In M. Del Giudice, *IL DISEGNO E L'INGEGNERE - BIM handbook for Building and Civil Engineering Students* (p. 34 - 39). Torino: Levrotto & Bella.

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* (p. 291 - 296). London: CRC Press/Balkema Taylor & Francis Group.

Barbero, A., Del Giudice, M., Ugliotti, F. M., & Osello, A. (2020). BIM model uses through BIM methodology standardization. *eWork and eBusiness in Architecture, Engineering and Construction* (p. 8). CRC Press/Balkema Taylor & Francis Group – IN STAMPA.

Barbero, A., Del Giudice, M., Ugliotti, F. M., Manzone, F., & Osello, A. (2019). SCENARI 360°+5 PER L'ARCHIVIO DEL FUTURO/360°+5 scenarios for the archive of the future. *Colloqui.AT.e 2019 - Ingegno e costruzione nell'epoca della complessità - Forma urbana e individualità architettonica* (p. 689-697). Torino: Edizioni Politecnico di Torino.

Del Giudice, M., Manzone, F., Rebaudengo, M., & Barbero, A. (2017). Effort evaluation of BIM process for existing buildings. *Urban Planning, Architecture & Design* (p. 565 - 572). Sofia: STEF92 Technology Ltd.

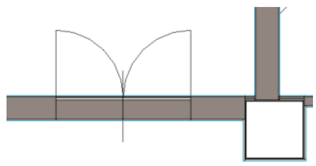
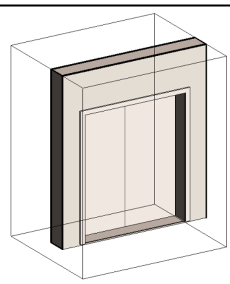
Vergari, R., Barbero, A., Ugliotti, F. M., Del Giudice, M., Osello, A., & Manzone, F. (2021). Automated semantic and syntactic BIM Data Validation using Visual Programming Language. (p.14) – IN STAMPA.

A.1 Journals

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. *DN*, 6-14.

Appendix B: Schedule of LOG and LOI

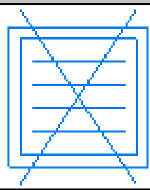
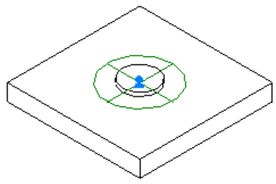
Table 37 – Example schedule of the expected value of LOG and LOI for the Architectural discipline

Component: Door				Loadable Family
LOD **C+**				
LOG C	View Level of Detail	Geometry	Object	Graphic representation
	Coarse	Elemento rappresentato mediante solido di estrusione.	Simbolo grafico 2D	
	Medium	Elemento rappresentato mediante solido di estrusione che ne permette la definizione dell'ingombro spaziale.	Solido 3D	
	Fine	Upgrade		
	Parameters	Description		
LOI F	Level	Livello di posizionamento a cui risulta legato l'oggetto appartenente alla categoria Door.		
	Thickness	Spessore totale della porta, definito a livello di modellazione.		
	Family	Nomenclatura della famiglia caricabile, definita sulla base delle indicazioni fornite dall'Allegato 01 e delle regole di nomenclatura contenute nell'Allegato 01.1		
	Type	Nomenclatura del tipo definita secondo le indicazioni fornite dall'Allegato 01 e le regole di nomenclatura definite nell'Allegato 01.1		
	Description	Definizione della descrizione della tipologia di oggetto analizzato.		

	Function	Parametro che consente di individuare, per l'oggetto porta analizzato, la sua funzione sulla base della tipologia di ambiente che delimita.	
	Altezza_std	Parametro geometrico indicante la dimensione dell'altezza, utilizzato in fase di modellazione dell'oggetto porta.	
	Larghezza_std	Parametro geometrico indicante la dimensione della larghezza, utilizzato in fase di modellazione dell'oggetto porta.	
	Classi di unità tecnologiche	Parametri UNI 8290	Elementi funzionali omogenei, raggruppati per funzione prevalente, per continuità fisica e funzionale.
	Unità tecnologiche		Insiemi di elementi tecnici che rappresentano funzioni finalizzate al soddisfacimento di esigenze dell'utenza.
	Classi elementi tecnici		Classi di prodotti che assolvono a funzioni proprie di una o più classi tecnologiche.
	Numero MasterFormat	Codice standardizzato per la classificazione degli elementi costituito dall'intero codice presente al 4° livello di classificazione dello standard MasterFormat e del relativo titolo.	
	Titolo MasterFormat		
	Asset Code	Codice identificativo univoco dell'oggetto porta, definito sulla base del sito, dell'edificio, della disciplina, del livello e della categoria di appartenenza.	
	Codice As Built	Codice identificativo della porta, impiegato operativamente dall'Appaltatore e presente all'interno della documentazione As-Built.	
	RAL	Identificativo della colorazione associata all'oggetto porta. Per le regole di popolamento occorre fare riferimento all'Allegato 02.1	
	Affidabilità	Numero indicante il grado di affidabilità delle informazioni utilizzate per la creazione dell'oggetto ed il suo posizionamento.	
	Sito	Nomenclatura identificativa del sito a cui appartiene l'oggetto porta.	
	Edificio	Nomenclatura identificativa dell'edificio a cui appartiene l'oggetto.	
	Codice piano	Nomenclatura del livello di coordinamento a cui risulta collegato l'oggetto.	
	Codice padre AR	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per la disciplina Architettonica. Da compilarsi con l'Asset Code dell'oggetto stesso.	
	Codice padre ST	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per la disciplina Strutturale. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto a tale disciplina.	
	Codice padre FN	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per la disciplina Arredi. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto porta a tale disciplina.	
	Codice padre EL	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per la disciplina Elettrica. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto porta a tale disciplina.	
	Codice padre BMS	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema di gestione BMS. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto porta a tale tipologia impiantistica.	
	Codice padre SP	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema dati e speciali. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto porta a tale tipologia impiantistica.	
	Codice padre UPS	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema UPS. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto porta a tale tipologia impiantistica.	
	Codice padre SCS	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema di gestione dell'intensità luminosa dei dispositivi connessi. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto porta a tale tipologia impiantistica.	
	Codice padre MC_HOT	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema meccanico con fluido termovettore/aria caldi. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto porta a tale tipologia impiantistica.	
	Codice padre MC_COLD	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema meccanico con fluido termovettore/aria freddi. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto porta a tale tipologia impiantistica.	
	Codice padre FP	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema antincendio. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto porta a tale tipologia impiantistica.	
	Caratteristiche resistenza al fuoco	Parametro da compilare secondo le caratteristiche REI dell'oggetto.	

