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Department of Architecture, Built Environment and Construction Engineering

Master of Science in: Management of Built Environment

BUILDING INFORMATION MODELING FOR FACILITY MANAGEMENT.

The BIM strategy for services organization, maintenance and economic management applied to a case study.

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ENGLISH

In the area of planned maintenance and management, also considering the development of Facility Management (FM) services, operators express an increasing demand of operative tools and procedures for the improvement of efficiency and effectiveness of the processes. In this scenario, the theme of information management and of development of knowledge inside of the services for existing building and urban assets appears to be rising and important. This theme can be faced in a proactive and innovative way by approaching it according to an integrated vision that assumes the perspective of the entire building process. The analysis of current practices highlights how the operations and maintenance phase, being the final stage of the building process, is mainly influenced by the problems connected with a not effective organization of information. In fact, setting up an information database is one of the most laborious and onerous activities and particularly in the development of a maintenance plan (maintenance manual and schedule). The theme was developed thanks to the case study application with the aim to create a tool that allows an update of the documentation easy to consult and with immediate extraction of the requested data. This provides a methodological and strategical procedure that allows professionals to have an economic vision of the entire building, in order to optimize and programmatically define expenditures over time. To do this, the analysis starts from the study of BIM that, fundamental for the digitization of the construction sector and continues with the definition of a methodological procedure, working through electronic spreadsheets. interconnected between them and with Revit software.

ABSTRACT

ITALIANO

L’ambito della manutenzione programmata e della gestione, anche in relazione allo sviluppo dei servizi di Facility Management, continua a far emergere una domanda di strumentazioni operative e di procedure per il miglioramento dell’efficacia e dell’efficienza dei processi. In questo scenario emerge come importante e trasversale, rispetto a molteplici ambiti applicativi, il tema del trattamento delle informazioni e delle modalità di organizzazione delle conoscenze all’interno dei processi legati alla gestione dei beni edilizi e urbani. Una possibile chiave di lettura attraverso la quale affrontare questo tema in termini propositivi e innovativi è quella della gestione dei dati secondo una visione integrata che assume la prospettiva dell’intero processo edilizio. L’analisi della prassi corrente evidenzia come la fase di gestione, quale terminale del processo edilizio, è quella che maggiormente risente di una inefficace organizzazione delle informazioni. La messa a punto della base di conoscenze preliminare è indispensabile per lo sviluppo delle attività strategiche e operative, è infatti una delle operazioni più onerose e complesse nella impostazione di un servizio di gestione in particolar modo nella realizzazione del piano di manutenzione (manuale e programma di manutenzione). Il tema è stato sviluppato grazie all’applicazione ad un caso studio con lo scopo di creare uno strumento che permetta un aggiornamento della documentazione di facile consultazione e immediata estrazione dei dati richiesti. Ciò fornisce un procedimento metodologico e strategico che dà ai professionisti una visione economica dell’intero edificio al fine di ottimizzare e definire in maniera programmatica le spese nel tempo. A tale proposito l'analisi parte dallo studio del BIM, fondamentale per la digitalizzazione del settore delle costruzioni e prosegue con la definizione di una procedura metodologica sviluppata attraverso fogli elettronici interconnessi tra loro e con il software Revit.

CHAPTER 1

INTRODUCTION

The term “BIM” first appeared as early as 1962, when Douglas Engelbart wrote his paper “Augmenting Human Intellect: A Conceptual Framework” and described architect entering specifications and data into a building design and watching a structure take shape. It was a concept very similar to modern parametric modeling and owes its popularity to a publication in 1992 and to a white book in 2003 by Autodesk entitled precisely “Building Information Modeling”. Only in recent years, BIM has come out, at least in the most advanced countries from this point of view, from the misunderstanding in which still seems relegated in Italy, that BIM = 3D model, for which the BIM and related tools are viewed as a mere evolution of CAD, aimed at the production of rendered photo-quality perspectives. Obviously, it’s different and BIM can be defined as a process that comprises the generation and the management of digital representations of the physical characteristics and functioning of an asset, that support the operators in the sector of constructions in the management of all phases of its life cycle, from its conception till its disposal.

In this phase of strong modernization of the building process in all its components, the BIM technology allows an optimization of the interventions and the control of the work itself. With this technology of the modeling product every element that composes it is a "parametrized" and "parametrizable" object, that is "a BIM object" that can contain multiple data and technical specifications. Certainly to obtain satisfactory and manageable results, in the initial phase the investment of time and technology (software) will be much greater than a traditional design. The expenditure of energy that will be apply in the initial phase of modeling with the inclusion of data and information will be well rewarded with the simplifications that will occur from the "three-dimensional model". Taking into account the complexity that often presents the creation and management of public and private work, surely the use of BIM methodology is the most suitable tool for the "quality control and check of the project and for a correct one maintenance planning and functionality of a work.

1.1 The future of BIM

The BIM methodology is a work in progress. As soon as its development progresses and its use will be increasingly widespread, the extent of its impact will become more evident on how to construct buildings. The next few years will see the broader adoption of basic BIM tools: BIM will help to achieve a higher level of prefabrication, greater flexibility and variety in construction methods, in building typology, fewer documents, many less mistakes, less inefficiencies and greater productivity. Construction projects will better respond to customer needs, thanks to better analysis and exploring more alternatives, lower costs and lower overruns of the program. In the future and medium term (10 years) the development of BIM will be guided by social, technical and economic motivations.

1.2 Current trends

In any sector technological and market trends are good indicators of the near future. The trends observed reveal the potential direction and influence that BIM will have in the construction sector. The trends that influence the forecast are:

- FOREFRONT CUSTOMERS. They increasingly require the use of BIM and have drawn up contractual conditions and guidelines to make it workable.

- THE DEMAND FOR PERSONNEL WITH NEW SKILLS. The gain in productivity and drafting of documentation for fabricate and concrete structure cast in place has been measured and examined establishing that it is around the 30-40%. For architectural design the consequence is the downsizing of staff in any kind of building design practices.

- THE DEVELOPMENT OF NEW MANAGEMENT ROLES. Model-managers play two fundamental roles: at the company level they provide software support services; at the project level they work with design teams to update the building model.

- THE ADOPTION OF BIM AMONG ARCHITECTS, ENGINEERS AND CONTRACTORS. In 2009, over 50% of each of these groups said they used BIM at a moderate or high level.

- SUCCESSFUL ACHIEVEMENTS IN THE CONSTRUCTION SECTOR. These have led contractors to review their procedures, starting to exploit the advantages they have identified at company level.

- GREATER DEMAND FOR ENVIRONMENTALLY FRIENDLY BUILDINGS. Presence of a public aware of the threats of climate change. BIM helps designers to achieve eco-sustainable buildings, providing tools for the analysis of energy requirements that make possible to request and use building products and materials with low environmental impact. BIM tools can also help in evaluating projects for LEED certification.

- MANUFACTURERS SUPPLY 3D CATALOGS. Content libraries provide large archives of building products for BIM: through search engines these contents are increasingly accessible.

- BIM MAKES THE CONSTRUCTION OF INCREASINGLY COMPLEX BUILDING SYSTEMS ECONOMICALLY AND GLOBALLY FEASIBLE. BIM provides reliable and free-error information and abbreviate delivery times; allows prefabrication in the factory of a larger portion of the building which reduces costs, improves quality and simplifies the implementation process.

PROCESS TREND:
▪ Customers request BIM and they are changing the contractual conditions to allow its use
▪ New skills and new roles are developing
▪ A recent survey showed that among all respondents the percentage of "very heavy" BIM users has grown from 34% in 2008 to 45% in 2009.
▪ Successful achievements in construction have led to wide corporate diffusion by the contractors
▪ The benefits of integrated practice are receiving large-scale observations and are tested continuously in practice
▪ Standardization attempts are taking shape
▪ Eco-friendly buildings are increasingly requested by customers
▪ The BIM tools and 4D CAD have become common tools in large offices

Table 1: Process trend
Source: Smart Market Report – web

TECHNOLOGICAL TREND:
▪ Automatic control to verify conformity and constructibility, using BIM models, it is becoming accessible
▪ The main suppliers of BIM platforms are adding features and are integrating project evaluation skills, providing ever richer platforms
▪ Salespeople are increasingly expanding their range of action and provide BIM tools for specific industries
▪ Manufacturers of building systems starting to provide parametric 3D catalogs
▪ BIM tools with site management functions are increasingly available
▪ BIM encourages prefabrication for increasingly complex subcomponents, that can be manufactured far away

Table 2: Technological trend
Source: Smart Market Report – web

1.3 Impact on customers

Customers will experiment changes in quality and nature of the services available and greater overall reliability of the project budget in the program compliance and delivery times. In the preliminary stages of a project, customers can expect to meet more 3D views and conceptual BIM models. With the increasing availability of internet technologies based on 3D, the owners will have more options for view the design models and use them for advertising, sales and evaluation of projects in the construction site context. They also allow customers and designers to elaborate and compare multiple design alternatives in the early stages of the project, when decisions have greater impact on costs and life cycle. Customers who build frequently will look for groups of designers and builders who have experience with BIM and know how to take advantage of these tools with lean processes. Likewise the improvements that BIM brings to the construction process will begin to become evident in lower construction costs and better performance. Customers will increasingly appreciate the power of these tools which improve the reliability of financial management and scheduling, as well as the overall quality of the project. The three main engines for a widespread adoption of this tool will be:

1. the demand for a better quality of service from customers;
2. increase in productivity in preparing the documentation;
3. the contractor's request to support a virtual construction

The competitive advantage that BIM provides will motivate individual companies to adopt it, not just for the improvements that this tool can make within the company but also, to obtain a competitive advantage on the market. Design studies will begin to expand their field of services, to include detailed energy and environmental analysis, study of the activities inside the structures, value engineering throughout the design process based on BIM cost estimatation. Initially these services will allow to differentiate themselves on the market, over time will be adopted more widely from most of the industry. As soon as these companies develop their new technical environments and new skills, those who adopted this tool only later or design studies that do not use BIM will find increasingly difficult to stay on the market. New professional qualifications are emerging, like the Building Modeler or Model Managers that require technical and design know-how. An important change that the trend IPD (Integrated Project Delivery) will lead to many work environments it is the location of designers from all disciplines in a single office. Working in a common office, with a large room for frequent coordination meetings focused on the representation of an integrated building model, represents a very different way compared to traditional working methods with each designer in their office.

