POLITECNICO DI TORINO

Master's degree in Building Engineering
(Green Building Engineering)

Business Intelligence integration for BIM data management

Application on a case study: Redevelopment of the Ex Buon Pastore building

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ABSTRACT

Building Information Modeling (BIM) has shown its potential as a resource for enhancing various operations related to Facility Management (FM) through efficient recovery, analysis, and processing of building-related data. Facility Management involves a range of multidisciplinary activities and, as a result, has remarkable information needs. A significant part of this information is generated during the design, construction, and commissioning stages of a project. Delivering accessible and comprehensive information to facility owners after construction has been a challenge for the industry. In such environments, a large amount of data is generated, creating an urgent need for organizations to benefit from this data; otherwise, its potential value may be lost. This thesis aims to show, through an actual case study, the high potential of Microsoft Power BI, a sophisticated business intelligence tool, to convert simple data into highly developed representations and entertaining reports. Based on an As Operate BIM model of the Ex Buon Pastore building, realized using Revit 2023 software, in this thesis is demonstrated how the integration of Revit and Construction Operations Building Information Exchange (COBie) with Power BI, can lead to a better data visualization method, which can drastically improve understanding of what is being done and can enable easier decision-making. Furthermore, the introduction of interactive dashboards can also encourage the systemic change in the construction industry towards more sustainable practices.

Key words: Building Information Modeling (BIM); Facility Management (FM); Business Intelligence; Microsoft Power BI; As Operate BIM model; COBie; data visualization; sustainable.

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1. INTRODUCTION

In the rapidly evolving construction and facility management industries, the integration of digital tools and methodologies has become essential for addressing the increasing complexity of modern projects. BIM has emerged as a transformative technology, offering a structured approach to managing and utilizing building-related data. Regardless of its potential, a significant challenge remains delivering accessible, comprehensive, and actionable information to facility owners and operators. Much of the critical data generated during the design, construction, and commissioning phases often remains not effectively used due to incompetency in its organization and presentation. Consequently, valuable opportunities for optimizing facility operations are lost.

Facility Management, a multidisciplinary field with extensive information needs, has the opportunity to gain greatly from innovations that enhance data accessibility and usability. An encouraging strategy lies in integrating BIM tools, such as Autodesk Revit, with advanced business intelligence platforms like Microsoft Power BI. By leveraging these technologies, it is possible to transform raw data into meaningful insights through interactive dashboards and dynamic visualizations. These tools not only improve data interpretation but also promote informed decision-making and support the adoption of sustainable practices across the construction and FM sectors.

This thesis explores the potential of such integrations through the case study of the Ex Buon Pastore building. Using an As Operate BIM model developed in Revit 2023 and employing the Construction Operations Building Information Exchange (COBie) standard, the study demonstrates how the combination of BIM data and Power BI can revolutionize data visualization and facility management practices. The implementation of interactive dashboards highlights the benefits of enhanced clarity, streamlined processes, and a stronger focus on sustainability within the construction industry.

By addressing critical issues in information management, this research underscores the value of innovative digital tools in driving systemic change. It aims to contribute to the ongoing discourse on improving operational efficiency and sustainability in construction and facility management, giving an initial input for broader adoption of these technologies.

2. STATE OF THE ART

This chapter explores the incorporation of Business Intelligence (BI) into Building Information Modeling (BIM), highlighting the transformative impact on the construction industry. It explores fundamental concepts such as BIM and Power BI, a leading BI tool that enhances data visualization and decision-making in construction projects. Additionally, the chapter reviews significant global policy developments, highlighting BIM's increasing adoption worldwide.

2.1. BIM

Building Information Model and the Building Information Modelling (both referred to as BIM) can be defined as follows: "*A Building Information Model is a digital representation of physical and functional characteristics of a facility.* [1]"

"*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, this is information such as specifications, building elements specifications, economy and programs.* [2]."

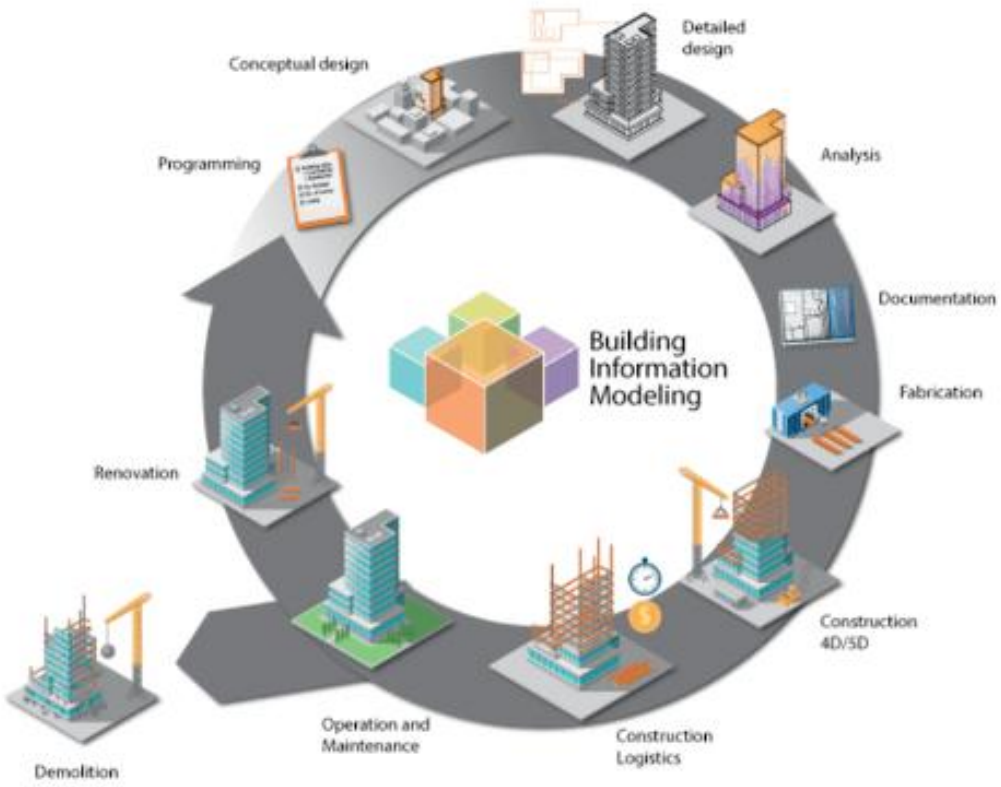


Figure 1. BIM Life Cycle

For the purposes of this thesis, I would like to highlight that BIM methodology is the way to overcome the challenges of inadequate information sharing in the construction industry, affecting both decision-making and operational tasks. Currently, BIM is the most effective management system to support Building Lifecycle Management (BLM). It provides a common platform to create and manage the representation of absolutely every feature of a construction project digitally, from the inception, design, and construction phases to the operation phase. BIM allows for the visualization of the final product in a simulated environment, helping to identify potential issues and risks. As a result, BIM can deliver significant benefits to all stakeholders involved in the construction industry. [3]

According to UNI 11337[1] there are different dimensions of BIM:

- **3D BIM**: This is the most basic dimension, focusing on three dimensional geometric and spatial representation of the physical characteristics of a building or infrastructure. It provides detailed digital representations of the building's physical and functional characteristics.
- **4D BIM**: Adds the element of time to 3D BIM, allowing for the visualization and management of construction schedules and project timelines. It helps in planning the sequence of construction activities, identifying potential conflicts, and optimizing the construction process.
- **5D BIM**: Integrates cost information with the 3D model, facilitating budgetary and cost management throughout the project lifecycle. This dimension allows for the estimation and tracking of costs based on the digital model's data, supporting more accurate and dynamic cost management.
- **6D BIM**: Focuses on the sustainability aspects and energy efficiency of a building. This dimension is used to analyze environmental impacts, perform energy consumption simulations, and design more sustainable and efficient buildings by incorporating environmental data into the BIM model.
- **7D BIM**: Concerns itself with facility management and operation, using the information within the BIM model to support maintenance and asset management over the building's life cycle.

[1] UNI 11337 is an Italian set of standards that provides guidelines and specifications for the management of digital processes in the construction sector through BIM.

Another important concept in the context of BIM process is that of Level of Development (LOD), sometimes referred to as Level of Detail. LOD defines the level of completeness, accuracy, and reliability of the information contained in a BIM model at various stages of a project's lifecycle. It specifies how much detail and information about an element is available in the model, helping to align expectations between project stakeholders (designers, contractors, owners, etc.) This term is widely recognized in BIM practices globally. It is also integral to the Italian standards for BIM, particularly within the UNI 11337, which defines LOD as follows [4]:

"*The Level of Development (LOD) of the digital objects that make up the models defines the quantity and quality of their information content and is functional to the achievement of the objectives of the phases (and stages) of the process and the uses and objectives of the model they refer to*."

Italy, with UNI 11337, is today at the head of the CEN table on European LODs. The Italian standard provides that any of the existing LOD scales can be used, without exclusions or priorities, depending on the specific needs of the contract and provided that the specific references, logic, objectives and structure for the purposes of the maximum transparency for interested parties. In this case, reference to the Italian LODs as defined in the standard itself can also be used (for public procurement, in particular, the UNI standard introduces a possible use of LODs compatible with the Procurement Code in Annex I to part 4).

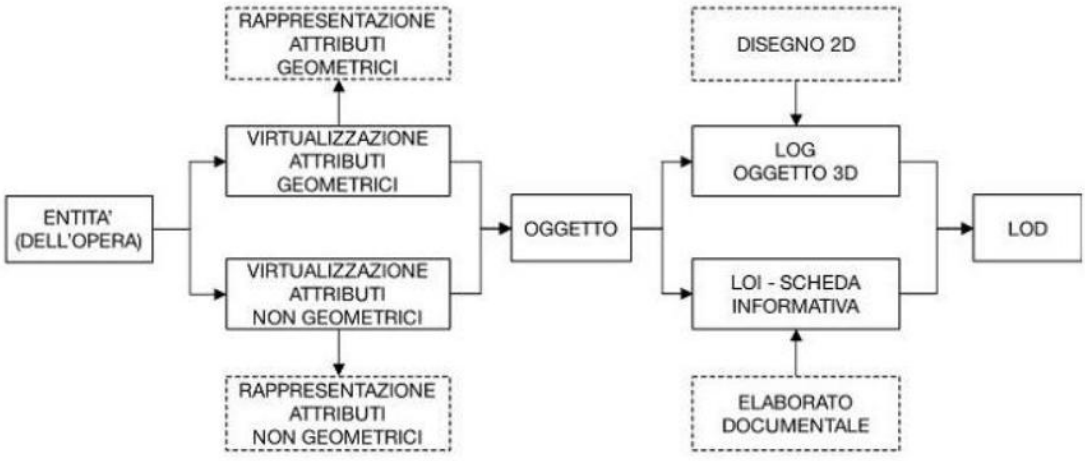


Figure 2. Structuring scheme of Italian LODs

Specific LOD scales have been defined for:

- new construction and recovery,
- the territory and infrastructure,
- the vehicles and equipment (first in the world);
- restoration and restricted assets (first in the world);

The particular category important to this thesis is “new construction and intervention” and the LOD is defined as follows:

- **LOD A** - The entities are graphically represented through a two-dimensional geometric schema. The quantitative and qualitative characteristics (performance, size, shape, location, cost, etc.) are indicative and can be statistically assumed by other models.

- **LOD B** - The entities are graphically represented through an elementary three-dimensional geometric system. The quantitative and qualitative characteristics (performance, dimensions, shape, location, cost, etc.) are approximate.

- **LOD C** - The entities are graphically virtualized through a defined three-dimensional geometric system. The main quantitative and qualitative characteristics (performance, dimensions, shape, location, cost, etc.) are defined.

- **LOD D** - The entities are graphically virtualized through a detailed three-dimensional geometric system. The quantitative and qualitative characteristics (performance, dimensions, shape, location, cost, etc.) are detailed.

- **LOD E** - The entities are graphically virtualized through a specific three-dimensional geometric system. The quantitative and qualitative characteristics (performance, dimensions, shape, location, cost, etc.) are specific to a single production system.

- **LOD F** - The objects express the virtualization verified on-site of the three-dimensional geometric system as executed/constructed (as-built). The quantitative and qualitative characteristics (performance, dimensions, shape, location, cost, etc.) are specific to the production system used.

- **LOD G** - The objects express the updated virtualization of the actual state of an entity at a defined time. It's a historicized representation of the lifespan of an updated three-dimensional geometric system compared to what was originally executed/constructed. The quantitative and qualitative characteristics (performance, dimensions, shape, location, cost, etc.) are updated with respect to the life cycle and a previous actual state. The level of wear/decay is defined.

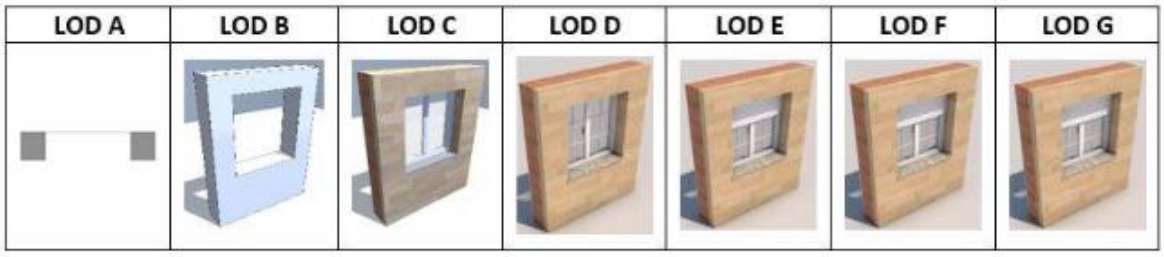


Figure 3. Example LOD according to UNI 11337

2.1.1. BIM adoption and utilization in the world

Nowadays BIM has gained global significance as it drives the digitization of the construction sector, optimizing efficiency across the entire industry value chain. Despite its established presence, BIM adoption necessitates significant cultural shifts, leading to varied levels of implementation across different stages and countries. [6]

The European Commission has actively supported, promoted, and developed various policies and initiatives to advance digitalization in the construction sector. These efforts include, among others, the *Strategy for the Sustainable Competitiveness of the Construction Sector and its Enterprises* (2012), the EU BIM Task Group, and the EU Digital Construction Platform. Additionally, the digitalization of the construction sector is integrated into other policy areas, such as the EU Directive on Public Procurement (2014), which encourages the use of BIM in construction projects. [7]

The US is the first country to adopt BIM followed by the UK, but neither of these countries AEC industries have fully adopted BIM. Europe hosts the greatest regional concentration of government-led BIM programs in the world (NBS, National BIM Report 2016, 2016). [6]

Following the directive, many countries have published BIM mandates. The following map shows the BIM adoption in Europe:

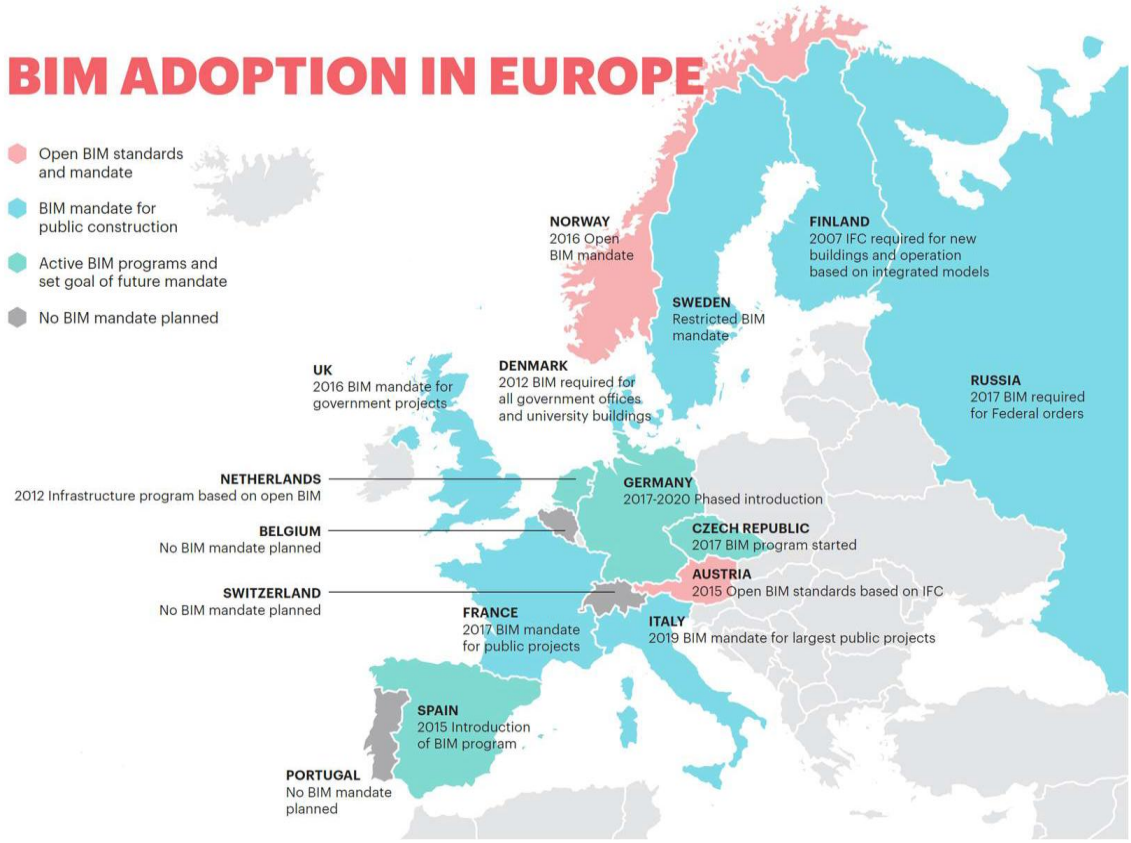


Figure 4. BIM adoption in Europe [8]

Italy is one of the countries that has established a BIM mandate, as outlined in Decreto Ministeriale 560/2017. This regulation, also known as the Baratono Decree, stipulates the gradual implementation of the mandatory use of BIM for public procurement projects. To further digitalization, Italy has adopted the UNI 11337 technical standards, which serve as the national annex to ISO 19650-1-2:2019. Article 6 of DM 560/2017 specifies the timelines for implementation and the cost of the works:

- From 1 January 2019 for all public works over 100 M euro;
- From 1 January 2020 for all public works over 50 M euro;
- From 1 January 2021 for all public works over 15 M euro;
- From 1 January 2023 for all public works over 5.35 M euro;
- From 1 January 2025 for all public works over 1 M euro.

2.3. BIM for Facility Management

The construction industry is a dynamic sector, engaging various stakeholders at different stages of the process. [6] BIM provides a common platform to create and manage the representation of absolutely every feature of a construction project digitally, from the inception, design, and construction phases to the operation phase. [8] Previous research indicates that the total lifetime cost of a project is three times the construction cost and seven times the initial investment. These costs are primarily incurred during the operation and maintenance phases. [9,10] For this reason, facility management is very important when it comes to the lifecycle of an establishment.

Facility management, by definition, involves supporting and sustaining the performance of structures to meet the strategic objectives of an organization. Additionally, it plays a critical role in extending the life cycle of a facility by integrating people, places, processes, and technology in order to support functions for the establishment's core operations. From this point of view, organizations must embrace innovation and enhance the development of advanced technological solutions to ensure effective facilities management and maintain sustainability. Meanwhile, data is recognized as a critical foundation for optimizing operations and supporting the maintenance of establishments within the scope of facilities management [11].

The advantages of the use of BIM in the scope of building management as a centralized database for all data about the building, supporting maintenance, and management, have been identified in the literature for many aspects of the building in operation, ranging from safety and health to energy consumption. [12]

During the project and construction phases, BIM is generally employed to support various tasks performed by professionals and experts, such as cost estimation, resource optimization, and task scheduling. In contrast, during a building's operational phase, the use of BIM-FM becomes more complex. This stage involves managing numerous attributes with frequent value changes, ensuring access to their historical records, dealing with high levels of attribute heterogeneity and varying formats, and making the information accessible to users who are not BIM experts. [12]

Even though data are considered the most important aspect to provide efficient operation during facilities management, data update and exchange have been one of the biggest challenges when it comes to the different phases of a building’s life cycle. [11]

2.3.1. BIM As Built, BIM As Is, BIM As Operate

When realizing a BIM-FM model, the primary consideration is the construction status of the building—whether it is new or existing. Next, the complexity of the asset and the scope of the real estate to be managed are evaluated. Depending on the specific purpose, it is essential to determine which BIM-FM model is most suitable based on criteria that influence the graphical and alphanumeric detail of the model. There are at least three options: As Built, As Is, As Operate. [6]

- **As Built** - A complete and detailed model that incorporates "as-constructed" information across all. Each object within the model is enriched with all available information at that point, including external documents and links to management platforms. One of the most valuable types of data to collect is the performance requirements of components, as defined by UNI 8290-2:1981 (UNI 8290-2:1983)[2]. This information, rarely accessible during operational phases, is crucial as it provides insights into the design performance of the building under normal conditions, offering key indicators for maintenance and replacement. Given the substantial amount of data involved, careful segmentation and structuring of the model are essential to ensure its manageability and facilitate updates. The "as-built" model represents an ideal Facility Management tool, offering a comprehensive historical record of the building—from design through construction and into management, but it requires significant investment in both time and cost to develop.

- **As Operate** - An operational model with an advanced but non-detailed geometric representation, including elements and parameters essential for Facility Management, is particularly suitable for complex buildings. In such cases, the spatial and functional relationships of elements need to be monitored. For existing buildings, where detailed information is often lacking, the model focuses on representing only the objects that require management. While aiming for a representation close to reality, the Level of Information (LOI) for objects is prioritized over the Level of Geometry (LOG) to establish a reliable management database. The model includes information about visible elements only, excluding

[2] Residential construction. Technological system. Requirements analysis.

systems and technological networks unless they are well-documented, to avoid inefficiencies in time and cost.

- **As Is** - A simplified representation of the building's current state, comprising a basic dataset of relevant information, serves as a useful starting point for asset analysis. Unlike the "As Operate" model, this approach is particularly suited for large public or private real estate portfolios. In such cases, it is preferable to gather limited, easily updatable information to ensure consistent and comparable data across the portfolio. For maximum effectiveness, the model should include data essential for assessing potential optimization measures in areas such as space utilization and energy management.

2.4. Business Intelligence Integration

As mentioned in chapter 2.3, paragraph 5, in order to provide efficient operation during facilities management, data update and exchange have been the biggest challenges when it comes to the different phases of a building's life cycle. Thus, there is an urgent need for organizations to take advantage of this large volume of data; otherwise, the value of information will be lost. This data needs to be treated to produce consistent and valuable information to support decision making in organizations. [13]

According to Narayanan and Kp [14] *"For a business to exist competently, the two things to keep up are: the management of time and better understanding of current status of the organization"*. Behind these issues is the importance of data visualization. The human brain is an expert in memorizing data as images, so data visualization is just a clever idea to uncomplicate the business universe [14].

Business intelligence (BI) is defined as "automatic data retrieving and processing systems that can help make intelligent decisions based on various data sources" [15]. Most BI solutions provide data analysis and visualization capabilities, which, when paired with appropriate data capture technology, should be able to treat data in real-time [16].

Some of the advantages of using BI tools are marked by Stecyk [17]:

- The ability of linking to any data source, building up analyses in real time and having an intuitive and straightforward interface that helps in data visualization.
- The ability to properly structure and relate the database and techniques about building key indicators (economic or performance) as well as dynamic reporting (visualization techniques).

Recently, the concept of "Storytelling with Data" has garnered attention. This concept involves a collection of processes and methods designed to help organizations present complex information derived from intricate datasets in the form of a cohesive narrative. To effectively implement this approach, organizations can use BI tools. However, it is crucial to first determine the appropriate amount of information needed to convey the message and apply suitable techniques to craft story-like statements [18].

Some common BI Tools are: Microsoft Power BI; Tableau; QlikView; Looker; SAP BusinessObjects.

2.4.1. Power BI

Power BI is a cutting-edge business intelligence and data visualization tool developed by Microsoft. It empowers organizations and individuals to transform raw data into valuable insights and visually compelling reports and dashboards. [19]

Some key features of Power BI are:

- **Data connections** – It connects to a wide range of data sources, including databases and online datasets.
- **Data transformation** – Allows to transform data using data query, by cleaning up, extending and making ready for the reports.
- **Interactive reports** – Power BI has an easy drag & drop interface, which allows you to create different visualizations like graphs, charts, snaps and tables.
- **Real-time insights** – By connecting Power Bi to Speckle and Revit we can see how if a change is made in Revit, it can be visualized in Power BI.
- **Natural language queries** – Recently Power BI has enabled a Q&A feature, which allows you to ask questions in natural language and receive answers instantly.

At the core of Power BI are its robust data visualization features. Users can design interactive and dynamic charts, graphs, maps, and tables, allowing them to explore data from multiple perspectives and easily uncover trends, patterns, and anomalies. [20]

Power BI, even though is a very powerful data visualization tool and allows you to get data visualization insights from data sources, does not really connect to AEC[3] applications, so your BIM, GIS, CAD data is stocked in the host applications. That's exactly where Speckle "shines".

The **Speckle Connector** is a tool that integrates Speckle, an open-source platform for data interoperability, with other software applications, allowing seamless exchange of 3D and 2D data between different tools commonly used in design, architecture, engineering, and construction (AEC). Some of the key features of Speckle are:

- Data Interoperability: It enables the sharing of complex datasets, including geometry, metadata, and other project information, across different platforms like Rhino, Revit, AutoCAD, Grasshopper, Blender, and even Power BI.

[3] AEC stands for Architecture, Engineering and Construction.

- Customizable Workflows: Speckle allows users to define and customize how data is exchanged and visualized.
- Real-Time Collaboration: Teams can use Speckle for live updates and synchronized changes, promoting efficient collaboration in distributed work environments.
- Integration with Power BI: The Speckle Connector for Power BI enables users to bring 3D or structured project data into dashboards.

Some of Speckle typical uses are the following ones:

- AEC Design Collaboration
- Data-Driven Decisions
- Visualization

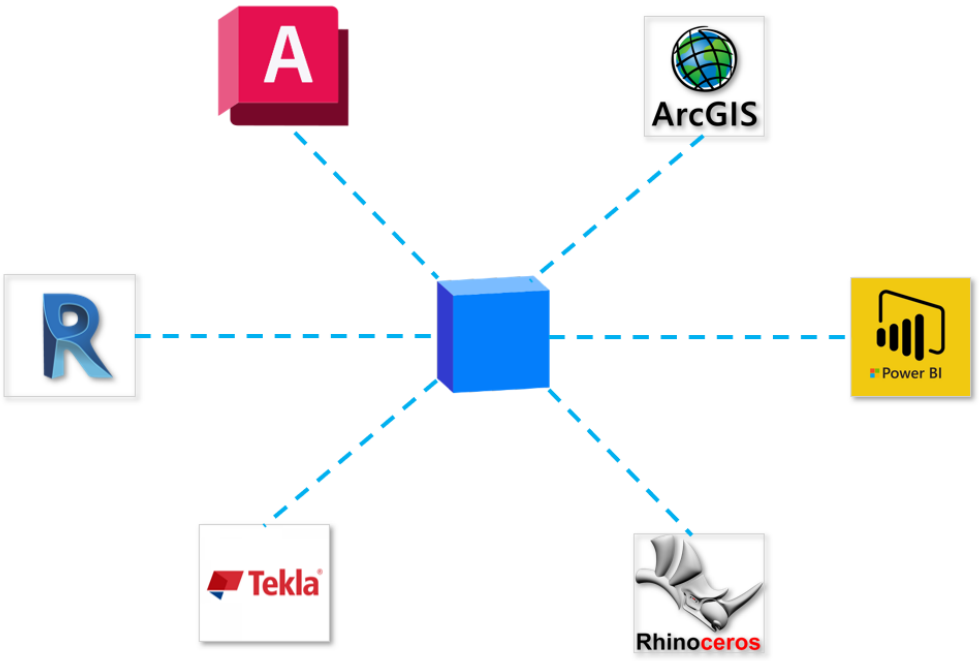


Figure 5. Scheme of Speckle Connector interaction with AEC applications and Power BI

What we are interested to highlight is how Speckle Connector allows the interaction between the AEC softwares and Power BI and the following process of data transformation and creation of interactive dashboards.

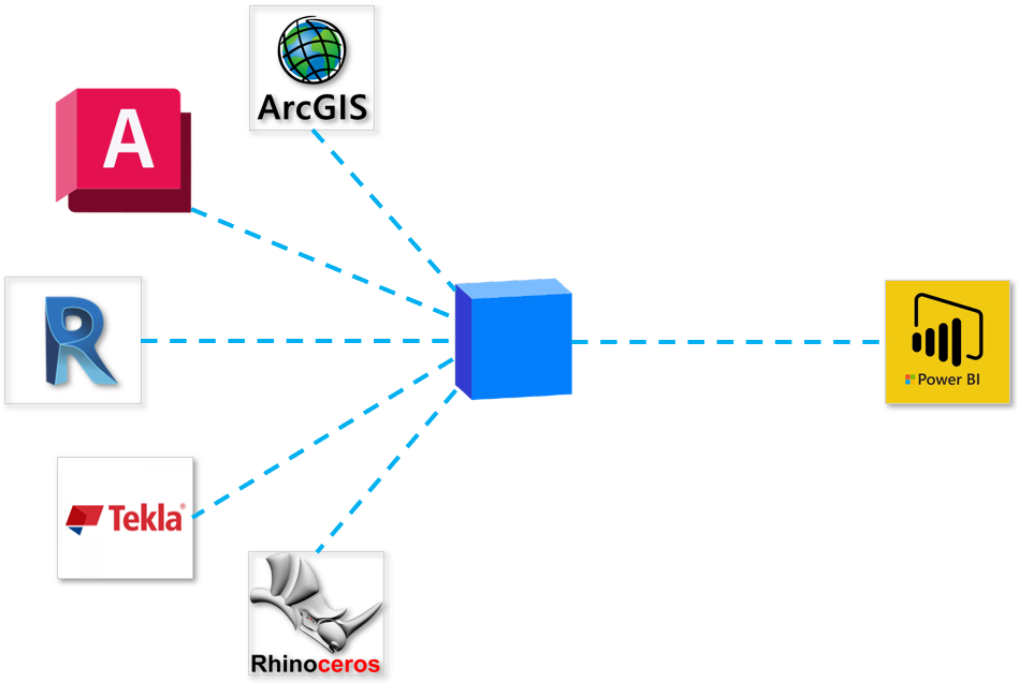


Figure 6. Scheme of Speckle allowing the interaction of AEC applications with Power BI

For the purposes of this thesis, we will focus on the interaction Revit-Speckle-Power BI.

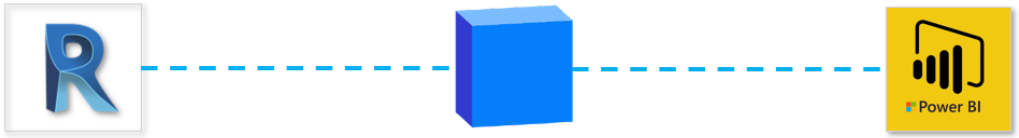


Figure 7. Interaction Revit - Speckle Connector - Power BI

This procedure can be articulated in the following steps:

1. Send data from Revit
2. Receive it in Power BI
3. View it in 3D inside the Power BI environment
4. Extracting metadata from what we send from Revit
5. Color the model
6. Link aspect of the connection
7. Extending Speckle data with external data sources (Excel)

3. CASE STUDY

"Buon Pastore" Institute

Figure 8. Buon Pastore Institute before renovation
(view from Corso Principe Eugenio)

The Buon Pastore Institute is a building complex on Corso Principe Eugenio at the corner of Via Moris, not far from Piazza Statuto. It was founded in 1843, by the King Carlo Alberto, with the aim of providing "educational opportunities" to young people in disadvantaged social conditions. After the Second World War, it officially became a women's "reformatory", entrusted to the care of the nuns of Our Lady of Charity of Angers, known as the "Buon Pastore". The institute remained in operation until 1977. After that, a good part of the complex found itself in a state of abandonment.

Figure 9. Buon Pastore Institute before renovation (view from Via Moris)

This situation continued until 2021, when, following a public auction, CO.GE.FA. S.p.A. was awarded the concession of the surface rights for 99 years. First of all, this provided for the change of use of the structure, from a former boarding school to a tertiary sector: the project has been carried out by and at the expense of CO.GE.FA. S.p.A. The project presented by the concessionaire provided for the recovery of the original system, which is in a large part protected as a historic building, for approximately 2,400 square meters. It is evident that plant and energy adaptation works have been carried out. Furthermore, the creation of a small parking area is contemplated, arranged as permeable greenery, with entrance from Via Moris. In addition, the concessionaire has provided the arrangement of the original green area. The latter, until now inaccessible, will become a public garden of almost 6300 square meters. This is clearly a strong improvement for a densely built-up area, not rich in usable green spaces. Last but not least, the project has received favorable opinions from the Local Commission for the Landscape and the Superintendence of Archaeology, Fine Arts and Landscape for the Metropolitan City of Turin.

a)

Coming to the present, the building is currently hosting the offices of CO.GE.FA. S.p.A. It has 3 above-ground floors, a basement floor and a livable attic. It was designed and

built prioritizing environmental sustainability, safety, and employee comfort, creating a workspace that promotes teamwork, inspiration, professionalism, and creativity. For this purpose, the internal space of the building is thoughtfully organized between working stations, offices, meeting rooms, relaxation areas, technical rooms, archives, reception and a designated lunch area in the basement. The result is a modern building, which at the same time hasn't lost its identity. It is essential to highlight that this redevelopment project has not only revitalized the former Buon Pastore Institute, but has also rejuvenated the entire neighborhood, which, after many years, is finally breathing.

b)

c)

Figure 10. a) b) c) Ex Buon Pastore Institute after renovation

4. METHODOLOGY

The overall methodology of this thesis work is summarized in the following scheme:

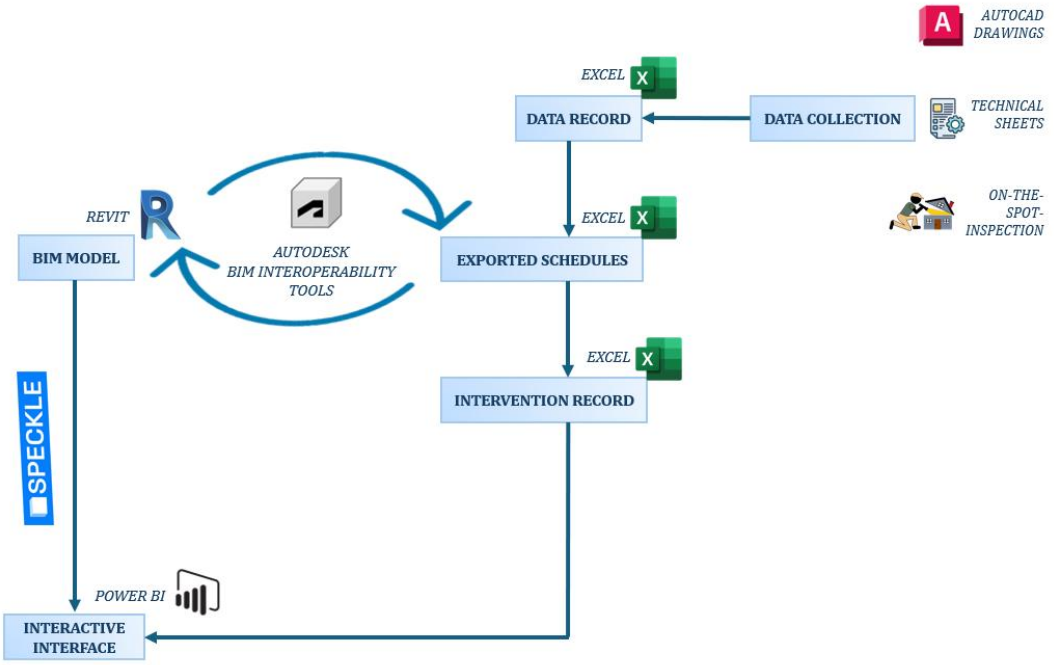


Figure 11. Schematic representation of the workflow

4.1. Data collection

As I mentioned in chapter 2.3.1, when realizing a BIM-FM model, the primary consideration is the construction status of the building—whether it is new or existing. My case study consists of an existing building. When dealing with an existing building, sometimes it can be more difficult to find all the necessary data for the Revit model. I started by collecting all the available data, which consisted of DWG drawings, technical sheets and often on-the-spot inspections. At the moment in which my data collection process initiated, the building was still under construction and that was very helpful, because allowed me to go on site and take a close look at the work in progress.