	Modello	Parametro da compilarsi mediante la dicitura inerente al modello dell'oggetto, così come riportato nella relativa scheda tecnica.
	Produttore	Parametro da compilarsi mediante la dicitura inerente al produttore dell'oggetto, così come riportato nella relativa scheda tecnica.
	Tipologia serratura	Identificativo della tipologia di serratura presente nell'oggetto porta.
	Materiale pannello	Parametro inerente alla tipologia di materiale costituente il pannello dell'oggetto porta, compilata secondo le indicazioni contenute nell'Allegato 02.1.
	Materiale telaio	Parametro inerente alla tipologia di materiale costituente il telaio dell'oggetto porta, compilata secondo le indicazioni contenute nell'Allegato 02.1.

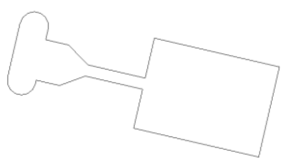
Table 38 – Example schedule of the expected value of LOG and LOI for the Electrical discipline

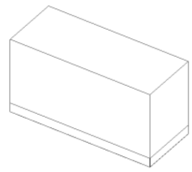
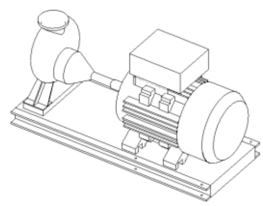
Component: Lighting Fixtures				Loadable Family
LOD C+				
LOG C	View Level of Detail	Geometry	Object	Graphic representation
	Coarse	Elemento rappresentato mediante simbologia 2D.	Simbolo 2D	
	Medium	Elemento rappresentato mediante un solido di estrusione che ne permette la definizione dell'ingombro spaziale di massima.	Solido 3D	
	Fine	Upgrade		
	Parameters	Description		
LOI F	Schedule Level	Livello di posizionamento a cui risulta legato l'oggetto appartenente alla categoria Lighting Fixtures.		
	Family	Nomenclatura della famiglia caricabile, definita sulla base delle indicazioni fornite dall'Allegato 01 e delle regole di nomenclatura contenute nell'Allegato 01.1		
	Type	Nomenclatura del tipo secondo le indicazioni fornite dall'Allegato 01 e le regole di nomenclatura definite nell'Allegato 01.1		
	Description	Definizione della descrizione della tipologia di oggetto analizzato.		
	Altezza_std	Parametro geometrico indicante la dimensione dell'altezza, utilizzato in fase di modellazione dell'apparecchio di illuminazione.		
	Larghezza_std	Parametro geometrico indicante la dimensione della larghezza, utilizzato in fase di modellazione dell'apparecchio di illuminazione.		
	Lunghezza_std	Parametro geometrico indicante la dimensione della lunghezza, utilizzato in fase di modellazione dell'apparecchio di illuminazione.		
	Diametro_std	Parametro geometrico indicante la dimensione del diametro, utilizzato in fase di modellazione dell'apparecchio di illuminazione.		
	Classi di unità tecnologiche	Parametri UNI 8290	Elementi funzionali omogenei, raggruppati per funzione prevalente, per continuità fisica e funzionale.	
	Unità tecnologiche		Insiemi di elementi tecnici che rappresentano funzioni finalizzate al soddisfacimento di esigenze dell'utenza.	
	Classi di elementi tecnici		Classi di prodotti che assolvono a funzioni proprie di una o più classi tecnologiche.	
	Numero MasterFormat			

	Titolo MasterFormat	Codice standardizzato per la classificazione degli elementi costituito dall'intero codice presente al 4° livello di classificazione dello standard MasterFormat e del relativo titolo.
	Asset Code	Codice identificativo univoco dell'oggetto apparecchio illuminante, definito sulla base del sito, dell'edificio, della disciplina, del livello e della categoria di appartenenza.
	Codice As Built	Codice identificativo dell'apparecchio illuminante, impiegato operativamente dall'Appaltatore e presente all'interno della documentazione As-Built.
	Affidabilità	Numero indicante il grado di affidabilità delle informazioni utilizzate per la creazione dell'oggetto ed il suo posizionamento.
	Sito	Nomenclatura identificativa del sito a cui appartiene l'oggetto apparecchio illuminante analizzato.
	Edificio	Nomenclatura identificativa dell'edificio a cui appartiene l'oggetto.
	Codice piano	Nomenclatura del livello di coordinamento a cui risulta collegato l'oggetto apparecchio illuminante analizzato.
	Codice padre AR	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per la disciplina Architettonica. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto a tale disciplina.
	Codice padre ST	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per la disciplina Strutturale. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto a tale disciplina.
	Codice padre FN	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per la disciplina Arredi. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto a tale disciplina.
	Codice padre EL	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per la disciplina Elettrica. Da compilarsi con l'Asset Code del componente padre, inteso come sorgente gerarchicamente superiore all'oggetto analizzato, relativamente al sistema di forza motrice.
	Codice padre BMS	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema di gestione BMS. Da compilarsi con l'Asset Code del componente padre, inteso come sorgente gerarchicamente superiore all'oggetto analizzato, relativamente al sistema BMS analizzato. Se il componente non appartiene a tale tipologia di sistema, il popolamento deve avvenire con la dicitura NA.
	Codice padre SP	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema dati e speciali. Da compilarsi con l'Asset Code del componente padre, inteso come sorgente gerarchicamente superiore all'oggetto analizzato, relativamente al sistema dati e speciali analizzato. Se il componente non appartiene a tale tipologia di sistema, il popolamento deve avvenire con la dicitura NA.
	Codice padre UPS	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema UPS. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto a tale tipologia impiantistica.
	Codice padre SCS	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema di gestione dell'intensità luminosa dei dispositivi connessi. Da compilarsi con l'Asset Code del componente padre, inteso come sorgente gerarchicamente superiore all'oggetto analizzato, relativamente al sistema analizzato. Se il componente non appartiene a tale tipologia di sistema, il popolamento deve avvenire con la dicitura NA.
	Codice padre MC_HOT	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema meccanico con fluido termovettore/aria caldi. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto apparecchio illuminante a tale tipologia impiantistica.
	Codice padre MC_COLD	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema meccanico con fluido termovettore/aria freddi. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto apparecchio illuminante a tale tipologia impiantistica.
	Codice padre FP	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema antincendio. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto apparecchio illuminante a tale tipologia impiantistica.
	Modello	Parametro da compilarsi mediante la dicitura inerente al modello dell'oggetto, così come riportato nella relativa scheda tecnica.
	Produttore	Parametro da compilarsi mediante la dicitura inerente al produttore dell'oggetto, così come riportato nella relativa scheda tecnica.