1.4 Obstacles to change

BIM must face numerous obstacles for its progress. These include technical barriers, legal and liability issues, inadequate business models, resistance to changes in occupational models and need to educate a large number of professionals. The main technical obstacle it is the need for sufficiently mature interoperability tools. Full adoption of BIM in every business takes from two to three years to become effective So, while it is unlikely that significant productivity gains will soon be found in the sector, can instead be foreseen significant reductions in construction costs. The first users of success both in the design and in the construction field will benefit from their foresight until the rest of the industry reaches them.

CHAPTER 2

BIM - BUILDING INFORMATION MODELING

2.1 What is BIM?

BIM or Building Information Modelling is a process for creating and managing information on a construction project across the project lifecycle. One of the key outputs of this process is the Building Information Model, the digital description of every aspect of the built asset. This model draws on information assembled collaboratively and updated at key stages of a project. Creating a digital Building Information Model enables those who interact with the building to optimize their actions, resulting in a greater whole life value for the asset.

Thanks to the BIM methodology, the building is “built” before its physical realization through a virtual model and through the collaboration of all the actors involved in the project. It brings together all of the information about every component of a building in one place and allows all interested parties to have access to the same information at the same time through interoperability between different technological platforms. In this way, the risk of mistakes or discrepancies is reduced, and abortive costs minimized. BIM data can be used to illustrate the entire building life-cycle, from the project to the construction, up to its demolition and disposal. With BIM it is possible to create - more than a three-dimensional representation - an information model dynamic, interdisciplinary, shared and constantly evolving that contains data on: geometry, materials, bearing structure, thermal characteristics and energy performance, installations, costs, safety, maintenance, life cycle, demolition and disposal.

Figure 1: BIM for life cycle
Source: cos'è il BIM – acca.it

B as BUILDING: indicate a set of objects or might connote a broader vision of building and architecture also extended to the environment and the surrounding context. It does take into account also a number of considerations such as direct links to those that might be strategic decisions, user ratings, subcontractor contribution, the concept of sustainability.

I as INFORMATION: is the easiest term to explain and it is also the heart of BIM because it is the management of information. BIM is revolutionary because change the way to manage and exchange information regarding the entire life cycle of a project and each of its parts. The information is not limited to the visual representation of the parts of the project but refer also to the physical and logical characteristics of their real-life counterparts, including non-visible information. This enables customers, designers, engineers, builders, manufacturers, owners to understand an entire project before its construction, refine the proposal in order to avoid errors and generate efficiencies.

M as MODELING: this is the term that has developed more debates in the field; its interpretation fluctuates between *model*/*modeling* and *management*. *Model* not specify what is to hold the model, if 2D and 3D objects, smart objects and/or the whole set of non-geometric information of the building. *Modeling* indicates an activity and not explicit whether the action should provide the creation, the collection, the updating and sharing of data, nor the authors of this information. *Management* implies the planning and the organization of resources and not only the easy production of information. The term takes on an even more comprehensive connotation when the management aspect includes not only information but especially the role of the actors in the process. Management is an essential ingredient in translating the information often complex and different according to a wide variety of sources, along the path leading to their updating and their use. From this point of view, *management* would represent the meaning more appropriate rather than the one provided by the *model*/*modeling* binomial.

2.2 BIM in the building process

The goal of BIM is to create a design that is less expensive, more efficient, and therefore more effective than the sum of the different phases of design that should be followed in a 2D approach. This has already led the major Italian construction companies to invest in BIM training, driven by the foreign market that has long been calling for it in international calls, and on this occasion have had the opportunity to directly verify the advantages of using the integrated design. In the construction sector BIM contributes efficiently and effectively to modernization in the management of a work to be carried out or to be recovered or simply to be maintained. The building sector includes a series of fields that benefit from the use of BIM:

- **Architectural design:** the “BIM” designer it is certainly more effective than those draw up the documents using traditional technology. The cost estimation, the processing of realistic images, the energetic certification and other things can talk and be integrated more easily through the new IT tools. The professionist is able to quickly transfer the design documents keeping all the qualitative aspects intact.The BIM tridimensional model, full of data, could be shared without losing effectiveness in the transmission of information to other studies and other IT platforms.

- **Structural design:** in the structural field BIM shows its usefulness in the decrease of interaction times between the calculation programs and the modeling software. Avoiding a new modeling for the structure reduces errors that the operator could make. Information on the construction elements and their characteristics, sections, materials, etc. are imported directly and quickly. With BIM software is easy import/export information and exchanges bidirectional data allowing the communication of BIM models through which is possible to evaluate new or alternative solutions with the professionals involved.

- **Plant design:** the plant design is definitely the most interested in BIM technology, of dialogue and integration with many computer tools makes the designer very efficient.The new technology allows to size and position the plants quickly, ensuring an excellent quality / price ratio which is also reflected in the management of the same.

- **Infrastructure design:** the planning of infrastructures through the “BIM oriented” allows to check and integrate the project with other disciplines. As for the other areas, BIM allows to avoid or at least drastically reduce errors and lack of information and data.

- **Project management:** this figure could benefit from the BIM implementation in the company. Through a training activity, it will be easy to relate with the interested parties and use the BIM tools available in the best way.

- **Construction site management:** according to BIM, it allows the works director to be always updated on the situation of the works. New technologies (marking of the elements and the possibility of verifying their storage and positioning at distance) facilitate work of the management office.

The BIM methodology allows the optimization of the whole building process, in fact it optimizes complex workflow among the designers, the works director, the customer, the construction company, suppliers and site director, significantly improving the decision making process. Unlike a traditional approach, BIM workflows are managed in a shared way by all the participants thanks to the centrality of the BIM itself, that contains all the information and changes in real time, allowing the whole team to be constantly aware about the project.

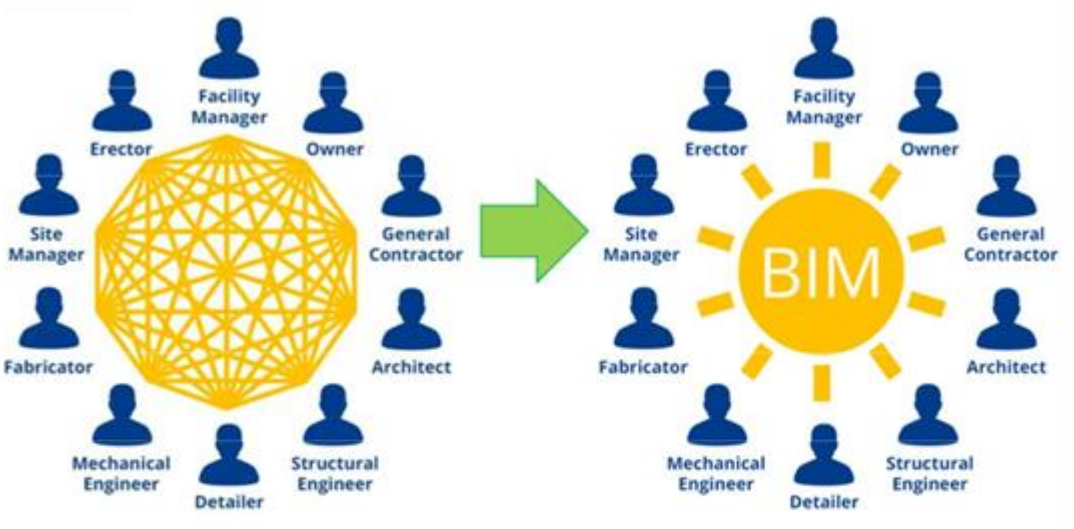


Figure 2: Differences between traditional and BIM approach
Source: Gianpiero Brioni's elaboration based on Tekla.com

Thanks to this approach based on sharing called "work-sharing", BIM is able to give support to the entire building process from concept, design and construction of the work up to its exercise and management. It is essential that the whole team has access to the central model, although the access is only intended to update on the progress of the work.