Since the amount of data to manage was huge, it was necessary to organize it, following the standard of the company. DWG files, PDF files and images were saved in separate folders. After that, I decided to create some Excel sheets (schedules) containing all the information relative to slabs, walls, internal/external windows and doors and materials. To every element was given a codification, which sometimes was already provided from the designers and sometimes I adopted a reasonable coding.

Abaco solai					
Codice	Descrizione	Categoria	Pianta Piano	Dimensioni [cm]	Note
S.E.1	Solaio su terrapieno vespaio 30 cm con pav. in gres porcellanato	Solai esterni - verso terra	Terra	74,3	
S.E.2	Solaio su terrapieno vespaio 30 cm con pav. in graniglio levigata	Solai esterni - verso terra	Terra	74,3	
S.E.3	Solaio su terrapieno vespaio 30 cm per locali tecnici	Solai esterni - verso terra	Interrato, terra	74,3	
S.E.4	Solaio su terrapieno vespaio 10 cm con pav. in gres porcellanato	Solai esterni - verso terra	Interrato	49,3	
S.E.4B	Solaio su terrapieno vespaio 50 cm con pav. in gres porcellanato	Solai esterni - verso terra	Interrato	89,3	
S.E.5	Solaio su terrapieno vespaio 10 cm con pav. tecnica tessile	Solai esterni - verso terra	Interrato	49,3	
S.E.6	Solaio su terrapieno vespaio 10 cm con pav. in pietra	Solai esterni - verso terra	Interrato	49,3	
S.E.7	Solaio su terrapieno vespaio 10 cm con trattamento antipolvere per pavimenti industriali	Solai esterni - verso terra	Interrato	49,3	
S.E.8	Solaio sollevato su terra nuovo volume ingresso	Solai esterni - verso terra	Terra	37,3	
S.E.9	Solaio su terrapieno locali tecnici esterni	Solai esterni - verso terra	Interrato	60	
S.E.10	Solaio su terrapieno vespaio 10 cm bocche di lupo e scala u.s. piano interrato	Solai esterni - verso terra	Interrato	72,3-74,3	
S.E.11	Copertura a falde	Solai esterni - coperture	Copertura		
S.E.12	Copertura abbani	Solai esterni - coperture	Copertura	22,5	
S.E.13	Copertura vano ascensore	Solai esterni - coperture	Copertura	34,5	
S.E.14	Solaio di copertura nuovo volume ingresso	Solai esterni - coperture	Terra, 1	36-44	
S.I.1	Nuovo solaio in c.a. con pav.in lastre di pietra per vani scala	Solai interni	Terra, 1, 2, sottotetto	22,1	Sopra il solaio in c.a. (specifiche negli elaborati strutturali)
S.I.2	Nuovo solaio in c.a. con isolamento e pavimentazione in graniglia levigata	Solai interni	Terra	22,1	Sopra il solaio in c.a. (specifiche negli elaborati strutturali)
S.I.3	Nuovo solaio in lamiera grecata con pav. in graniglia levigata	Solai interni	Terra	22,1	Sopra il solaio in lamiera grecata (specifiche negli elaborati strutturali) + doppia lastra antincendio
S.I.4	Nuovo solaio su volte esistenti con pav. in graniglia levigata	Solai interni		30	Sopra la volta esistente
S.I.5	Nuovo solaio in c.a. con pav.in gres porcellanato	Solai interni	Terra, 1, sottotetto	22,1	Sopra il solaio in c.a. (specifiche negli elaborati strutturali)
S.I.6	Nuovo solaio in lamiera grecata con pav. in gres porcellanato	Solai interni	Terra, 1, 2, sottotetto	22,1	Sopra il solaio in lamiera grecata (specifiche negli elaborati strutturali) + doppia lastra antincendio
S.I.7	Nuovo solaio su volte esistenti con pav. in gres porcellanato	Solai interni	Terra, 1, 2	30	Sopra la volta esistente
S.I.8	Nuovo solaio in c.a. con pav.in legno	Solai interni	Terra, 2	22,1	Sopra il solaio in c.a. (specifiche negli elaborati strutturali)
S.I.9	Nuovo solaio in lamiera grecata con pav. in legno	Solai interni	2, sottotetto	22,1	Sopra il solaio in lamiera grecata (specifiche negli elaborati strutturali) + doppia lastra antincendio
S.I.10	Nuovo solaio su volte esistenti con pav. in legno	Solai interni	2	30	Sopra la volta esistente
S.I.11	Nuovo solaio in c.a. con trattamento antipolvere per pavimenti industriali	Solai interni	Terra, 1, 2	22,1	Sopra il solaio in c.a. (specifiche negli elaborati strutturali)
S.I.12	Nuovo solaio in lamiera grecata con trattamento antipolvere per pavimenti industriali	Solai interni	Sottotetto	22,1	Sopra il solaio in lamiera grecata (specifiche negli elaborati strutturali) + doppia lastra antincendio
S.I.13	Nuovo solaio su volte esistenti con trattamento antipolvere per pavimenti industriali	Solai interni	1, 2	30	Sopra la volta esistente
S.I.14	Nuovo solaio in c.a. con isolamento e con trattamento antipolvere per pavimenti industriali	Solai interni		22,1	Sopra il solaio in c.a. (specifiche negli elaborati strutturali)
S.I.15	Nuovo solaio in lamiera grecata con isolamento e con trattamento antipolvere per pavimenti industriali	Solai interni		22,1	Sopra il solaio in lamiera grecata (specifiche negli elaborati strutturali) + doppia lastra antincendio

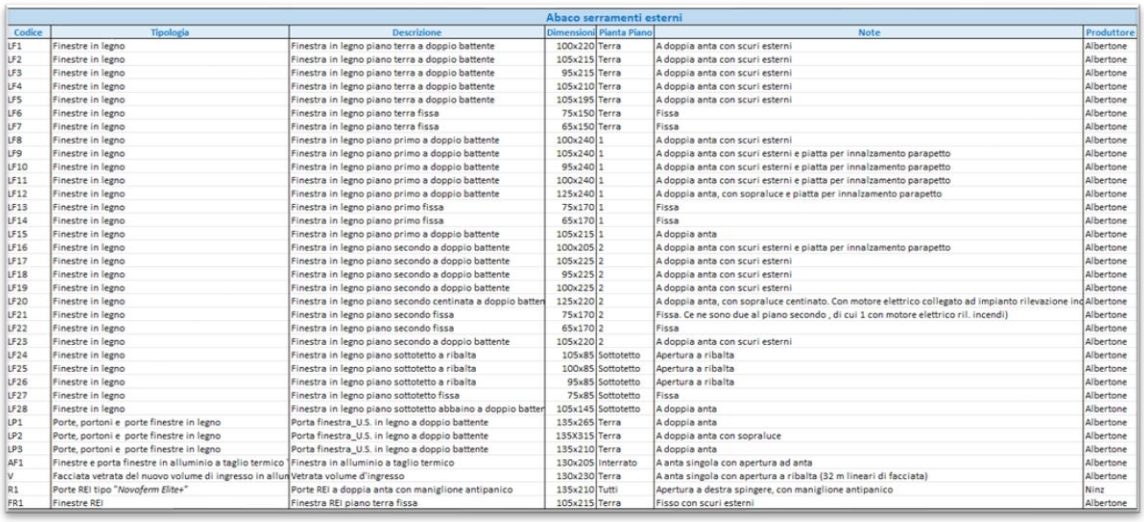
Table 1. Slabs' schedule

Abaco murature				
Codice	Descrizione	Categoria	Pianta Piano	Dimensioni [cm]
M.I.S.1	Parete a secco_parete divisoria ambienti asciutti, sp. 10 cm	Murature interne a secco tipo M.I.S		10
M.I.S.2	Parete a secco_parete divisoria tra stalli dei servizi igienici, sp. 10 cm	Murature interne a secco tipo M.I.S		10
M.I.S.3	Parete a secco_parete divisoria ambienti asciutti, sp. 15 cm	Murature interne a secco tipo M.I.S		15
M.I.S.4	Parete a secco_parete divisoria tra ambienti asciutti/servizi igienici, locali umidi, sp. 15 cm	Murature interne a secco tipo M.I.S		15
M.I.S.5	Parete a secco_parete divisoria tra servizi igienici, locali umidi, sp. 15 cm	Murature interne a secco tipo M.I.S		15
M.I.S.3R	Parete a secco_parete divisoria ambienti asciutti, sp. 15 cm_REI 120	Murature interne a secco tipo M.I.S		15
M.I.S.4R	Parete a secco_parete divisoria tra ambienti asciutti/servizi igienici, locali umidi, sp. 15 cm_REI 1	Murature interne a secco tipo M.I.S		15
M.I.S.6	Parete a secco_parete divisoria ambienti asciutti, sp. 30 cm	Murature interne a secco tipo M.I.S		30
M.I.S.7	Parete a secco_parete divisoria tra ambienti asciutti/servizi igienici, locali umidi, sp. 30 cm	Murature interne a secco tipo M.I.S		30
M.I.S.8	Parete a secco_parete divisoria tra servizi igienici, locali umidi, sp. 30 cm	Murature interne a secco tipo M.I.S		30
M.I.S.9	Parete a secco_controparete in ambienti asciutti, sp. 7,5 cm	Murature interne a secco tipo M.I.S		7,5
M.I.S.10	Parete a secco_controparete in ambienti umidi, servizi igienici, sp. 7,5 cm	Murature interne a secco tipo M.I.S		7,5
M.I.S.11	Parete a secco_controparete in ambienti asciutti_interrato, sp. 7,5 cm	Murature interne a secco tipo M.I.S		7,5
M.I.S.12	Parete a secco_parete divisoria tra locale tecnico e sala del consiglio	Murature interne a secco tipo M.I.S		21,25
M.I.M.1	Parete in muratura_parete di completamento di murature esistenti interne	Murature in laterizio interne e murature tecniche		var
M.I.M.2	Parete in muratura_parete in laterizio con finitura ad intonaco, sp.13 cm	Murature in laterizio interne e murature tecniche		13
M.I.M.3	Parete in muratura_parete in laterizio con finitura ad intonaco, sp.23 cm	Murature in laterizio interne e murature tecniche		23
M.I.T.1	Parete tecnica di tamponamento, sp.10 cm_REI 120	Murature in laterizio interne e murature tecniche		10
M.E.1	Parete in muratura_parete di completamento di murature esistenti esterne	Murature esterne		var
M.E.2	Parete esterna controterra_locale tecnico interrato	Murature esterne		37,8
M.E.3	Parete esterna controterra_bocche di lupo	Murature esterne		22,8
M.E.4	Parete esterna controterra_scala U.S.	Murature esterne		27,8
D.1	Dettaglio scarico su parete a secco, sp.30 cm	Dettagli		30
D.2	Dettaglio sistema di correzione ponte acustico su attacco parete/solaio tipo	Dettagli		
D.3	Dettaglio incasso estintore su parete a secco	Dettagli		30
D.4	Dettaglio incasso estintore su parete a secco_REI	Dettagli		35
D.5	Dettaglio incasso estintore su parete in muratura	Dettagli		

Table 2. Walls' schedule

Abaco serramenti interni							
Codice	Tipologia	Descrizione	Dimensioni	Pianta Piano	Note	Produttore	Scheda tecnica
R1S	R-Porte REI tipo *"Novoferm Elite+"*	Porte REI 70/200 ad anta unica	80x205	Sottotetto	Apertura a sinistra spingere	Bertolotto	Biwall EI60
R2S	R-Porte REI tipo *"Novoferm Elite+"*	Porte REI 80/210 ad anta unica	90x215	Terra, 1, 2	Apertura a sinistra spingere	Bertolotto	Biwall EI61
R2D	R-Porte REI tipo *"Novoferm Elite+"*	Porte REI 80/210 ad anta unica	90x216	Terra, 1, 2	Apertura a destra spingere	Bertolotto	Biwall EI62
R3S	R-Porte REI tipo *"Novoferm Elite+"*	Porte REI 90/210 ad anta unica	90X215	Interrato, terra, sottotetto	Apertura a sinistra spingere	Bertolotto	Biwall EI63
R3D	R-Porte REI tipo *"Novoferm Elite+"*	Porte REI 90/210 ad anta unica	90X215	Interrato, terra, sottotetto	Apertura a destra spingere	Bertolotto	Biwall EI64
R4S	R-Porte REI tipo *"Novoferm Elite+"*	Porte REI 125/210 a doppia anta, con maniglione antipanico	135x215	Interrato, terra, sottotetto	Apertura a sinistra spingere con maniglione antipanic	Bertolotto	Biwall EI65
R4D	R-Porte REI tipo *"Novoferm Elite+"*	Porte REI 125/210 a doppia anta, con maniglione antipanico	135x215	Interrato, 1, 2	Apertura a destra spingere con maniglione antipanicc	Bertolotto	Biwall EI66
FR1	Porte Filomuro REI tipo *"Garofoli Rasomuro REI"*	Porte REI rasomuro ad anta unica	80x210	Terra, 1, 2	Apertura sinistra spingere complanare lato spingere	Bertolotto	
FR2	Porte Filomuro REI tipo *"Garofoli Rasomuro REI"*	Porte REI rasomuro ad anta unica	115x210	Terra	Apertura sinistra spingere complanare lato spingere	Bertolotto	
F1SS	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro ad anta unica	70x210	Terra	Apertura sinistra spingere complanare lato spingere	Bertolotto	
F1DS	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro ad anta unica	70x210	Terra	Apertura destra spingere complanare lato spingere	Bertolotto	
F1ST	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro ad anta unica	70x210	Interrato, terra, 1, 2	Apertura sinistra spingere complanare lato tirare	Bertolotto	
F1DT	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro ad anta unica	70x210	Interrato, terra, 1, 2, sottotettto	Apertura destra spingere complanare lato tirare	Bertolotto	
F2S	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro ad anta unica	80X210	Terra, 1, 2, sottotetto	Apertura sinistra spingere complanare lato spingere	Bertolotto	
F2D	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro ad anta unica	80X210	1, 2, sottotetto	Apertura destra spingere complanare lato spingere	Bertolotto	
F3DT	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro ad anta unica	90X210	Interrato, terra, 1, 2, sottotettto	Apertura destra spingere complanare lato tirare	Bertolotto	
F3DS	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro ad anta unica	90X210	Interrato, sottotetto	Apertura destra spingere complanare lato spingere	Bertolotto	
F3ST	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro ad anta unica	90X210	Interrato	Apertura sinistra spingere complanare lato tirare	Bertolotto	
F4	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro a doppia anta	120x210	Interrato	Apertura sinistra spingere complanare lato tirare	Bertolotto	
F5S	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro a doppia anta con maniglione antipanico	125x210	Interrato, 2	Apertura sinistra spingere complanare lato spingere	Bertolotto	
F5D	Porte Filomuro tipo *"Bertolotto Walldoor minima"*	Porte rasomuro a doppia anta con maniglione antipanico	125x210	Terra, 1, sottotetto	Apertura destra spingere complanare lato spingere	Bertolotto	
MA1	Porte Multiuso tipo *"Novoferm Elite + Metal Alettata"*	Porte a doppia anta alettata	200x245	Interrato	Apertura destra spingere	Bertolotto	
MA2	Porte Multiuso tipo *"Novoferm Elite + Metal Alettata"*	Porte a doppia anta alettata	160x245	Interrato	Apertura destra spingere	Bertolotto	
B	Bussola interna *"Asso Abloy SL 500"*	Bussola interna a sesamo ingresso principale	100x270	Terra	Bussola scorrevole + porzioni laterali fisse	Bertolotto	

Table 3. Internal windows' schedule



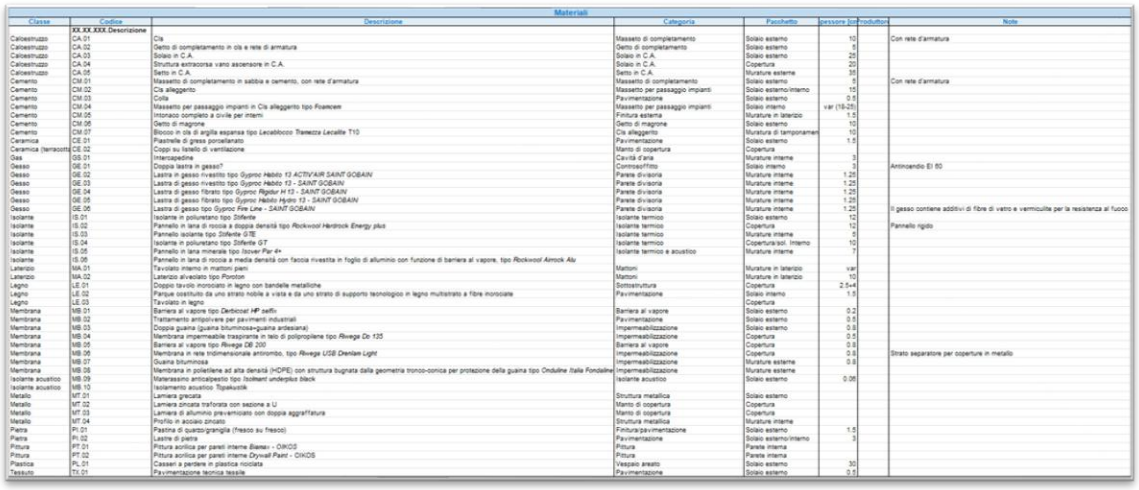
Abaco serramenti esterni

Codice	Tipologia	Descrizione	Dimensioni	Pianta Piano	Note	Produttore
LF1	Finestre in legno	Finestra in legno piano terra a doppio battente	100x220	Terra	A doppia anta con scuri esterni	Albertone
LF2	Finestre in legno	Finestra in legno piano terra a doppio battente	105x215	Terra	A doppia anta con scuri esterni	Albertone
LF3	Finestre in legno	Finestra in legno piano terra a doppio battente	95x215	Terra	A doppia anta con scuri esterni	Albertone
LF4	Finestre in legno	Finestra in legno piano terra a doppio battente	105x210	Terra	A doppia anta con scuri esterni	Albertone
LF5	Finestre in legno	Finestra in legno piano terra a doppio battente	105x195	Terra	A doppia anta con scuri esterni	Albertone
LF6	Finestre in legno	Finestra in legno piano terra fissa	75x150	Terra	Fissa	Albertone
LF7	Finestre in legno	Finestra in legno piano terra fissa	65x150	Terra	Fissa	Albertone
LF8	Finestre in legno	Finestra in legno piano primo a doppio battente	100x240	1	A doppia anta con scuri esterni	Albertone
LF9	Finestre in legno	Finestra in legno piano primo a doppio battente	105x240	1	A doppia anta con scuri esterni e piatta per innalzamento parapetto	Albertone
LF10	Finestre in legno	Finestra in legno piano primo a doppio battente	95x240	1	A doppia anta con scuri esterni e piatta per innalzamento parapetto	Albertone
LF11	Finestre in legno	Finestra in legno piano primo a doppio battente	100x240	1	A doppia anta con scuri esterni e piatta per innalzamento parapetto	Albertone
LF12	Finestre in legno	Finestra in legno piano primo a doppio battente	125x240	1	A doppia anta, con sopraluce e piatta per innalzamento parapetto	Albertone
LF13	Finestre in legno	Finestra in legno piano primo fissa	75x170	1	Fissa	Albertone
LF14	Finestre in legno	Finestra in legno piano primo fissa	65x170	1	Fissa	Albertone
LF15	Finestre in legno	Finestra in legno piano primo a doppio battente	105x215	1	A doppia anta	Albertone
LF16	Finestre in legno	Finestra in legno piano secondo a doppio battente	100x205	2	A doppia anta con scuri esterni e piatta per innalzamento parapetto	Albertone
LF17	Finestre in legno	Finestra in legno piano secondo a doppio battente	105x225	2	A doppia anta con scuri esterni	Albertone
LF18	Finestre in legno	Finestra in legno piano secondo a doppio battente	95x225	2	A doppia anta con scuri esterni	Albertone
LF19	Finestre in legno	Finestra in legno piano secondo a doppio battente	100x225	2	A doppia anta con scuri esterni	Albertone
LF20	Finestre in legno	Finestra in legno piano secondo centinata a doppio batter	125x220	2	A doppia anta, con sopraluce centinato. Con motore elettrico collegato ad impianto rilevazione inc	Albertone
LF21	Finestre in legno	Finestra in legno piano secondo fissa	75x170	2	Fissa. Ce ne sono due al piano secondo , di cui 1 con motore elettrico ril. incendi)	Albertone
LF22	Finestre in legno	Finestra in legno piano secondo fissa	65x170	2	Fissa	Albertone
LF23	Finestre in legno	Finestra in legno piano secondo a doppio battente	105x220	2	A doppia anta con scuri esterni	Albertone
LF24	Finestre in legno	Finestra in legno piano sottotetto a ribalta	105x85	Sottotetto	Apertura a ribalta	Albertone
LF25	Finestre in legno	Finestra in legno piano sottotetto a ribalta	100x85	Sottotetto	Apertura a ribalta	Albertone
LF26	Finestre in legno	Finestra in legno piano sottotetto a ribalta	95x85	Sottotetto	Apertura a ribalta	Albertone
LF27	Finestre in legno	Finestra in legno piano sottotetto fissa	75x85	Sottotetto	Fissa	Albertone
LF28	Finestre in legno	Finestra in legno piano sottotetto abbaino a doppio batter	105x145	Sottotetto	A doppia anta	Albertone
LP1	Porte, portoni e porte finestre in legno	Porta finestra_U.S. in legno a doppio battente	135x265	Terra	A doppia anta	Albertone
LP2	Porte, portoni e porte finestre in legno	Porta finestra_U.S. in legno a doppio battente	135X315	Terra	A doppia anta con sopraluce	Albertone
LP3	Porte, portoni e porte finestre in legno	Porta finestra_U.S. in legno a doppio battente	135x210	Terra	A doppia anta	Albertone
AF1	Finestre e porta finestre in alluminio a taglio termico	Finestra in alluminio a taglio termico	130x205	Interrato	A anta singola con apertura ad anta	Albertone
V	Facciata vetrata del nuovo volume di ingresso in allun	Vetrata volume d'ingresso	130x230	Terra	A anta singola con apertura a ribalta (32 m lineari di facciata)	Albertone
R1	Porte REI tipo "*Novoferm Elite+*"	Porte REI a doppia anta con maniglione antipanico	135x210	Tutti	Apertura a destra spingere, con maniglione antipanico	Ninz
FR1	Finestre REI	Finestra REI piano terra fissa	105x215	Terra	Fisso con scuri esterni	Albertone

Table 4. External windows' schedule

For slabs, walls, internal and external windows I maintained the codification given by the designer, in order to avoid future inconsistencies.

For what concerns the materials, the codification was invented by me under the guide of the CO.GE.FA's BIM office, following the "*LINEA GUIDA Processo BIM (Building Information Modelling",* because the codification given to the materials was then going to be used as input information for Revit. [21]



Materiali

Classe	Codice	Descrizione	Categoria	Pacchetto	Spessore [cm]	Produttore	Note
	XX.XX.XXX.Descrizione						
Calcestruzzo	CA.01	Cls	Massetto di completamento	Solaio esterno	10		Con rete d'armatura
Calcestruzzo	CA.02	Getto di completamento in cls e rete di armatura	Getto di completamento	Solaio esterno	5		
Calcestruzzo	CA.03	Solaio in C.A.	Solaio in C.A.	Solaio esterno	25		
Calcestruzzo	CA.04	Struttura estroversa vano ascensore in C.A.	Solaio in C.A.	Copertura	20		
Calcestruzzo	CA.05	Setto in C.A.	Setto in C.A.	Murature esterne	35		
Cemento	CM.01	Massetto di completamento in sabbia e cemento, con rete d'armatura	Massetto di completamento	Solaio esterno	5		Con rete d'armatura
Cemento	CM.02	Cls alleggerito	Massetto per passaggio impianti	Solaio esterno/interno	15		
Cemento	CM.03	Colla	Pavimentazione	Solaio esterno	0.5		
Cemento	CM.04	Massetto per passaggio impianti in Cls alleggerito tipo *Foamcem*	Massetto per passaggio impianti	Solaio interno	var (10-25)		
Cemento	CM.05	Intonaco completo a civile per interni	Finitura esterna	Muratura in laterizio	1.5		
Cemento	CM.06	Getto di magrone	Getto di magrone	Solaio esterno	10		
Cemento	CM.07	Blocco in cls di argilla espansa tipo *Lecablocco Tramezza Lecalite T10*	Cls alleggerito	Muratura di tamponamen	10		
Ceramica	CE.01	Piastrelle di gress porcellanato	Pavimentazione	Solaio esterno	1.5		
Ceramica (terracotta)	CE.02	Coppi su listello di ventilazione	Manto di copertura	Copertura			
Gas	GS.01	Intercapedine	Cavità d'aria	Muratura interne	3		
Gesso	GE.01	Doppia lastra in gesso?	Controsoffitto	Solaio interno	3		Antincendio EI 60
Gesso	GE.02	Lastra in gesso rivestito tipo *Gyproc Habito 13 ACTIV'AIR SAINT GOBAIN*	Parete divisoria	Muratura interne	1.25		
Gesso	GE.03	Lastra di gesso rivestito tipo *Gyproc Habito 13 - SAINT GOBAIN*	Parete divisoria	Muratura interne	1.25		
Gesso	GE.04	Lastra di gesso fibrato tipo *Gyproc Rigidur H 13 - SAINT GOBAIN*	Parete divisoria	Muratura interne	1.25		
Gesso	GE.05	Lastra di gesso fibrato tipo *Gyproc Habito Hydro 13 - SAINT GOBAIN*	Parete divisoria	Muratura interne	1.25		
Gesso	GE.06	Lastra di gesso tipo *Gyproc Fire Line - SAINT GOBAIN*	Parete divisoria	Muratura interne	1.25		Il gesso contiene additivi di fibre di vetro e vermiculite per la resistenza al fuoco
Isolante	IS.01	Isolante in poliuretano tipo *Stiferite*	Isolante termico	Solaio esterno	12		
Isolante	IS.02	Pannello in lana di roccia a doppia densità tipo *Rockwool Hardrock Energy plus*	Isolante termico	Copertura	10		Pannello rigido
Isolante	IS.03	Pannello isolante tipo *Stiferite GTE*	Isolante termico	Muratura interne	5		
Isolante	IS.04	Isolante in poliuretano tipo *Stiferite GT*	Isolante termico	Copertura/sol. Interno	10		
Isolante	IS.05	Pannello in lana minerale tipo *Isover Par 4+*	Isolante termico e acustico	Murature interne	7		
Isolante	IS.06	Pannello in lana di roccia a media densità con faccia rivestita in foglio di alluminio con funzione di barriera al vapore, tipo *Rockwool Airrock Alu*					
Laterizio	MA.01	Tavolato interno in mattoni pieni	Mattoni	Murature in laterizio	var		
Laterizio	MA.02	Laterizio alveolato tipo *Poroton*	Mattoni	Murature in laterizio	10		
Legno	LE.01	Doppio tavolo incrociato in legno con bandelle metalliche	Sottostruttura	Copertura	2.5+4		
Legno	LE.02	Parque costituito da uno strato nobile a vista e da uno strato di supporto tecnologico in legno multistrato a fibre incrociate	Pavimentazione	Solaio interno	1.5		
Legno	LE.03	Tavolato in legno		Copertura			
Membrana	MB.01	Barriera al vapore tipo *Derbicoat HP selfix*	Barriera al vapore	Solaio esterno	0.2		
Membrana	MB.02	Trattamento antipolvere per pavimenti industriali	Pavimentazione	Solaio esterno	0.5		
Membrana	MB.03	Doppia guaina (guaina bituminosa+guaina ardesiana)	Impermeabilizzazione	Solaio esterno	0.8		
Membrana	MB.04	Membrana impermeabile traspirante in telo di polipropilene tipo *Rivega Dc 135*	Impermeabilizzazione	Copertura	0.5		
Membrana	MB.05	Barriera al vapore tipo *Rivega DB 200*	Barriera al vapore	Copertura	0.5		
Membrana	MB.06	Membrana in rete tridimensionale antirombo, tipo *Rivega USB Drenlam Light*	Impermeabilizzazione	Copertura	0.8		Strato separatore per coperture in metallo
Membrana	MB.07	Guaina bituminosa	Impermeabilizzazione	Murature esterne	0.8		
Membrana	MB.08	Membrana in polietilene ad alta densità (HDPE) con struttura bugnata dalla geometria tronco-conica per protezione della guaina tipo *Onduline Italia Fondalene*	Impermeabilizzazione	Murature esterne			
Isolante acustico	MB.09	Materassino anticalpestio tipo *Isolmant underplus black*	Isolante acustico	Solaio esterno	0.06		
Isolante acustico	MB.10	Isolamento acustico *Topakustik*					
Metallo	MT.01	Lamiera grecata	Struttura metallica	Solaio esterno			
Metallo	MT.02	Lamiera zincata traforata con sezione a U	Manto di copertura	Copertura			
Metallo	MT.03	Lamiera di alluminio pre-verniciato con doppia aggraffatura	Manto di copertura	Copertura			
Metallo	MT.04	Profilo in acciaio zincato	Struttura metallica	Murature interne			
Pietra	PI.01	Pastina di quarzo/granaglia (fresco su fresco)	Finitura pavimentazione	Solaio esterno	1.5		
Pietra	PI.02	Lastre di pietra	Pavimentazione	Solaio esterno/interno	3		
Pittura	PT.01	Pittura acrilica per pareti interne *Biamax - OIKOS*	Pittura	Parete interna			
Pittura	PT.02	Pittura acrilica per pareti interne *Drywall Paint - OIKOS*	Pittura	Parete interna			
Plastica	PL.01	Cassoni a perdere in plastica riciclata	Vespaio areato	Solaio esterno	30		
Tessuto	TX.01	Pavimentazione tecnica tessile	Pavimentazione	Solaio esterno	0.5		

Table 5. Materials' schedule

In the following table, there are all the codes used for naming the materials, which have later been inserted to the Revit model.

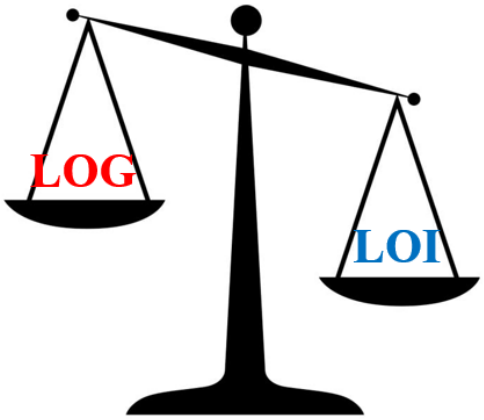
CLASS	CODE
Concrete (calcestruzzo)	CA
Cement (cemento)	CM
Ceramic (ceramica)	CE
Gas (intercapedine)	GS
Gesso (gypsum board)	GE
Thermal insulation (isolante termico)	IS
Brick (laterizio)	MA
Wood (legno)	LE
Membrane	MB
Acoustic insulation (isolante acustico)	MB
Metal	MT
Stone (pietra)	PI
Painting (pittura)	PT
Plastic	PL
Fabric (tessuto)	TX

Table 6. Codification of the materials

Next, depending on the specific purpose, it was essential to determine which BIM-FM model was going to be used. To obtain a good result it is essential to define the results that we want to obtain upstream of the modeling process. Creating a digital model of a building is a process that involves a continuous activity of choice, deriving mainly from the level of detail we want to achieve. The person in charge of modeling should therefore have to make continuous choices, but these choices have to be coherent and able to orient the model that is being created along different paths. Therefore, it turns out it is essential to have a clear understanding of the purpose of the modeling activity in order to create a digital model optimal. The main objectives for the case study are the realization of a Revit model, which would be a rich and powerful database for Facility Management, the

activity of rationalization and optimization of spaces and the subsequent data visualization in Power BI.

In order to achieve the objectives, the As Operate model was the most suitable one, because it was not important to have a very precise geometric representation of the objects contained in the building, but to concentrate on the information input relative to each object. Also, since the building was very complex, the model was focused only on the representation of the object that would require maintenance. While aiming for a representation close to reality, the Level of Information (LOI) for objects was prioritized over the Level of Geometry (LOG) to establish a reliable management database.



4.2. Developing the As Operate BIM model

4.2.1. Setting up the parametric model

At the moment in which the work was transferred to Revit, the first step was creating the walls and floors families. All the information mentioned before was included in the Revit families.

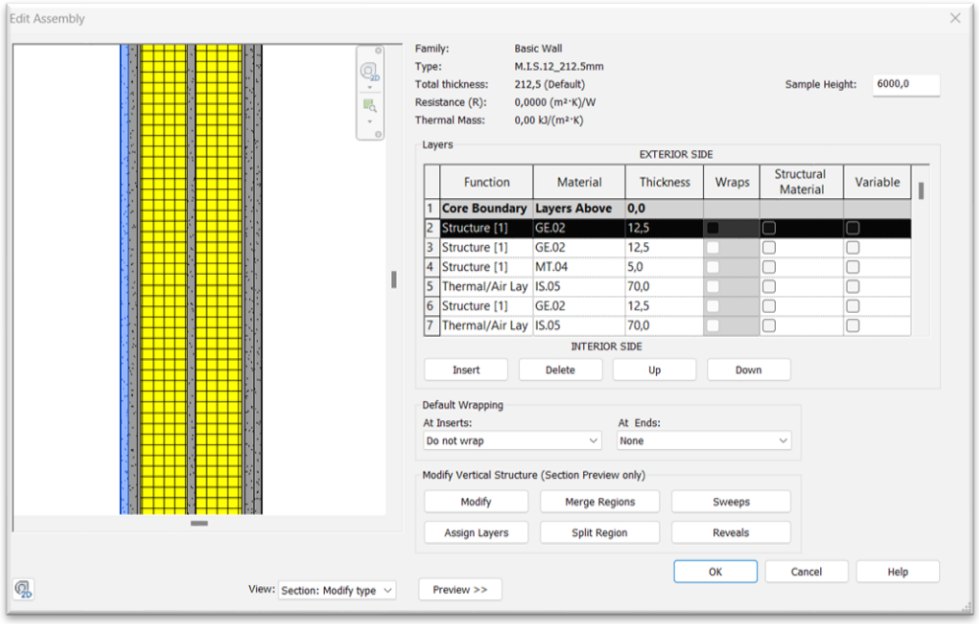


Figure 12. Screen capture - wall family (Revit 2023)

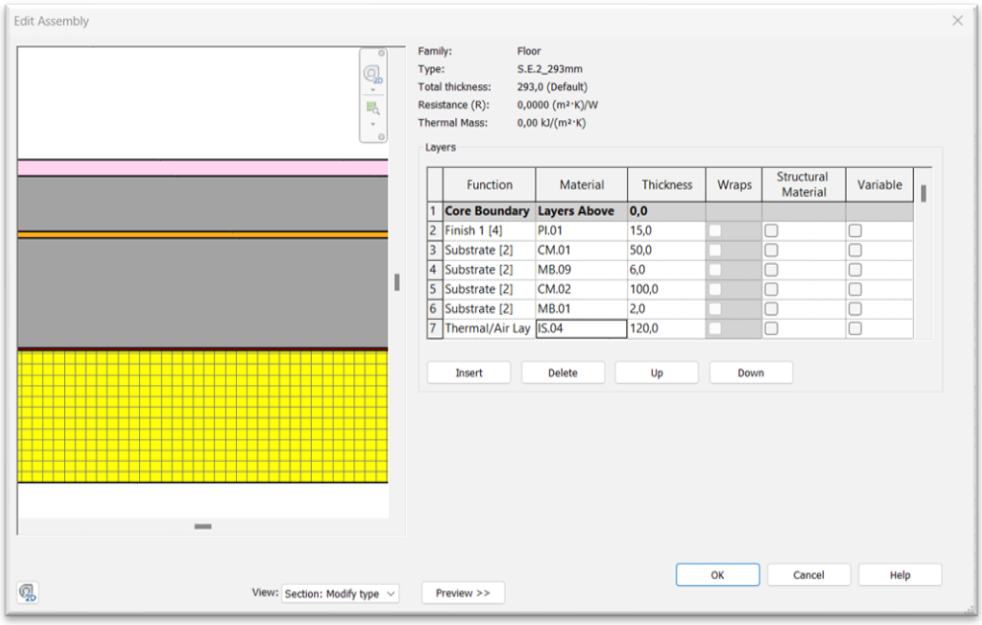


Figure 13. Screen capture - floor family (Revit 2023)

Existing CAD documentation

The existing documentation relating to the case study is as follows:

1) Architectural CAD plans updated to 15/05/2024.