	Voltaggio	Parametro da popolarsi, per gli apparecchi di illuminazione, con il valore del voltaggio espresso in Volt. L'inserimento di tale parametro deve avvenire all'interno della singola famiglia, procedendo al linkaggio dello stesso al parametro Built-in "Voltage" proprio del connettore elettrico, al fine di effettuare una sola volta l'inserimento del dato all'interno dell'oggetto MEP.
	Potenza nominale	Parametro da popolarsi, per gli apparecchi di illuminazione, con il valore della potenza nominale espresso in Watt. L'inserimento di tale parametro deve avvenire all'interno della singola famiglia, procedendo al linkaggio dello stesso al parametro Built-in "Wattage" proprio del connettore elettrico, al fine di effettuare una sola volta l'inserimento del dato all'interno dell'oggetto MEP.
	Codice impianto EL	Parametro da compilarsi mediante l'inserimento della nomenclatura da As-Built del circuito al quale l'oggetto appartiene.
	Codice impianto SP	Parametro da compilarsi mediante la nomenclatura da As-Built del circuito dati al quale l'apparecchio di illuminazione appartiene
	Linea di alimentazione	Parametro da compilarsi mediante l'inserimento della tipologia di linea a cui l'apparecchio di illuminazione appartiene, con riferimento a quanto riepilogato nell'Allegato 02.1.
	Tipologia cavo EL	Parametro da valorizzare mediante la tipologia/modello del cavo in ingresso al componente analizzato che ne consente l'alimentazione elettrica, riportandone la relativa nomenclatura da As-Built.
	Tipologia cavo SP	Parametro da valorizzare mediante la tipologia/modello del cavo in ingresso al componente analizzato che ne consente l'alimentazione dati, riportandone la relativa nomenclatura da As-Built.
	Tipologia cavo BMS	Parametro da valorizzare mediante la tipologia/modello del cavo in ingresso al componente analizzato che ne consente il collegamento al rispettivo modulo BMS di gestione, riportandone la relativa nomenclatura da As-Built.
	Materiale	Parametro inerente alla tipologia di materiale prevalente dell'oggetto analizzato, compilato secondo le indicazioni contenute nell'Allegato 02.1.
	Gruppo impianto	Parametro identificativo dell'impianto a cui appartiene, a livello manutentivo, l'apparecchio di illuminazione analizzato. Per le nomenclature da adottare, occorre far riferimento all'Allegato 02.1
	Manutenzione da normativa	Parametro da popolare sulla base della presenza o meno di attività manutentive obbligatorie per legge da svolgere sull'apparecchio di illuminazione analizzato.
	Libreria	Parametro da compilarsi con l'indicazione della libreria BIM eventualmente utilizzata dall'Appaltatore come base di partenza per la realizzazione dell'oggetto parametrico.
	Autonomia	Parametro da compilarsi con il numero di ore di autonomia di cui risulta dotato l'apparecchio di illuminazione, nel caso in cui questo sia autoalimentato. Per le regole di inserimento, occorre far riferimento a quanto indicato nell'Allegato 02.1
	Accensione	Parametro da compilarsi con la dicitura inerente alla modalità con cui avviene l'accensione/spegnimento dell'apparecchio di illuminazione. Per le regole di inserimento, occorre far riferimento a quanto indicato nell'Allegato 02.1
	Cavetto di sicurezza	Parametro da popolare sulla base della presenza o meno di un cavetto di sicurezza agganciato all'oggetto analizzato, che ne evita la caduta.

Table 39 – Example schedule of the expected value of LOG and LOI for the Mechanical discipline

<table>
<tr><th colspan="4">Component: Elettropompa</th><th>Loadable Family</th></tr>
<tr><td colspan="5">LOD C+</td></tr>
<tr><td rowspan="2">LOG C</td><td>View Level of Detail</td><td>Geometry</td><td>Object</td><td>Graphic representation</td></tr>
<tr><td>Coarse</td><td>Elemento rappresentato mediante simbologia 2D.</td><td>Simbolo 2D</td><td></td></tr>
</table>