2.2.1 Actors and roles

The realization of civil work involves high complexity of procedures and at the same time a high number of involved professionals. Both aspects, if not managed through an efficient co-ordination process, determine inevitable conflicts. Such conflicts during the construction, often create delays, need for variations, disputes, faults and executive defects, resulting in waste of time and of economic resources. To have a successful BIM, serve people who manage it; in fact, there are many definitions of roles of people within the BIM and the main are:

- **BIM Manager**, whose tasks and responsibilities are those of coordinating the use of BIM within the contract, determine the programming of uses, carry out quality control, define responsibilities and documents within a BiM Execution Plan and approve the exchange of information among the figures taking part in the contract. He manages and updates the BIM model for all disciplines coordinating the activities of the other figures. It also guarantees the coordination of the project, managing the roles and involved phases, and identify the interference reassigning their correction within the project team. He is a person to contact for difficult questions and that acts as a problem solver and facilitator since he is a guide that helps team members to make the right decisions. The manager sets the project models, standards and protocols for BIM.

- **BIM Coordinator**: he sets up the modeling environment in order to deliver the output as specified by the BIM manager. He coordinates the BIM specialist involved in the project to ensure the application of standards and processes. It also develops and updates BIM content (bookcases and standards). The BIM coordinator is able to use the software tools necessary for the coordination of drafting activities, control and management of the project. He will deliver his model according to the time schedule and to the quality required by the BIM manager.

- **BIM specialist:** deals with the creation and development of the 3D model and subsequent extraction of the 2D documentation and calculation data. It also performs technical analysis (structural, plant engineering, environmental sustainability). He has the role of "information modeller”.

2.2.2 BIM technology in Europe and Italy

Absolute reference point in the European context regarding the regulatory introduction of BIM is the “European Union Public Procurement Directive” 2014/24 of 26 February 2014. The Directive voted in January 2014 from the European Parliament and later adopted, invites member states of UE, within 2016, to "encourage, specify or impose” the use of BIM, as a reference standard, for all projects and works with public funding.

As a matter of fact, the directive 2014/24/EU on public procurement clearly expresses the indication to introduce the Building Information Modeling within the procurement procedures of member states. The adoption of the directive provides that the 27 member states encourage the use of BIM in their respective countries for publicly funded projects in the European Union starting from 2016. The first countries to move were those of the north: the Netherlands, Denmark, Finland and Norway who have already arranged the BIM maturity diagram, that are legislative measures requiring the use of the building information model approach. In Italy the obligatory nature of specific electronic methods and design tools was introduced by the new Procurement Code. Its aim is to rationalize design activities and related checks, going to improve and streamline processes that until today have influenced times and ways of participation in tenders. On 1st of December 2017 the Minister of Infrastructure and Transport signed the decree which defines the methods and timing of introduction the mandatory use of electronic construction modeling methods, tools and infrastructure in the contracting stations, to rationalize the design activities and the related checks. The provision also regulates the preliminary requirements of the contracting authorities who will have to adopt a training plan for their staff; an acquisition of maintenance plan and management software for decision-making, information processes and an organizational act that explicit the control and management process, data managers and conflict management. The obligation to use the methods and electronic modeling tools starts from the *1st January 2019 for works of an amount equal to or greater than 100 million of euros*, and then gradually for smaller amounts: in 2020 for complex works over 50 million, in 2021 for works over 15 million, in 2022 for those over 5.2 million, in 2023 for works over 1 million and from the *1st of January 2025 for all new works.*

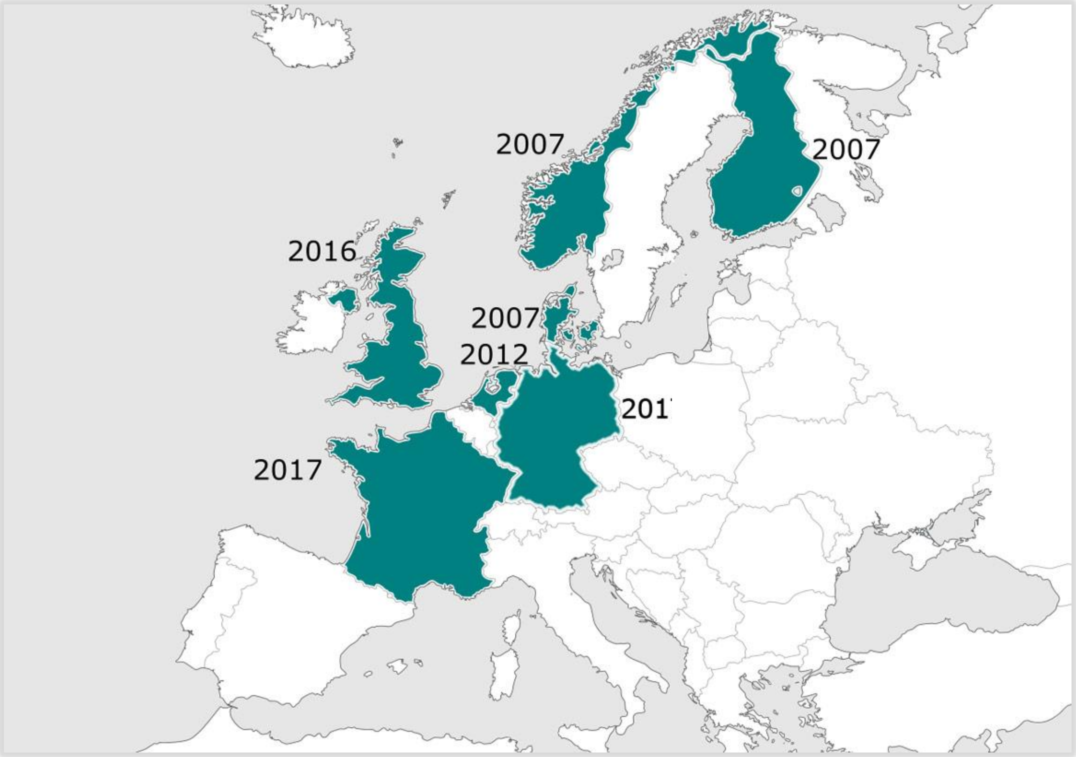


Figure 3*: Map of countries where BIM has became part of the construction acts*
Source: Bim Tech page 2017 - web

2.3 BIM benefits: main differences with traditional design

The general benefits derived from the adoption of BIM are manifold and probably will become more numerous in the future, as practices will evolve towards a full cooperation between the actors. BIM allows to overcome inefficiencies typical of the traditional design method of conventional professional practices, allowing, for the first time in the history of construction, to achieve full integration between the planning and the executive phase. All evaluations in terms of efficiency, process control and transversal sharing of the information expressed in relation to the design phase of the work are valid and find their most effective expression also in the transition to the construction phase. Selection of offers, procurement management, subcontracting, industrial accounting and works, construction of the work, progress of work are just some of the passages in which completeness and sharing of information, contained in a three-dimensional model developed according to the BIM approach, have important advantages in terms of process optimization and control, costs and management of any variants.

In a traditional CAD application there are only lines and geometric figures that do not contain any kind of information or relationship; changes to the variations must be made several times and especially updated in every table. While in the BIM, the design always remains at the center of the design process. To each object are associated not only geometric and dimensional values, but also all the necessary parametric data and constraints. Use of a standard protocol (IFC) allows to interface this information with additional data among which structural ones, plant engineering and technical / management, calculations, estimations, work scheduling, cost / budget analysis etc. creating an organic view of the project in all its conceptual, executive and management phases.

The advantages of the Building Information Modeling compared to traditional project management methods are evident both in terms of optimization of operating flows and productivity. BIM it is not limited to enlarge the basis of the data contained in the three-dimensional models of the project and the possibilities of sharing them; precisely such advantages, in fact, involve important consequences also in terms of cost optimization. Next to the obvious time savings, equally important is the total elimination of errors, duplications, interferences, thanks to the update in real time of all the project tables depending on the variations made, and the consequent reduction of errors and subsequent corrections.

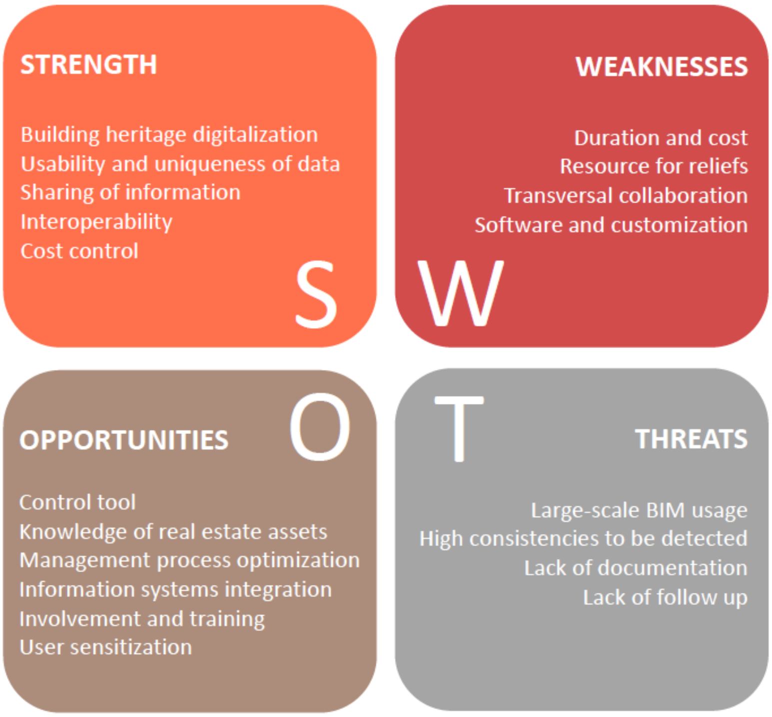
After describing the main differences between BIM and traditional design, it is worth trying to identify what positive and negative effects would have the implementation of a new BIM software. In a complex and variable competitive scenario, the role of the manager in a company includes the analysis of the environment in which the company operates in order to identify opportunities that can be exploited to its own advantage or threats. The evaluation of these elements is also known with the acronym SWOT Analysis: alternatively called SWOT matrix, this is a structured planning method that evaluates Strengths, Weaknesses, Opportunities and Threats of a project, a business or of other situations in which a company or a person must make a decision to reach a goal.