Figure 14. Architectural plan - Ground floor, Ex Buon Pastore building

2) CAD sections and elevations updated to 26/03/2024.

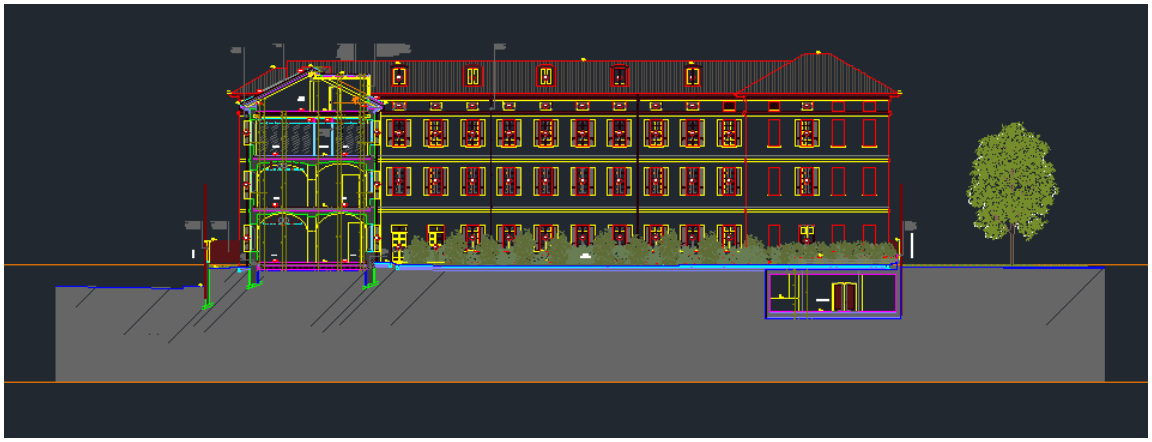


Figure 15. Section B-B, Ex Buon Pastore building

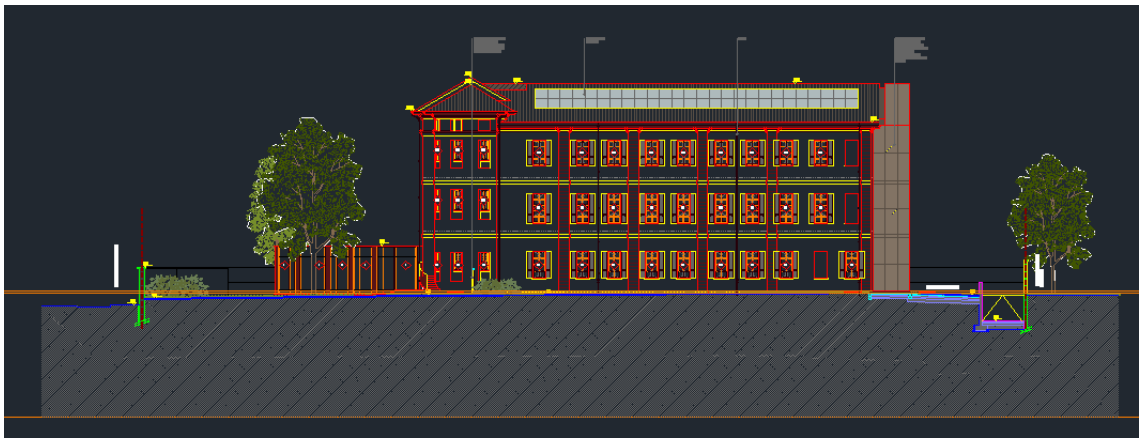


Figure 16. East elevation, Ex Buon Pastore building

3) CAD drawings of windows and doors updated to 26/03/2024.

Figure 17. CAD drawings of windows and doors, Ex Buon Pastore building

Having the updated and correct plans, we chose to use them as the basis for the modeling three-dimensional, therefore the CAD files of the individual floors were linked to the Revit project and were positioned on the relative level.

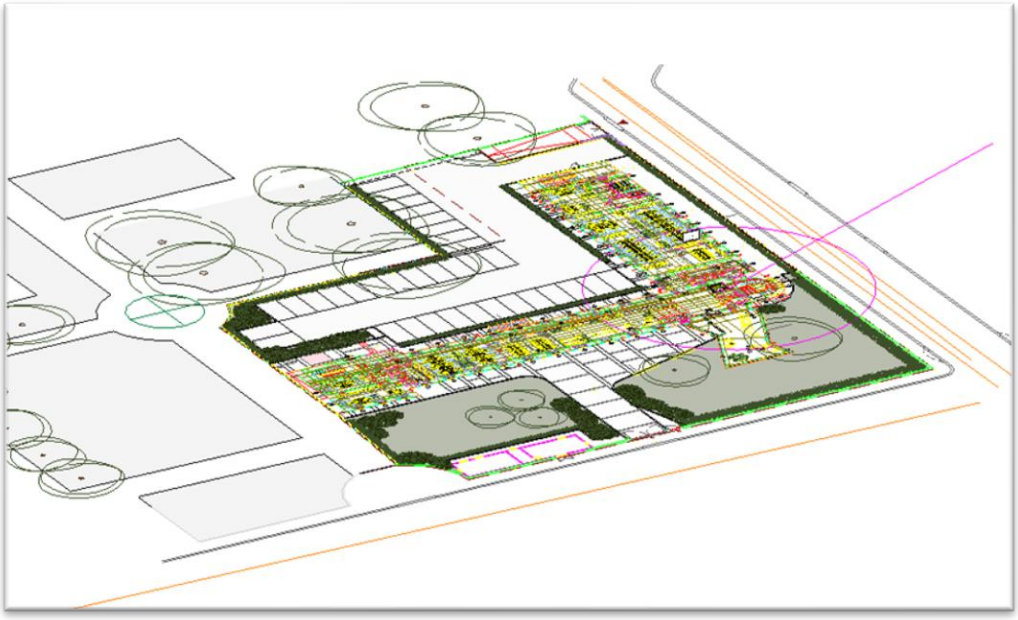


Figure 18. Example of DWG drawing linked to the Revit model (Ground Floor)

Parametric families were created for windows and doors, in order to facilitate the process and to allow future usage of the created families.

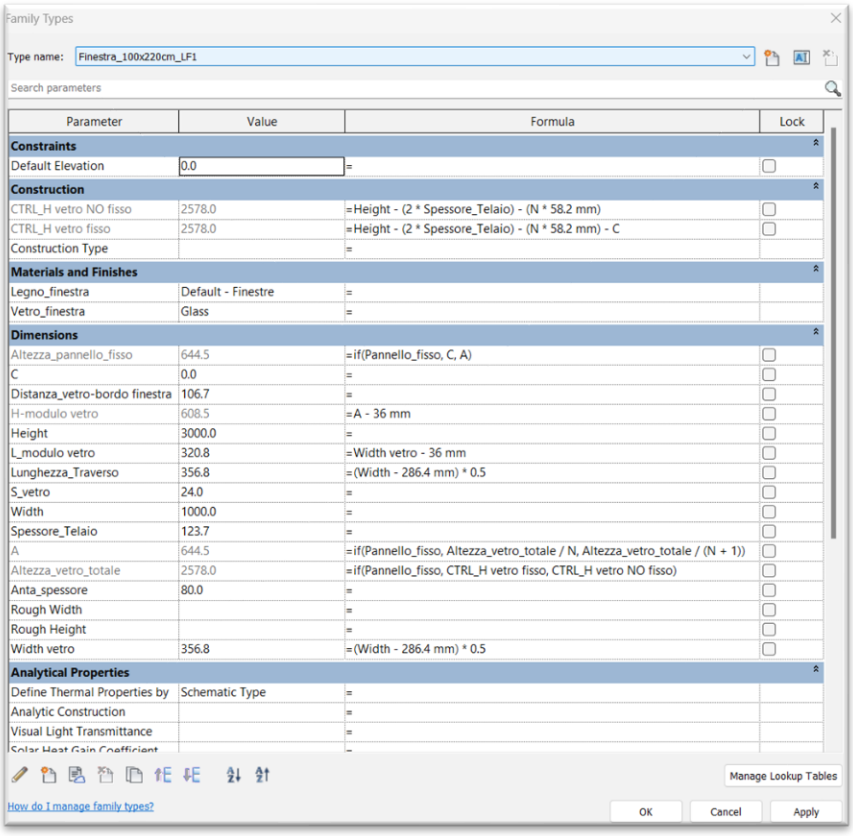


Figure 19. Screen caption - formulas used for the parametric window family

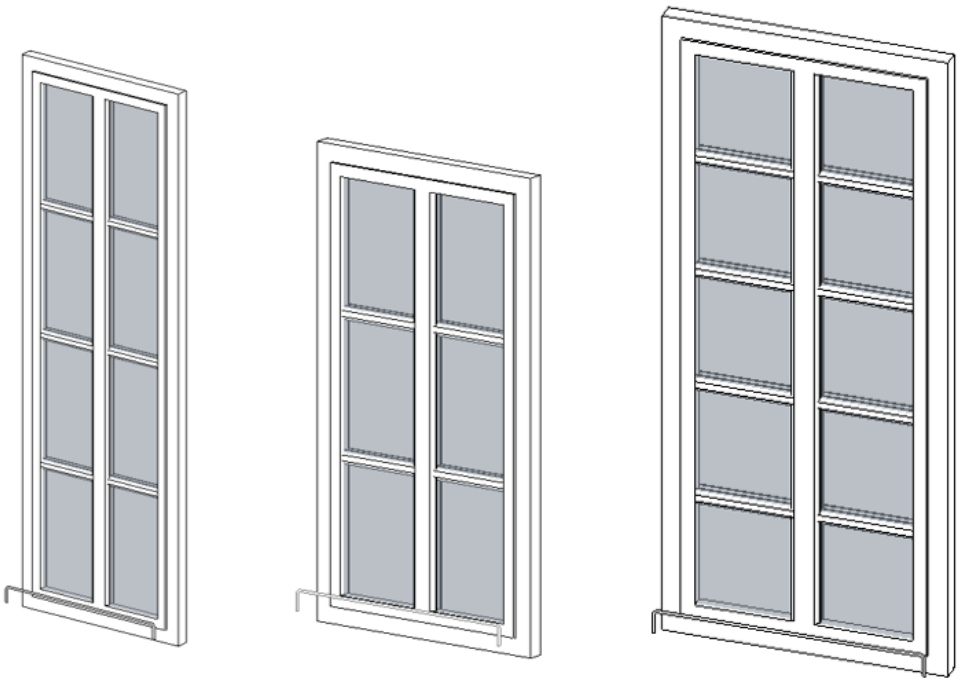


Figure 20. Windows modeled using the same parametric family

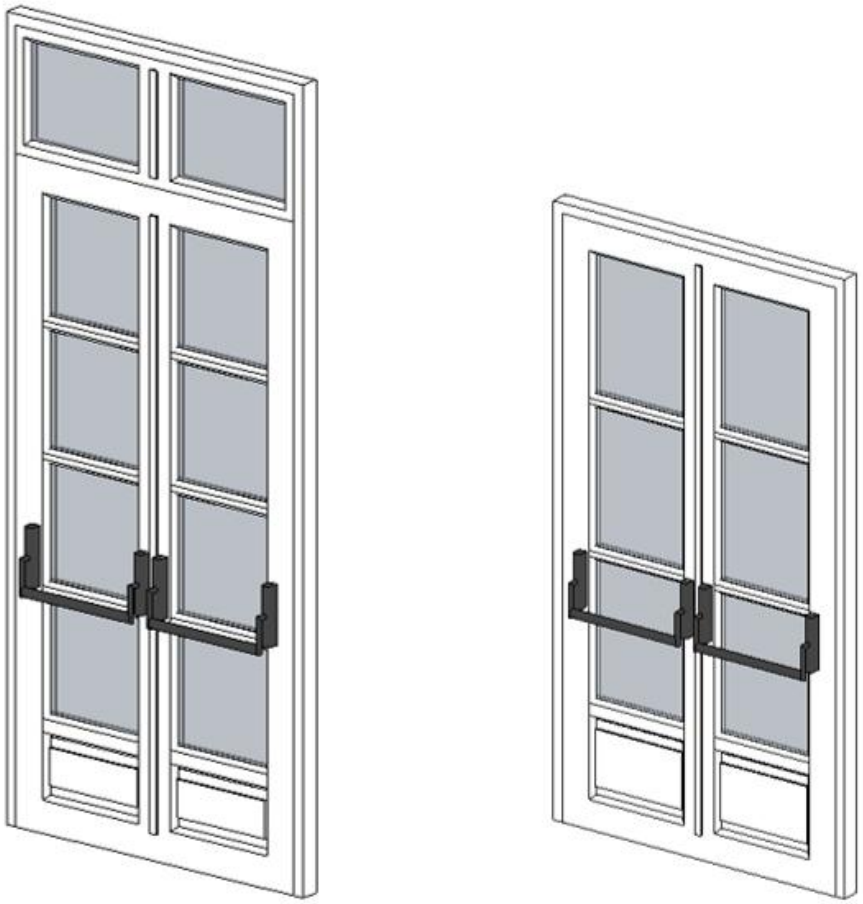
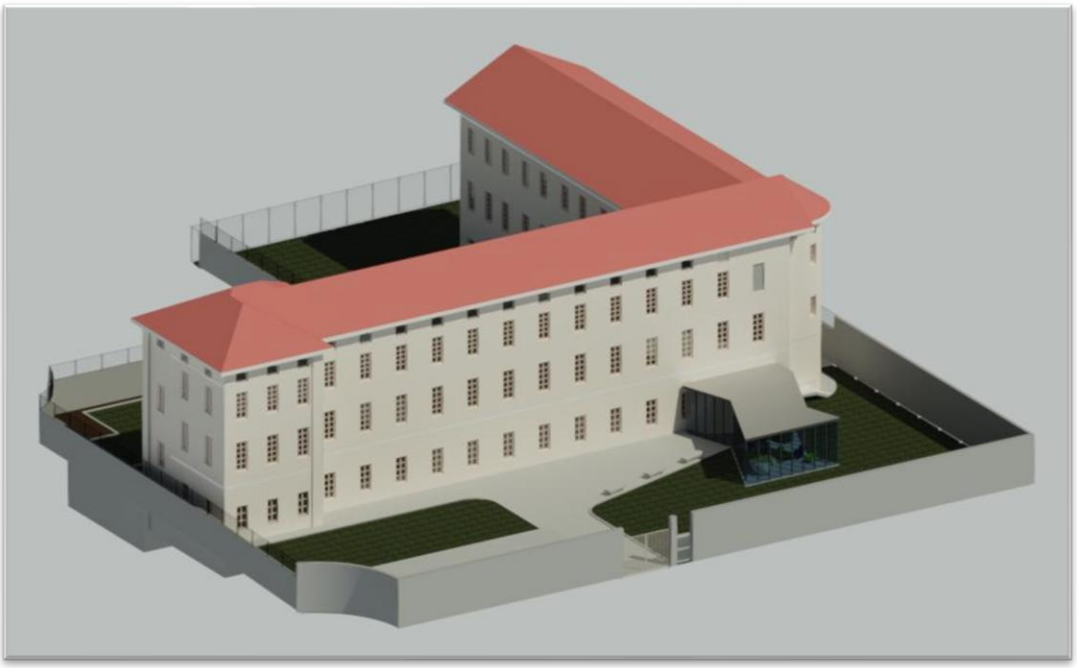


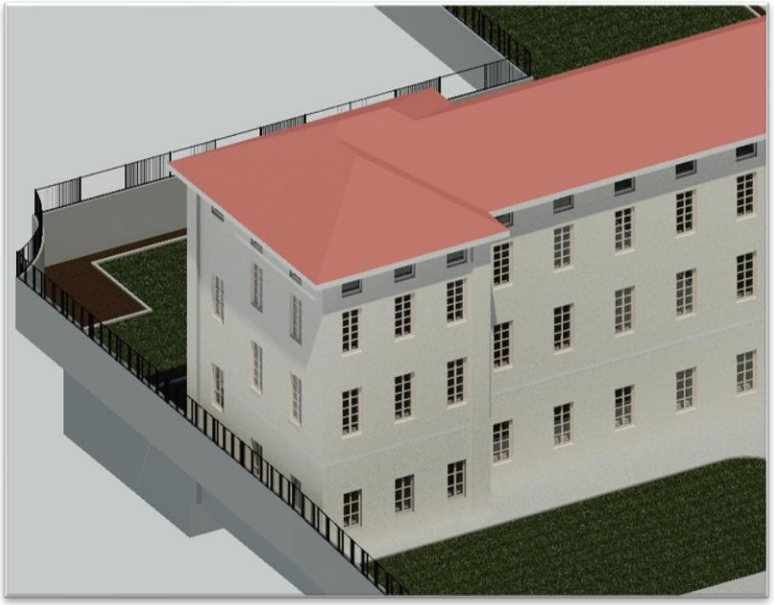
Figure 21. Doors modeled using the same parametric family



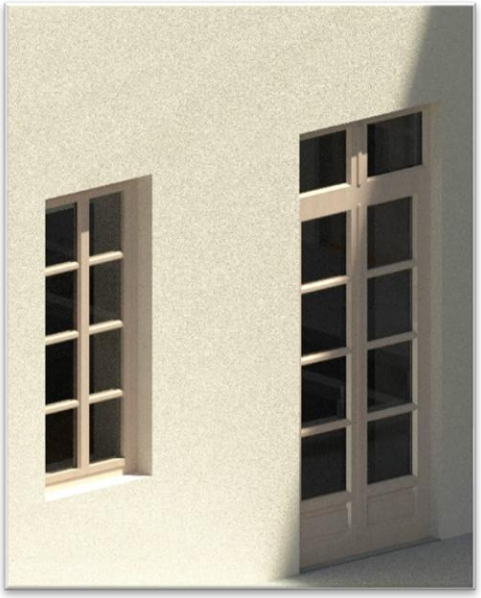
a)

b)

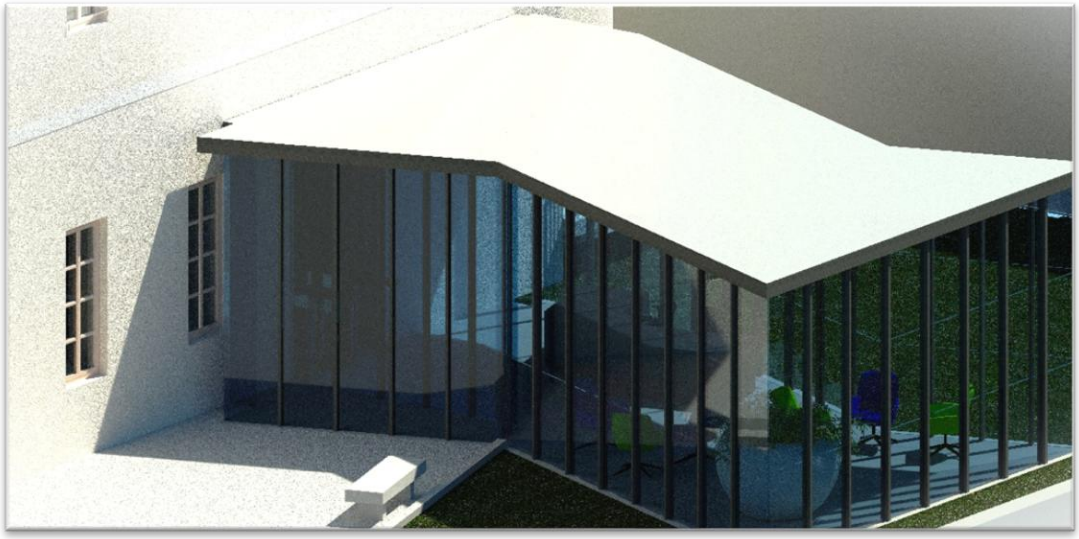
c)



d)



e)



f)

Figure 22. a) b) c) d) e) f) Renders of the Revit model - Ex Buon Pastore building (CO.GE.FA. S.p.A. Offices)

4.2.2. Shared parameters and Room custom labels

First of all, before doing the labels and the shared parameters, I created the rooms. For the creation of rooms, it is sufficient to click on the Revit "Room" button and position in the middle of a specific space. Revit can automatically recognize a room, when it's delimited by walls.

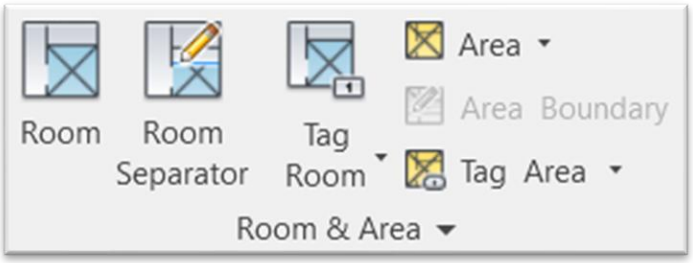


Figure 23. Screen capture - "Room" and "Room Separator" commands, Revit 2023

There was a particularity while working on the room positioning of this building, because most of the offices have been thought of being open spaces, so they don't have walls separating them one from another. For this reason, most of the "rooms" have been created using the "Room Separator" command, which allows spatial division of areas in absence of walls.

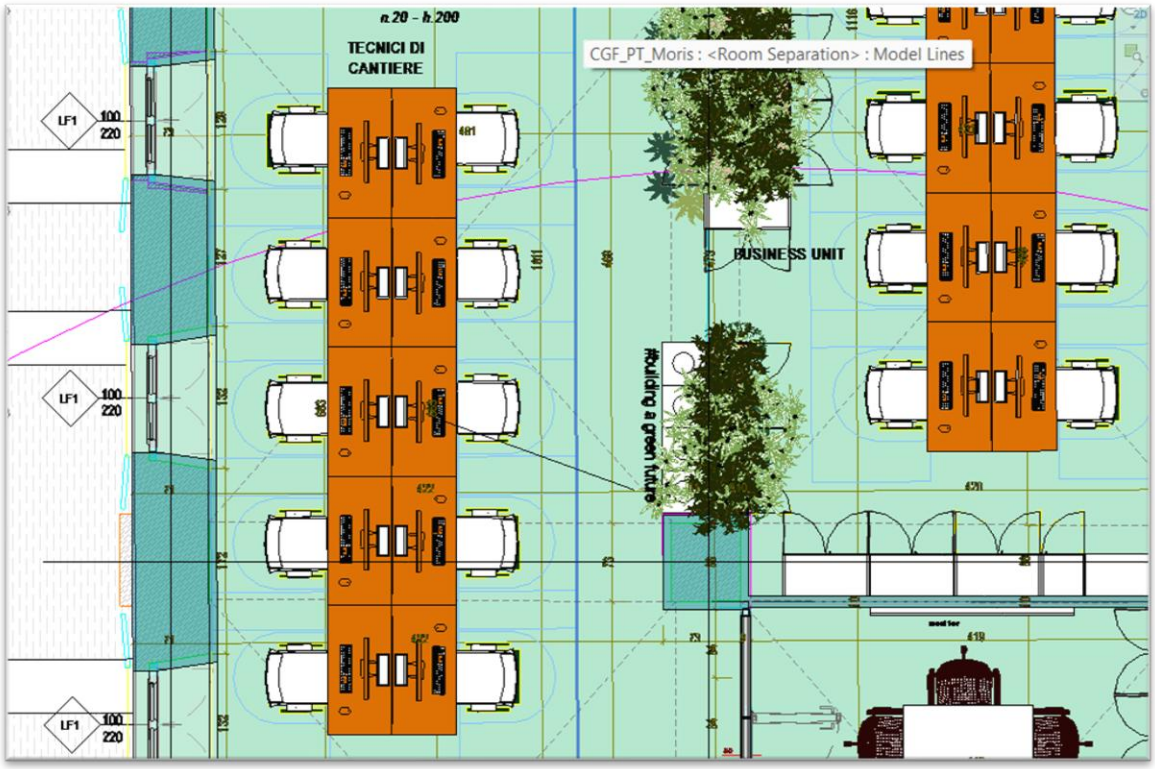


Figure 24. Screen capture - "Room Separator" command utilization,

Ground floor, Ex Buon Pastore building

Shared parameters

Project parameters alone are insufficient to fully characterize objects with all the information required for effective facility management. Shared parameters offer the only solution to extend the informational objective of building components in Revit. Their use has been extensively explored to boost the parametric definition of models and to improve interoperability across different platforms.

This approach enables the inclusion of various types of additional information—such as text, numbers, URLs, or Yes/No values—across multiple families, thereby enriching the building database's query capabilities. These attributes can be grouped typologically (e.g., identity data, dimensions etc) for better organization and access through the family properties interface. Shared parameters are stored in an independent .txt file, allowing them to be defined and reused across multiple families or projects. Unlike standard parameters, information added via shared parameters can be displayed in tags and schedules, making them a fundamental tool for facility management. They enable the creation of thematic views, comprehensive item lists, and significant object selections, as illustrated in the subsequent chapter. Additionally, shared parameters allow for the display of different family categories in a multi-category schedule, as they can be uniformly applied across categories. [6]

For my case study, based on literature and in the specific needs of the company, the following shared parameters have been created for the characterization of rooms:

Shared parameter	Type
CGF_Accessible	**YES/NO**
CGF_Nr.porte	**Integer**
CGF_Codice livello	**Text**
CGF_Nr. finestre	**Integer**
CGF_Numero locale	**Integer**
CGF_Localizzazione	**Text**
CGF_Codifica locale	**Text**
CGF_U.S	**YES/NO**
CGF_Occupanti	**Integer**
CGF_Aperto al pubblico	**YES/NO**
CGF_Descrizione	**Text**
CGF_Codice categoria	**Text**
CGF_Volte	**YES/NO**
CGF_Compartimentazione	**YES/NO**

Table 7. Shared parameters created for the characterization of the rooms

The shared parameter named “CGF_Codice categoria”, corresponds to a codification that I have decided to attribute to the rooms of this building.

CGF_Codice categoria	
Office	**0**
Meeting room	**M**
Distribution area	**X**
Toilet	**W**
Technical room	**T**
Printing area	**P**
Lift	**A**
Stairs	**S**

Table 8. Codification of the rooms

For what concerns the shared parameter “CGF_Codifica locale”, it is a 4 elements code consisting of:

- The first element is relative to the “CGF_Codice categoria”, which has been explained before;
- The second element is relative to the level in which the room is located, so it equals to “0” for ground floor, “1” for first floor and so on;
- The third and fourth elements of the codification represent the progressive number of the specific room, starting from “01”, “02” and continuing to the last one.

For example, a room having the following “CGF_Codifica locale” : M002, means that it is a meeting room, located at the ground floor of the building and it’s progressive number is 2.

Codes are assigned to rooms to univocally identify them. It is very helpful to establish since the beginning the registry building structure, in order to use the same approach for all phases of the process (e.g. survey sheets, BIM models, facility management platform) and in our case also for the dashboards creation in Power BI. It is recommendable to start numbering the rooms on each floor and always follow the same distribution logic (e.g. from left to right, following the shape of the building).

Room custom label

Room labels are actual annotation symbols, i.e. 2D components that document the model and maintain the scale on the drawings for printing: like all documentation objects, when changing the View also changes the size of the room labels and its contents. Since labels are a family of standard components, they can be modified and customized as we prefer. Rooms and room labels are two distinct and at the same time related components of Revit (in fact to be able to assign a Label to a room, it is first necessary to add the room to the project). In the room labels there are texts that report the values of the related parameters, such as the number of the room, the name, the calculated area and the volume of the room itself; the Label in fact, remaining connected to the room in which it is inserted, it is perfectly capable of detecting these characteristics. To define the template, a custom label was created. To create a label customized in a project model, the following procedure was used:

- Defining the information we want to label

It is necessary to define in advance the information you want to display in the customized label. In the specific case we chose to display the final coding of the room, the category it belongs to and its area.

- Creation of a new metric Local Label family

Once the shared parameters and the related project parameters have been created, it will be necessary to create the family of personalized annotations (Label) by inserting the newly created parameters.

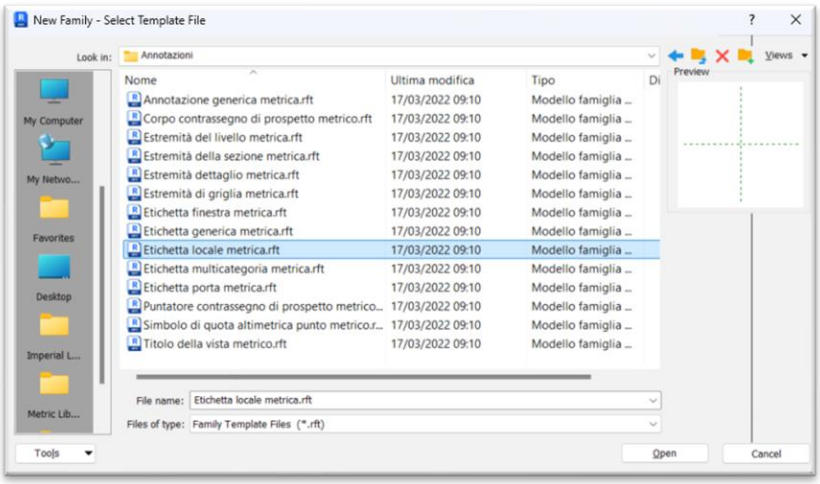


Figure 25. Screen capture-Selection of the base template for the creation of the metric label

- Insertion of label text

Now we need to enter the label texts we wish to display, we can do this operation to create/Label text. At this point, clicking on the family field opens a form where we can choose which parameter to associate with the label text. To be able to use the parameters created previously is necessary to recall the relevant shared parameters with the 'Add parameter' command which allows us to select the saved shared parameters.

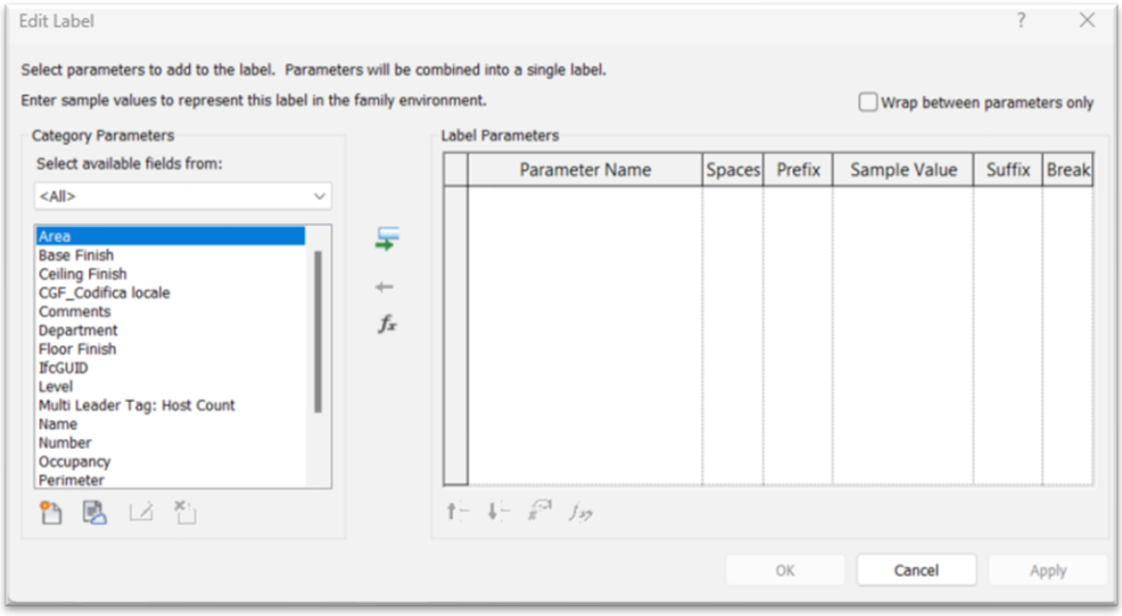


Figure 26. Screen capture - Modification of the label text

- Loading Label family into the project

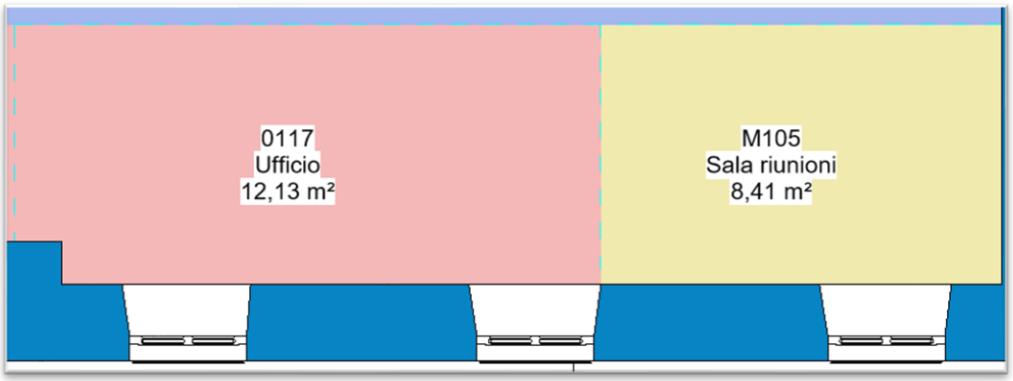


Figure 27. Example of utilization of the custom labels inside the project

Once the label has been defined, it can be loaded into the template and used in the design phase. The result in the project will be that by inserting a room it will be created automatically a label containing the information we desire.

Thematic views

In order to have a better representation of the rooms according to their destination of use, containing also the already created labels, we can use thematic views. A thematic view in Revit refers to a graphical representation of a building model that highlights specific information or attributes based on a particular criterion. This type of view is useful for focusing on certain aspects of the model, such as system classifications or other customized parameters. The thematic view that we are going to use is a color-coded view, used to distinguish spaces based on the room usage. They are shaded differently to indicate their function (e.g., offices in red, conference rooms in green).

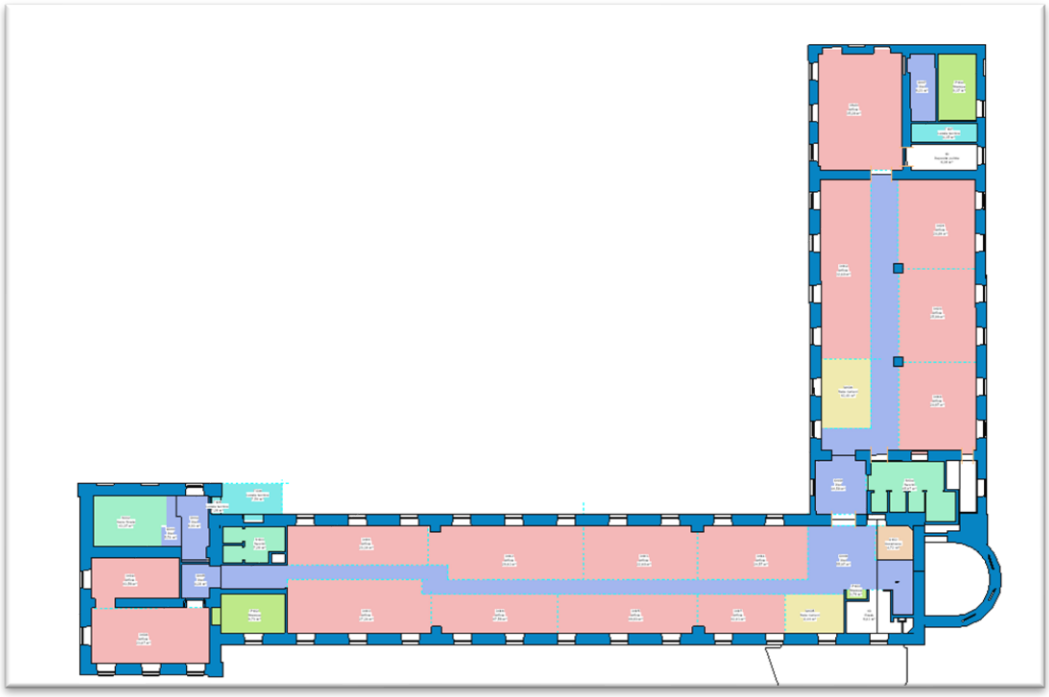


Figure 28. Thematic plan - First floor, Ex Buon Pastore building

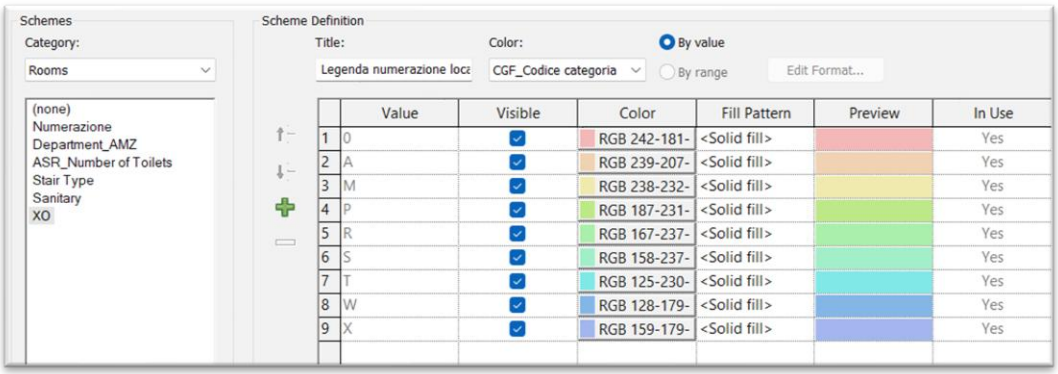


Figure 29. Legend of the thematic plan

4.2.3. Use of schedules and DiRoots plugin

Schedules in Revit are tables and lists that are extracted directly from the properties of the Revit model elements. Schedules are project views in the form of lists that catalog all the model elements and their related information: objects, materials, quantities, areas, volumes, etc.