	Medium	Elemento rappresentato mediante un solido di estrusione che ne permette la definizione dell’ingombro spaziale di massima.	Solido 3D	
	Fine	Elemento rappresentato mediante un solido di estrusione dettagliato che ne permette la definizione dell’effettivo ingombro spaziale.	Solido 3D con dettagli	
	Parameters	Description		
LOI F	Schedule Level	Livello di posizionamento a cui risulta legato l’oggetto appartenente alla categoria Mechanical Equipment.		
	Family	Nomenclatura della famiglia caricabile, definita sulla base delle indicazioni fornite dall’Allegato 01 e delle regole di nomenclatura contenute nell’Allegato 01.1		
	Type	Nomenclatura del tipo secondo le indicazioni fornite dall’Allegato 01 e le regole di nomenclatura definite nell’Allegato 01.1		
	Description	Definizione della descrizione della tipologia di oggetto analizzato.		
	Classi di unità tecnologiche	Parametri UNI 8290	Elementi funzionali omogenei, raggruppati per funzione prevalente, per continuità fisica e funzionale.	
	Unità tecnologiche		Insiemi di elementi tecnici che rappresentano funzioni finalizzate al soddisfacimento di esigenze dell’utenza.	
	Classi di elementi tecnici		Classi di prodotti che assolvono a funzioni proprie di una o più classi tecnologiche.	
	Numero MasterFormat	Codice standardizzato per la classificazione degli elementi costituito dall’intero codice presente al 4° livello di classificazione dello standard MasterFormat e del relativo titolo.		
	Titolo MasterFormat			
	Asset Code	Codice identificativo univoco dell’oggetto elettropompa, definito sulla base del sito, dell’edificio, della disciplina, del livello e della categoria di appartenenza.		
	Codice As Built	Codice identificativo dell’oggetto analizzato, impiegato operativamente dall’Appaltatore e presente all’interno della documentazione As-Built.		
	Affidabilità	Numero indicante il grado di affidabilità delle informazioni utilizzate per la creazione dell’oggetto ed il suo posizionamento.		
	Sito	Nomenclatura identificativa del sito a cui appartiene l’oggetto elettropompa analizzato.		
	Edificio	Nomenclatura identificativa dell’edificio a cui appartiene l’oggetto.		
	Codice piano	Nomenclatura del livello di coordinamento a cui risulta collegato l’oggetto elettropompa analizzato.		
	Codice padre AR	Parametro inerente alla strutturazione gerarchica all’interno del software IWMS per la disciplina Architettonica. Da compilarsi con la dicitura NA, data la non appartenenza dell’oggetto a tale disciplina.		
	Codice padre ST	Parametro inerente alla strutturazione gerarchica all’interno del software IWMS per la disciplina Strutturale. Da compilarsi con la dicitura NA, data la non appartenenza dell’oggetto a tale disciplina.		
	Codice padre FN	Parametro inerente alla strutturazione gerarchica all’interno del software IWMS per la disciplina Arredi. Da compilarsi con la dicitura NA, data la non appartenenza dell’oggetto a tale disciplina.		

	Codice padre EL	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per la disciplina Elettrica. Da compilarsi con l'Asset Code del componente padre, inteso come sorgente gerarchicamente superiore all'oggetto analizzato, relativamente al sistema di forza motrice.
	Codice padre BMS	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema di gestione BMS. Da compilarsi con l'Asset Code del componente padre, inteso come sorgente gerarchicamente superiore all'oggetto analizzato, relativamente al sistema BMS analizzato.
	Codice padre SP	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema dati e speciali. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto elettropompa a tale tipologia impiantistica.
	Codice padre UPS	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema UPS. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto elettropompa a tale tipologia impiantistica.
	Codice padre SCS	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema di gestione dell'intensità luminosa dei dispositivi connessi. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto elettropompa a tale tipologia impiantistica.
	Codice padre MC_HOT	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema meccanico con fluido termovettore/aria caldi. Da compilarsi con l'Asset Code del componente padre, inteso come sorgente gerarchicamente superiore all'oggetto analizzato, relativamente al sistema di adduzione che lo alimenta. Se tale oggetto rappresenta la sorgente dell'impianto, allora la valorizzazione del campo deve avvenire con l'Asset Code di sé stesso.
	Codice padre MC_COLD	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema meccanico con fluido termovettore/aria freddi. Da compilarsi con l'Asset Code del componente padre, inteso come sorgente gerarchicamente superiore all'oggetto analizzato, relativamente al sistema di adduzione che lo alimenta. Se tale oggetto rappresenta la sorgente dell'impianto, allora la valorizzazione del campo deve avvenire con l'Asset Code di sé stesso.
	Codice padre FP	Parametro inerente alla strutturazione gerarchica all'interno del software IWMS per il sistema antincendio. Da compilarsi con la dicitura NA, data la non appartenenza dell'oggetto elettropompa a tale tipologia impiantistica.
	Modello	Parametro da compilarsi mediante la dicitura inerente al modello dell'oggetto, così come riportato nella relativa scheda tecnica.
	Produttore	Parametro da compilarsi mediante la dicitura inerente al produttore dell'oggetto, così come riportato nella relativa scheda tecnica.
	Voltaggio	Parametro da popolarsi con il valore del voltaggio espresso in Volt. L'inserimento di tale parametro deve avvenire all'interno della singola famiglia, procedendo al linkaggio dello stesso al parametro built-in "Voltage" proprio del connettore elettrico, al fine di effettuare una sola volta l'inserimento del dato all'interno dell'oggetto MEP.
	Potenza nominale	Parametro da popolarsi con il valore della potenza nominale espresso in Watt. L'inserimento di tale parametro deve avvenire all'interno della singola famiglia, procedendo al linkaggio dello stesso al parametro built-in "Wattage" proprio del connettore elettrico, al fine di effettuare una sola volta l'inserimento del dato all'interno dell'oggetto MEP.
	Codice impianto EL	Parametro da compilarsi mediante l'inserimento della nomenclatura da As-Built del circuito al quale l'oggetto appartiene.
	Linea di alimentazione	Parametro da compilarsi mediante l'inserimento della tipologia di linea elettrica a cui l'elettropompa appartiene, con riferimento a quanto riepilogato nell'Allegato 02.1.
	Tipologia cavo BMS	Parametro da valorizzare mediante la tipologia/modello del cavo in ingresso al componente analizzato che ne consente il collegamento al rispettivo modulo BMS di gestione, riportandone la relativa nomenclatura da As-Built.
	Codice impianto MC	Parametro da compilarsi per tutti gli oggetti appartenenti alle sottodiscipline meccaniche secondo le nomenclature previste nel file inerente i sistemi impiantistici, seguendone le rispettive logiche..
	Gruppo impianto	Parametro identificativo della tipologia di impianto a cui appartiene, a livello manutentivo, l'elettropompa analizzata. Per le nomenclature da adottare, occorre far riferimento all'Allegato 02.1

	Materiale	Parametro inerente alla tipologia di materiale prevalente dell’oggetto analizzato, compilato secondo le indicazioni contenute nell’Allegato 02.1 e le rispettive logiche operative.
	Manutenzione da normativa	Parametro da popolare sulla base della presenza o meno di attività manutentive obbligatorie per legge da svolgere sull’oggetto analizzato.
	Libreria	Parametro da compilarsi con l’indicazione della libreria BIM eventualmente utilizzata dall’Appaltatore come base di partenza per la realizzazione dell’oggetto parametrico.