Starting from the following definitions:

- *Strengths* are characteristics of the business that give it an advantage over others to achieve a goal;
- *Weaknesses* are the characteristics of the business that place it at disadvantage compared to others in the achievement of a goal;
- *Opportunities* are the elements in the environment that the business or project could exploit to its advantage to achieve a goal;
- *Threats* are the risks in the external environment that could cause troubles for the business.

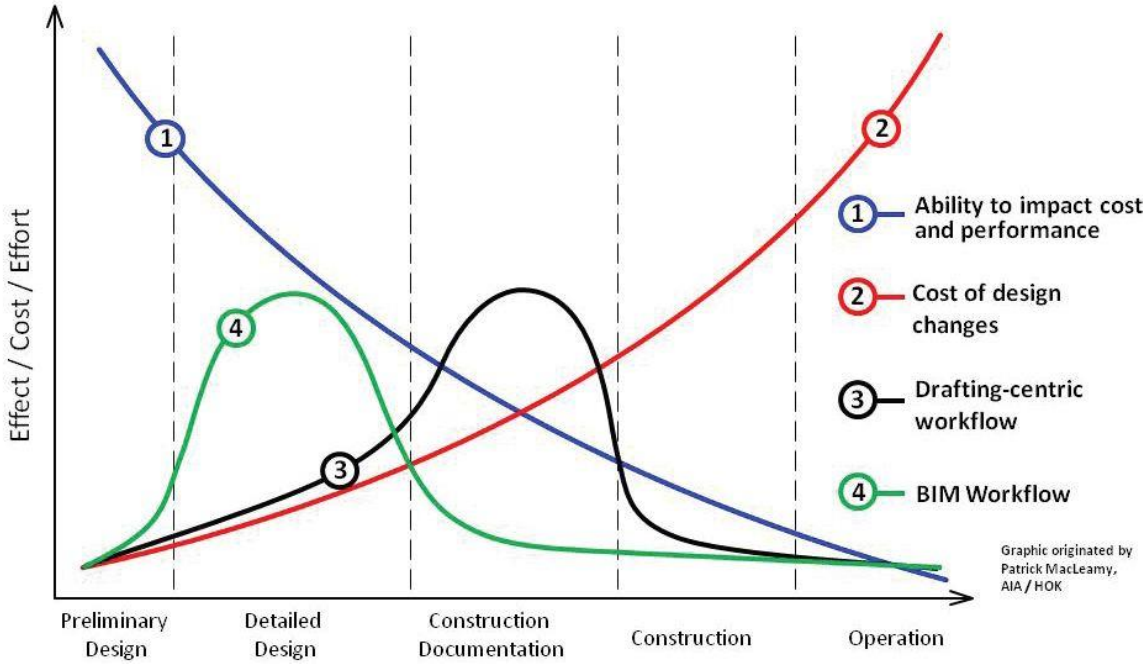
The SWOT analysis evaluates the above mentioned factors in order to:

- exploit all strengths;
- improve all weaknesses;
- exploit and take advantage of all opportunities;
- reduce all threats.



Charts 1: SWOT analysis of Building Information Modeling software
Source: elaboration by the author

So, the implementation of BIM in the construction process can be a great solution for management problems that characterize the construction industry, but involves a considerable initial investment mainly related to three items: the acquisition of software solutions aimed at building information modeling and management (BIMM), the purchase of hardware systems suitable to the management of database that is onerous from the point of view of the complexity of the files and the creation of human capital specialized in the generation and administration of these systems. But hardly companies, especially the smallest, are able to cope these costs. The problem is always analysed from the point of view of the Return of Investment (ROI), highlighting how the investments return curve has an exponential growth. As it is possible to see, the graph shows the classic bell curve of the traditional design process with the peak of effort and resources in the middle of the construction and documentation phase and shows how the BIM shifts the peak about the resources usage at the end of the preliminary design stage. It also shows that the effective design changes are easier and less expensive in the early stages of the process and less effective and more expensive later.



Charts 2: MacLeamy curve
Source: ingenio.web

In summary, in order to obtain a reduction in design costs, it is strategic consider the following aspects: the development of open source building information modeler (BIM), cost reduction for sharing in cloud building databases; the creation of specialized human capital by universities and training institutions.

2.3.1 Interoperability

Interoperability is the prerequisite so that BIM is used in a growing number of projects as a methodology and not only as a simplified model used during the design phase. Interoperability in architecture, engineering, and construction (AEC) industry allows systems and applications to work together and freely exchange design and construction data. It revents data from being “locked in” specific applications or vendors and it is a key to driving end-to-end Building Information Modeling (BIM) process across teams, projects, and applications including building operations.

The interoperability of the software identifies the continuous exchange of data at the software level between different applications, each of them may have an internal data structure. The main objective of interoperability is the ability to have the right data in the right format at the right time, in order to eliminate waste in the stages of recreating, editing and converting of data during the entire building process, in which is created a large amount of information. BIM community is unanimous in saying that the key to true interoperability of the information resides in the use of open standards, since they allow different actors to interact even if they don't use the same software package; non-use of open standards may result in a lack of opportunities for works and collaborations that provide for a wider project team. It's important to analyze the main open standards and their characteristics:

- **XML (Extensible Markup Language)** is an open standard widely used. Its structure is derived from the known HTML (Hypertext Markup Language) format used for coding Web pages and it was developed as an alternative to the IFC model to simplify the exchange of data between AEC applications and to link information of digital models using Web services. This standard is divided into different types of format depending on the use. For example, Green Building XML (gbXML) was developed to allow interoperability between BIM modeling software and platforms that deal with energy simulation. Others BIM schemes based on XML are aecXML, ifcXML and BIMXML.

- **IFC (Industry Foundation Classes)** file format supports interoperability and is: a platform-neutral, object-based, open file format designed to transfer 3D geometry and attribute information. It is a commonly used collaboration format to share information within BIM-based projects including Architectural and Structural disciplines. IFC is supported by about 150 software applications worldwide to enable better workflows in AEC industry. It is an open standard developed and maintained by buildingSMART[1], freely available to software developers and user community, to support the interoperability of BIM data. It is registered by ISO and is an official International Standard ISO 16739:2013.

- **COBie (Construction Operations Building Information Exchange)** is an open international standard used for the transmission of data during the life cycle of the building, particularly required for the Facility Management operations. There is no a specific software for Cobie but it can be integrated with over 20 commercial software available in the market through specific spreadsheets. The main difference between XML formats, IFC and COBie is that the first two are designed to work within the interactions between software and computers. Instead, the organization of data in Cobie is developed through the drafting of spreadsheets which allows a "human reading" of the exchange of information. The majority of the users in the US and in the UK are familiar with this format thanks to the ability to import Cobie files into Excel.

2.3.2 BIM dimensions

The UK government has recognised that the process of moving the construction industry to 'full' collaborative working will be progressive, with distinct and recognizable milestones being defined within that process, in the form of 'levels'. These have been defined within a range from 0 to 3:

- LEVEL 0 - Unmanaged CAD, in 2D, with paper (or electronic paper) data exchange.

- LEVEL 1- Managed CAD in 2D or 3D format with a collaborative tool providing a common data environment with a standardized approach to data structure and

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[1] buildingSMART is a non-profit organization created by the National Institute of Building Sciences and having offices and links worldwide. Its purpose is to promote the standardization of BIM processes and workflows. Certainly, it represents one of the most important points of reference for those who deal with BIM, in fact within the web portal you can find accurate descriptions of open BIM standards, guidelines and pilot projects

format. Commercial data will be managed by standalone finance and cost management packages with no integration.

- LEVEL 2 - A managed 3D environment held in separate discipline 'BIM' tools with data attached. Commercial data will be managed by enterprise resource planning software and integrated by proprietary interfaces or bespoke middleware. This level of BIM may utilise 4D construction sequencing and/or 5D cost information. The Government’s BIM Strategy Paper called for the industry to achieve Level 2 BIM by 2016.

- LEVEL 3 - A fully integrated and collaborative process enabled by 'web services' and compliant with emerging Industry Foundation Class (IFC) standards. This level of BIM will utilize 4D construction sequencing, 5D cost information, 6D sustainability information and 7D project lifecycle management information.