At the end of a project, the compilation of the component lists, room lists, and cost estimations is a monotonous, boring and often infinitely long activity. The ability to create and update schedules quickly is one of the bedrock of BIM systems, which allows for quick updates of the data in case of changes. It is possible to extract both physical properties and managerial properties, such as material, color, code, cost etc. Furthermore, the schedules of Revit behave in the same way as views: every change made to the schedule is reflected in the model and consequently also to all other views. Schedules are project views at all effects, and can be inserted inside the tables, just like all the other views. The more the model of the building is accurate, the more information we will be able to extract and calculate through the schedules.

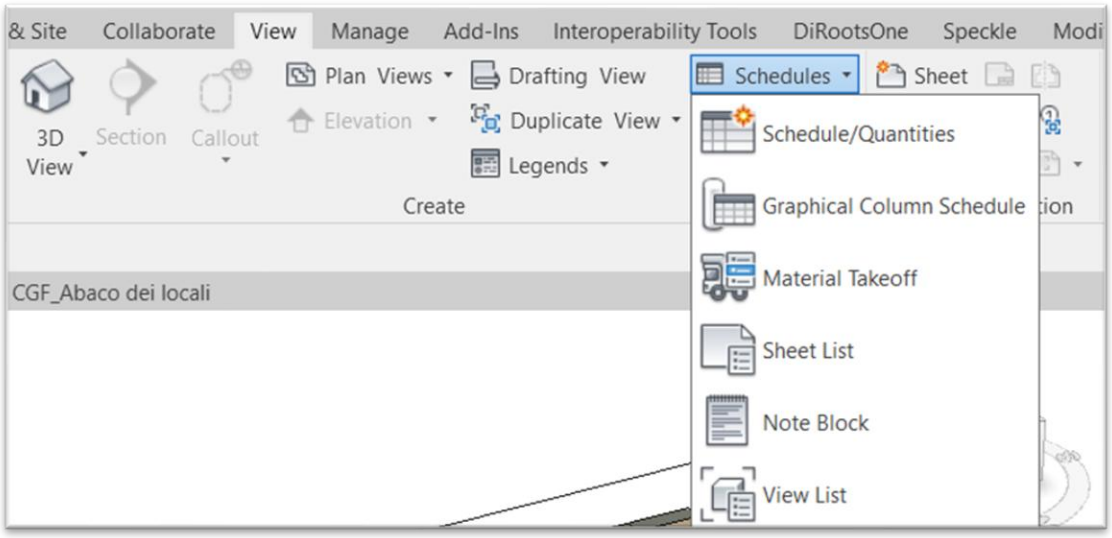


Figure 30. Screen capture - Creation of schedules, inside the View tab - Revit 2023

At the moment in which we click on “New schedule”, Revit will open a dialogue window that allows us to select a category of elements to catalog. We have chosen the category “rooms”, as it is the one in which we are focusing. The software automatically assigns a name to the schedule, which can be later modified.

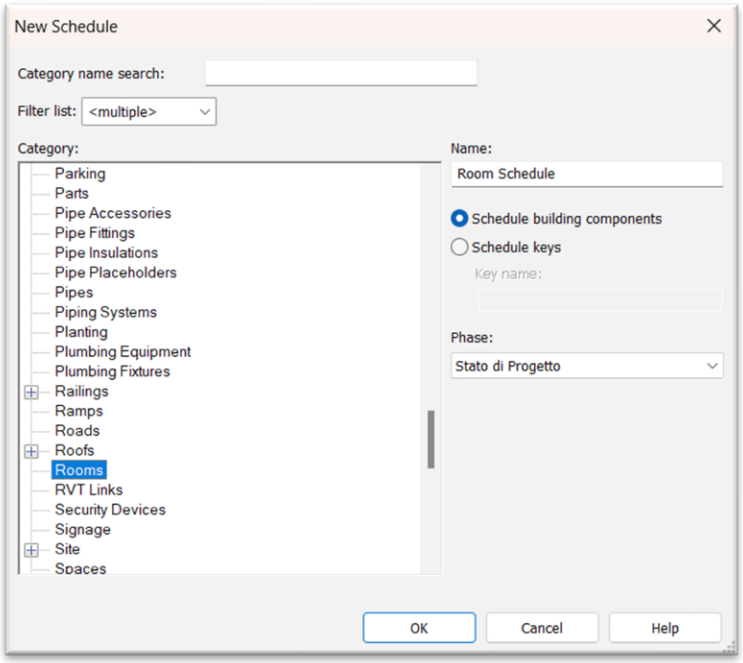


Figure 31. Window that allows us to select the category we want to catalog

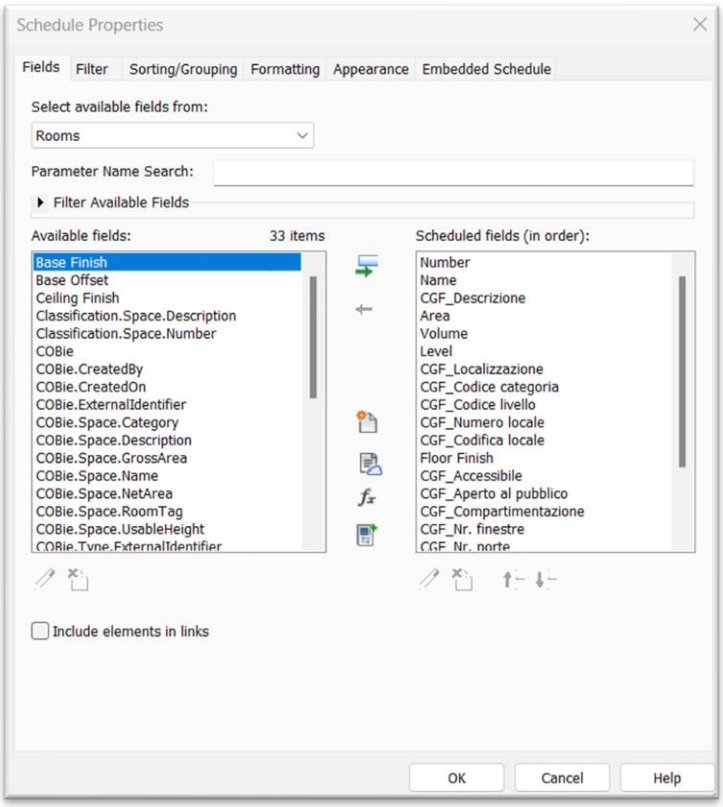


Figure 32. Dialogue window that allows us to select the Schedule Properties

After that, it will be shown the Schedule Properties dialog box: from here we can organize and edit schedules, insert new entries, control their display order and appearance of the schedule. We can select the parameters that we want to be included in the schedule that we are creating. We can choose between the Project Parameters that Revit offers (related to the category that has been selected) and the shared parameters that we created before.

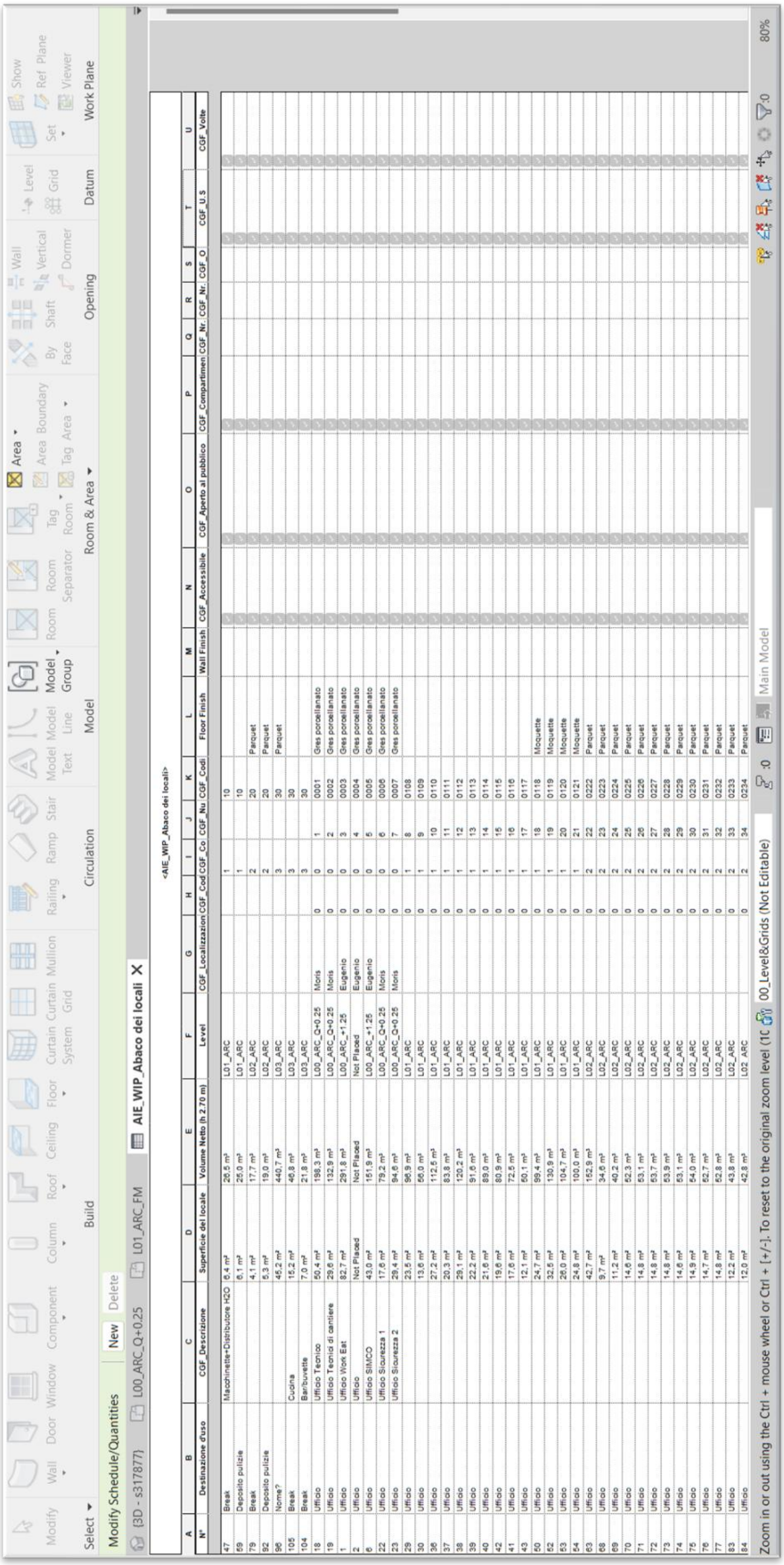


Figure 33. Screen capture - Rooms Schedule - Revit 2023

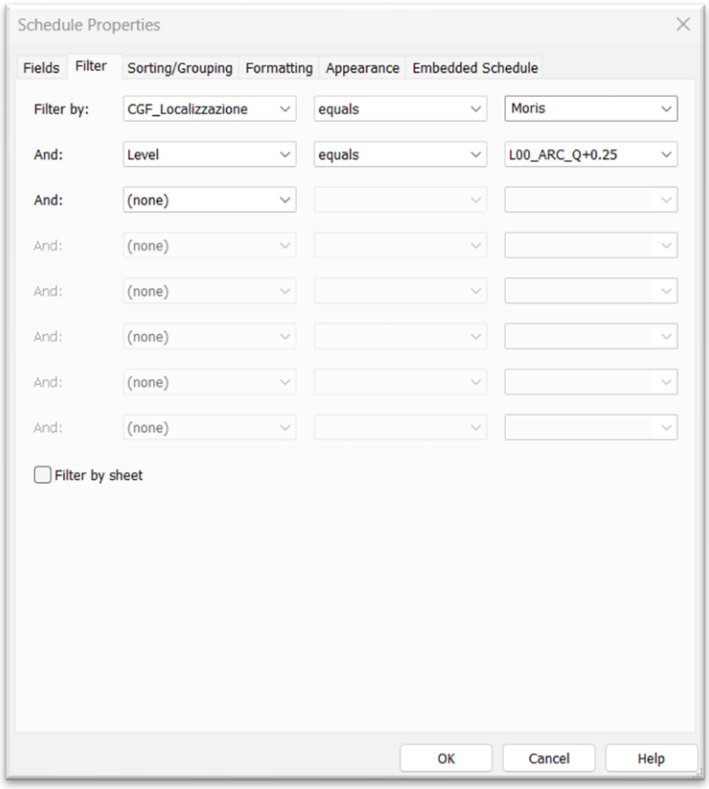


Figure 34. Filters applied to the Rooms Schedule

It is also possible to apply a filter inside the Schedule, in order to visualize only some of the rooms of the building. In this case, I wanted to visualize only the rooms located on the ground floor, in the Via Moris wing. For this purpose, I have applied two filters. The fact that the relationship between the two filters is specified by the conjunction “and” means that they both should be true at the same time in order to be visible.

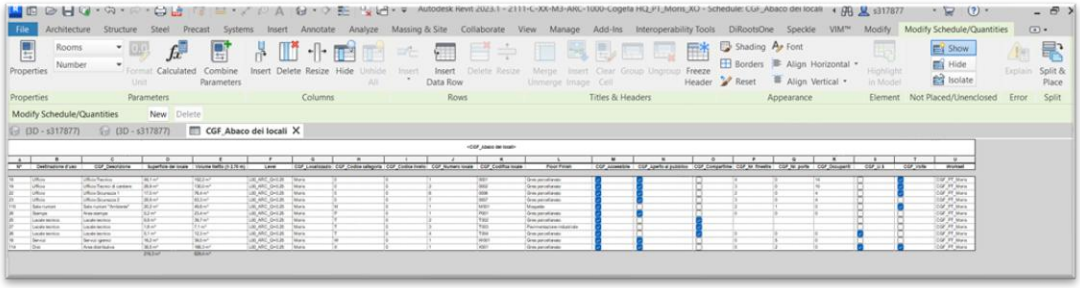


Figure 35. Rooms Schedule referred to the rooms located in the Via Moris wing

As in the rooms located in the Via Moris wing, I have also put all the furniture according to the furnished floor plans, I wanted to have the possibility to obtain the number of each type of furniture in each room and to visualize it inside the previous schedule. To do so, the first step consists in opening each of the furniture families, one by one, and activating the “Room Calculation Point”. It allows the furniture element to “understand” in which part of the building is located and to which room belongs.

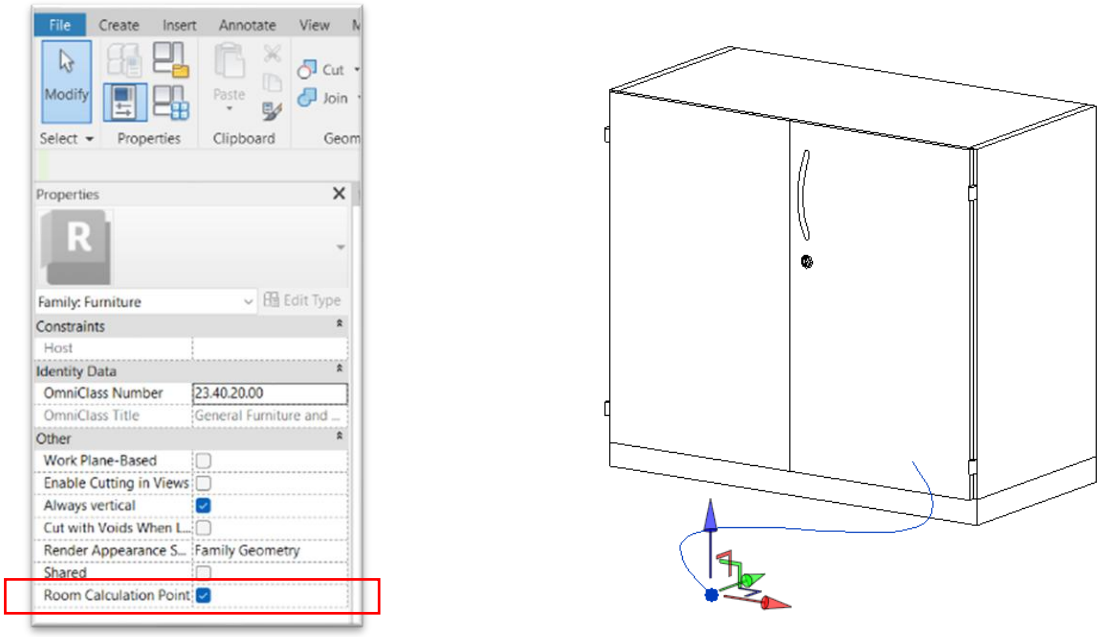


Figure 36. "Room Calculation Point" function activation

The compilation of the schedule can be done directly from Revit, by simply opening the Schedule, or by using the **DiRoots plugin**. The DiRoots plugin for Revit is a suite of free tools which enhance BIM workflows. DiRoots helps improve project delivery, data management, and overall productivity in BIM workflows.

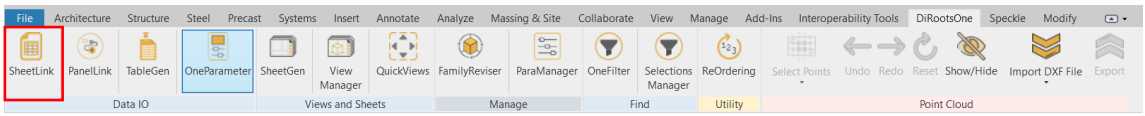


Figure 37. DiRootsOne plugin visualization in Revit 2023

Once we have installed the plugin, we can open it on Revit, click on “SheetLink” and export the schedules that we want. It will download the schedule as an Excel file and we can compile it as an usual Excel table. After finishing, we can import it again to the Revit model, using DiRoots, and it will automatically update all the data related to the schedule.

Some of the advantages of using “SheetLink” function are the following:

- Allows users to export, modify, and import data between Revit and Excel.
- Useful for managing schedules, sheets, and parameter data.
- Enables bidirectional editing, making it easy to update Revit elements from Excel and vice versa.

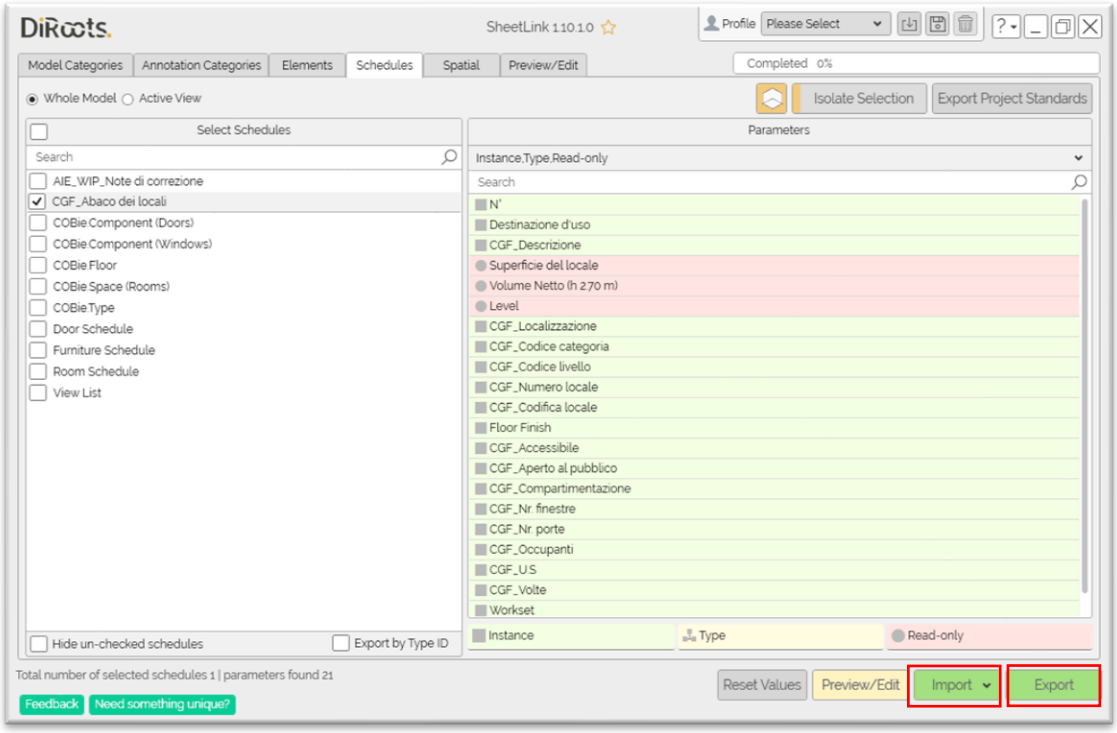


Figure 38. DiRoots - SheetLink - Allows to import and Export schedules from Revit

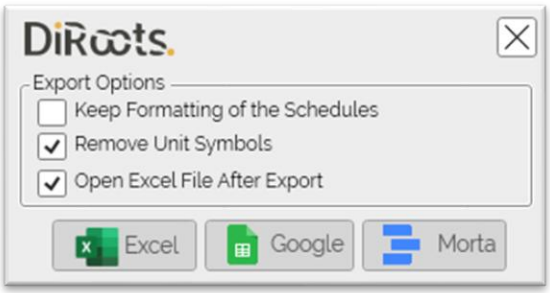


Figure 39. DiRoots Export Options

After clicking on the "Export" button, it is possible to choose in which format we want the schedule to be downloaded. In this case, I chose "Excel" and that automatically generated an Excel sheet relative to the "Rooms" schedule.

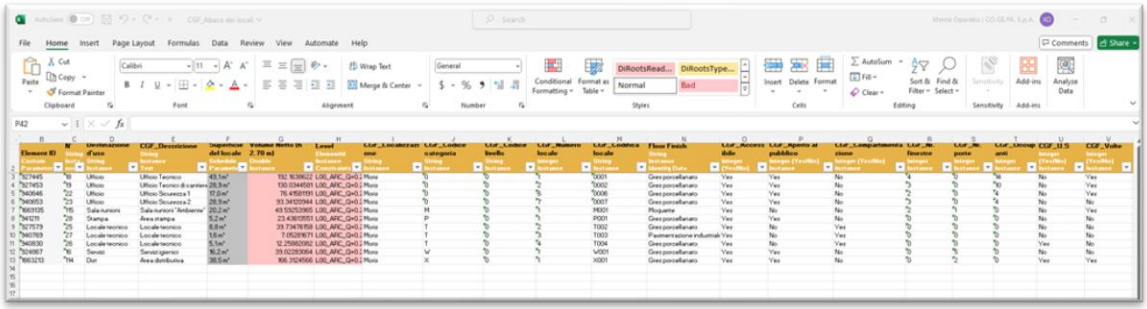


Figure 40. Excel table relative to the "Rooms" schedule after Export

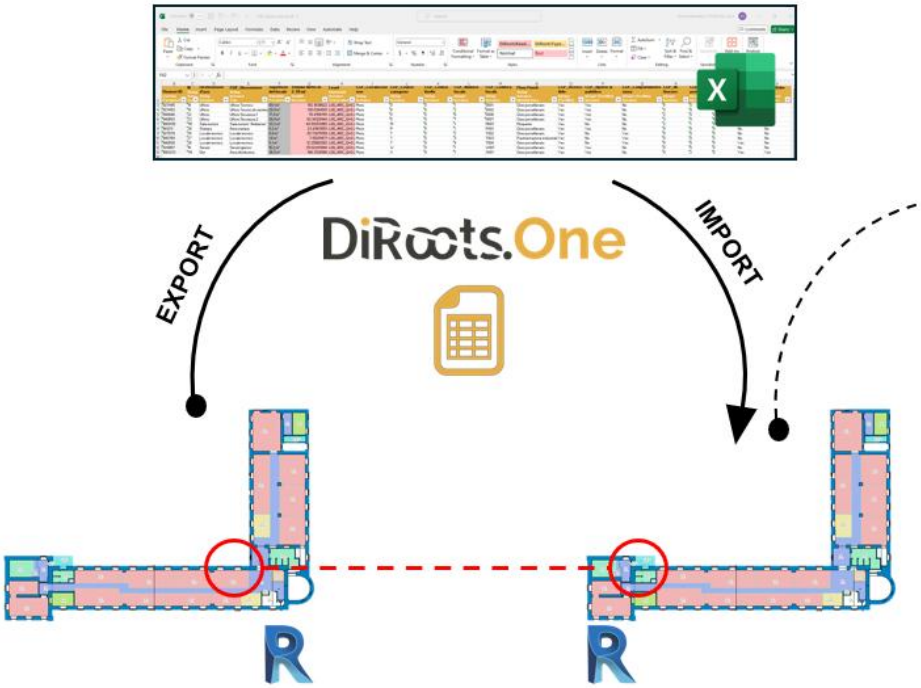
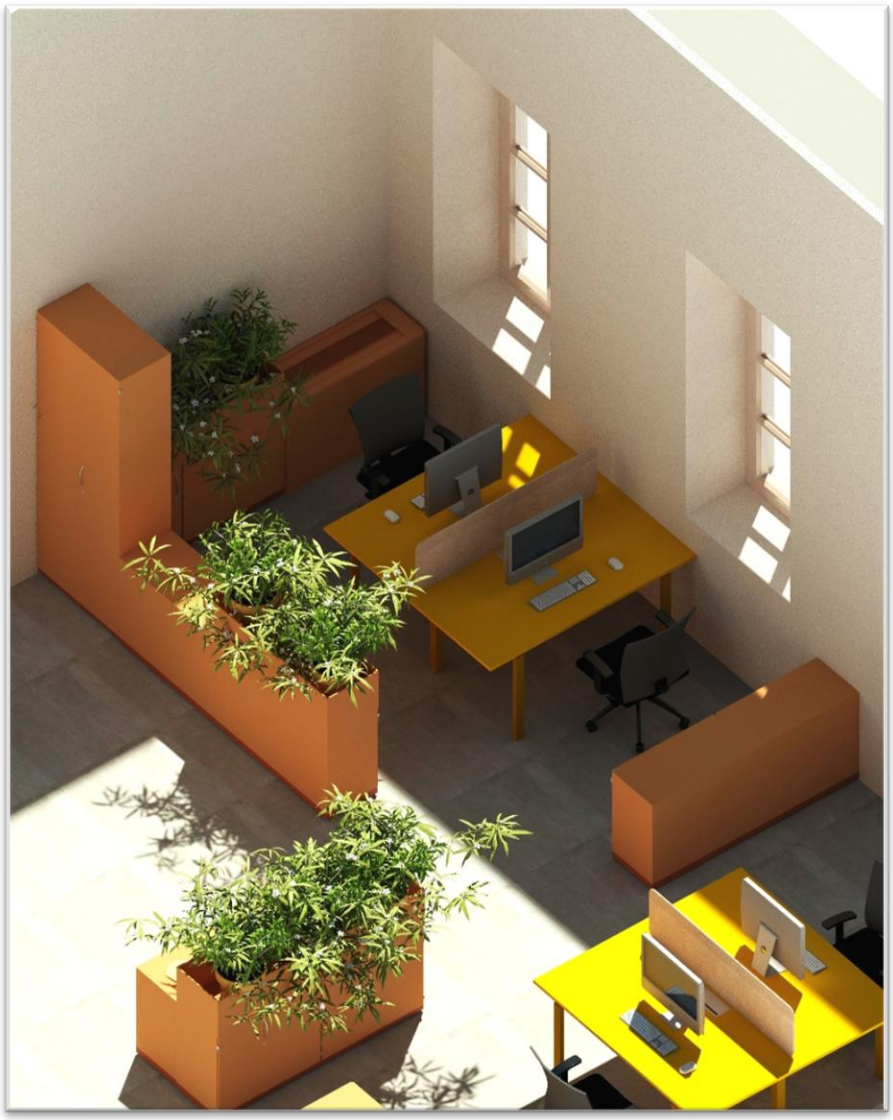
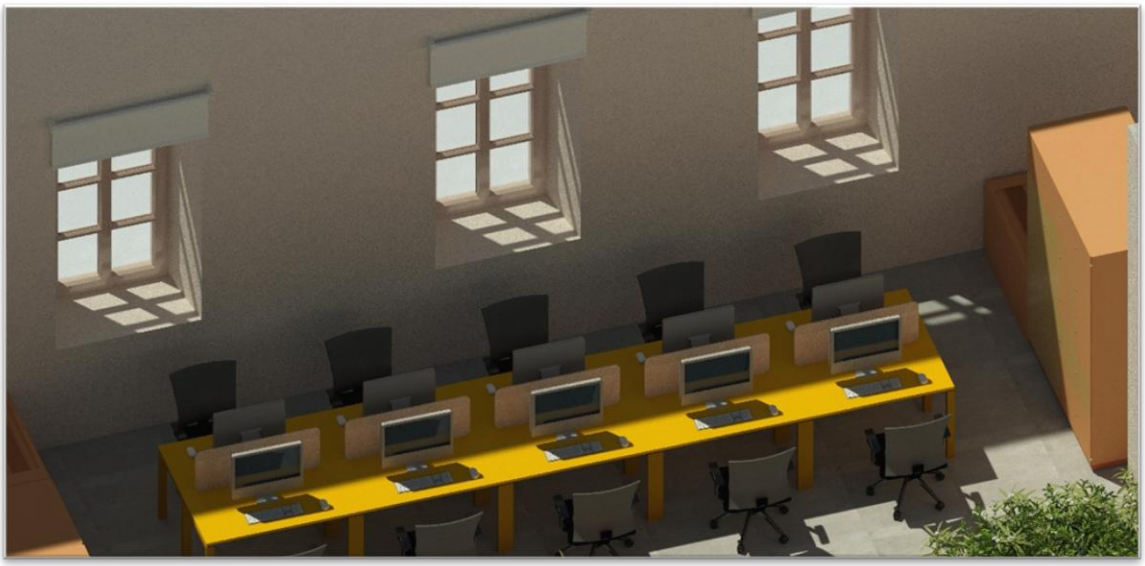


Figure 41. Schematic representation of DiRoots interaction with Revit

4.2.4. Furnished floor plan model

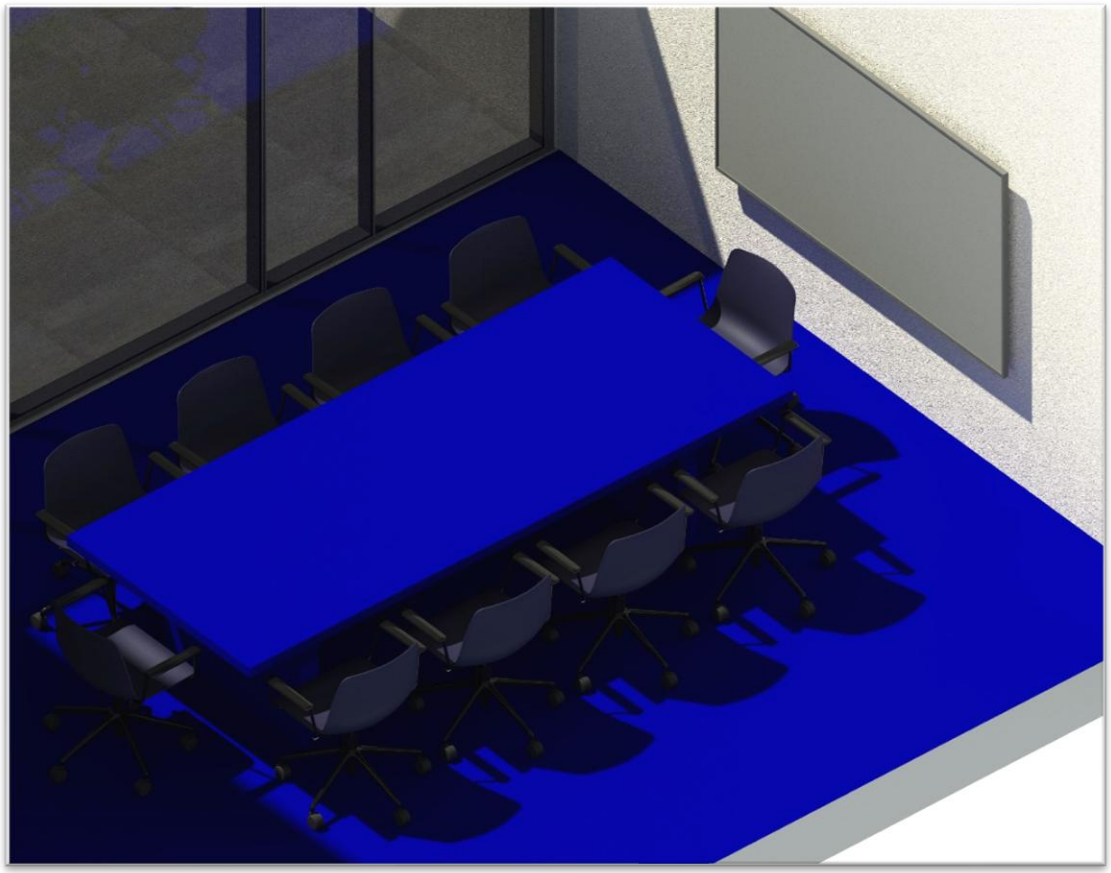


a)



b)

c)



d)

Figure 42.a) b) c) d) Different renders of the interior of Buon Pastore building

4.3. The COBie standard

With the Revit model of the building available-serving as an as-operated model specifically designed to function as a comprehensive database for maintenance purposes- I considered advancing further into the maintenance process.

Regardless of numerous researchers highlighting the benefits of integrating BIM and FM, there is limited evidence in the literature of standardized procedures and processes for BIM-FM integration, as well as documented tangible benefits. To address challenges associated with BIM-to-FM data transfer—such as issues with data interoperability, integration, and the reliance on manually re-entering data from paper-based manuals—the COBie (Construction Operations Building Information Exchange) standard was developed. [22] COBie is a vendor-neutral data exchange format, which can be delivered in various open file formats such as STEP, XML, and Spreadsheet. Currently, the most commonly used data transfer file format is spreadsheets because of the fact that most of the construction industry professionals are familiar with it. [22]

Figure 43. Figurative representation of COBie proposed by its developers

The COBie standard was developed by Bill East, a member of the US Army Corps of Engineers in 2007, within the Construction Engineering Research Laboratory. The objective of the project was to compact in digital form all that series of paper data regarding delivery and completion documents. In the following years East subsequently led the development of COBie through buildingSMART International. In 2011 it became part of the NBIMS-US[4], and a few years later it was also introduced in Europe, thanks to the BIM Working Party Strategy in the United Kingdom. In 2019 it also became mandatory in the USA, as an integral part of the documentation to be provided in document P-100

[4] NBIMS-US - National BIM Standard-United States

(The Facilities Standards for the Public Buildings Service). Also in January 2019 the UK National Annex to BS/EN/ISO 19650-2 states that exchanges of non-geometric information in open data formats should be structured in the COBie format. The COBie standard was therefore developed on the basis of North American and English legislation, and in Italy there is still no direct regulatory reference for the use of this standard. The use of this open bi-directional exchange format is based on improving the performance of facility asset information delivery (BEP, PIM, AIM). The main function of the COBie standard is in fact to facilitate the electronic compilation of O&M Manuals as well as the exchange of data with CAFM/CMMS [5] software without additional costs [22]. Data generation occurs through the use of applications with BIM authoring platforms (bi-directional interoperability), provided by the same software houses. These applications allow the integration of parameters within BIM models, allowing both export and import. The data can then be exported in various formats by users, namely: IFC STP, IFC XML, spreadsheetML & COBieLite. The standard IFC format is used in many cases, such as xml (required for delivery to the UK). However, COBie also adds specifications and templates for data collection/delivery based on a spreadsheet called spreadsheet, exported in .xlsx format. The simple structure of this spreadsheet makes it possible to participate in an openBIM workflow without any specific BIM tool and without knowledge of the IFC data model, simply using MS Excel to read the spreadsheet.