Appendix C: List of checklist and rulesets

Table 40 – Checklist of the Architectural discipline

CHECKLIST - ARCHITECTURAL DISCIPLINE																	
	Autodesk Revit categories																
	SYSTEM FAMILIES										LOADABLE FAMILIES						
Parameters	Walls	Parts	Floors	Slab Edges	Ceiling	Roofs	Stairs	Railings	Roof Gutter	Ramps	Doors	Column	Windows	Site	Furniture	Structural Framing	Curtain Panels
Phase	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Level	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Family	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Type	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Thickness		■			■	■					■						
Structural material	■															■	
Material		■		■													
Finish			■		■	■											
Structural usage																■	
Description	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Function	■		■				■			■	■						
Classi di unità tecnologiche	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Unità tecnologiche	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Classi di elementi tecnici	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Numero MasterFormat	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Titolo MasterFormat	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Asset Code	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Codice As Built	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Codice spazio		■	■		■							■					■
Affidabilità	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Codice piano	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	
Edificio	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Sito	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre AR	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre ST	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre FN	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre EL	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre BMS	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre SP	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Codice padre UPS																	
Codice padre SCS																	
Codice padre MC_HOT																	
Codice padre MC_COLD																	
Codice padre FP																	
Classe di reazione al fuoco																	
Caratteristiche resistenza al fuoco																	
Caratterizzazione grafica																	
RAL																	
Modello																	
Produttore																	
Spazio netto_cm																	
Tipologia zoccolino																	
Rivestimento scale																	
Tipologia pedata																	
Altezza totale parapetto																	
Materiale																	
Tipologia serratura																	
Materiale telaio																	
Materiale pannello																	
ID elemento																	
Voltaggio																	
Potenza nominale																	
Linea di alimentazione																	
Codice impianto EL																	
Gruppo impianto																	
Capacità deflusso																	
Deflusso effettivo																	
Numero																	
Numero parcheggio																	
Assegnatario																	
Tribuna servita																	
Settore																	
Tipologia numero																	
Larghezza_std																	
Lunghezza_std																	
Diametro_std																	
Altezza_std																	
Altezza																	
Lunghezza																	

Table 41 – Rulesets of the Architectural discipline

<table>
<tr><th>Parameters</th><th>Step 1</th><th>Step 2</th><th>LF</th><th>SF</th><th>Type of check</th><th>Rulesets</th></tr>
<tr><td>Denominazione Family</td><td></td><td></td><td></td><td></td><td></td><td>Famiglie di sistema nessun controllo, per le famiglie caricabili regola strutturata in accordo ad Allegato 01 LG BIM (controllo formale).
Massimo 32 caratteri, solo A-Z, 0-9 e "_" ammessi.</td></tr>
<tr><td>Denominazione Type</td><td></td><td></td><td></td><td></td><td></td><td>Massimo 32 caratteri solo A-Z, 0-9 e "_" ammessi. Strutturazione della regola in accordo ad allegato 01 LG BIM</td></tr>
<tr><td>Phase</td><td></td><td></td><td></td><td></td><td></td><td>Controllare che la fase di tutti gli elementi sia in "Stato di Fatto"</td></tr>
<tr><td rowspan="4">Level</td><td></td><td></td><td></td><td></td><td></td><td>Level (Floors, Ceilings, Doors, Windows, Site, Furniture)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Reference Level (Structural Framing)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Base Level (Parts, Roofs, Stairs, Railings, Ramps, Column)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Base Constraint (Walls)</td></tr>
<tr><td>Thickness</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che sia compilato</td></tr>
<tr><td>Structural material</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^(WL)(_)[A-Z]{2,3}$|^(WL)(_)[A-Z]{1}[0-9]{2}$|^(WL)(_)[A-Z]{2,3}(_)[A-Z]{1,3}$|^(WL)(_)[A-Z]{2,3}(_)[A-Z]{2,3}(_)[A-Z]{2,3}$|^(CE)(_)[A-Z]{2,3}$|^(SM)(_)[A-Z]{2,3}$)</td></tr>
<tr><td>Material</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[A-Z]{2}(_)[A-Z]{2,3}$|^[A-Z]{2}(_)[A-Z]{1}[0-9]{2}$|^[A-Z]{2}(_)[A-Z]{2,3}(_)[A-Z]{1,3}$|^[A-Z]{2}(_)[A-Z]{2,3}(_)[A-Z]{2,3}(_)[A-Z]{2,3}$)</td></tr>
<tr><td>Structure (Structure)</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^(CE)(_)[A-Z]{3}$|^(CE)(_)[A-Z]{3}(_)[A-Z]{3}$|^(CE)(_)[A-Z]{3}(_)[A-Z]{3}(_)[A-Z]{3}$)</td></tr>
<tr><td>Structure (Finish)</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^(FL)(_)[A-Z]{3}$|^(FL)(_)[A-Z]{3}(_)[A-Z]{3}$)</td></tr>
<tr><td>Structure (Substrate)</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^(RF)(_)[A-Z]{1}[0-9]{2}$)</td></tr>
<tr><td>Structural usage</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che sia compilato con il termine "Other" per gli Structural Framing</td></tr>
<tr><td>Description</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che sia compilato (numero massimo di caratteri 256), con verifica dell'utilizzo dei caratteri speciali</td></tr>
<tr><td>Function</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (Interior|Exterior|Soffit)</td></tr>
<tr><td>Classi di unità tecnologiche</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0|00)</td></tr>
<tr><td>Unità tecnologiche</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0.0|00.00|ND)</td></tr>
<tr><td>Classi di elementi tecnici</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0.0.0|00.00.00|ND)</td></tr>
<tr><td>Numero MasterFormat</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (00 00 00|00 00 00.00)</td></tr>
<tr><td>Titolo MasterFormat</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che il parametro sia compilato</td></tr>
<tr><td>Asset Code</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AR_L00_AA_00000) - Controllo univocità</td></tr>
<tr><td>Codice As Built</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che il parametro sia compilato</td></tr>
<tr><td>Codice spazio</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (ND|NA|L01000|L02000|..L07000 separati dall'"_").</td></tr>
<tr><td>Affidabilità</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (1|2|3)</td></tr>
<tr><td>Sito</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA)</td></tr>
<tr><td>Codice piano</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (L00)</td></tr>
<tr><td>Edificio</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (ST)</td></tr>
<tr><td>Codice padre AR</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AR_L00_AA_00000)</td></tr>
<tr><td>Codice padre ST</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre FN</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre EL</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_EL_L00_AA_00000 | NA)</td></tr>
<tr><td>Codice padre BMS</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre SP</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre UPS</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre SCS</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
</table>