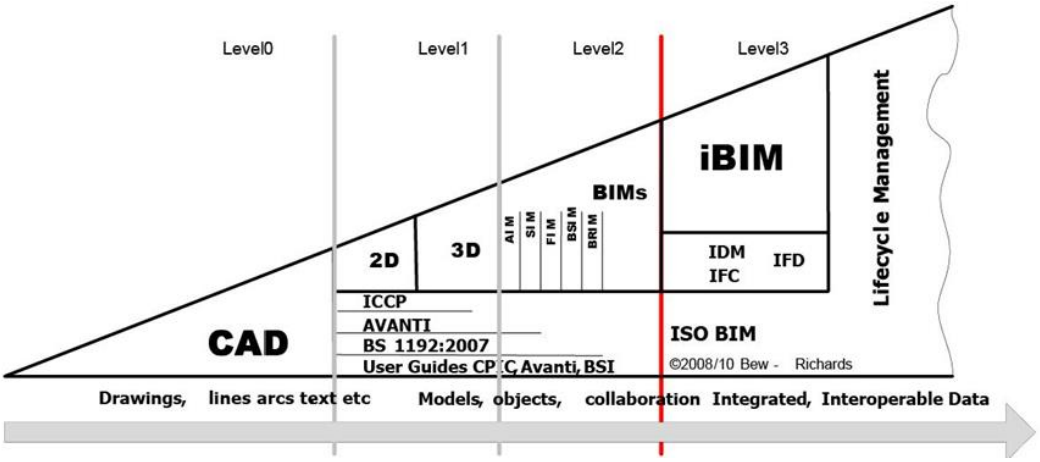


Figure 4: BIM maturity levels
Source: Bew Richards ‘’BIM maturity levels’’ – 2008

- BIM 3D – *Parametric data in a collaborative model*. The basic platform for the various types of analysis used in the different phases is the 3D one. During the whole process different types of models are created (architectural, structural model for plants etc..) which are grouped into a single coordinated BIM model. 3D modeling helps participants manage their multidisciplinary collaboration effectively with the possibility of analyzing complex spatial and structural problems. The control determined by the 3D modeling and the information contained, greatly reduces the possibility of errors, omission and oversights which would entail additional costs and resources if detected in the construction phases (just think of the most common conflicts like those between plants and structural or architectural parts). It has been estimated that the identification of inconsistencies or defects in the design phase results in 10% savings on construction costs, minimizing the risks of incurring changes during construction.

- BIM 4D – *Scheduling*. A more advanced model of BIM is 4D modeling subject to a dynamic state, used for related activities of construction planning. The fourth dimension of BIM allows participants to extract and view the progress of various activities through the project life cycle. The use of 4D-BIM technology improves conflict control or complexity of changes occurring during a construction project, providing methods for management and displaying site status information, changes in the project, in addition to supporting communication in different situations like inform the staff on site or risk warning.

- BIM 5D – *Estimation*. The BIM 5 D allows the estimation of the costs of the work, the quantification of building materials and the various components, thus being able to evaluate also the costs related to different scenarios and the progress of the various activities.

- BIM 6D – *Sustainability*. It allows to perform the energy analysis of the building, estimating the energy consumption in a complete and precise way. It also allows measurement and verification during construction.

- BIM 7D – *Facility Management*. The seventh dimension, concerns the *Facility Management* regarding the operation and maintenance of the building throughout its life cycle, allowing to extract and track important data like the state of the components, specifications, maintenance / user manual, warranty data etc.

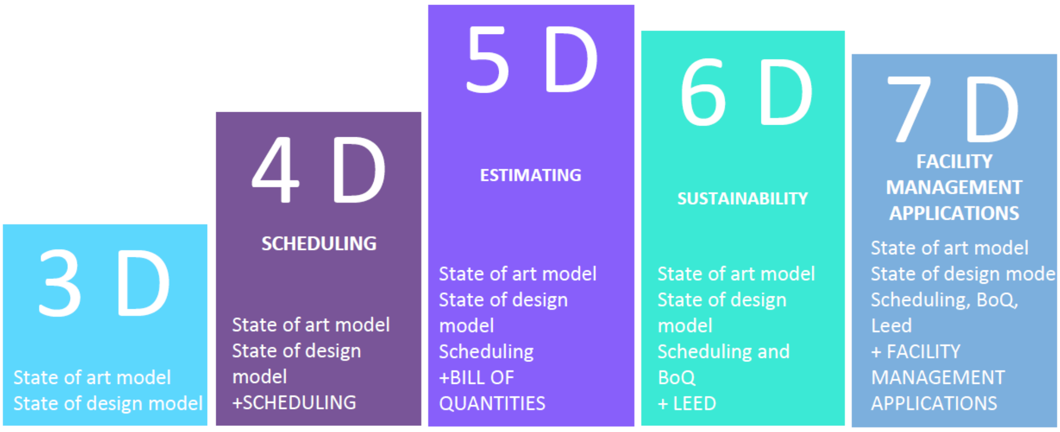


Figure 5: the BIM dimensions
Source: BIM platform - web

CHAPTER 3

BIM FOR FACILITY MANAGEMENT

3.1 Introduction to Facility Management

Real estate assets are often a fundamental asset for a private company or for a public body. Therefore it is essential that everything works in the best way and that there are no inefficiencies.

The IFMA (International Facility Management Association) defines the *Facility Management* as "the design, implementation and control process through which the facilities (the buildings and services necessary to support and facilitate the company's activity) are identified, specified, found and supplied in order to provide and maintain those levels of service able to meet business needs, creating a quality work environment with a cost as low as possible". It is clear that this is a complex discipline in which knowing is the premise to manage and it is therefore necessary to have a great deal of information extremely different from each other. That of the Facility Management it is an integrated approach that, through the design, planning and provision of support services to the company's main activity, aims to increase the effectiveness of the organization and to make it capable of adapting easily and quickly to changes in the market.

The three main aspects that characterize the discipline of Facility Management are: strategic, analytical and management. The strategic aspect concerns every decision on the management and procurement policy of services, distribution of resources to be used to support goals of supplier choice, etc. The analytical aspect is related to the understanding of customers' needs relating to services, to control the results of management and efficiency in the provision of the service, to the identification of new techniques and technologies that support the company business. This is therefore a fundamental aspect to make sure that the Facility Management contribute effectively to the achievement of the company's objectives.

The management-operational aspect concerns the management and coordination of all services overall intended (not of the individual services) and includes the definition of systems and procedures and the implementation and reengineering of supply processes.

The term “facility” indicates both the property where the work is carried out, both all service activities. When we talk about facility we indicate the work activity container but also all the services necessary to make it possible. We can therefore say that the area of application of the discipline is that of strategic management of properties and services that is, all the business support activities of a company.

Thanks to BIM, the management phase is conceived since the initial stages of the process, according to the principle of “begin with the end in the mind”. In fact, once the construction is completed, the data for management and maintenance operations should be available for be used in an accessible and well-defined shape. This allows to create a continuity in the data exchange along the entire life cycle of an asset and to engender an integration between BIM and FM services.

It’s important to highlight that assets are constantly in change, areas can be used for functions different from the original one, mechanical and electronic components can be replaced and systems can be modified. So, BIM/FM system, if regularly updated, can be the main instrument to deal with these changes and to track the current condition of the assets.

Figure 6: Characteristics of Facility Management
Source: - elaboration by the author

3.2 Facility Management in Europe and Italy

In Europe the market of Facility Management spreads starting from the United Kingdom in the first half of the 80s and then in Holland, in the second half of the 80s. In France, unlike what happened in the United States, where the initial link with property management appears tight, the Facility Management develops starting from the theme of the management of general services in organizations, in the late 70s and the first half of the 80s, to evolve towards the real estate Facility Management in the 90s. Germany sees development outsourcing processes since the early 1980s, driven by the cleaning sectors, of security, of catering and later from the Information Technology sectors, while it is with the end of the 80s that it is affirming a real market of the Facility Management and then in the 90s also in the Scandinavian countries. In Italy the market of Facility Management moves his first steps between the end of the 80s and the first half of the 90s, to grow powerfully in the last 20 years.

How it is easy to imagine, the legislation is addresses in particular at the public sector of the Facility Management market. In fact, in the last few years the European Union has updated the rules on the awarding of public works contracts, supplies and services. The goal was to coordinate previous community regulationsthrough a simplification and update of the legislation, necessary in light of technological and economic innovations and with a view to strengthening the principles of competition and transparency. The result of this commitment was the merger of the four existing European directives in two legislative acts, that are:

- Directive 2004/18CE of the European Parliament and of the Council 31 March 2004: “Coordination of procedures for the award of public works, supply and service contracts”

- Directive 2004/17/CE of the European Parliament and of the Council 31 March 2004: “Coordination of procurement procedures for water and energy supply companies, of institutions providing transport services and postal services”. There are then several specific rules in the field of Facility Management that have been processed, approved and published by CEN (European Commitee for Standardisation). The first rules go back to the 2006 and aim to provide basic normative references for all operators in the European market of Facility Management services, intervening on the terminology and the contracts.