In simple terms, COBie is a spreadsheet that stores digital information on the materials and equipment of a building once it has been completed. It ensures that information essential for the operation and maintenance of a facility is systematically captured and shared. To make an overall review of the advantages of COBie, the main ones are:

- **Standardized Format**: COBie organizes building data into a structured, tabular format, making it easier to manage and interpret.
- **Maintenance Efficiency**: Provides detailed data on assets (for example manufacturer details, warranties, and maintenance schedules) enabling better planning and execution of facility maintenance.
- **Lifecycle Support**: Facilitates the transition of a building from construction to operation, ensuring that critical data is not lost or overlooked.

5 CAFM – Computer-Aided Facilities Management; CMMS – Computerized Maintenance Management System

- **Interoperability**: COBie is platform-independent and works seamlessly with various BIM tools and facility management systems, improving data sharing among stakeholders.
- **Reduced Miscommunication**: By standardizing information, it minimizes errors or misunderstandings during the handover process.
- **Reduced Data Duplication**: Eliminates the need for re-entering data at different stages, saving time and resources.
- **Minimized Operational Costs**: Provides accurate data for efficient facility operations, reducing long-term operational expenses.
- **Supports BIM Processes**: COBie aligns with BIM workflows, promoting a data-driven approach to project delivery and facility management.
- **Long-Term Usability**: By using an open standard like COBie, data remains accessible and usable regardless of software changes or advancements.

Fire-doors maintenance

I decided to focus on the maintenance of the fire doors present on the ground floor of the building, via Moris wing. My idea was to integrate the COBie standard, which is an international standard, with the Italian standard UNI 11473. The UNI 11473 standard is the regulatory reference point for installers and maintainers of fire doors (or REI doors).

Elenco attività ai fini della manutenzione

Attività	Frequenza	Circostanza	Documenti	Operazioni
PRESA IN CARICO	N.A.	Alla firma del contratto o come operazione preliminare alla 1° visita di controllo periodico	Verbale di registrazione della presa in carico	Verifiche
SORVERGLIANZA	In relazione al Documento Valutazione Rischi dell'attività	Secondo il piano di manutenzione redatto dal responsabile dell'attività	Registrazione di avvenuta sorveglianza e delle eventuali anomalie riscontrate	Controllo visivo
CONTROLLO PERIODICO[1)]	Almeno 2 volte l'anno con cadenza semestrale	Durante le uscite del manutentore, come da programmazione (vedere punto 7.3)	Compilazione del rapporto di intervento ed aggiornamento del cartellino	Interventi tecnici
MANUTENZIONE ORDINARIA	Occasionale in caso di lievi anomalie riscontrate	Secondo esigenza per riparazioni definite manutenzione ordinaria[a)]	Compilazione del rapporto di intervento (vedere punto 7.3)	Interventi tecnici
MANUTENZIONE STRAORDINARIA	Occasionale in caso di non conformità rilevate	Secondo esigenza per riparazioni definite manutenzione straordinaria[a)]	Compilazione del rapporto di intervento	Interventi tecnici

a) Per i criteri di sostituzione dei componenti vedere punto 7.2.3.
1) Le frequenze sono stabilite ogni 6 mesi dal Decreto 10 marzo 1998; le fasi di sorveglianza e controllo possono essere intensificate a seconda del rischio specifico riscontrato o delle indicazioni del fabbricante.

Figure 44. Table extracted from the UNI 11473 standard

Based on this table, I created some shared parameters which have been determined based on my thorough review of the relevant standard.

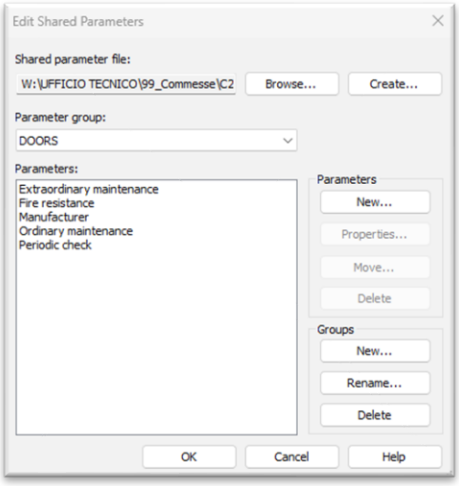


Figure 45. Shared parameters created based on the complete review of the UNI 11473

4.3.1. Compilation of the COBie standard

For what concerns the generation of the COBie standard of a complete BIM model on Autodesk Revit, it takes place via the "BIM Interoperability Tools" plugin (available for free download from the following website: *https://www.biminteroperabilitytools.com/*).

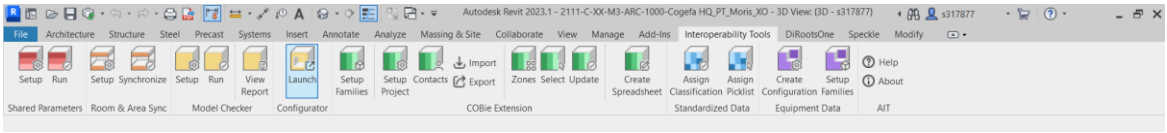


Figure 46. BIM Interoperability Tools 2023 tab within the Revit 2023 interface

Inside the plugin, as can be seen from the previous figure, we find the extensions "Standardized Data", "Model Checker" and "COBie Extension".

The procedure for assigning the COBie standard is as follows:

1. Applying one or more classification systems to the model (Standardized Data)
2. Model Checker
3. Setting up and generating the COBie standard (COBie extension)

By following the configuration of the ribbon, it is therefore possible to carry out all the steps necessary for the correct compilation of the COBie standard.

Assignment and compilation of classification systems

The first step consists in the application of a classification system. The classification systems are defined by the ISO 12006/2015 standard and are included within a BIM order for the definition of LOINs[6]. The standard proposes a series of tables in which it shows the possible applications of various types of systems and their organization, which can be summarized in two large categories, namely classification by form or classification by function. There are two major classification systems valid at an international level.

- **OmniClass**, American classification system, divided into MasterFormat (for the product of the processes) and UniFormat II (for the elements).
- **UniClass**, English classification system.

Both systems are organized through a series of tables that select data depending on the function of the system. In Italy the classification system adopted is that of the UNI 8290-1/1981 standard, which is applied manually in the project.

For our case study it was decided to adopt the American classification system, as it is more complete as it includes two classification systems, and as Revit already has a predisposition for the application of this system. In fact, the family categories already have the OmniClass number and the title OmniClass, which define the highest level of hierarchization of the classification system.

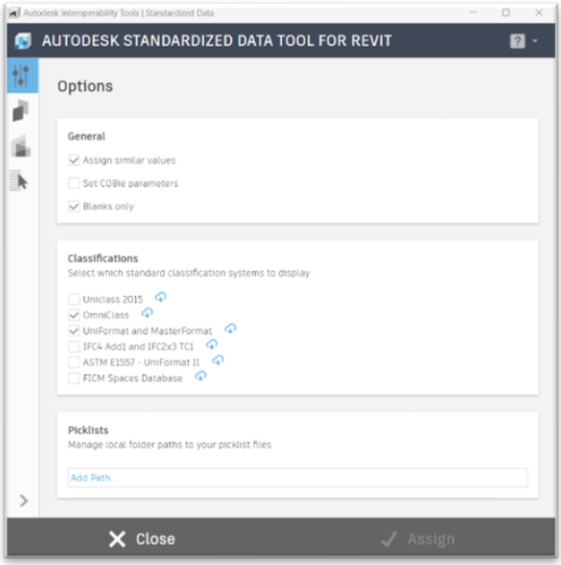


Figure 47. “Setup” screen, Standardized Data Tool for Revit

The application of the UniFormat and MasterFormat classification systems is supported by Revit, which inserts the OmniClass number and title into the family parameters within the "Identity Data" group. This parameter is tied to the family category and allows the Classification Manager within the BIM Interoperability Tool to read the OmniClass code. OmniClass compilation codes are instance parameters, with names

6 LOIN - The Level of Information Need (LOIN) is the evolution of the concept of LOD and represents the level of information considered necessary for the project.

created based on the classification system selected in the "Setup" screen of the Standardized Data Tool.

The previous screen contains a public library from which various classification systems can be selected, including UniClass.

To assign the correct classification code to instances we should first select an instance. Then, in the "Assign" screen, the correct code can be chosen, and by clicking "assign," the code will be applied to all appropriate instance parameters

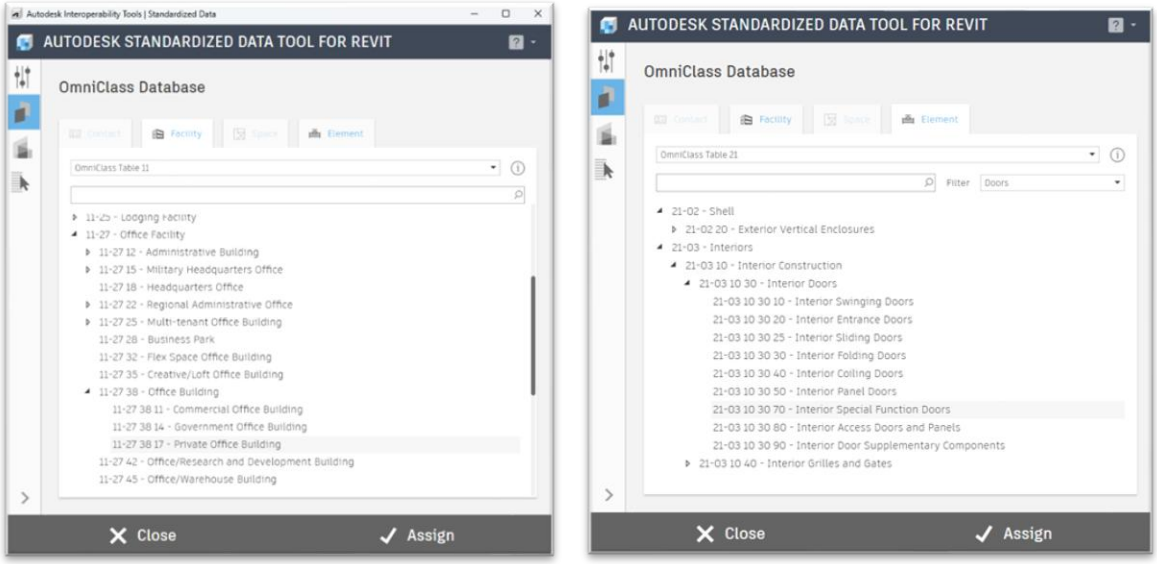


Figure 48. Assignment of classification to Fire Doors

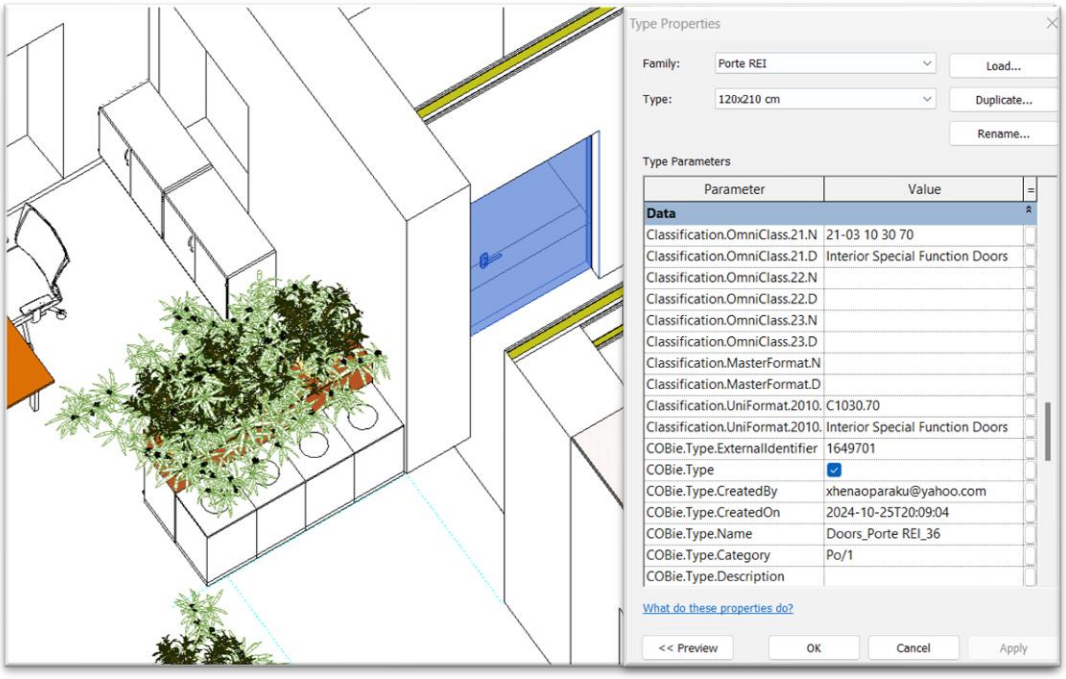
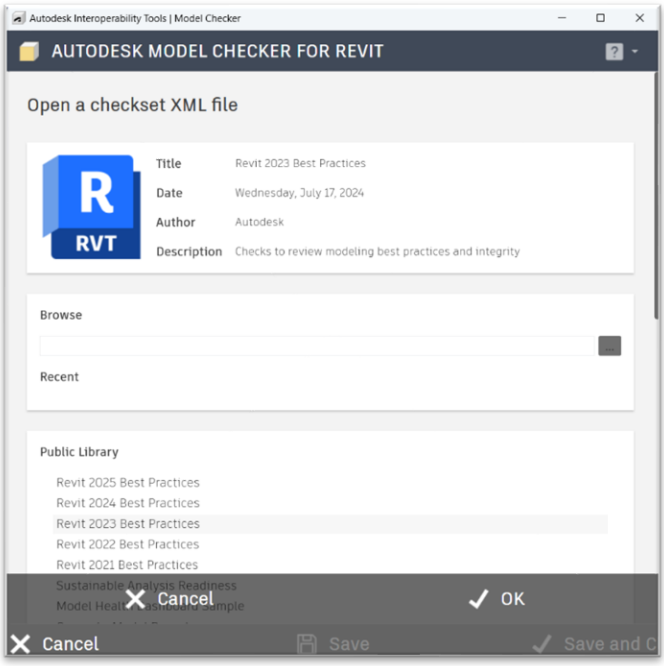


Figure 49. Assignment screen and the related values that appear in the properties

Model checker

The next phase involves checking the model using the model checker application. By clicking on the setup button, we access the application configuration. Here it is possible to access a public library of control standards (Public Library) in which there are various standards, almost all applicable to the Anglo-Saxon market (in particular the versions of Revit, called Best Practices).



These verify that the model is developed according to precise inputs, in order to avoid problems during the delivery phase. The checking tool is certainly one of the most valid in the hands of the BIM Manager, as it checks for inconsistencies in a systematic manner, entrusting some of the most critical activities of the professional figure to the same software.

Figure 50. Principal screen Model Checker for Revit

For our case study, the Revit 2023 Best Practices standard was chosen, in line with the software used for modeling. Once selected from the library it is possible to set the checking phases from the drop-down menu. External files, families of other disciplines (as they were not present) and annotative elements were excluded from checking. Only the Arch System Families are selected, as the element that we are taking into exam is part of this family.

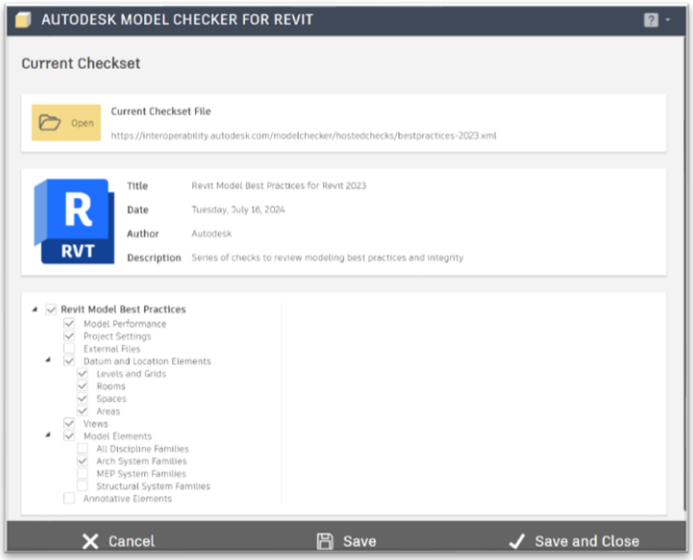


Figure 51. “Select best practices” screen, Model Checker for Revit

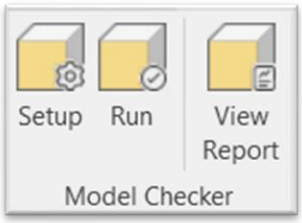


Figure 52. "Run" button

The next step is to click the "Run" button on the ribbon. The model checking start screen will appear here, which allows the generation of a Report in which the inconsistencies with Autodesk standards and the integrity of the file are verified.

Once we click on "Run Report", the application will check for inconsistencies, the result of which is displayed in the "View Report" screen in the ribbon bar. The generated report prominently displays a percentage assessment of whether the model matches the selected standard. Below is the check carried out on the 2111-C-M3-ARC-1000-Cogefa HQ_PT_Moris_XO file.

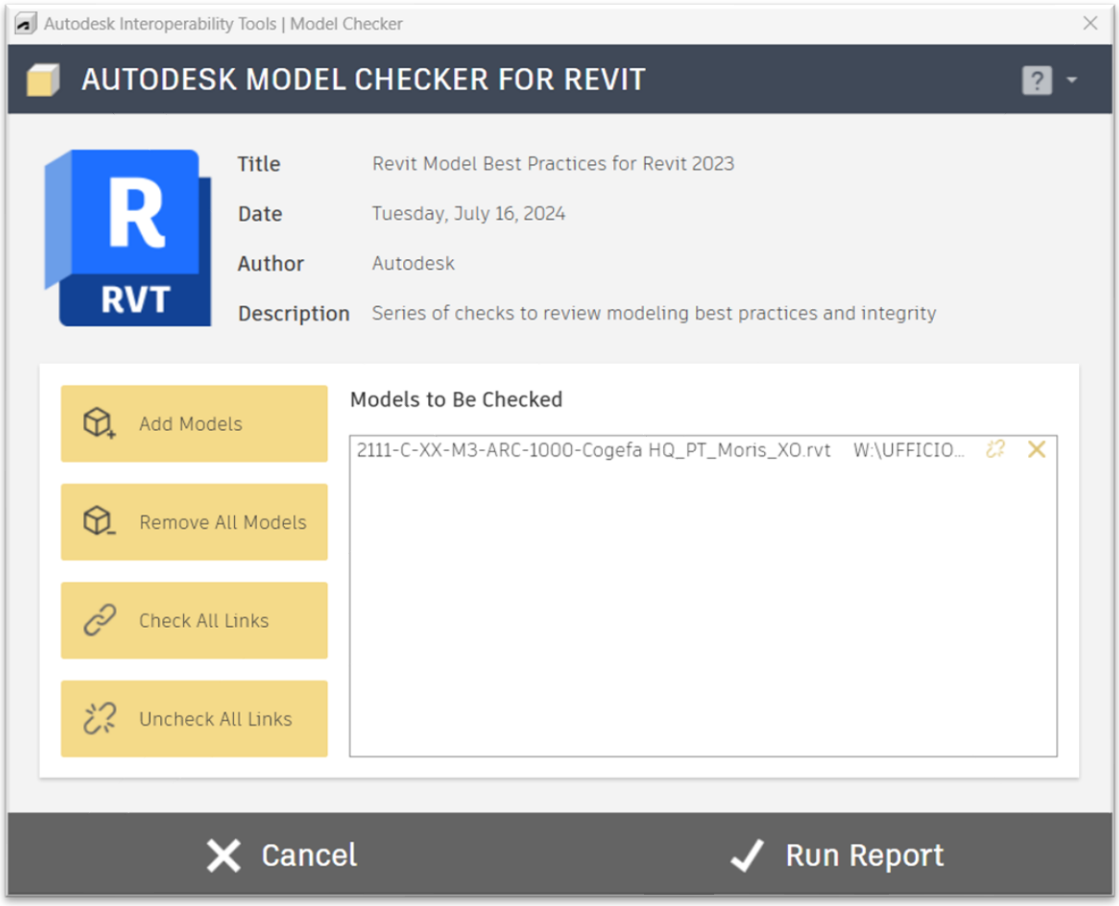


Figure 53. Screen of "Run Report", Model Checker for Revit

The result achieved, equal to 83%, is analyzed below at every point, which can be accessed via the drop-down menus at the bottom of the screen.

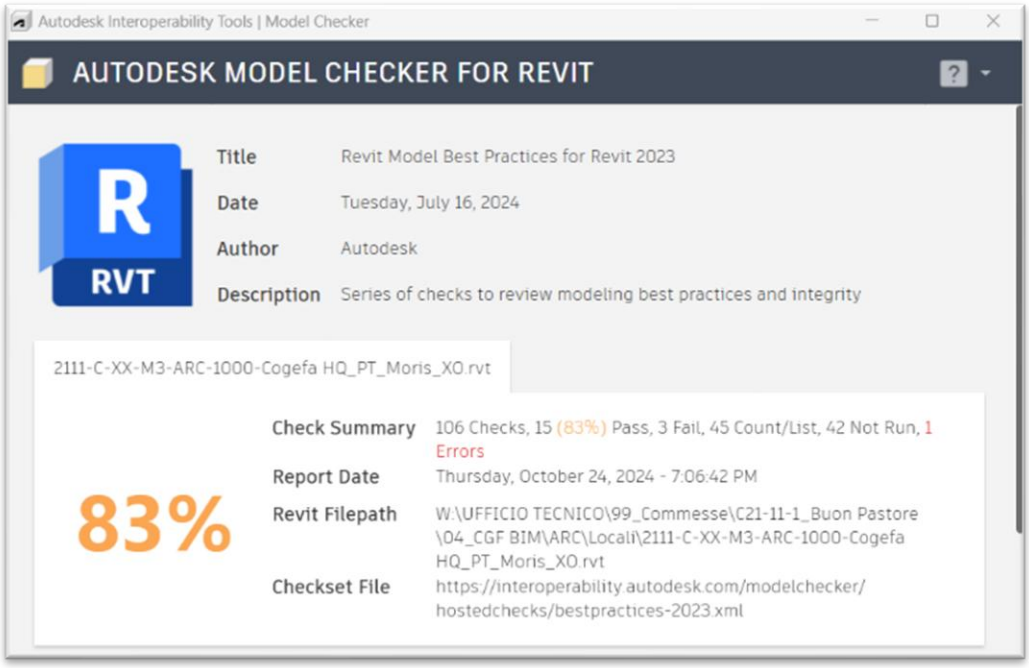


Figure 54. Screen “View Report”, Model Checker for Revit

The first item listed in the "Revit Model Best Practices" list is "Model Performance". This item does not affect the calculation of the percentage, as it analyzes the model in its entirety. The data shown here illustrates a useful global overview of the BIM model, from its size to the number of families modeled in it, as well as the count of Warnings messages. This first item is very useful to the modeler as it allows us to keep under control the major critical issues that would lead to non-approval of the model in the final stages of a BIM order.

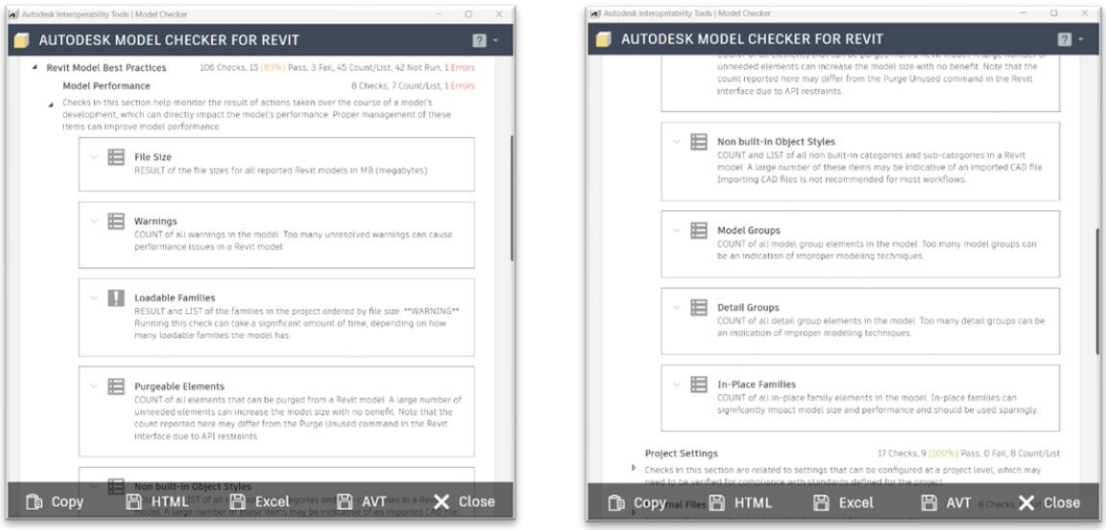


Figure 55. Model Checker - Model Performance

The second item in the list instead reports a breakdown of the evaluation of the project settings. The individual parts analyzed do not influence the calculation of the percentage.

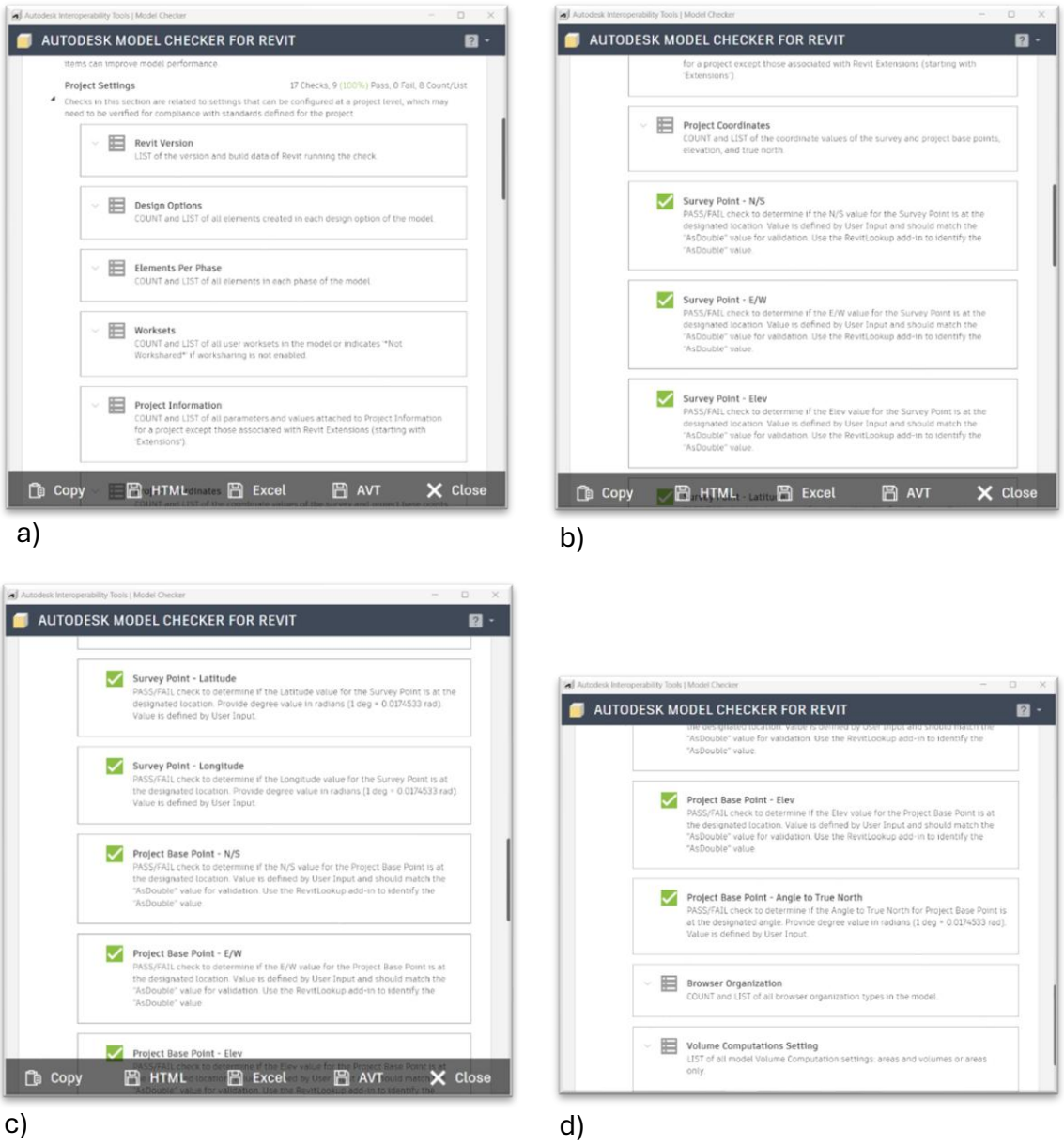


Figure 56.a) b) c) d) Model Checker - Project Settings

The next item concerns the analysis of external files, which as previously specified has been chosen not to deal with.

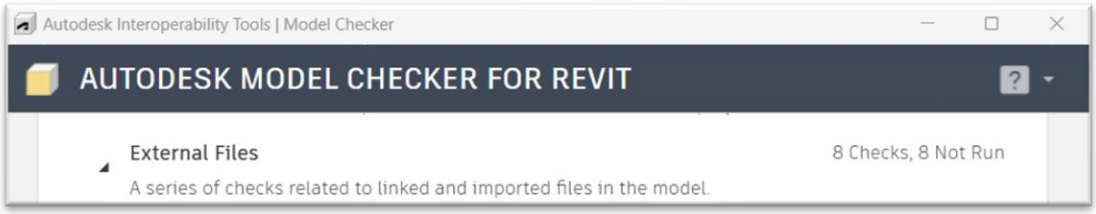


Figure 57. Model Checker - External Files

We then proceed with the analysis of the fourth item, entitled "Datum and Location Elements". This part contains an analysis of the correct assignment of levels, rooms, spaces and areas.

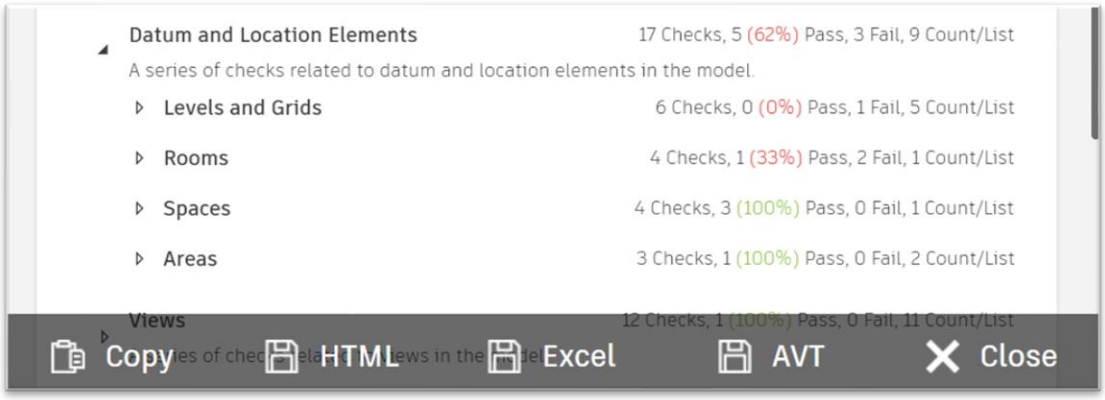


Figure 58. Model Checker - Datum and Location Elements

As can be noticed, have been verified three errors, two of them connected to the levels and grids and the third one connected to the rooms. We can open the table related to each of these elements and understand better what the errors stand for.

- Levels and grids:

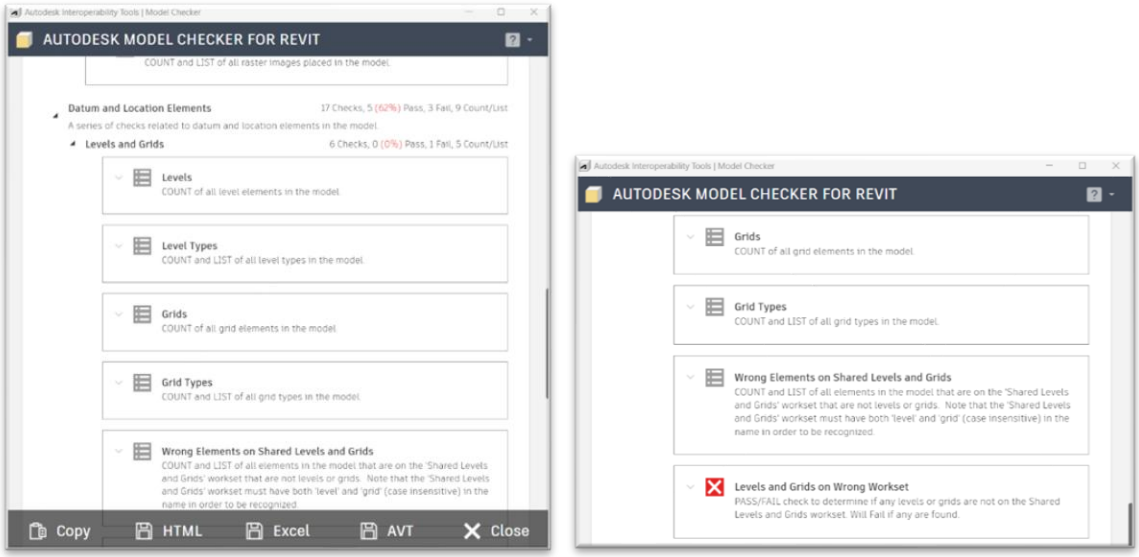


Figure 59. Model Checker - Levels and Grids

In this part the application analyzes the correct setting of the levels and grids, verifying their correct assignment to the "Shared Levels and Grids" workset. In fact, in best practices, Autodesk recommends inserting all layers and grids into a separate workset, so that they can possibly be shared or deactivated in other models.

➢ Rooms:

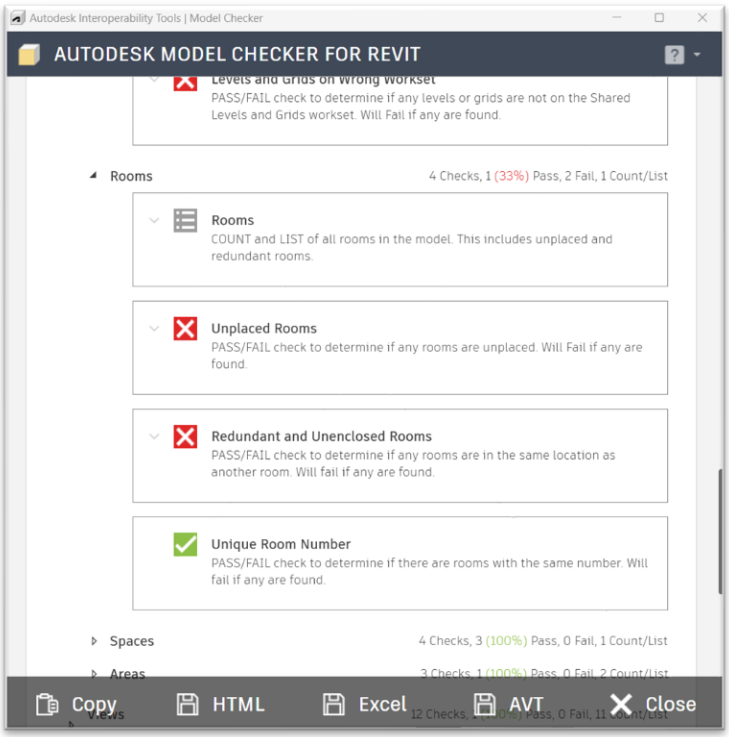


Figure 60. Model Checker - Rooms

For what concerns the rooms, the Model Checker has verified errors related to the fact that there are unplaced rooms, unclosed or redundant. This is due to the fact that the ground floor of the building, where we have focused our analysis, is organized as an open space, there are not many walls to divide the different rooms one from another. For this reason, there has been used the "room separator" command, which needs to be very precise to avoid unclosed rooms. We need to check the room separators placed in the model.

The fifth item of the form examines the views, checking a series of data associated with them that are very important from the point of view of managing the information model. Here too we find a best practice suggested by Autodesk, namely the creation of a specific 3D view for export to Navisworks, called "Navis".