Codice padre MC_HOT						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)
Codice padre MC_COLD						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)
Codice padre FP						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)
Classe di reazione al fuoco						Parametro di istanza - controllare che il parametro sia compilato
Caratteristiche resistenza al fuoco						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (REI 00|REI 000|EI 00|EI 000|R 00|R 000|ND|NA)
Caratterizzazione grafica						Parametro di istanza - controllare che il parametro sia compilato
RAL						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0000|Aa|Aa_Aa|ND|NA)
Modello						Parametro di istanza - controllare che il parametro sia compilato
Produttore						Parametro di istanza - controllare che il parametro sia compilato
Spazio netto_cm						Parametro di istanza - controllare che il parametro sia compilato
Tipologia zoccolino						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (Z00|ND)
Rivestimento scale						Parametro di istanza - controllare che il parametro sia compilato
Tipologia pedata						Parametro di istanza - controllare che il parametro sia compilato
Altezza totale parapetto						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (00cm|000cm)
Materiale						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (AA_AA|AA_AAA|AA_AAA_AAA|AA_AAA_AAA_AAA|AA_AAA_A|AA_A00|AA_AA_AAA|AA_AAA_AA_AAA)
Tipologia serratura						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (SE|SA|MK1-8|J|ND|NA)
Materiale telaio						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (AA_AAA|AA_NA)
Materiale pannello						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (AA_AAA|AA_NA)
ID elemento						Parametro di istanza - controllare che il parametro sia compilato
Voltaggio						Parametro di tipo - controllare che sia compilato
Potenza nominale						Parametro di tipo - controllare che sia compilato
Linea di alimentazione						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM - rif. disciplina EL (N|P|S1|S2|S3|S4|C1|C2|C3|C4|TD|SP|TD_SP|BROADCASTING|TELECOM|MT|VUOTA|RIPRESE TV - ENERGIA|RIPRESE TV - SEGNALE|NA)
Codice impianto EL						Parametro di istanza - controllare che il parametro sia compilato
Gruppo impianto						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (effettiva nomenclatura - rif. disciplina EL)
Capacità deflusso						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (000x00M|J|ND|NA)
Deflusso effettivo						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (J|0000_0000|ND|NA)
Numero						Parametro di istanza - controllare che il parametro sia compilato
Numero parcheggio						Parametro di istanza - controllare che il parametro sia compilato
Assegnatario						Parametro di istanza - controllare che il parametro sia compilato con la nomenclatura prevista da LG_BIM (J|NA)
Tribuna servita						Parametro di istanza - controllare che il parametro sia compilato
Settore						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (000|NA|ND)
Tipologia numero						Parametro di tipo - controllare che il parametro sia compilato
Larghezza_std						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})
Lunghezza_std						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})
Diametro_std						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})
Altezza_std						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})
Altezza						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})
Lunghezza						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})

Check if the parameter has been compiled or not.

- Check if the parameter has been compiled following the disposition of the BIM guidelines.
- Check if the parameter has been compiled accordingly to the specific nomenclature defined in the BIM guidelines.

Table 42 – Checklist of the Electrical discipline

CHECKLIST - ELECTRICAL DISCIPLINE												
	Autodesk Revit Category											
	SYSTEM FAMILIES		LOADABLE FAMILIES									
Parameters	Cable Trays	Conduits	Electrical Equipment	Cable Trays Fittings	Conduit Fittings	Electrical Fixtures	Fire Alam devices	Lighting Fixtures	Communication Devices	Structural framing	Furniture	Mechanical Equipment
Phase	■	■	■	■	■	■	■	■	■	■	■	■
Level	■	■	■	■	■	■	■	■	■	■	■	■
Family	■	■	■	■	■	■	■	■	■	■	■	■
Type	■	■	■	■	■	■	■	■	■	■	■	■
Description	■	■	■	■	■	■	■	■	■	■	■	
Altezza_std			■			■	■	■	■			
Larghezza_std			■			■	■	■	■			
Lunghezza_std			■			■	■	■	■			
Diametro_std							■	■	■			
Altezza			■									
Larghezza			■									
Lunghezza			■									
Classi di unità tecnologiche	■	■	■	■	■	■	■	■	■	■	■	
Unità tecnologiche	■	■	■	■	■	■	■	■	■	■	■	
Classi di elementi tecnici	■	■	■	■	■	■	■	■	■	■	■	
Numero MasterFormat	■	■	■	■	■	■	■	■	■	■	■	
Titolo MasterFormat	■	■	■	■	■	■	■	■	■	■	■	
Asset Code	■	■	■	■	■	■	■	■	■	■	■	
Codice As Built	■	■	■	■	■	■	■	■	■	■	■	
Affidabilità	■	■	■	■	■	■	■	■	■	■	■	
Sito	■	■	■	■	■	■	■	■	■	■	■	
Edificio	■	■	■	■	■	■	■	■	■	■	■	
Codice piano	■	■	■	■	■	■	■	■	■	■	■	
Codice padre AR	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre ST	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre FN	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre EL	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre BMS	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre SP	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre UPS	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre SCS	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre MC_HOT	■	■	■	■	■	■	■	■	■	■	■	■
Codice padre MC_COLD	■	■	■	■	■	■	■	■	■	■	■	

Codice padre FP												
Modello												
Produttore												
Voltaggio												
Potenza nominale												
Codice impianto EL												
Linea di alimentazione												
Tipologia cavo EL												
Tipologia cavo SP												
Tipologia cavo BMS												
Materiale												
Manutenzione da normativa												
Libreria												
Codice impianto SP												
Autonomia												
Batterie												
Codice impianto FP												
Quantità prese schuko												
Quantità prese poli in linea												
Quantità interruttore MT												
Quantità interruttore MTD												
Quantità tappi												
Quantità frutti dati												
Quantità CEE 2PT 16A 230V												
Quantità CEE 2PT 32A 230V												
Quantità CEE 2PT 63A 230V												
Quantità CEE 3PT 16A 400V												
Quantità CEE 3PT 32A 400V												
Quantità CEE 3PT 63A 400V												
Quantità CEE 3PT 125A 400V												
Quantità CEE 3PNT 16A 400V												
Quantità CEE 3PNT 32A 400V												
Quantità CEE 3PNT 63A 400V												
Quantità CEE 3PNT 125A 400V												
Accensione												
Cavetto di sicurezza												
Percentuale di occupazione												
Separatori												
Accessibilità operativa												
RAL												
Rivestimento												
Gruppo impianto												