Unlike other countries, in Italy today there is no precise definition of the role of the Facility Manager, of his responsibilities and position in the company, there is no common experience that precisely identifies this role. In Italian companies this activity is mainly carried out by the head of general services, which often is the director of staff. This role is generally played by people without adequate preparation and cultural background, often they are technicians or simply "administrative" or people that, living in the company for many years possess the historical memory of the building, but do not have decision-making powers. This implies the impossibility of an overall assessment of the real estate assets at the expense of planning activities, savings on operating costs and above all the lack of correct investments in order to increase real estate income. Our country comes from a tradition in which the real estate assets it has been for a long time economically poorly controlled and managed, so that businesses and institutions who have made substantial real estate investments over time today they have to manage a heritage whose entities and status are often little known. This is particularly evident in the case of real estate belonging to public institutions, but also in the case of some large private organizations.

In general, the state of Italian real estate assets is characterized by a management that does not allow to obtain a good economic return and therefore the property demonstrates a widespread disinterest in the deterioration-maintenance of buildings over time. The immediate consequence is that generally Italy is characterized by a degraded heritage, with little possibility of adaptation to new needs (technology, safety, comfort), if not with substantial investments. Unlike the American situation in which the average life of a building is around 40-50 years, after which the profitability of the building construction is exhausted, in Italy, for culture and tradition, buildings tend to "live" longer and therefore a more efficient program is indispensable in the management of the economic performance of the building. The main causes of the physical degradation of buildings are to be found in factors of an economic nature: design is considered an activity having the aim of minimizing construction and installation costs, reducing as much as possible expenses in the short term without any consideration for the usability and efficiency of the space-structures in the long term. Even with a quick glance is perceives how the extent of real estate assets, in the disposal phase, has a very significant size in all Italian cities. One of the reasons why in Italy the Facility Management finds widespread interest it derives above all from the need to reduce management costs of the vast real estate assets and the need to redevelop the spaces of the tertiary buildings making them dynamic and functional. Indeed, the mutability of the activities, the transformation of organizations increases the need for spaces / buildings able to be variable and flexible respect to the the occupant’s needs. Organizations express a strong need for quality spaces (with innovative plant engineering) and dynamic, that is, able to transform, adapting to the needs of the organization; this "quality" must have certain and schedule costs, getting this from a property is neither easy, neither immediate.

3.3 Services organization

Facility management and its managerial practices include a high number of services offered to the companies. In the past, these services were reception, cleaning, security, catering, internal logistics, mailing, space and layout management and document management. The continuous evolution of the FM sector has increased the number of outsourced support processes, thus enlarging the offer of services in the market. No-core services, either outsourced or not, can be classified into homogeneous classes according to the different management areas. As mentioned above, the main field of facility management services is real estate. Three no-core services classes are related to it:

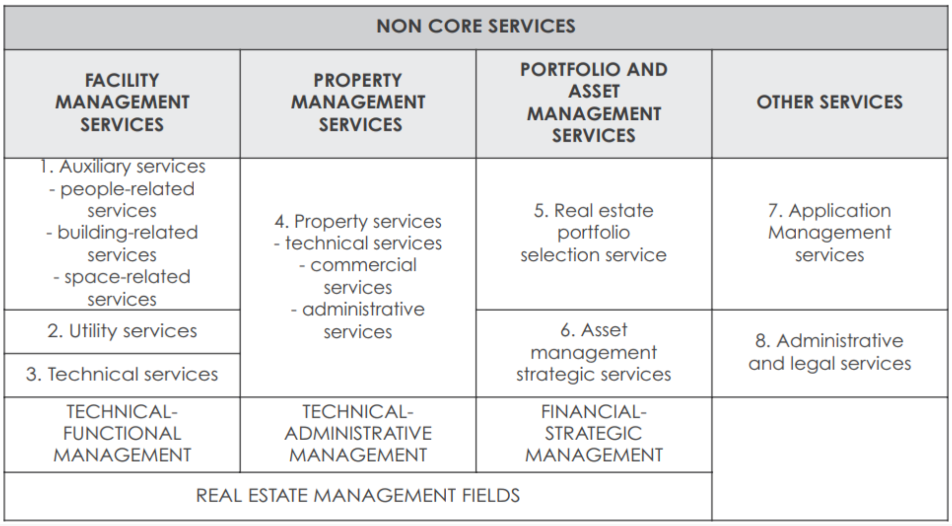
- facility management services;
- property management services;
- asset and portfolio management services.

To each class correspond a management focus:

- technical-functional management;

- technical-administrative management;
- strategic-financial management.

The following table shows the three classes of real estate related services as well as other non core services.



NON CORE SERVICES			
FACILITY MANAGEMENT SERVICES	PROPERTY MANAGEMENT SERVICES	PORTFOLIO AND ASSET MANAGEMENT SERVICES	OTHER SERVICES
1. Auxiliary services - people-related services - building-related services - space-related services	4. Property services - technical services - commercial services - administrative services	5. Real estate portfolio selection service	7. Application Management services
2. Utility services		6. Asset management strategic services	8. Administrative and legal services
3. Technical services			
TECHNICAL-FUNCTIONAL MANAGEMENT	TECHNICAL-ADMINISTRATIVE MANAGEMENT	FINANCIAL-STRATEGIC MANAGEMENT	
REAL ESTATE MANAGEMENT FIELDS			

Table 3: Non-core services and their management fields
Source: the facility management (2009) – De Toni F., Nonino F., chapter 1

3.3.1 Auxiliary services

In the facility management field, auxiliary services are the most characteristic ones because they support the primary activities of an organization. Using the instructions contained in the appendix B UNI 15221-1:2007 and merging by typologies, is possible to distinguish the following facility management services subdivided into three groups depending on what/whom they are related to:

•**Building-related services**: Their management is defined building management that is the management of the activities designed to monitor, to periodically inspect, to take care of the out-of-order and emergency signals, and to logistically support building and real estate maintenance activities. (Building maintenance and functioning, restructuring, disposals, building efficiency securing, technical plant and equipment functioning, cleaning, green area up keeping, etc.)

•**Space-related services**: The management of these services is defined space management. (Space allocation, configuration and reconfiguration, office signals, space use monitoring and inspection, office activity supporting, archives management, office layout, office furnishing and equipment, etc.)

•**People-related services**. Their management is defined as employee service management. (Reception, catering, cleaning, staff transportation, porterage, couriers, mail distribution, etc.)

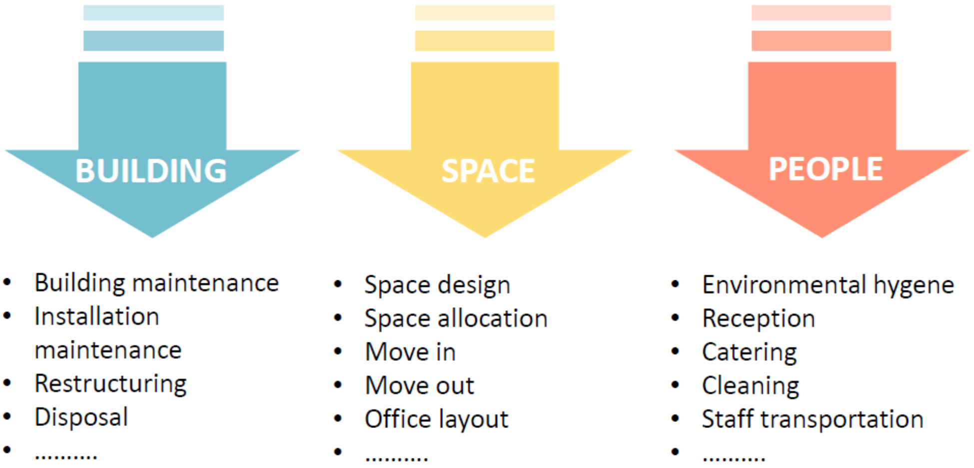


Figure 7: Application areas of facility management
Source: elaboration by the author

The process of outsourcing of the Facility Management services it is particularly delicate and complex. Below are analyze the various phases that compose it and on which depends the success or failure of the activities. It is clear that the activity of a company it is all the more efficient as much as his level of services is adequate for the needs expressed by production. In order to outsource services correctly and efficiently it is necessary to follow a consolidated process that is summarized here.

- **Decision-making phase.** It is the initial phase of the outsourcing services process turns out to be of great importance because lays the foundation for all the subsequent ones. Gli aspetti sui quali deve concentrarsi l’azienda consistono essenzialmente nelle seguenti attività:

- Analysis of internal needs, which occurs through managerial choices, internal audit or benchmarking on companies operating in the same sector.
- Identification of the necessary services, to distinguish between "basic" and "advanced" services.
- Definition of the spending budget.
- Definition of the outsourcing model to be applied.

- **Technical Phase.** In this second phase are deepened the aspects related to the services to be requested emerged in the first phase. In particular they proceed with:

- definition of Service Levels Agreement (SLA);
- elaboration of the technical specifications.

3.3.2 Audit for Facility Management

It is believed that in the decision-making phase are of fundamental importance time and dedicated resources to the audit of services. In fact his allows to verify the effective efficiency of the model in relation to characteristics and production needs of the company, through the verification of all the factors involved in the process. The internal audit represents a first qualitative assessment tool of its service management model, which has as its goal to bring out the strengths, criticalities and possible margins for improvement of the management model in one in the reference company.