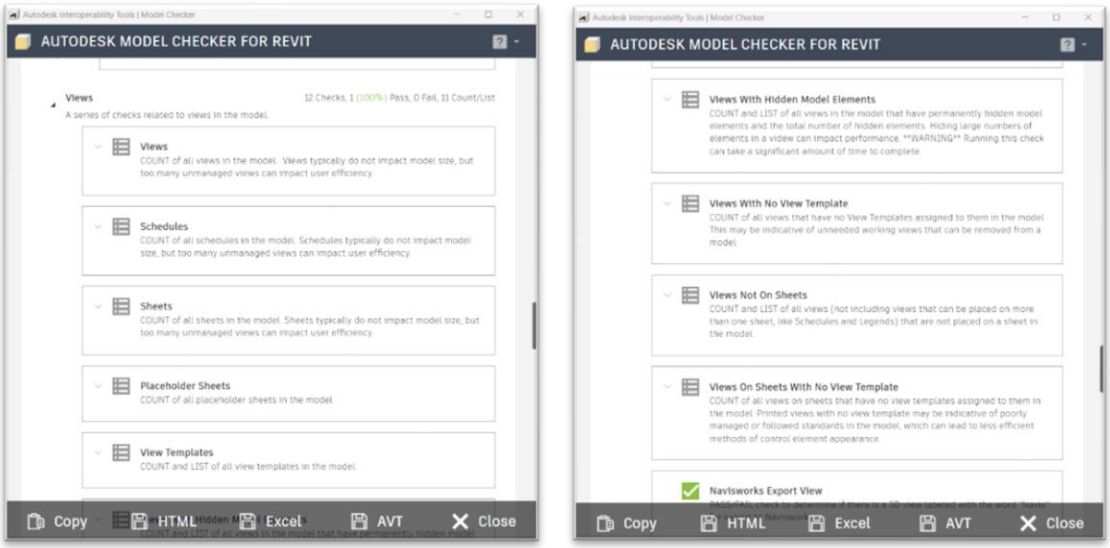


Figure 61. Model Checker - Views

The sixth and last item (since the seventh "annotative elements" has not been selected) concerns the analysis of the elements (i.e. the instances) of the project. It is the part that has the greatest impact on the percentage evaluation of the congruence of the model.

We should focus only on the ARC family, because for the other ones we decided not to check them and as a result they haven't been run.

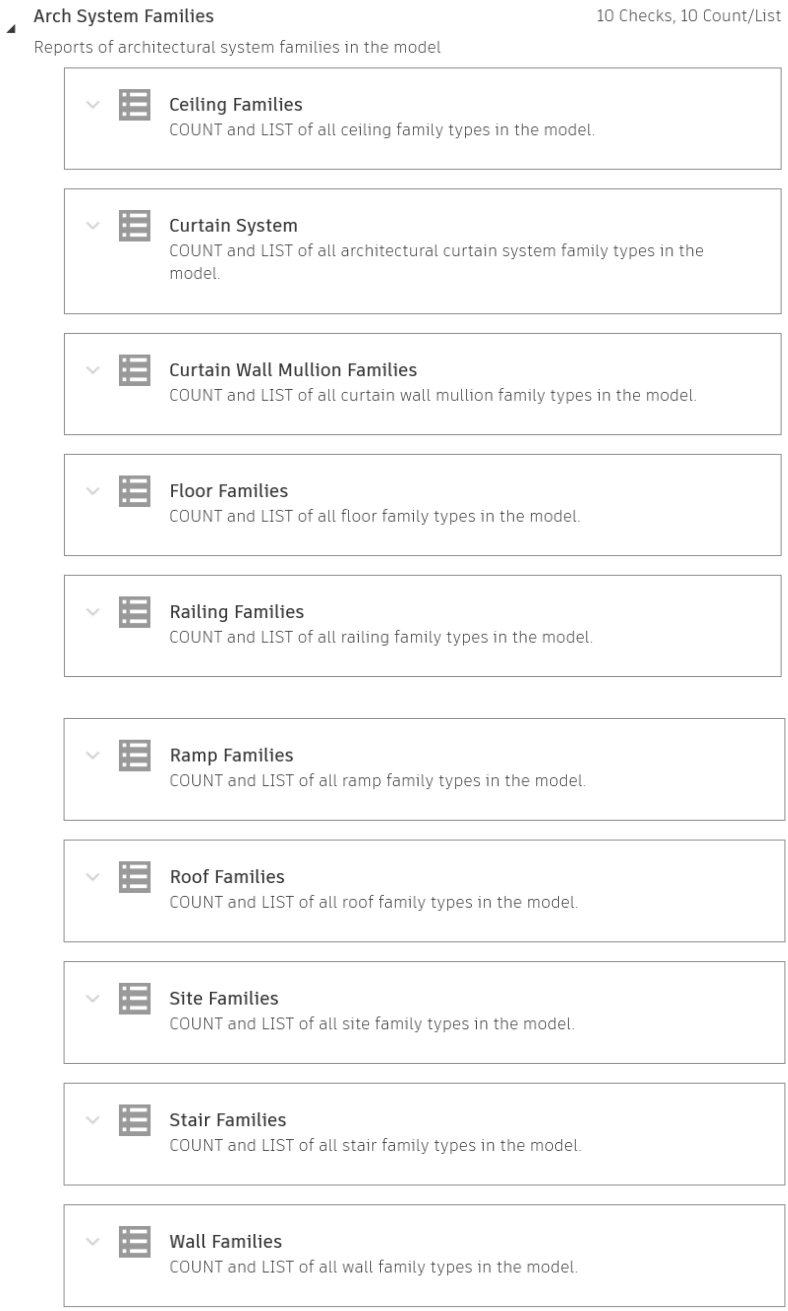


Figure 62. Model Checker - ARCH system family

COBie extension

Once the model checking has been completed and verified to ensure that the information model complies with the agreed standards, the process of defining the COBie standard can begin. The structure of the spreadsheet in .xlsx format, the end goal of generating the standard, consists of a series of tabs that the user can modify according to specific needs. The tabs are organized as a list of items, with characteristics described in columns whose values are type/instance parameters within the Revit file. Everything in the first column represents a component of the BIM model, while everything in the other columns represents values defined by the user through type/instance parameters set via the COBie extension application, manually or through scripting.

The tabs within the spreadsheet are as follows:

- **Instruction**: Contains instructions for using the file.
- **Contact**: Manages all contacts within the project.
- **Facility**: Dedicated to coding the BIM model.
- **Floor**: Contains all levels and their characteristics.
- **Space/Zone**: There must be at least one tab dedicated to spaces or zones to identify the location of instances.
- **Type**: Contains the complete list of all types and their coding.
- **Component**: Contains the complete list of all instances and their coding.

The COBie extension application, found within the BIM Interoperability Tools tab, presents a series of buttons, which represent, in sequence (similar to the Model Checker application), the procedure to set up, apply, and generate the COBie standard.

The first button, "Setup Families" is the first step in defining the COBie parameters. These are type parameters that are created within each family, and which allow the application to compile the standard. They can be modified both directly from the individual instances and from the specific schedules that the application generates.

The second button, "Project Settings", allows the general setting of the spreadsheet, divided into 9 panels accessible at the side of the screen. The first panel, "Setup General", shows the general settings of the COBie standard. It can be noted that only the USA and UK are available as locations, as this standard is rarely applied to the European market.

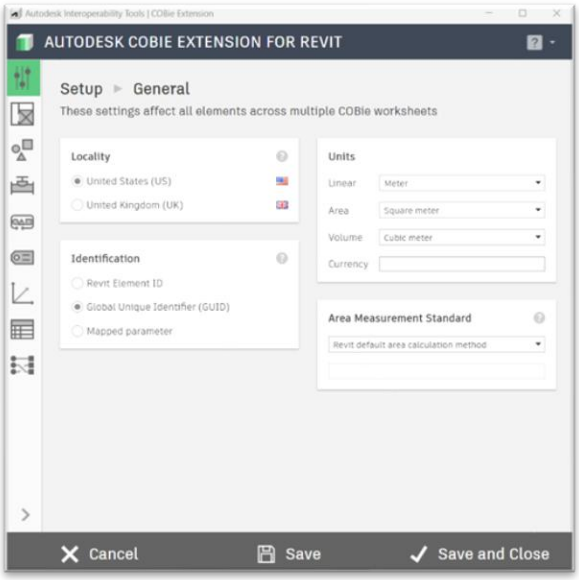


Figure 63. COBie Extension - General Setup

Since the UniClass classification system had already been used, it was therefore decided to choose the United States as the location, however setting the metric unit of measurement system. The Identification point refers to the setting of the automatic compilation of the "COBie.Type.ExternalIdentifier" parameter, a parameter set automatically by the application using the default Revit Element ID (progressive ID number of each instance), a code generated by the application (GUID) or a parameter set by the user, such as the identification code in our case.

The second panel of the "Project Settings" button has the function of choosing how to identify the position of the components, via Room or Spaces. The difference between the two consists in the fact that the Rooms belong exclusively to the architectural discipline,

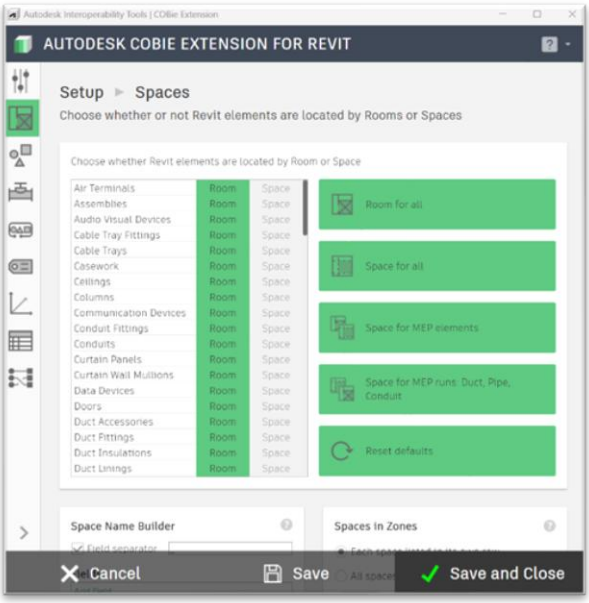


Figure 64. COBie Extension - Spaces Setup

while the Spaces are dedicated to the calculation of volumes in the MEP context. As we are working on an Architectonic model, we choose Rooms. By clicking on "Room for all" the rooms were used to identify the location of all instances in the project. It is also possible to select the nomenclature method of the rooms and their arrangement in the spreadsheet (spaces in zones).

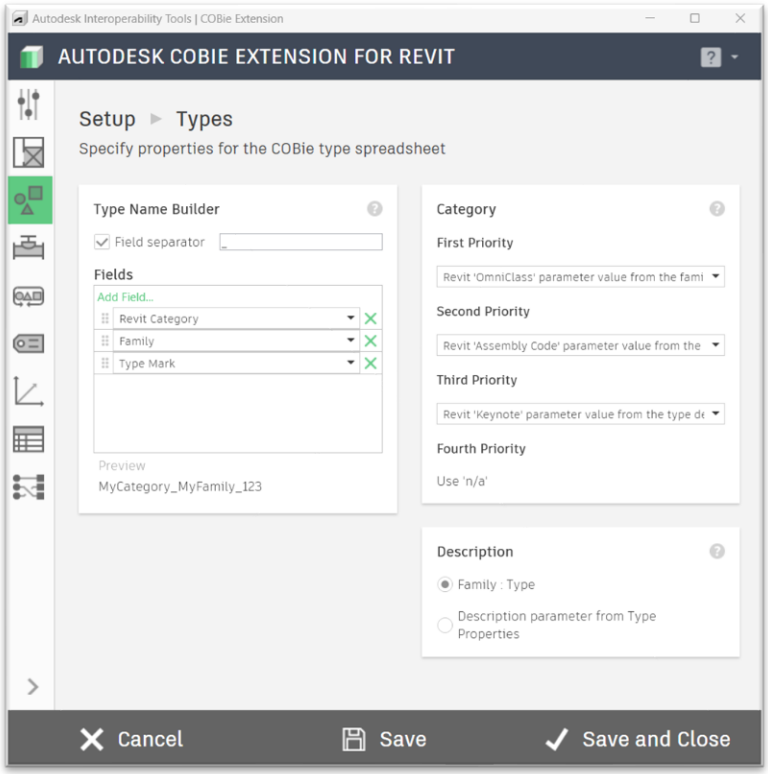


Figure 65. COBie Extension - Types Setup

The third panel consists of calling up the "Setup Families" button to the first screen. previously described. The panel takes care of setting the Type tab within the spreadsheet. From here, however, it is not possible to select the assignment of type parameters to families.

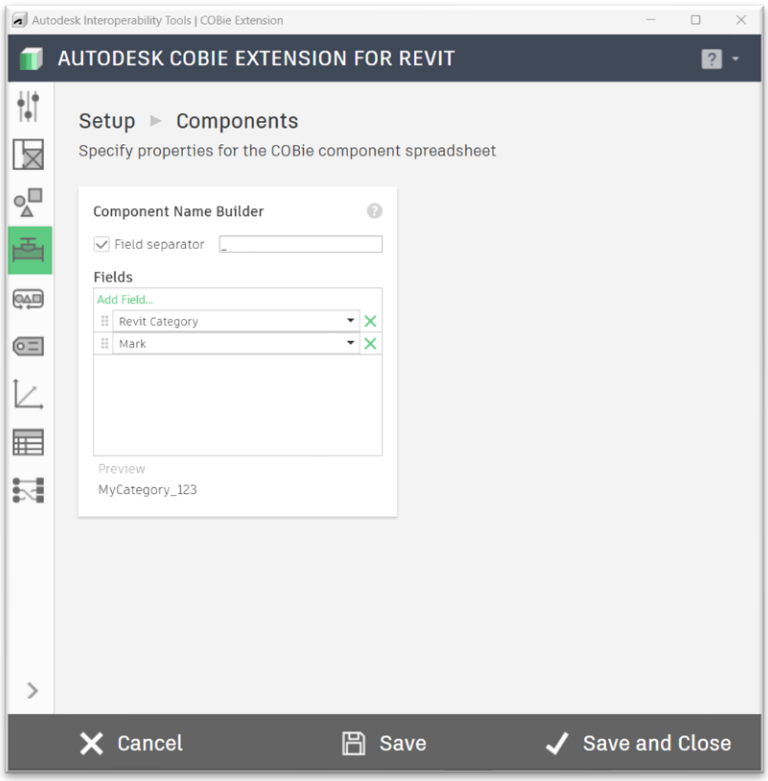


Figure 66. COBie Extension - Components Setup

The fourth panel is dedicated to the nomenclature of the MEP elements in the "component" tab of the spreadsheet. This tab contains all the instances of the model's MEP categories, the name can be set according to the user's preference. I chose to leave the default setting, i.e. "Model Category/Mark".

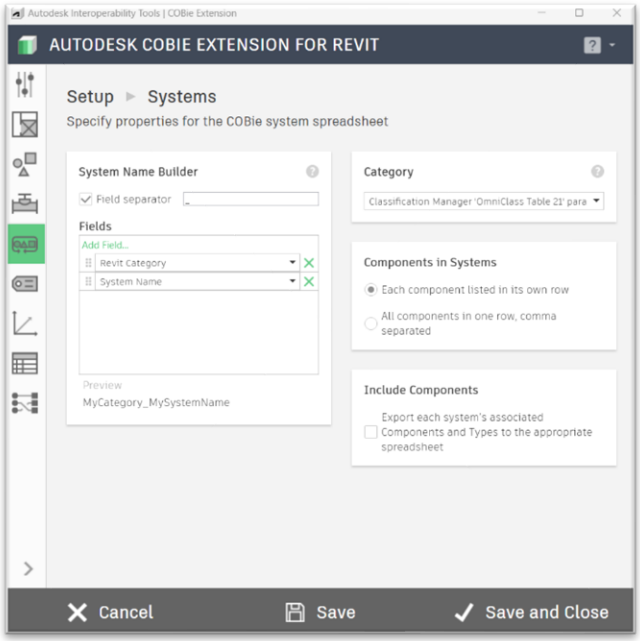


Figure 67. COBie Extension - Systems Setup

The next panel is about setting up the "System" tab within the spreadsheet. In fact, inside the Excel file there is a tab specifically dedicated to the systems. In the panel, the naming method of the systems and their category can be set, the name of which can be defined via a classification system or with its own system. Furthermore, we chose to group all the components of a system by selecting the appropriate box in "Components in Systems".

The sixth panel allows the import of parameters that are not part of the default COBie standard into the spreadsheet. These can be selected in the appropriate menu which represents a model breakdown structure of the type and instance parameters. It was decided to add the shared parameters that we created before.

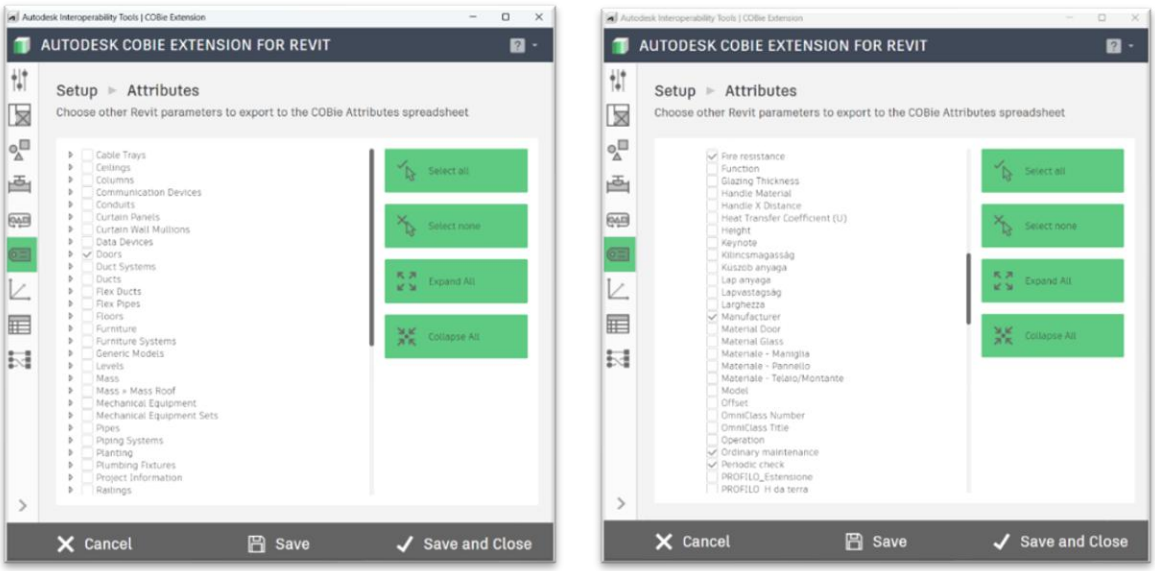


Figure 68. COBie Extension - Attributes Setup

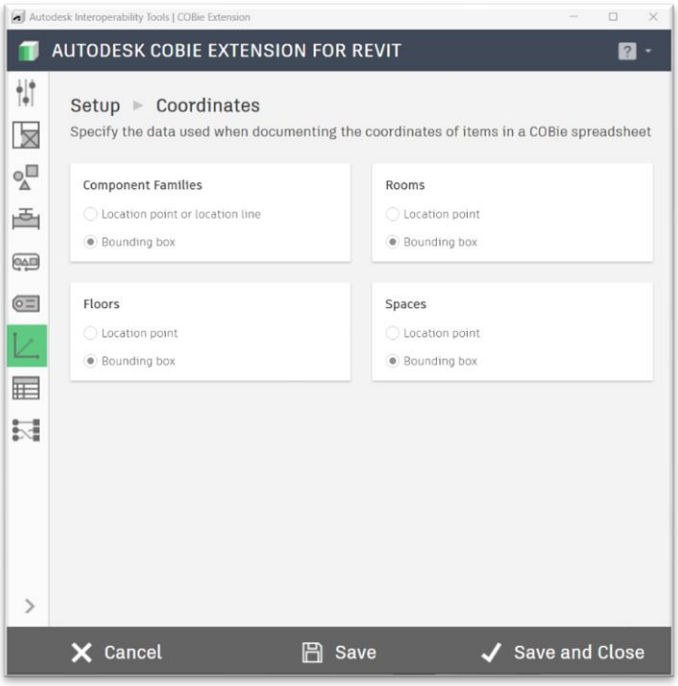


Figure 69. COBie Extension - Coordinates Setup

The seventh panel allows us to set the "coordinates" tab within the spreadsheet. This tab lists all the instances of the project with their respective coordinates, reported according to the global coordinate system (Location Points) or with respect to the Bounding box, i.e. a parallelepiped of such volume as to contain the instance, represented by the Bounding Box XYZ class at internal of the Revit environment. The Bounding Box has three properties: Min, Max and Transform. The Min and Max values are two points that represent two opposite corners of the parallelepiped, while Transform represents the rotation of the model with respect to the global Cartesian reference system. I chose to use the default setting, i.e. Bounding Boxes, as this system possibly allows the use of the file for clash detection operations.

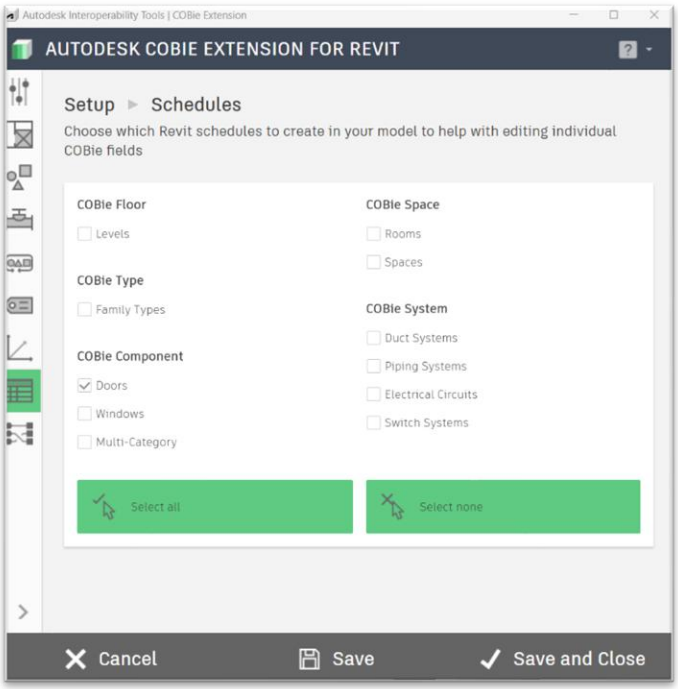


Figure 70. COBie Extension - Schedules Setup

This panel is dedicated to setting the optional tabs contained in the spreadsheet. By checking the various options, we can choose whether or not to generate a card. The options are divided into Floor, Type, Components (instances), Space and System. Since I decided to apply the COBie standard only on the Fire Doors' maintenance, it was chosen to generate the sheets which belong only to this component "Doors".

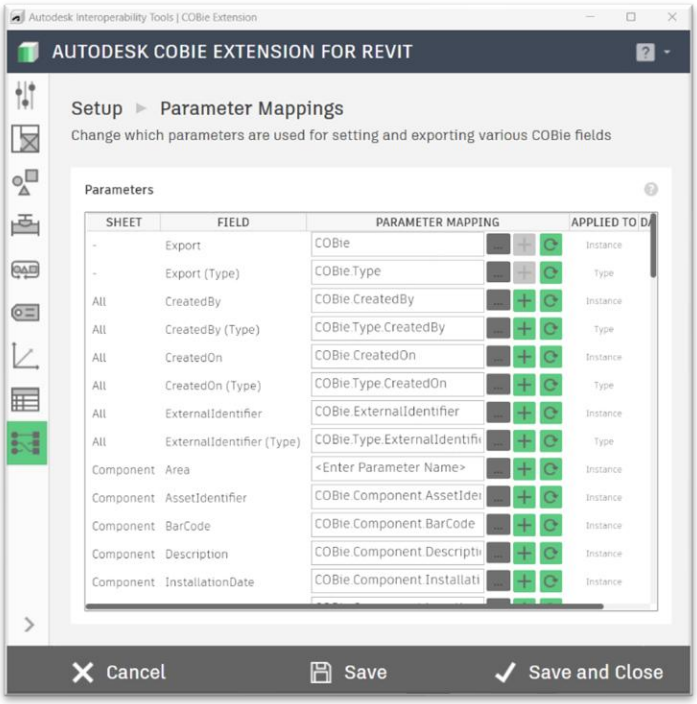


Figure 71. COBie Extension - Parameter Mappings Setup

The last panel, "Parameter Mappings" is finally the setting of the actual parameters, i.e. the content of the individual spreadsheet tabs, represented by type/instance parameters within the Revit model. Here we can set all the parameters, both mandatory and optional, that will be applied to the instances/types. As previously stated, these are represented in the spreadsheet by the column names of the individual cards.

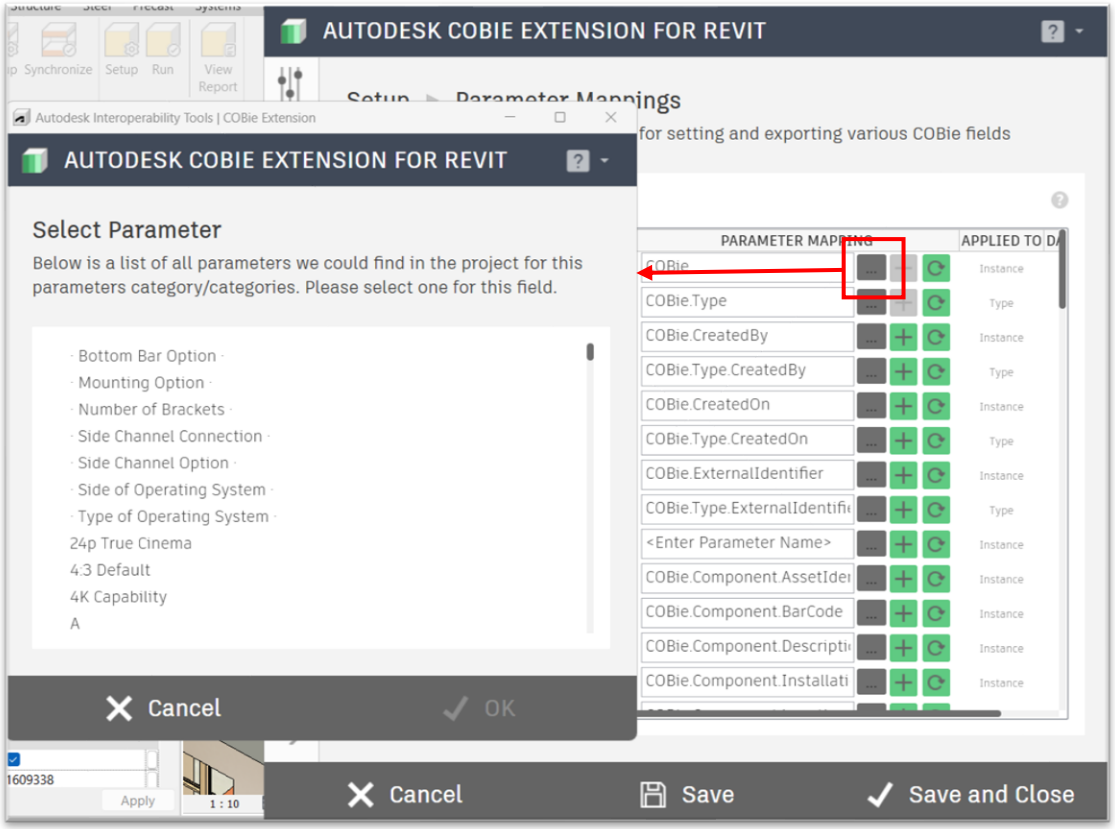


Figure 72. COBie Extension - Dialogue window for Parameter Mapping

By clicking on the three-dots symbol beside each parameter, a dialogue window will open automatically in which are listed all the parameters present in the project. Subsequently, we can choose which one to “map” instead of an existing parameter of COBie.

My intention was to "map" inside the existing parameters of COBie the shared parameters that I created before, based on the Standard relative to the Maintenance of the Fire Doors, i.e. UNI 11473. The parameter mapping should be done following logical reasoning. It ensures that data from Revit's properties and shared parameters populate the correct fields in the COBie structure. For example, in the list of COBie parameters there is a parameter named "Serial Number". If I don't want this parameter to be populated by the serial number of the element, I can create a shared parameter named "Sample Designation Parameter" and map it to the previous one. The parameters that I wanted to map inside COBie weren't compatible to any of the existing parameters of COBie. Anyhow, if I tried to map them to a random parameter, COBie allowed me to do so, even though the result would have been not correct.

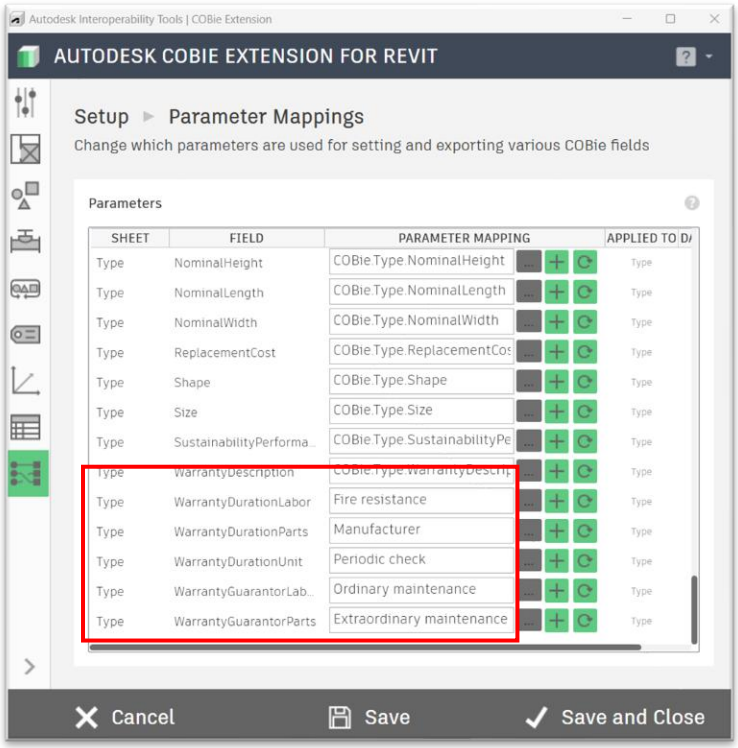


Figure 73. Example of parameter mapping

In this example, I have mapped my shared parameters to some COBie parameters which are not related to them. For instance, by doing so I would have a COBie schedule, where in correspondence to the column named "Warranty Duration Labor" I would find the values of the parameter "Fire Resistance".

That's the point where I started thinking about the weaknesses of the COBie standard and tried to present them in a summarized way.

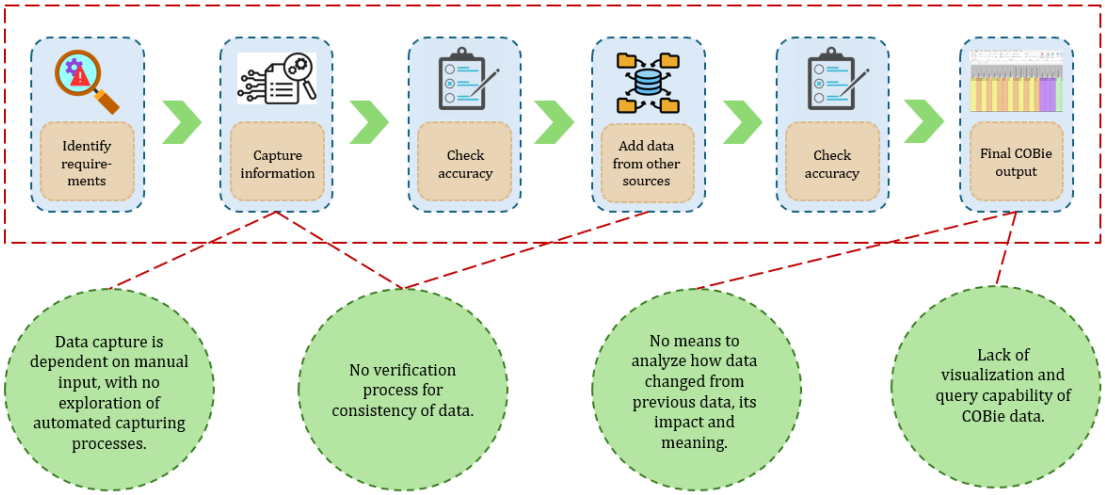


Figure 74. Challenges in COBie - data capturing and delivery process

Data capture is a critical aspect of a COBie deliverable. While some of the data in the COBie datasheet is sourced from the BIM model, a significant portion must be manually entered across multiple worksheets. This manual entry process is error-prone and can lead to data duplication, resulting in mismatches between the BIM model and the COBie datasheet. Moreover, manual data entry often fails to preserve the relationships among data points in the COBie workbook. This lack of automation has significant implications. Users must continuously check for data consistency and identify errors, adding to the workload. [22]

Data Consistency has been pointed out as one of the biggest issues in COBie. These inconsistencies often stem from COBie's allowance for data modification after being exported from BIM software. Such errors may include data deletion, missing data dependencies, unintended data changes, or incorrect data formatting. It is crucial to approach the COBie datasheet not as an isolated dataset but as a progressively evolving resource. This perspective highlights the importance of tracking and validating data changes to maintain consistency and reliability in COBie datasets. [22, 24]

Data Changes is related to the fact that as the project progresses, updates are made to the existing data. However, data within the COBie framework can undergo significant changes between phases. These changes may include the deletion, addition, modification of values, or alteration of relationships within the COBie datasheet. Despite this variability, such issues with COBie have not been thoroughly addressed in previous studies. The primary purpose of COBie data drops-periodic generation of COBie

datasheets-is to monitor data consistency, analyze changes, and identify discrepancies. However, this approach does not effectively focus on tracking and interpreting these changes to derive meaningful insights. To fully leverage the COBie data drop process, it is essential to go beyond merely verifying data. Instead, it should be understood as a dynamic process that captures how project data evolves and identifies whether data recorded in one phase is missing in subsequent phases. This is particularly crucial since COBie integrates data extracted from both BIM models and external sources. [25]

Data Visualization: The lack of effective visualization and query capabilities has been identified as a significant challenge in handling COBie datasheets. Previous works have not adequately addressed the dynamic nature of COBie data or the need to visualize changes within it. Treating the COBie datasheet as a static and independent entity overlooks the importance of capturing patterns and changes across multiple data drops. Visualizing these patterns and changes is critical for understanding how project modifications impact COBie data. [22]

Following this analysis, I decided to adopt a slightly different strategy for the maintenance of fire doors. I realized that using COBie as the sole outcome was not the most appropriate approach for this case, as I aimed to incorporate the principles outlined in UNI 11473 as well.

Consequently, I opted to utilize the COBie-generated results as background information. Specifically, I exported the table containing all parameters generated by COBie based on the input data I provided. From this, I selected only the parameters that I deemed most significant and used them to create shared parameters in Revit. This approach enabled me to produce a Doors' Schedule that integrates parameters aligned with UNI 11473 alongside those derived from COBie.

This revised strategy resulted in a more comprehensive and accurate maintenance plan for the fire doors.

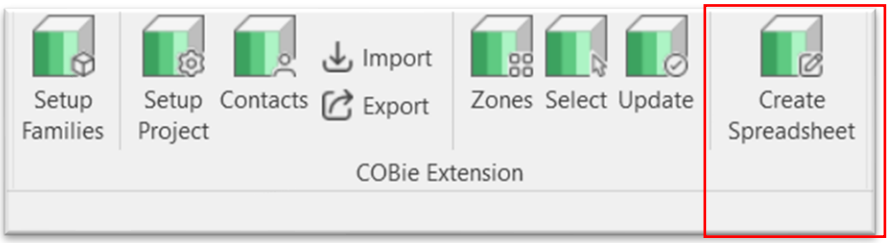


Figure 75. Spreadsheet generation in COBie

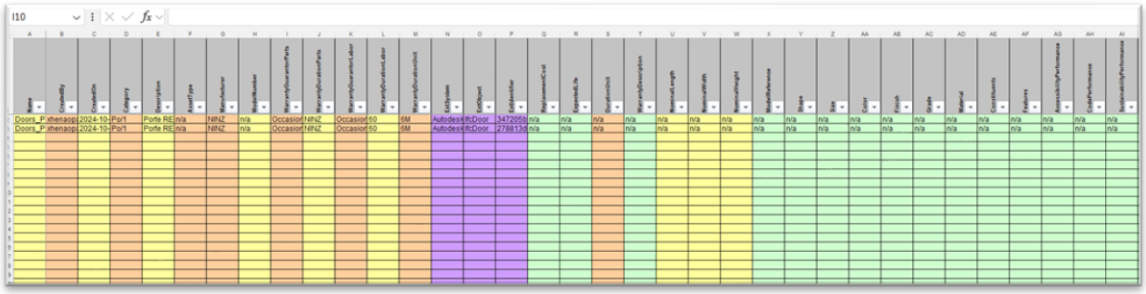


Figure 76. COBie spreadsheet

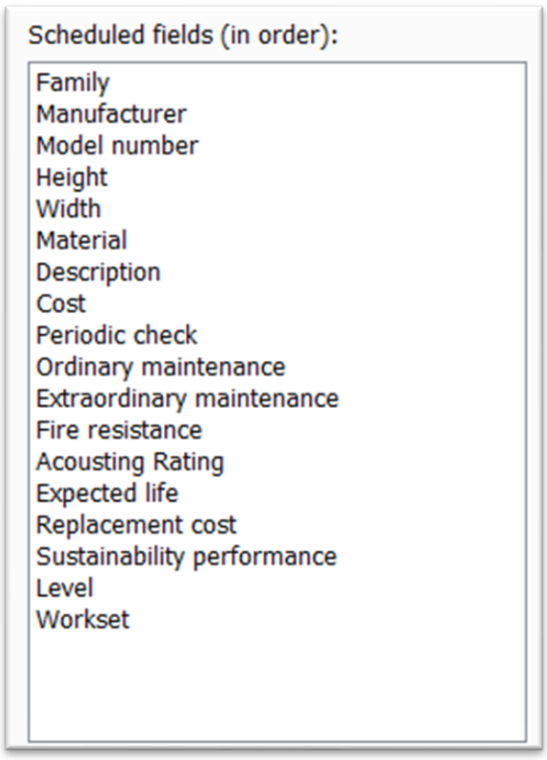


Figure 77. Shared parameters relative to the doors' maintenance

From the parameters present in the previous table, I chose to transfer to Revit the followings: Model Number, Nominal Height, Nominal Width, Material, Expected Life, Replacement Cost, Sustainability Performance.