Table 43 – Rulesets of the Electrical discipline

<table>
<tr><th>Parameters</th><th>Step 1</th><th>Step 2</th><th>LF</th><th>SF</th><th>Type of check</th><th>Rulesets</th></tr>
<tr><td>Denominazione Family</td><td></td><td></td><td></td><td></td><td></td><td>Famiglie di sistema nessun controllo, Famiglie caricabili verificare struttura (EL_S|C|T|E|A_SOTTOCATEGORIA_descrizione_descrizione_descrizione). Massimo 32 caratteri, primi 3 campi maiuscoli, solo a-z, 0-9 e "_" ammessi.</td></tr>
<tr><td>Denominazione Type</td><td></td><td></td><td></td><td></td><td></td><td>Massimo 32 caratteri, campi maiuscoli, solo A-Z, 0-9 e "_" ammessi. Strutturazione della regola in accordo ad Allegato 01 LG BIM</td></tr>
<tr><td>Phase</td><td></td><td></td><td></td><td></td><td></td><td>Controllare che la fase di tutti gli elementi sia "Stato di Fatto"</td></tr>
<tr><td rowspan="3">Level</td><td rowspan="3"></td><td rowspan="3"></td><td></td><td></td><td></td><td>Level (Cable tray fittings, Furniture, Conduit Fitting)</td></tr>
<tr><td></td><td></td><td></td><td>Reference Level (Cable tray, Conduits)</td></tr>
<tr><td></td><td></td><td></td><td>Schedule level (Electrical Equipment, Electrical Fixtures, Lighting Fixtures, Fire Alarm Devices, Communication Devices, Structural Framing, Mechanical Equipment)</td></tr>
<tr><td>Description</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che sia compilato (numero massimo di caratteri 256), con verifica dell'utilizzo dei caratteri speciali</td></tr>
<tr><td>Altezza</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})</td></tr>
<tr><td>Larghezza</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})</td></tr>
<tr><td>Lunghezza</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})</td></tr>
<tr><td>Altezza_std</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})</td></tr>
<tr><td>Larghezza_std</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})</td></tr>
<tr><td>Lunghezza_std</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})</td></tr>
<tr><td>Diametro_std</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (^[0-9]{1,3}(,)[0-9]{6})</td></tr>
<tr><td>Classi di unità tecnologiche</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0|00)</td></tr>
<tr><td>Unità tecnologiche</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0.0|00.00)</td></tr>
<tr><td>Classi di elementi tecnici</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0.0.0|00.00.00)</td></tr>
<tr><td>Numero MasterFormat</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (00 00 00|00 00 00.00)</td></tr>
<tr><td>Titolo MasterFormat</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di tipo - controllare che il parametro sia compilato</td></tr>
<tr><td>Asset Code</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_EL_L00_AA_00000) - Controllo univocità</td></tr>
<tr><td>Codice As Built</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che il parametro sia compilato</td></tr>
<tr><td>Affidabilità</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (1|2|3)</td></tr>
<tr><td>Sito</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA)</td></tr>
<tr><td>Edificio</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (ST)</td></tr>
<tr><td>Codice piano</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (L00)</td></tr>
<tr><td>Codice padre AR</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre ST</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre FN</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre EL</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_EL_L00_AA_00000|NA)</td></tr>
<tr><td>Codice padre BMS</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000 | NA)</td></tr>
<tr><td>Codice padre SP</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000 | NA)</td></tr>
<tr><td>Codice padre UPS</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000 | NA)</td></tr>
<tr><td>Codice padre SCS</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000 | NA)</td></tr>
<tr><td>Codice padre MC_HOT</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre MC_COLD</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)</td></tr>
<tr><td>Codice padre FP</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000 | NA)</td></tr>
<tr><td>Modello</td><td></td><td></td><td></td><td></td><td></td><td>Parametro di istanza - controllare che il parametro sia compilato</td></tr>
</table>

Produttore						Parametro di istanza - controllare che il parametro sia compilato
Voltaggio						Parametro di tipo - controllare che il parametro sia compilato
Potenza nominale						Parametro di tipo - controllare che il parametro sia compilato
Codice impianto EL						Parametro di istanza - controllare che il parametro sia compilato
Linea di alimentazione						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (N|P|S1|S2|S3|S4|C1|C2|C3|C4|TD|SP|TD_SP|BROADCASTING|TELECOM|MT)
Tipologia cavo EL						Parametro di istanza - controllare che il parametro sia compilato
Tipologia cavo SP						Parametro di istanza - controllare che il parametro sia compilato
Tipologia cavo BMS						Parametro di istanza - controllare che il parametro sia compilato
Gruppo impianto						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (effettiva nomenclatura)
Materiale						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (AA_AAA|AA_AA)
Manutenzione da normativa						Parametro di istanza - controllare che il parametro sia compilato
Libreria						Parametro di tipo - controllare che il parametro sia compilato
Codice impianto SP						Parametro di istanza - controllare che il parametro sia compilato
Autonomia						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (00h|ND|NA)
Batterie						Parametro di istanza - controllare che il parametro sia compilato
Codice impianto FP						Parametro di istanza - controllare che il parametro sia compilato
Quantità prese schuko						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità prese poli in linea						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità interruttore MT						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità interruttore MTD						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità tappi						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità frutti dati						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 2PT 16A 230V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 2PT 32A 230V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 2PT 63A 230V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 3PT 16A 400V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 3PT 32A 400V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 3PT 63A 400V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 3PT 125A 400V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 3PNT 16A 400V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 3PNT 32A 400V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 3PNT 63A 400V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Quantità CEE 3PNT 125A 400V						Parametro di istanza - controllare che il parametro sia compilato correttamente a livello formale ([0-6]{1}(,)(0){6})
Accensione						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (Da BMS|Da Locale|Sempre accesa|ND)
Cavetto di sicurezza						Parametro di istanza - controllare che il parametro sia compilato
Percentuale di occupazione						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM ([0-9]{1,3}(,)(0){6})
Separatori						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM ([0-9]{1,2}|(ND))
Accessibilità operativa						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (Scala|NA|ND)

RAL						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0000|Aa|Aa_Aa|ND|NA)
Rivestimento						Parametro di istanza - controllare che il parametro sia compilato

Check if the parameter has been compiled or not.