The audit develops with the following steps:

- identification of managerial services;

- identification of the company function responsible for the management of services;
- analysis of the service execution model;
- analysis of service management procedures;
- processing of information collected;
- identification of managed services. The importance of this step stay in the possibility to build an overall picture of the service management process that the company must to coordinate.

About that it is first of all necessary to identify and classify services in relation to macro thematic areas, that are: services to the business, to the person, to the building.

In general, the tasks of the functions responsible for managing the services are:

- study and update on regulations and on the procedures for the fulfillment of legal obligations;
- cost planning;
- selection and coordination of external suppliers;
- administration of internal staff involved in the provision of services;
- quality control of the services provided;

▪ Analysis of the services execution model. The three models can be summarized as follows:

- in-house: the personnel assigned to the provision of the services is an employee of the company where the service is performed;
- outsourcing: the personnel assigned to the provision of the services is an employee of a service company (supplier) different from that at which the service is performed (client);
- mixed: the personnel assigned to the provision of the services in part is an employee of the company where the service is performed, in part it is employee of a company whose business is the provision of services.

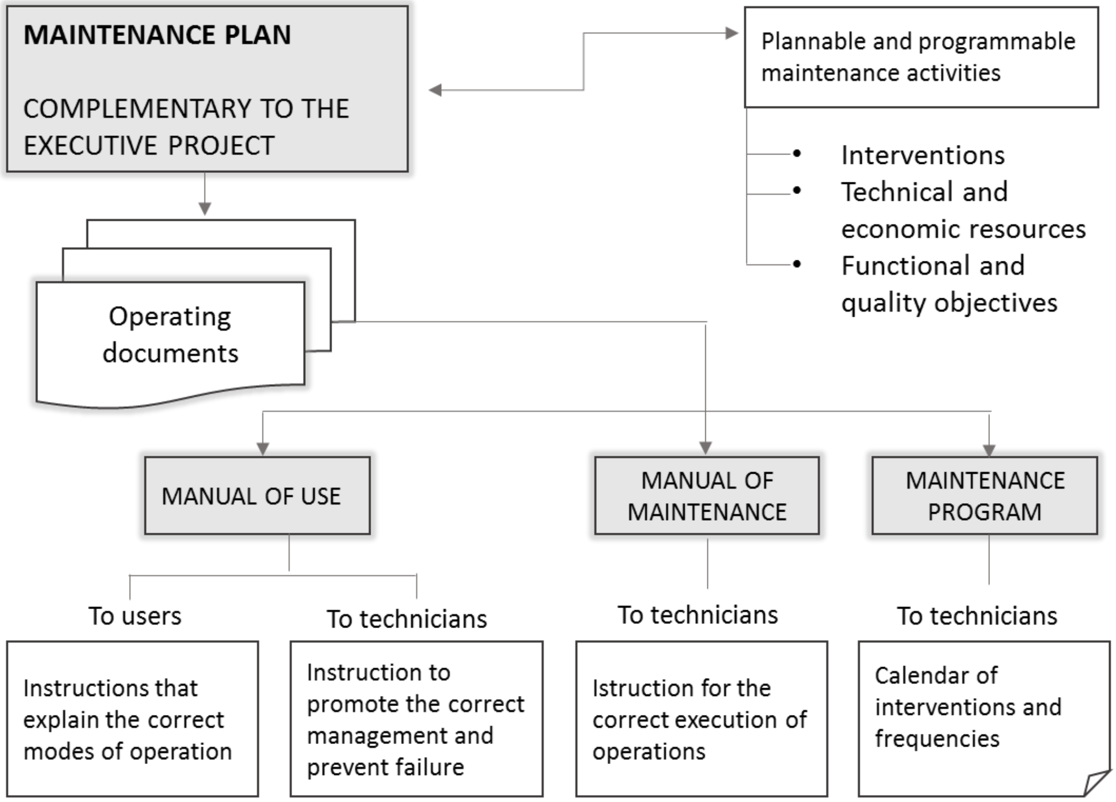
3.4 The binding legislation: basic requirements for planning maintenance activities

The maintenance plan is a fundamental tool to organize interventions within the integrated services of buildings technical management. The maintenance plan, according to the definition contained in the standard UNI 11257:2007, consists in the lists of operations, organized according to appropriate maintenance strategies. This type of interventions will be execute to allow the correct functioning of the building asset for all the time duration of the plan.

The obligation to adopt a building maintenance plan was born, at least formally as regards public works, in 1994 with the emanation of the first version of the law 109/ 94 better known as “legge Merloni”. The law 109/94, then abrogated, is replaced by the current DLgs 163/2006 “Codice dei contratti pubblici” which provides, since the design phase, a maintenance plan that works through a specific document to supplement the executive project. Subsequently the DPR 554/99 has specified the minimum contents of the maintenance plan and the ways in which it must be updated and made operative by the construction supervisor. The minimum contents of the required maintenance plan are described by the DPR 554/99 in the article n° 40:

“*The maintenance plan… consists of the following operational documents:*

a) the user manual;
b) the maintenance manual;
c) the maintenance schedule.”



Charts 3: Maintenance plan and its operating documents
Source: Talamo C. (2013) – "Procedimenti e metodi della manutenzione edilizia

The term "maintenance plan" and its relationship with the other schedule tools, are aspects that, for a complete understanding, must be determined in relation to different application areas. The maintenance manual, plan and schedule can be present in different situations and phases of the building process:

- in the elaboration of the executive project of a new work;
- in the start-up phase of a building or at the end of the construction phase;
- in the redevelopment, recovery and reuse of a project;
- in the operational phase of an existing building.

The latter is the case that interest the work thesis about an existing building, so below is shows a table that focuses on the particular information that interest this stage.

-

STAGE	ON EXISTING BUILDING
ACCEPTION	Management tool for maintenance activities
VALENCE	• Collection of project documentation • Analysis of the conservation status • Preparation / update of maintenance manuals • Forecasting and planning of interventions
NORMATIVE REQUIREMENTS	• UNI 10604: 1997 • UNI 10874: 2000 • UNI 11136: 2001 • UNI 10998: 2002 • UNI 11257: 2007
TIME FRAME	The service duration

Table 4: Application areas of the maintenance plan for an existing building
Source: Talamo C. (2013) – "Procedimenti e metodi della manutenzione edilizia

3.5 Maintenance of an existing building

In the operation phase of an existing building, two main situations are possible:

1. A first situation is one of which exists a documentation consisting of maintenance manuals, plan and schedule developed, for example, by a previous maintenance service provider. In this case it is necessary to proceed with the verification, and eventually with updating, of this documentation both regarding the aspects of personal data census and forecasts operations.

2. A second situation, referred to the case study taken into consideration, is the one in which there is no planning documentation of the maintenance activities and the whole procedure described below must therefore be undertaken.

- PREPARATORY PHASE of the client needs definition. Basic information and diagnosis of the status and operating conditions of the building technical elements. The initial preliminary phase involves the acquisition, selection, collection and analysis of information in order to construct a preliminary framework of basic knowledge. The assumption of indications and guidelines from the property is a fundamental and preliminary action of a cognitive nature to be considered as a sort of start-up stage for the entire planning procedure. This implies a process of acquisition of information regarding needs and property strategies.

CHAPTER 4

CASE STUDY

4.1 General overview: day care center “Il Capannone”:

The case study analyzed in the work thesis consists of a project which provides change of intended use, acquisition of new spaces and the subsequent renovation of some of them inside the building located in Inzago at via Giuseppe di Vittorio 2G, municipality of Milan. Inside the building there are large areas rented by the social cooperative “Punto d'Incontro” for a total period of ten years. The no-profit social association organizes and manages, with own resources, activities for disadvantaged people; it deals with planning, implementing and managing social and health services, day care and residential assistance for people with disabilities.

4.2 Customers requests

The cooperative Punto d'Incontro is a no-profit organization supported through donations and public or private funding. Therefore, the association can not afford planning and maintenance expenses that exceed the expected annual economic budget. This is the reason why the thesis project aims to provide a model for the economic management of the entire structure in order to define a limited expense that meets the organization demands. Customers asks for the realization of the building architectural model using BIM software that allows interoperability, easy sharing and management of information, a reduction in planning duration and a limited margin of errors that avoids waste of money in favour of an economic sustainability. The aim is to create a tool that allows an updated documentation, easy to consult and immediately extract the required data. For this reason is necessary to use the BIM methodology that allow a better control of the whole planning process abandoning the update of every single CAD file. The idea is to create a BIM system that, starting from the setting of parametric buildings models, relates all the useful management information from the technical registry to the maintenance and economic savings. The main innovation carried by the BIM methodology is represented by the possibility to be unique, shared and updated for building lifecycle management from which receive data, through intelligent databases, to obtain an overall picture of the buildings and their heritage. The heart of the architecture was created by a single three-dimensional building model which includes both the graphic and the numerical aspects, so the building and plant components are characterized by metadata that can be exported and use the interaction between different software platforms. Then data are entered into the model only once and then exchanged in order to guarantee univocity and reliability. Thanks to a BIM software, it is possible to move from the simple building three-dimensional representation to a collaborative platform that shows the correct use of energy resources for the sensitization of user.