The parameters that I created in Revit are presented in the Figure 77. They are the result of both standards, UNI 11473 and COBie. I associated project parameters to the shared parameters created and then added them in the doors' schedule created in Revit.

The schedule can be visualized and compiled inside Revit, or we can export it using DiRoots plugin (as explained in chapter 4.2.3) and compile it as a simple Excel sheet. After completing the compilation, the Excel sheet can be imported inside the Revit model again.

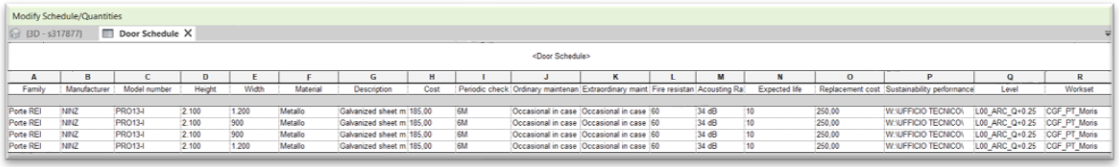


Figure 78. Door Schedule - Revit 2023

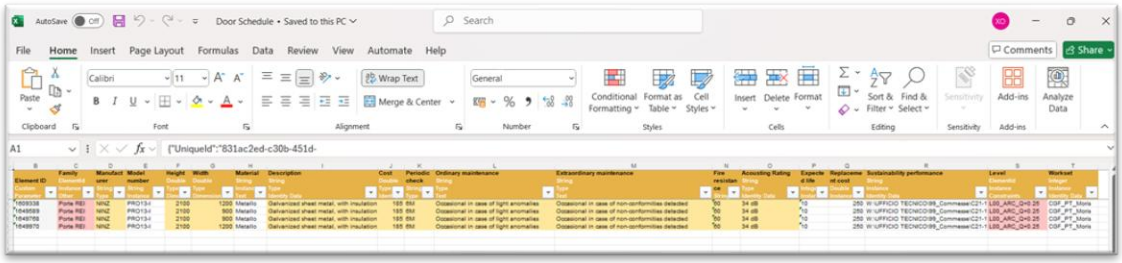


Figure 79. Door Schedule - Microsoft Excel

4.4. Data visualization via Power BI

4.4.1. Connecting Power BI to Revit

As I mentioned at Chapter 2.4.1, Power BI, even though is a very powerful data visualization tool and allows us to get data visualization insights from data sources, does not really connect to AEC applications, so all the BIM, GIS, CAD data is stocked in the host applications. That's why we need to use Speckle, to help us realize the connection between Power BI and the AEC application, which in this case is Revit.

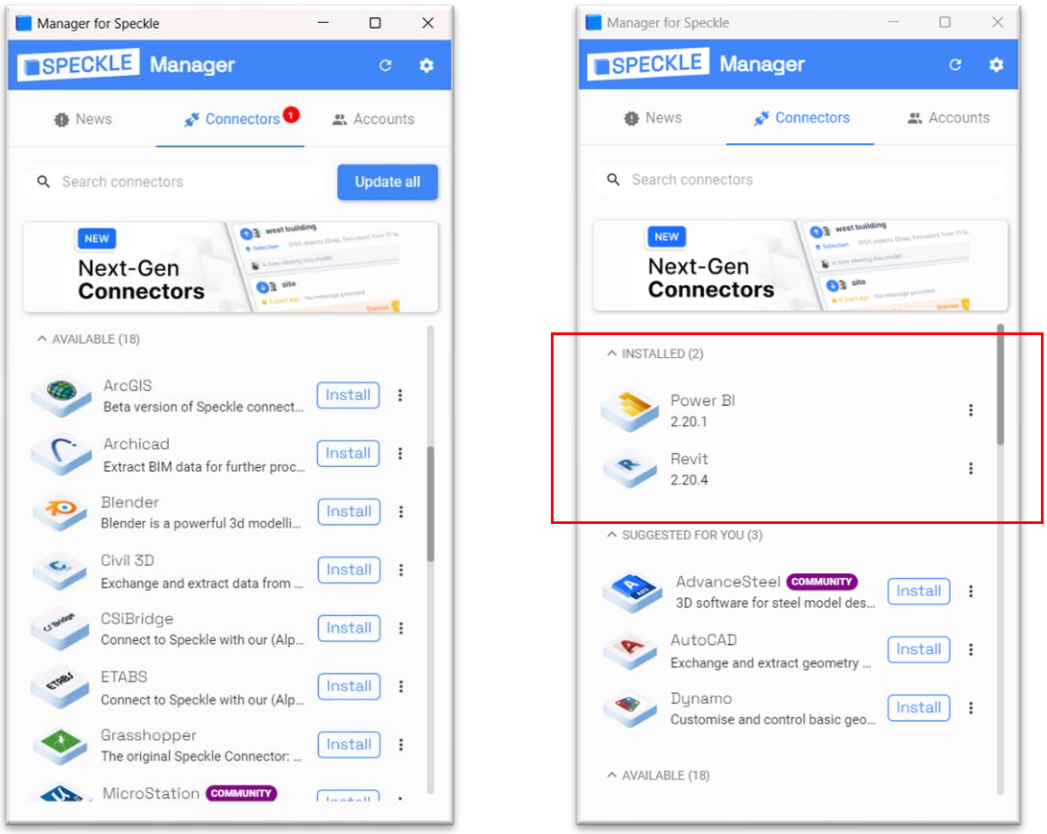


Figure 80. Speckle Connectors' Installation

The first step consists in the installation of "Manager for Speckle", which allows us to subsequently install the connectors that we want. There are different connectors for almost every AEC software. I chose to install Speckle Connector for Revit and for Power BI (Figure.76), as they were going to be the softwares/platforms that I was going to use.

After that, we can open our Revit model and see that Speckle PlugIn has been installed and appears at the Ribbon of the Revit interface.

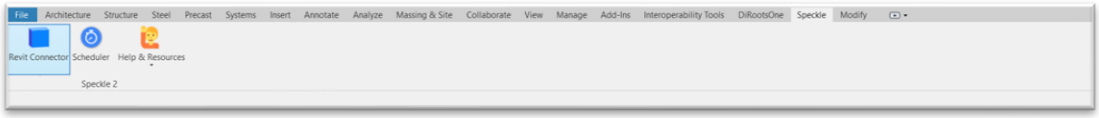
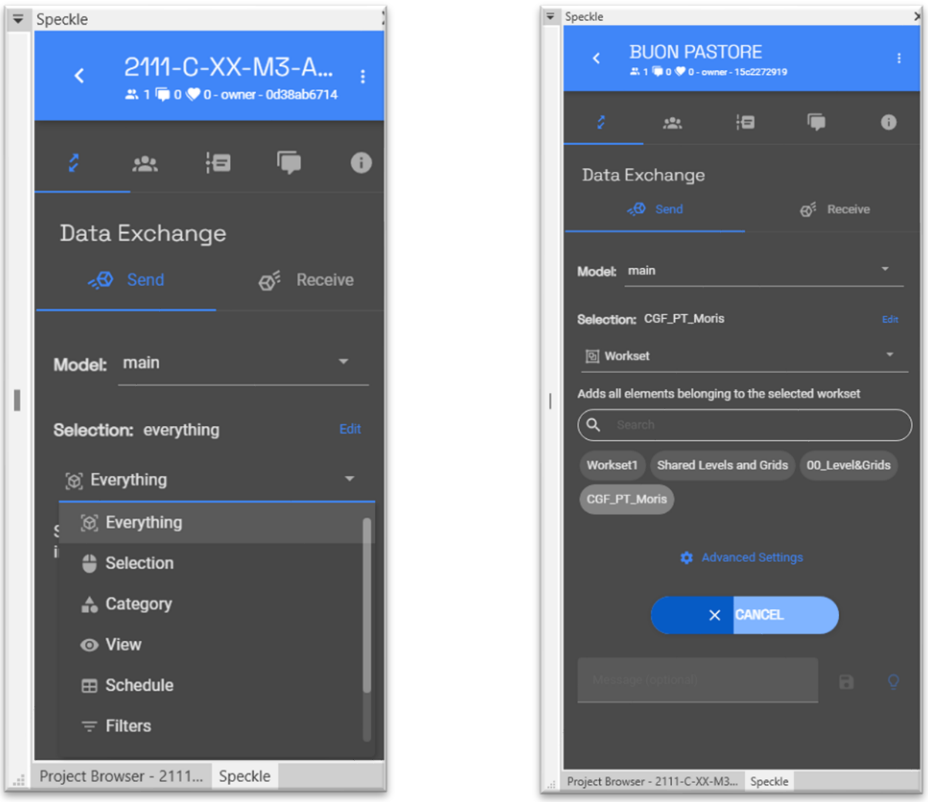


Figure 81. Speckle Plugin appears at the Ribbon after installation

It is possible to decide which part of the model we want to send to Speckle. We can choose to send everything, only the selection or choose between the different categories, views, schedules, filters. After having chosen, we should click on "Send" and the process will start automatically, giving us continuous feedback on its progress.



a) b)

Figure 82. a) b) Speckle Plugin visualization in Revit interface

In Figure 78.b), I have shown an example of model export based on the workset[7]. It has been chosen the workset "CGF_PT_Moris", which means that only the elements of the model that belong to this workset will be "transported" to Speckle.

[7] Workset is a feature used to enable collaborative work in a project by dividing the model into manageable sections that multiple team members can work on simultaneously.

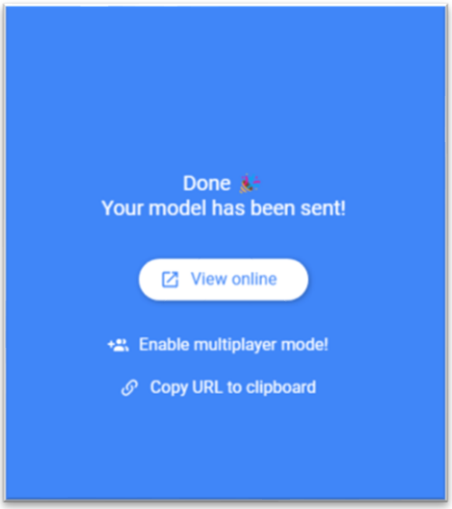
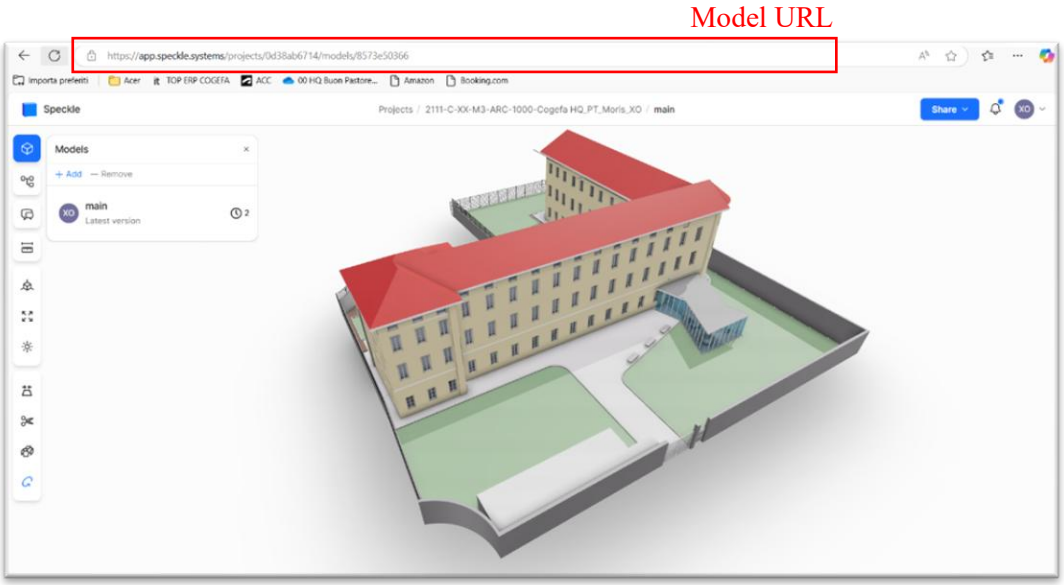
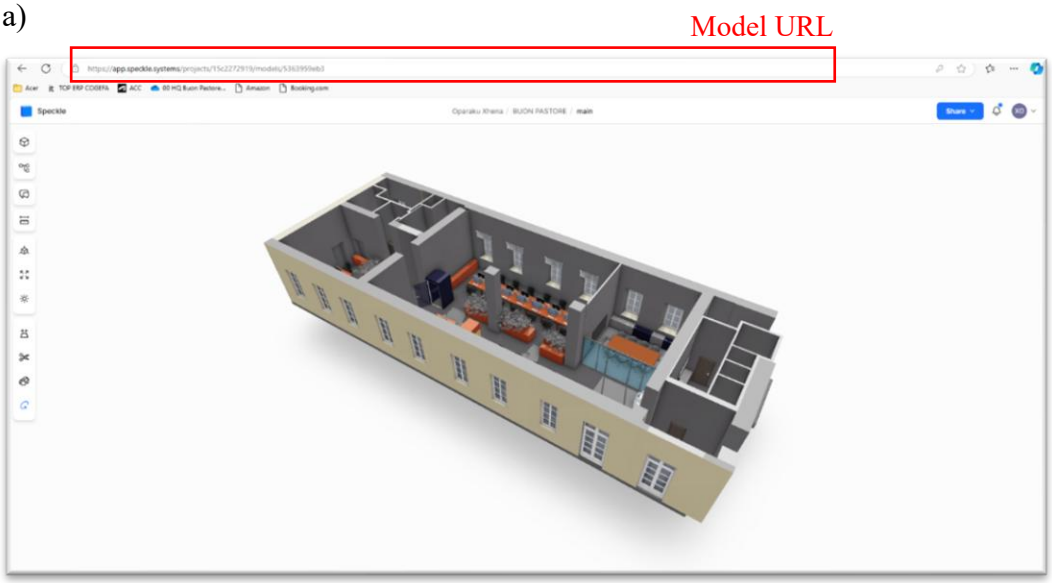


Figure 83. Speckle notification when the model has been sent

When the delivery process is finished, Speckle shows us this notification and the possibility to view the model online. Speckle creates a workspace for us, in which all the models that we send from Revit are saved under the name "Projects". Speckle interface autogenerates a model having the same name as the Revit model. From this interface we can have information related to all the elements of the model, by simply clicking on them. What is the most important part of this interface, is the URL generated at the upper part of it, which is later going to be used to connect Power BI to this model.



a)



b) Figure 84.a) b) Speckle interface autogenerates a "twin" model of the Revit one

At this point we can open Power BI (after having installed it for free: https://www.microsoft.com/en-us/power-platform/products/power-bi/downloads) and the first interface is the following:

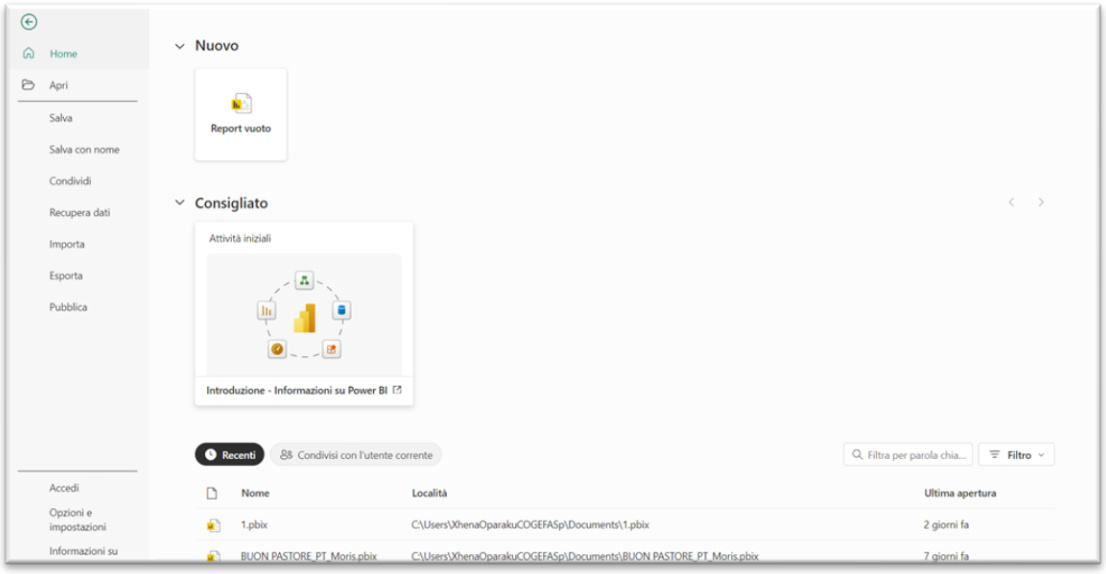


Figure 85. Power BI first interface

If we have no other project created in Power BI, we should click on "Report Vuoto" in order to create a new one. Otherwise, we can find the list of projects that have been created in Power BI and can open them by simply clicking on the name of the project. If we choose to create a new report, we will be in front of the following interface, which offers all the necessary instruments to create a new report.

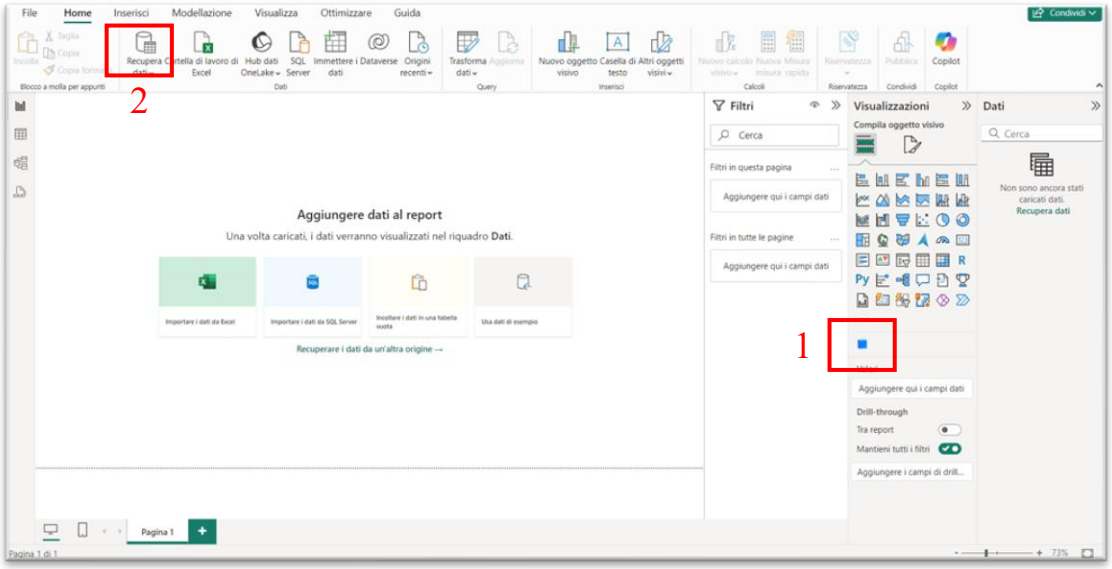


Figure 86. Power BI "Create a new report" interface

In order to visualize the Revit model on Power BI, we should click on the Speckle icon (the small blue cube at the right) and then on “Recupera dati” – “Altro”. This selection allows us to bring data from more possible sources.

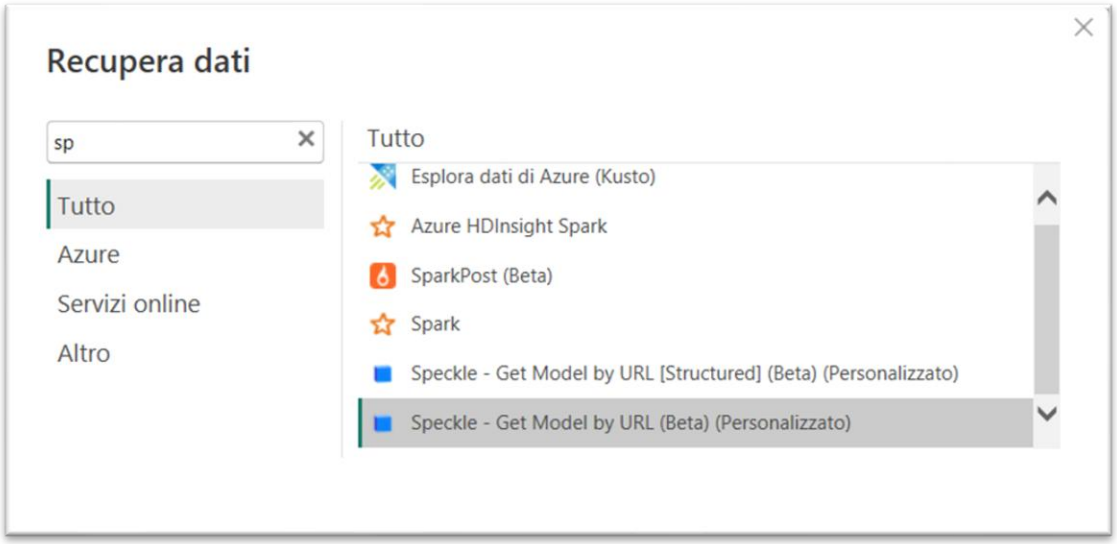


Figure 87. Screen capture - Get data from Speckle

After clicking on “Speckle” as the source from which Power BI has to get the data to generate our model, we will have to deal with a dialogue window. In this window we should paste the URL that we copied before from the Speckle interface. Each project that we have sent to Speckle has a different URL.

Figure 88. Dialogue window on Power BI - Get model by URL

At the moment in which we click “OK”, a table containing all the data of the chosen project will open and we should click on “Load/carica” to get all that information transferred to Power BI.

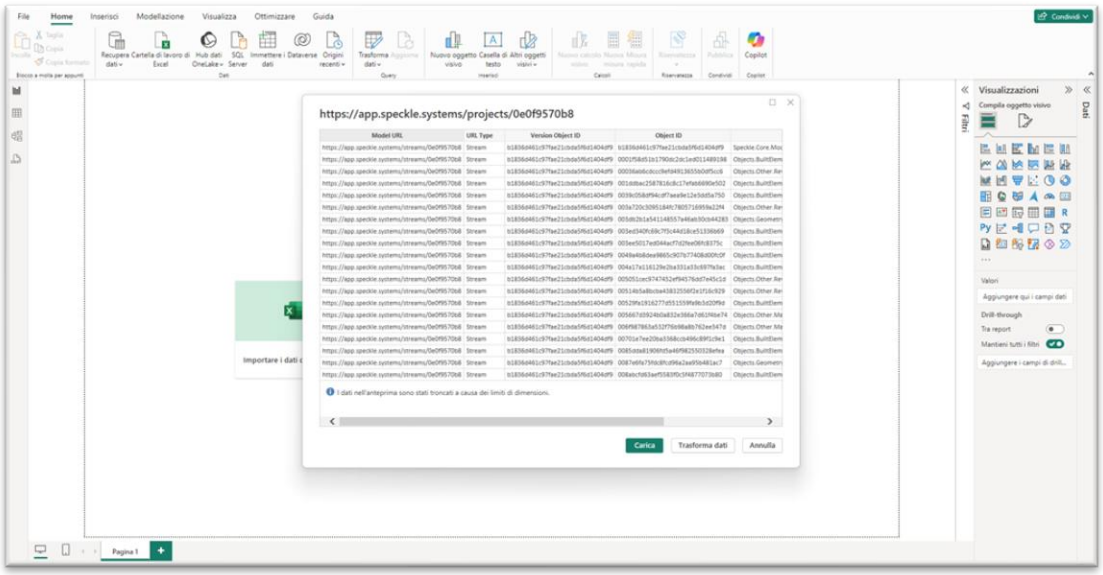


Figure 89. Table of Speckle data ready to be transferred to Power BI

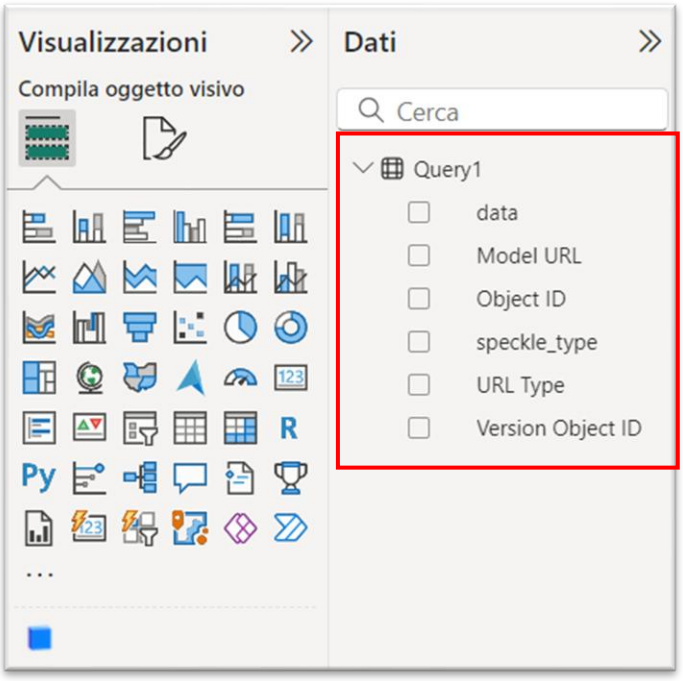


Figure 90. Speckle Data brought to Power BI under the form of queries

We can understand that data has been successfully sent to Power BI when we see that in correspondence of the Data column there is a new element named “Query 1”. If we click on “Query 1”, it will open a list of information contained inside it. It is all Speckle data, so it needs to be manipulated in order to be used inside Power BI for dashboard creation.

The window in which we can see the Revit model in Power BI is called “visual” (Figure 88). To create a visual we should firstly click on the Speckle icon and then bring the data into it. Everything that is inside the column “Visualizzazioni” is referred to the visuals, while the data that is on the right is related to all the Speckle data brought to Power BI.

We decide what input we want to give to the visual. It can be done by a simple “drag & drop” process. We drag “Model URL” to “Stream URL”, Object ID” to “Object ID” and “Version Object ID” to “Commit Object ID”.

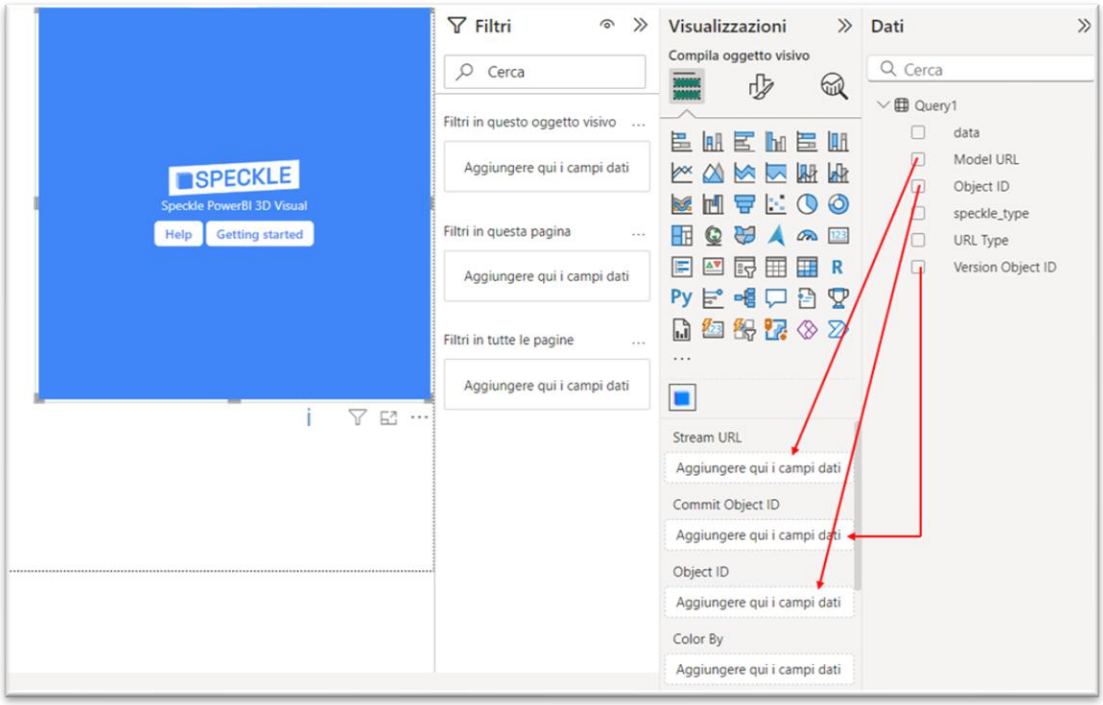


Figure 91. Creation of a visual

Figure 92. Visualization of the model inside the visual

Accessing categories from Revit in Power BI

To this point, we have managed to create a visual in Power BI, but the main purpose of this business intelligence tool is the creation of beautiful and interactive dashboards for data visualization. How can we do that?

I would like to highlight the fact that the data we have received in Power BI is actually “raw data”. This means that all the information that we need is there, but Power BI can not read or understand it all. For this reason, we need to manipulate data and help Power BI in the realization of the dashboards. We start the manipulation of data imported from Speckle connector, by clicking on “Modify query”. The original query has been renamed “Raw_Speckle_data”, because we don’t want to edit the reference table, we want to create a link to it. To do so, we click on “Reference” and create a new query named “extracted_category”.

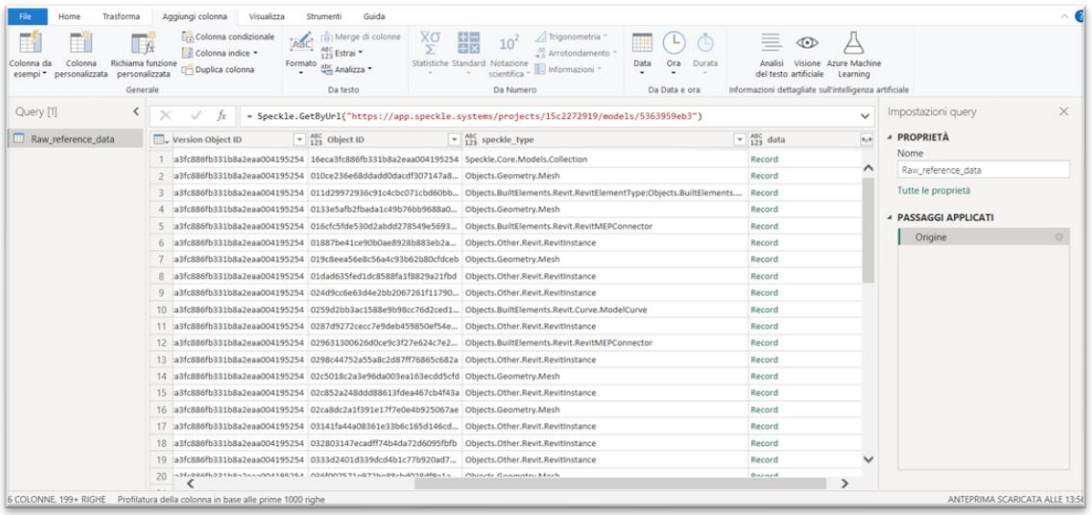


Figure 94. Data manipulation - Speckle data used as reference data

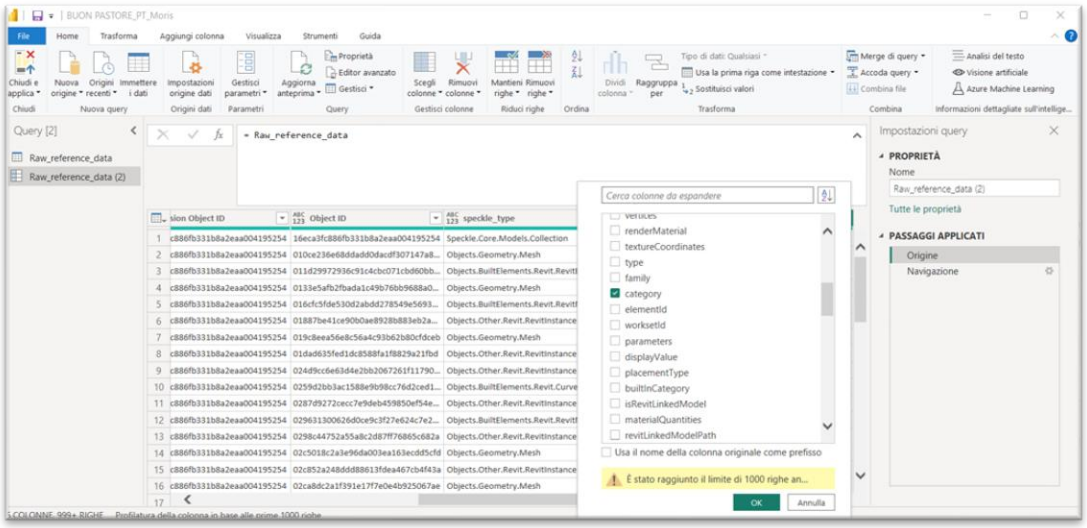


Figure 93. Data manipulation - Add new custom column

In this new query we want to add a column named “category” in which we want to read the categories of Revit. This can be achieved by clicking on “Aggiungi colonna”, and then “Colonna personalizzata”. In the dialogue window shown in Figure 91, we need to write a formula that tells Power BI that in this new custom column we want to read the categories of Revit.

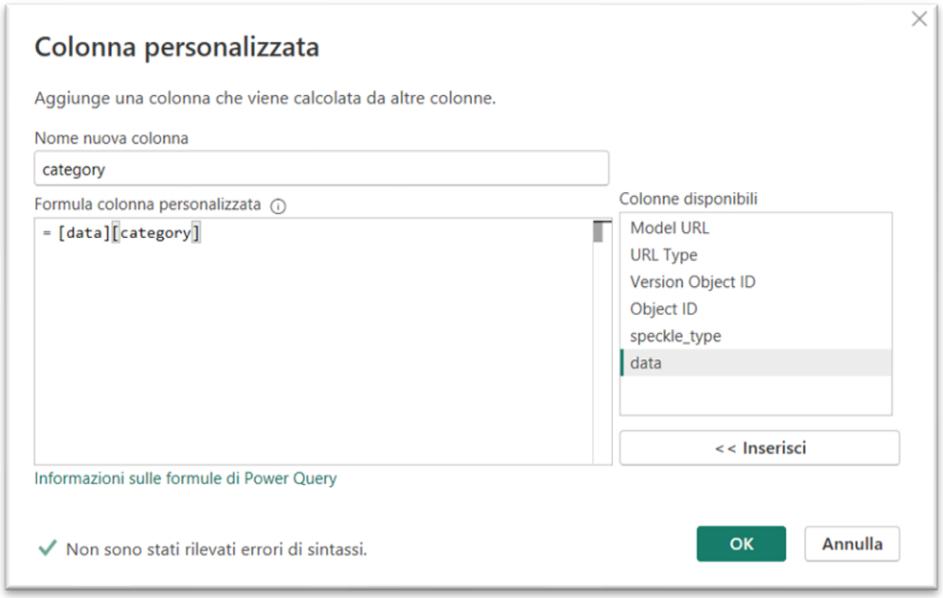


Figure 95. Formula for accessing the categories

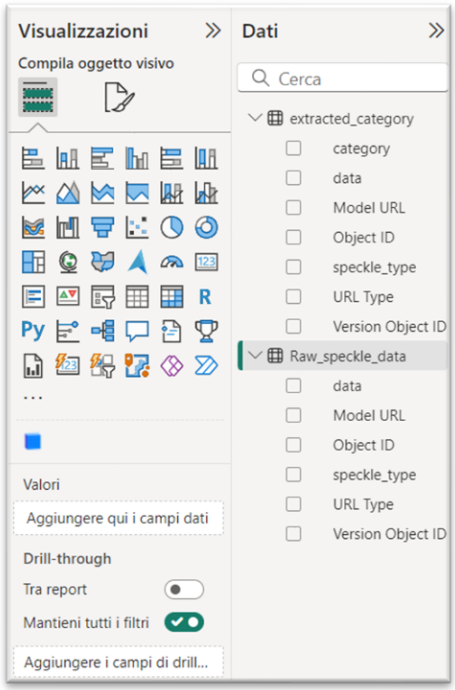


Figure 96. New query created

After clicking on “Applica e chiudi”, we can see that a new query has been added to the Power BI interface. In this new query we see all the columns of the reference query plus the new custom column that we created, i.e. “category”. What we can do now is add some slicers to the Power BI interface and “tell” them what to show by dragging and dropping the columns of the queries to the left.