Check if the parameter has been compiled following the disposition of the BIM guidelines.

Check if the parameter has been compiled accordingly to the specific nomenclature defined in the BIM guidelines.

Table 44 – Checklist of the Thermal sub-discipline

CHECKLIST - THERMAL SUB-DISCIPLINE										
	Autodesk Revit Category									
	SYSTEM FAMILIES			LOADABLE FAMILIES						
Parameters	Ducts	Flex Ducts	Pipes	Pipes Fittings	Duct Accessories	Mechanical Equipment	Plumbing Fixtures	Pipe Accessories	Duct Fittings	Air Terminals
Phase										
Level										
Family										
Type										
Description										
Classi di unità tecnologiche										
Unità tecnologiche										
Classi di elementi tecnici										
Numero MasterFormat										
Titolo MasterFormat										
Asset Code										
Codice As Built										
Affidabilità										
Sito										
Edificio										
Codice piano										
Codice padre AR										
Codice padre ST										
Codice padre FN										
Codice padre EL										
Codice padre BMS										
Codice padre SP										
Codice padre UPS										
Codice padre SCS										
Codice padre MC_HOT										
Codice padre MC_COLD										
Codice padre FP										
Modello										
Produttore										
Codice impianto FP										

Gruppo impianto										
Materiale										
Manutenzione da normativa										
Libreria										
Rivestimento										
Cavi scaldanti										
Voltaggio										
Potenza nominale										
Codice impianto EL										
Linea di alimentazione										
Tipologia cavo BMS										
Capacità										
Codice impianto MC										
RAL										
Accessibilità operativa										

Table 45 – Rulesets of the Thermal sub-discipline

Parameters	Step 1	Step 2	LF	SF	Type of check	Rulesets
Denominazione Family						Famiglie di sistema nessun controllo, Famiglie caricabili verificare struttura (TE_S|C|T|E|A_SOTTOCATEGORIA_descrizione_descrizione_descrizione). Massimo 32 caratteri, primi 3 campi maiuscoli, solo a-z, 0-9 e "_" ammessi.
Denominazione Type						Massimo 32 caratteri, campi maiuscoli, solo A-Z, 0-9 e "_" ammessi. Strutturazione della regola in accordo ad Allegato 01 LG BIM
Phase						Controllare che la fase di tutti gli elementi sia "Stato di Fatto"
Level						Level (Pipe Fittings, Pipe Accessories, Duct Fittings, Duct Accessories)
						Reference Level (Pipes, Ducts, Flex Ducts)
						Schedule level (Mechanical Equipment, Plumbing Fixtures, Air Terminals)
Description						Parametro di tipo - controllare che sia compilato (numero massimo di caratteri 256), con verifica dell'utilizzo dei caratteri speciali
Classi di unità tecnologiche						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0|00)
Unità tecnologiche						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0.0|00.00)
Classi di elementi tecnici						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0.0.0|00.00.00)
Numero MasterFormat						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (00 00 00|00 00 00.00)
Titolo MasterFormat						Parametro di tipo - controllare che il parametro sia compilato
Asset Code						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_TE_L00_AA_00000) - Controllo univocità
Codice As Built						Parametro di istanza - controllare che il parametro sia compilato
Affidabilità						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (1|2|3)
Sito						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA)
Edificio						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (ST)
Codice piano						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (L00)
Codice padre AR						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)
Codice padre ST						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)
Codice padre FN						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)
Codice padre EL						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_EL_L00_AA_00000 | NA)

Codice padre BMS						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000 | NA)
Codice padre SP						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000 | NA)
Codice padre UPS						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000 | NA)
Codice padre SCS						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)
Codice padre FP						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (NA)
Codice padre MC_HOT						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000 |NA)
Codice padre MC_COLD						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (STA_ST_AA_L00_AA_00000|NA)
Modello						Parametro di istanza - controllare che il parametro sia compilato
Produttore						Parametro di istanza - controllare che il parametro sia compilato
Codice impianto MC						Parametro di istanza - controllare che il parametro sia compilato
Linea di alimentazione						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (MCT|MFT|RCT|RFT|ScG|GAS)
Gruppo impianto						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (Impianto termico)
Materiale						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (AA_AAA|AA_AA)
Manutenzione da normativa						Parametro di istanza - controllare che il parametro sia compilato
Libreria						Parametro di tipo - controllare che il parametro sia compilato
Rivestimento						Parametro di istanza - controllare che il parametro sia compilato
Voltaggio						Parametro di tipo - controllare che il parametro sia compilato
Potenza nominale						Parametro di tipo - controllare che il parametro sia compilato
Codice impianto EL						Parametro di istanza - controllare che il parametro sia compilato
Tipologia cavo BMS						Parametro di istanza - controllare che il parametro sia compilato
Capacità						Parametro di tipo - controllare che il parametro sia compilato
Codice impianto FP						Parametro di istanza - controllare che il parametro sia compilato
Cavi scaldanti						Parametro di istanza - controllare che il parametro sia compilato
RAL						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (0000|Aa|Aa_Aa|ND|NA)
Accessibilità operativa						Parametro di tipo - controllare che il parametro sia compilato
Caratteristiche resistenza al fuoco						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (REI 00|REI 000|EI 00|EI 000|ND|NA)
Accessibilità operatori/material e						Parametro di tipo - controllare che il parametro sia compilato
Azionamento						Parametro di tipo - controllare che la compilazione del parametro rispetti quanto previsto da LG BIM (Automatico|Manuale|NA)
Ubicazione						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG_BIM (STA_ST_L00000|NA)
Locali compartimentati						Parametro di istanza - controllare che la compilazione del parametro rispetti quanto previsto da LG_BIM (STA_ST_L00000_STA_ST_L00000)

Check if the parameter has been compiled or not.

Check if the parameter has been compiled following the disposition of the BIM guidelines.

Check if the parameter has been compiled accordingly to the specific nomenclature defined in the BIM guidelines.