Extracting Revit Parameters in Power BI

I decided to focus on the “Rooms” category. First of all, has been created another query which contains only two columns, in the first one are all the categories and in the second one all the information related to each category is grouped together.

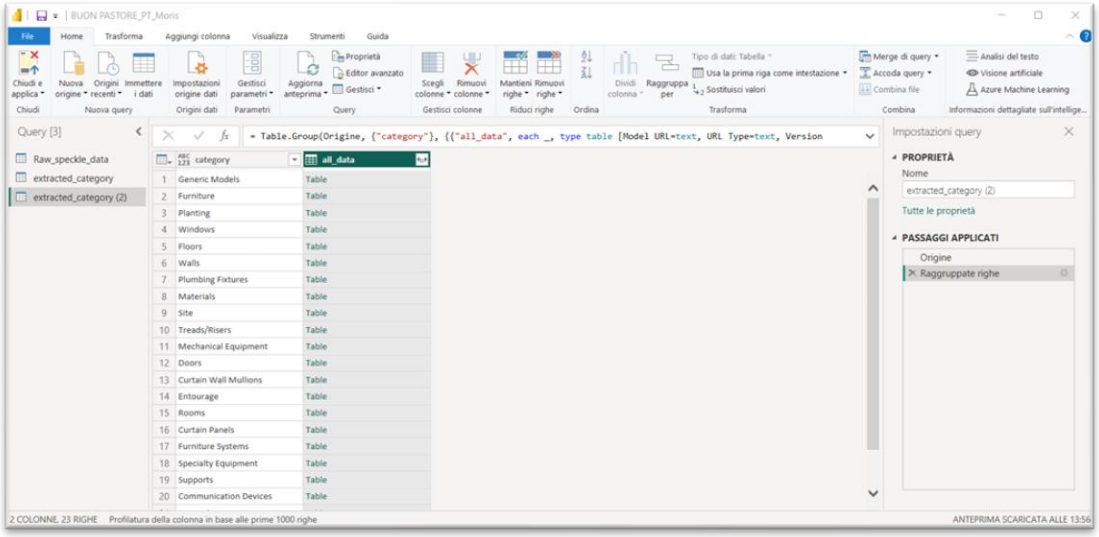
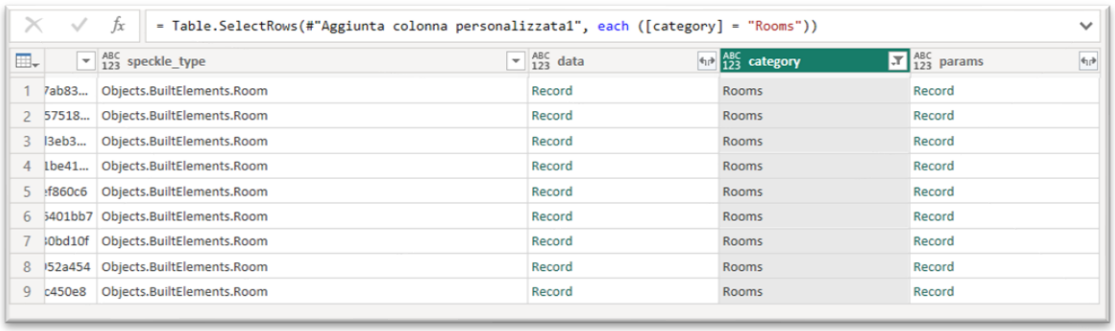


Figure 97. Query containing grouped data based on their category

After that, I applied a filter and created another query in which only the category “rooms” is isolated.



	speckle_type	data	category	params
1	7ab83... Objects.BuiltElements.Room	Record	Rooms	Record
2	57518... Objects.BuiltElements.Room	Record	Rooms	Record
3	13eb3... Objects.BuiltElements.Room	Record	Rooms	Record
4	1be41... Objects.BuiltElements.Room	Record	Rooms	Record
5	f860c6 Objects.BuiltElements.Room	Record	Rooms	Record
6	5401bb7 Objects.BuiltElements.Room	Record	Rooms	Record
7	0bd10f Objects.BuiltElements.Room	Record	Rooms	Record
8	52a454 Objects.BuiltElements.Room	Record	Rooms	Record
9	c450e8 Objects.BuiltElements.Room	Record	Rooms	Record

Figure 98. Filtered query - "Rooms" category isolated

We can see that the parameters related to each room, visible in the column “params”, are under the form of records. This is due to the fact that Revit parameters are very complex, they can be instance parameters, type parameters, shared, project ones etc. Power BI, or better saying Speckle Connecter, can not read them all automatically. For this reason, they are saved under the form of record. If we click on one of them, what we can see is represented in Figure 96:

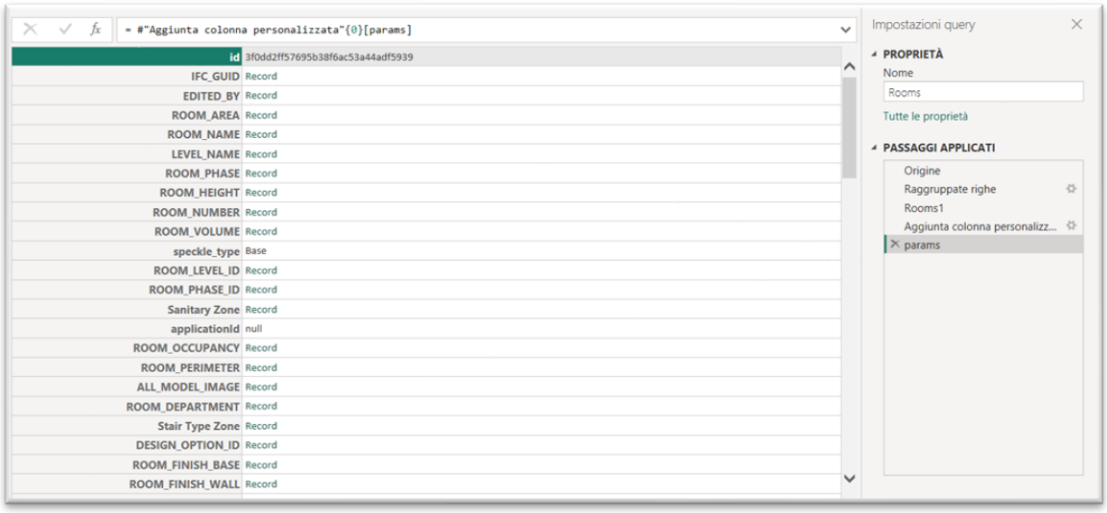


Figure 99. Speckle data inside Power BI is saved under the form of "records"

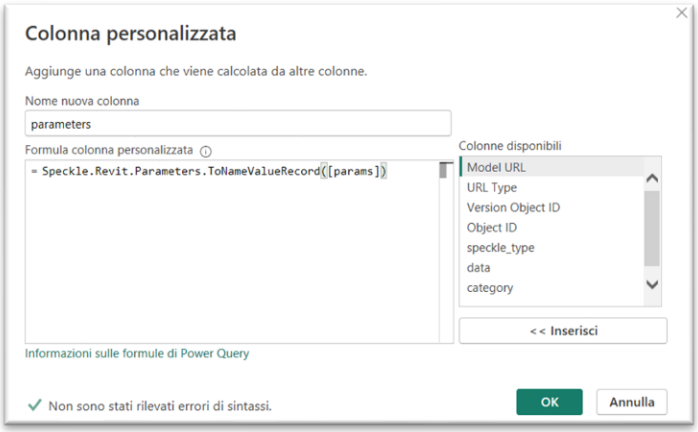


Figure 100. Formula that allows Power BI to read the parameters of Revit

To give Power BI the possibility to see through these records, we should "help" him by using another formula: Doing so, we have added another personalized column, named "parameters", in which the parameters are still written as "records", but if we click on them we will have the possibility to read the exact value of each parameter as we can do using Revit.

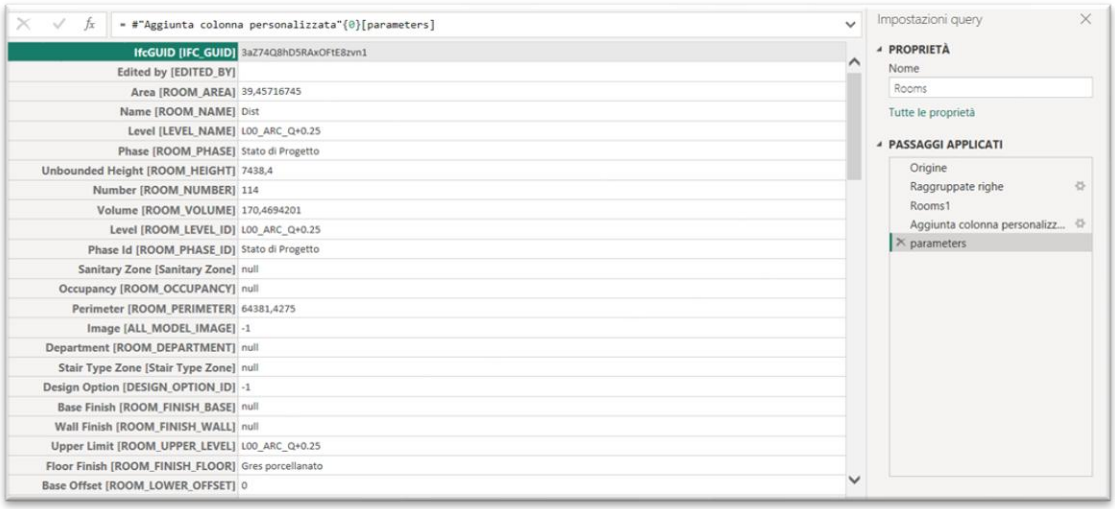


Figure 101. Data is not appearing as "record" after applying the previous formula

Furthermore, by clicking on the expand icon near the name of the column “parameters”, it will open a dialogue table in which we can see all the parameters that are present in the Revit model. In this way we can select only the ones that we want to import to Power BI in order to create the dashboards that we want. After selecting the parameters that we want, the column “parameters” will be substituted by as many columns as parameters we have selected.

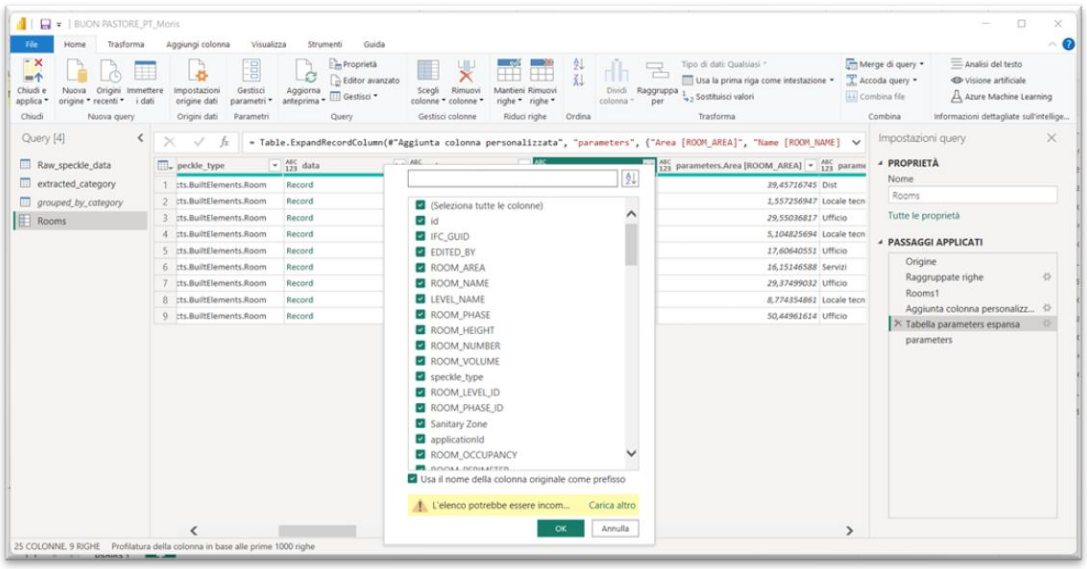


Figure 102. Selection of parameters that we want to import to Power BI

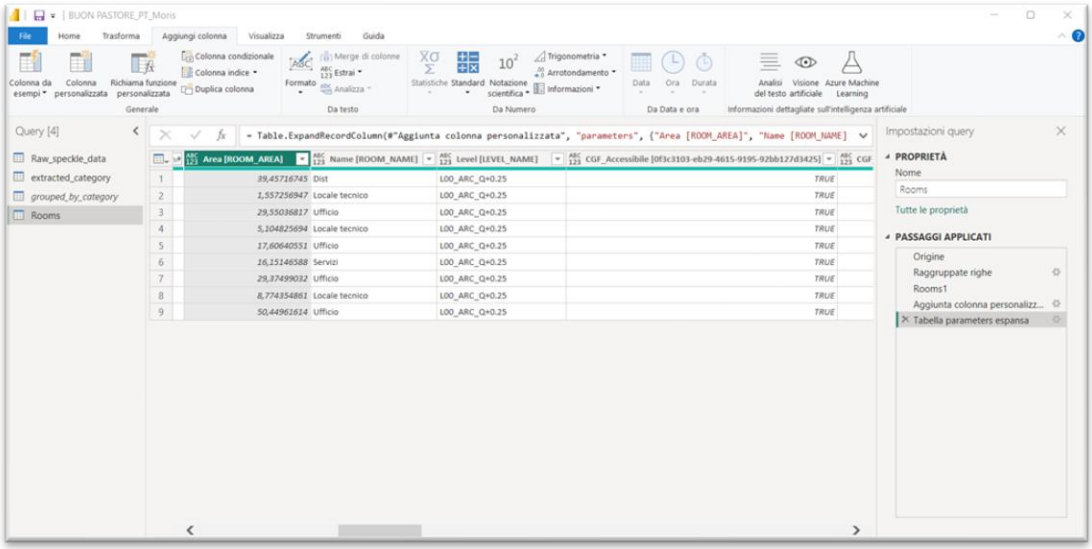


Figure 103. Added columns in correspondence to all the parameters selected previously

4.4.2. Power BI dashboards

Now we have the possibility to create a lot of beautiful, useful and interactive dashboards. According to what we need to visualize, we can filter using the parameters that have been imported to Power BI and create different reports.

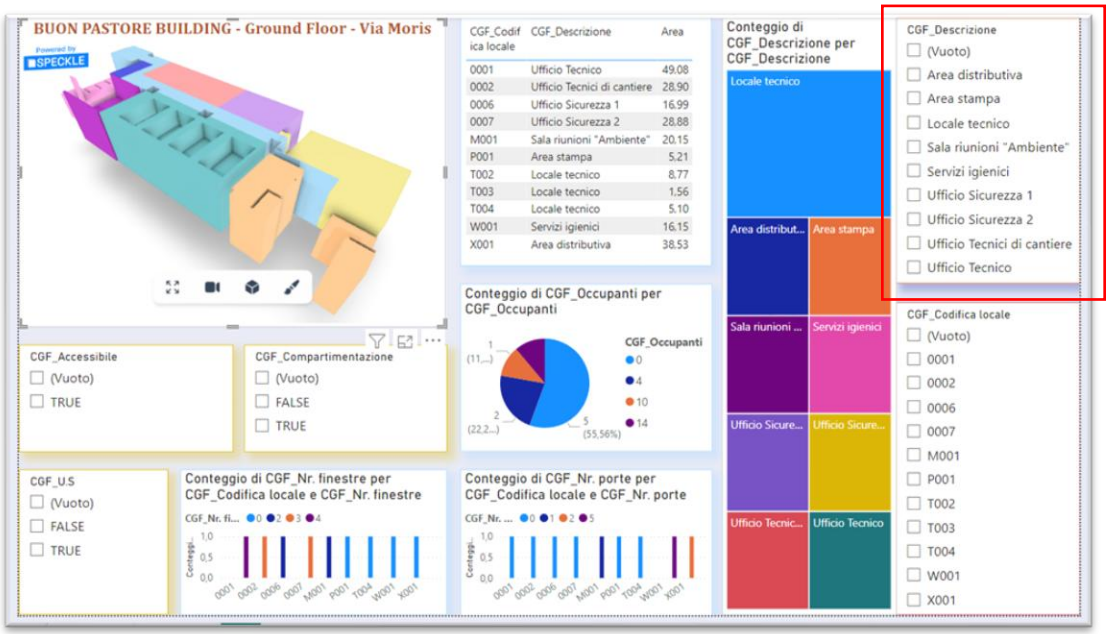


Figure 104. Dashboard related to the model of the Buon Pastore building - Ground Floor - Via Moris

The element inside the red rectangular shape in Figure 104 is called **slicer.** A slicer in Power BI is a visual tool that allows users to filter data in a report interactively. It acts as a control panel for filtering, enabling users to select specific values or ranges from a field in the data model, which dynamically updates the visuals on the report page to reflect the filtered data.

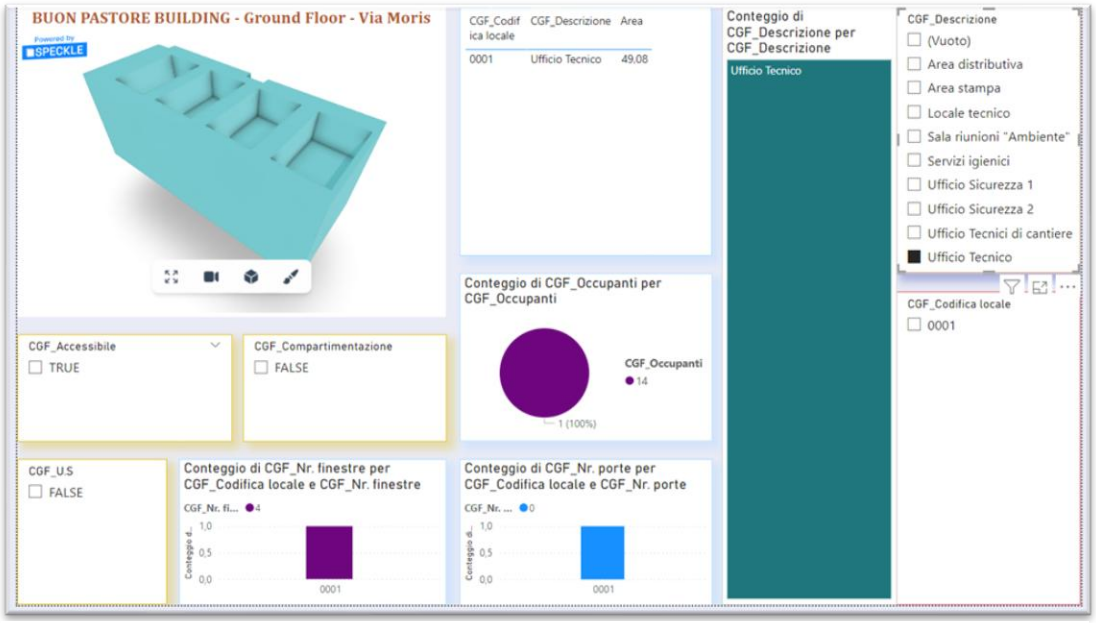


Figure 105. Filtered dashboard 1

In Figure 105, I have filtered based on the rooms' description (parameter: CGF_Descrizione). Clicking on "Ufficio Tecnico", the dashboard will filter all the data and will allow us to visualize only the data related to "Ufficio Tecnico".

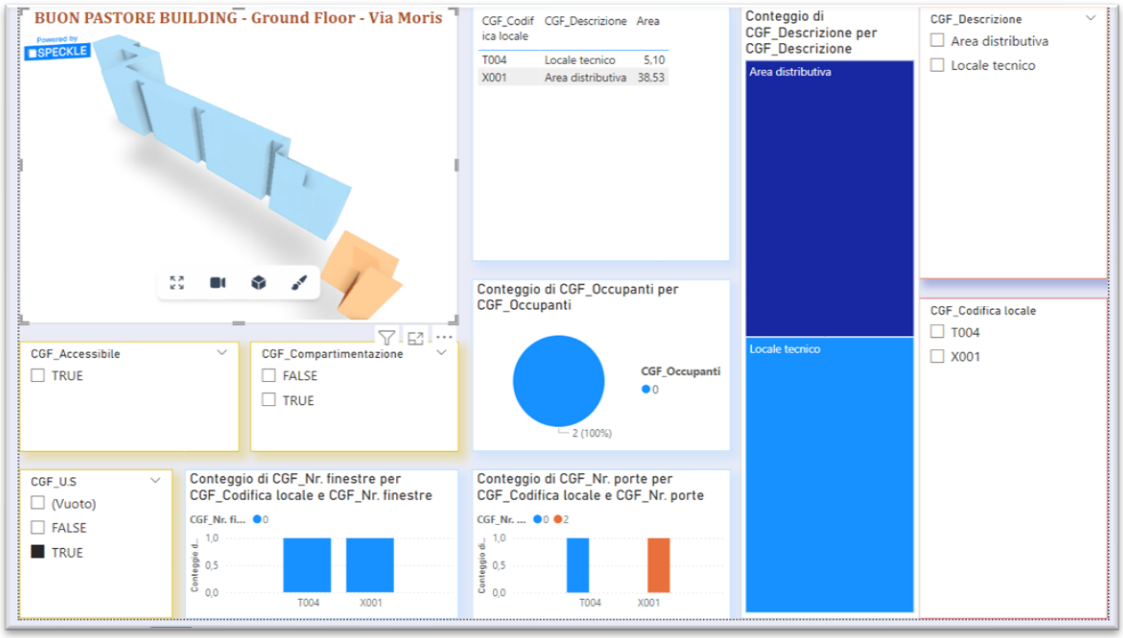


Figure 106. Filtered dashboard 2

In this other example, Figure 106, I have filtered based on the presence of the emergency exits (parameter: CGF_U.S). I clicked on "TRUE", which means that I wanted to visualize only the rooms that have emergency exits.

The dashboards that we can create using the available data are infinite. We just need to have a clear idea of what we want to achieve, and Power BI allows for the best possible visualizations of our objective.

4.4.3. Relate Excel Data with Revit in Power BI

Sometimes we may have some data in an Excel sheet and don't want to transfer it to Revit. This can also be related to the fact that the person who is managing this data is not a BIM Specialist, so they don't know how to insert it to the Revit model. Fortunately, when dealing with Power BI, it is not a mandatory passage. We can integrate both data coming from Revit and data coming from Excel sheets. What's important in this case is that the data should not be the same. Otherwise, it doesn't make sense performing the integration. I have presented an example of this data integration, using the model of the whole Buon Pastore building.

Room code	Floor Finish
0001	Gres porcellanato
0002	Gres porcellanato
0003	Gres porcellanato
0004	Gres porcellanato

Figure 107. Exctacted part of the table BP_Floor finish

I decided to transfer to Power BI an Excel sheet containing the room codes and the corresponding floor finish for each room.

First of all, we should get the Excel data in Power BI. It can be done by simply clicking on "Cartella di lavoro di Excel". After that, we should select the Excel sheet that we want to bring into Power BI.

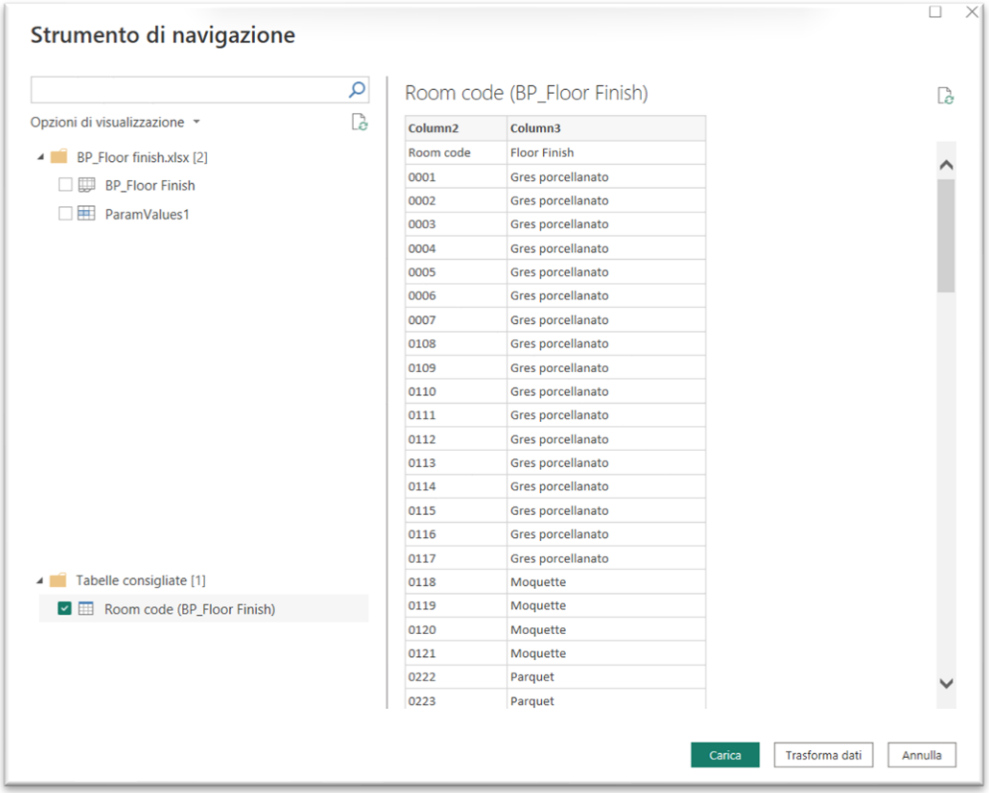
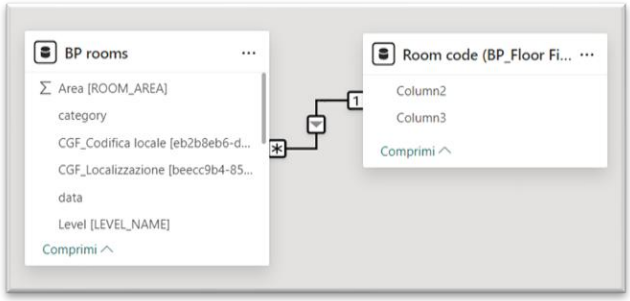


Figure 108. Import of an Excel table in Power BI

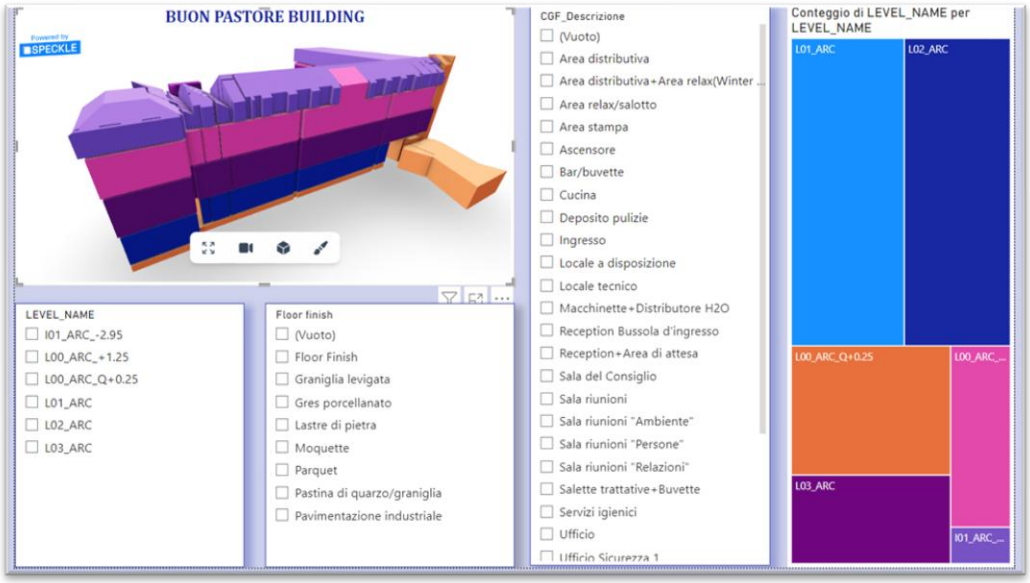
After that, we should create the connection between the Speckle data that already exists inside our Project of Power BI and the Excel data. To do so, we should click on the "Visualizzazione modello" icon. It allows us to have a general review of all the queries that are in Power BI, and create the needed connections between their data. In my case, I connected the "CGF_Codifica locale", which is a Speckle data, with "Column 2", which corresponds to the Excel sheet, and is the column where the room codes are written.



These two elements represent two columns of the queries in Power BI, coming from different sources, but containing the same information.

Figure 109. Connection between Speckle data and Excel data

The dashboard below corresponds to the whole building, the coloring of the model has been done based on the level parameter. As can be seen, I have created slicers using Speckle data and also the Excel data that we just added to the Power BI project.



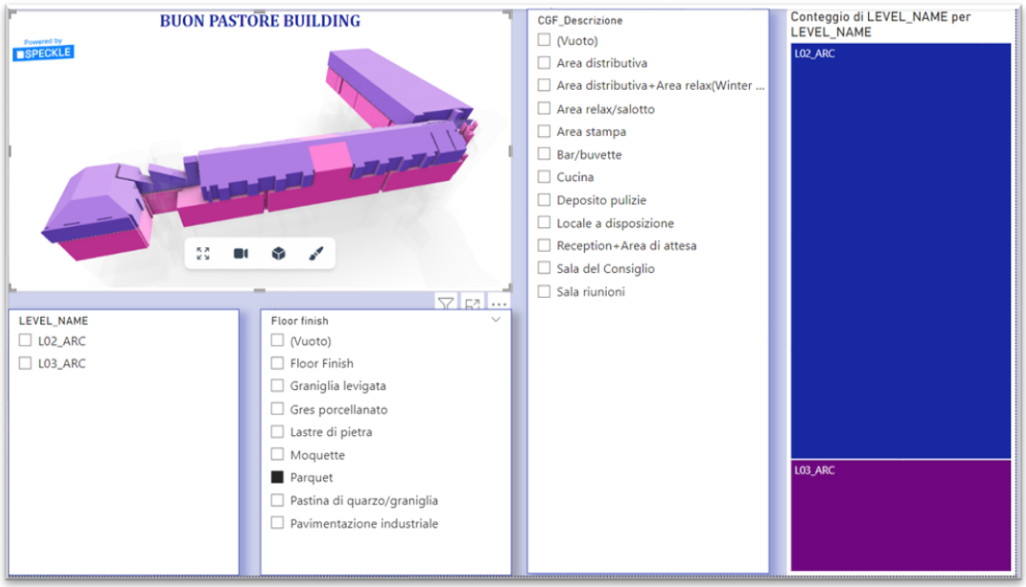


Figure 110. a) b) Dashboards relative to the Buon Pastore building

5. CONCLUSIONS AND FUTURE DEVELOPMENT

This thesis explored the integration of Building Information Modeling (BIM), specifically an As Operate BIM model developed in Revit 2023, with Construction Operations Building Information Exchange (COBie) and Microsoft Power BI to enhance data visualization for Facility Management (FM). The study highlights the considerable potential of using advanced business intelligence tools to address the ongoing challenges of managing and utilizing complex building data produced throughout a project's lifecycle. Through the case study of the Ex Buon Pastore building, this study showcased how integrating BIM and COBie with Power BI enables the transformation of static data into dynamic and interactive visualizations. These visualizations provide facility managers and stakeholders with actionable insights, improving their ability to analyze, interpret, and act on information. The use of Power BI dashboards was shown to facilitate better decision-making by simplifying complex datasets and making key information more accessible and comprehensible.

In conclusion, this thesis contributes to the growing body of knowledge on the use of business intelligence tools like Microsoft Power BI in FM. It underscores the value of integrating BIM and COBie for enhanced data management and decision-making while emphasizing the potential of such tools to drive innovation and sustainability in the construction industry. Future research could expand on this work by exploring applications across diverse building types and further refining these methods for broader industry adoption.

A future development of this thesis could involve the integration of **VIM[8] Enterprise** as an intermediate step in the workflow. VIM Enterprise is a middleware platform that facilitates the efficient handling, sharing, and synchronization of BIM data. It is particularly adept at enabling seamless collaboration across different tools and platforms within the AEC industry. By acting as a bridge, VIM Enterprise can streamline data interoperability, ensuring that BIM models, including those in Revit or COBie formats, are accessible and usable across a variety of applications.

[8] VIM stays for Virtual Information Modeling

In this context, incorporating VIM Enterprise could enhance the current process by enabling better data exchange between Revit, COBie, and Microsoft Power BI while also introducing Autodesk Construction Cloud (ACC) into the workflow. ACC is a powerful suite of construction management tools designed for project collaboration, data tracking, and operational efficiency. With VIM Enterprise serving as the intermediary, data from the BIM models could be seamlessly integrated into ACC, ensuring a more robust pipeline for managing construction and facility management data.

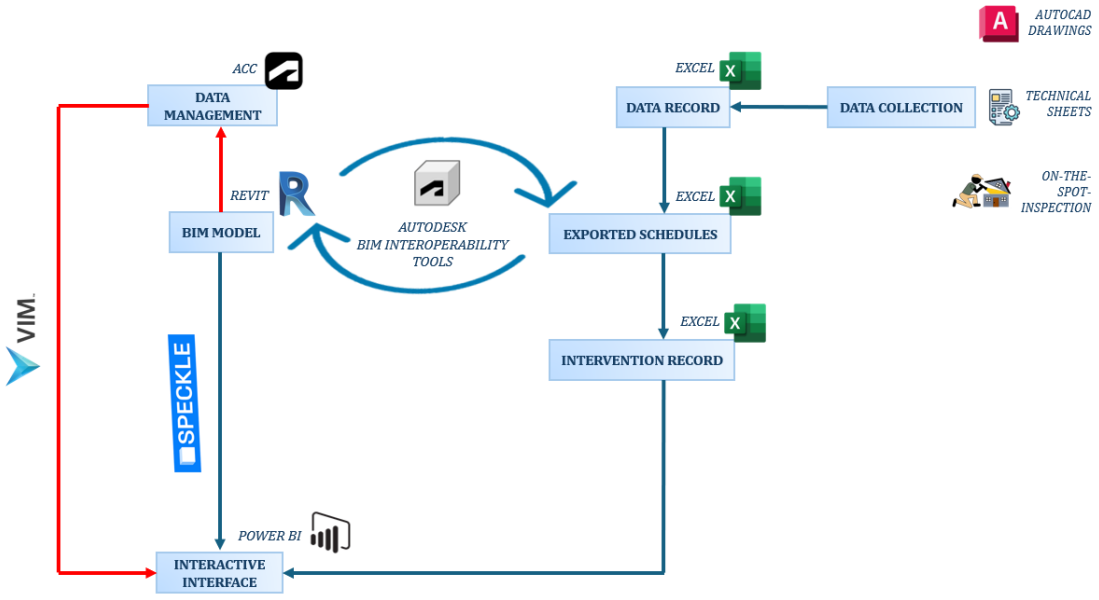


Figure 111. Schematic representation of an alternative workflow (including VIM Enterprise)

This integration would expand the potential applications of the workflow developed in this thesis, offering a more comprehensive system for managing project data and facilitating real-time updates and collaboration. Additionally, it would further align the process with industry trends toward centralized, cloud-based solutions, enhancing scalability and long-term utility.

LIST OF FIGURES

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