After these premise, the project was analyzed and subsequently represented through the use of the Revit software, a program that allows the design of parametric elements typical of Autodesk house design. Inside, in addition to the 3D and 2D architectural representation, including the respective graphic tables, there are all the information that the software is automatically able to provide (surfaces calculation, volumes, products quantity, space breakdown, etc.) plus those that have been manually entered about construction site phases, design, maintenance and cost management. Specifically regarding Facility Management activities, the model will be able to contain information about planned and extraordinary maintenance and the services/costs management for a total period of ten years, time estimated for the rental contract of the building by the cooperative Punto d'Incontro. For this purpose, the software gives back information regarding the materials used, the products state of consistency, their classification and location in space. This allowed to organize a maintenance plan that involves the execution of different interventions for each element, then to assign priorities and frequency scheduling (maintenance schedule). With the organization of this information it was possible to make an estimation of the annual expenses, divided by spaces, that take into account the costs of architectural maintenance, of technological systems, management services and rental costs of the entire structure.

4.3 Graphic representation through Revit software

The Revit software it has been designed as an intelligent program for planning and management in the construction phase for any kind of infrastructures. It is a software that, in a single and specific multidisciplinary BIM platform makes possible to implement and design all phases which mainly precede, but also accompany and follow, the construction and consequent the building management. The most important possibility which makes this software so close to customer needs is given by the fact that it is a program through which is possible to have a full and faithful example of reality thanks to three-dimensional elements, axonometric and perspective, without the slightest mistake. The entire building was represented in Revit thanks also to the collaboration of Catherine Ballinari, student of the Polytechnic of Milan. Her thesis, still under realization, aims to organize the construction process of the Capannone Punto d’Incontro through the BIM methodology.

4.3.1 The building structure

The entire building is composed by a prefabricated structure typical of industrial warehouses that have a load-bearing scheme with horizontal flat and a double slope beams. The building layout presents a rectangular scheme where are arranged prefabricated pillars with single or double fork that give a regular division to spaces. The external structure is finished with prefabricated concrete reinforcement panels while the covering of the roof is composed by corrugated sheet panels both flat at the second level and with double slope corresponding to the shed.

Figure 8: Screenshot of the “Capannone” front
Source: software Revit

Figure13: Screenshot of the “Capannone” 3D model
Source: software Revit

The building consists of a ground floor and two upper levels. The connection between the various floors is allowed by the presence of stairs inside, one elevator and one freight-lifts placed outside the structure while the body of the building doesn’t have, at the various levels, an horizontal connections between the right and the left side from which it is possible to access only through the external area at the ground floor. (see attachments of the Revit graphic tables at the end of the thesis pages).

4.3.2 Areas of pertinence

On the ground floor of the building there are some local that doesn’t belong to the cooperative but they are managed and rented to other entity. The space intended for commercial use is divided between: the "Made in Italy" pizzeria, the "Job Services" technical computer assistance and the hot-drink distributor "Nuova Cosmo SRL". Instead on the back of the construction there is a large area rented to third parties for production purpose.

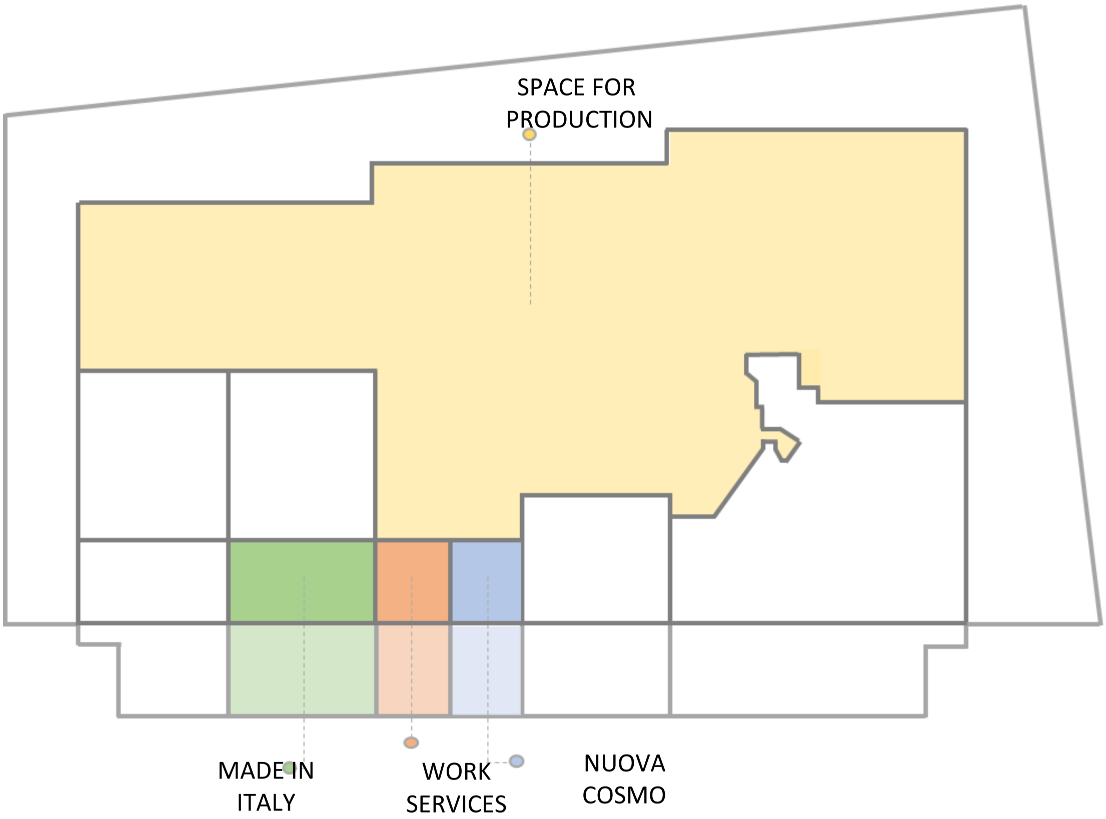


Figure 9: Areas of pertinance - ground floor
Source: software Revit

The day care services offered by the cooperative Punto d'Incontro are configured as CSE – Socio Educational Center and they are multi-purpose services that perform a social and welfare function through the implementation of socio-educational, animative and recreational activities. The project of "Il Capannone" is made up of four modules used as a Socio Educational Center - C.S.E. one of which prepares disadvantaged peoples for training and job placement (CSE Basevi). In addition there are a laboratory, a Day care Centre for Disabled - C.D.D. and a community housing to occasionally accommodate the parents of peoples with behavioral disabilities. The spaces breakdown structure inside the building is the following:

GROUND FLOOR

- CSE “Basevi”
- CSE “Da Vinci
- Laboratory “Ex Oro di Napoli”

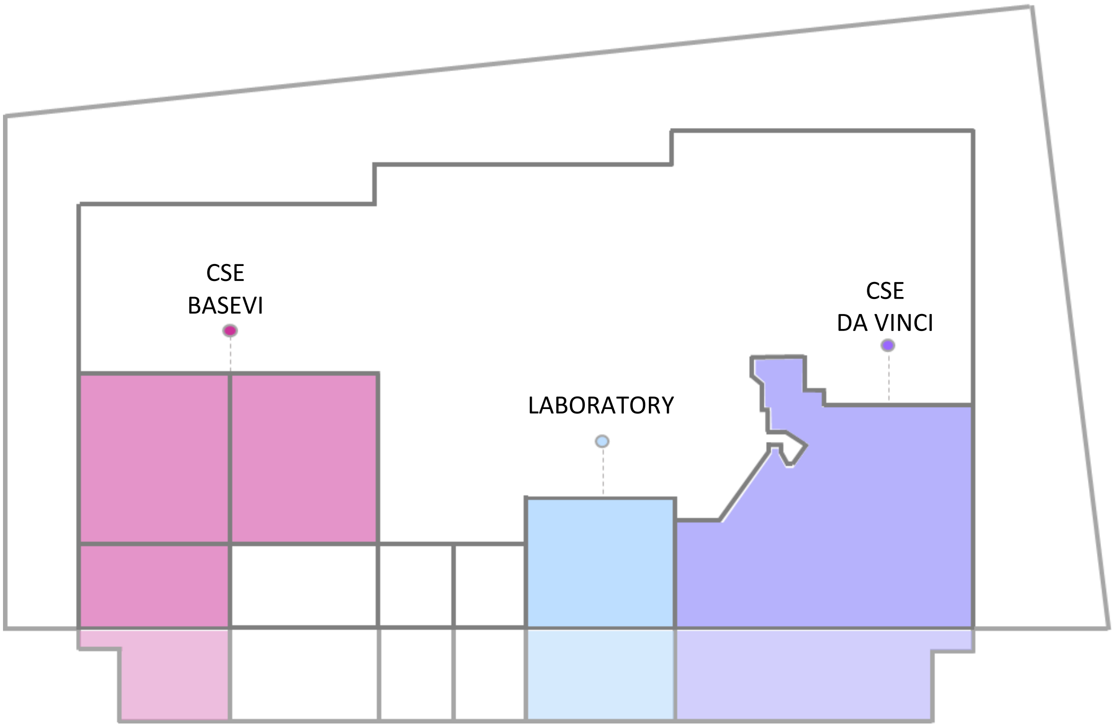


Figure 10: Space division - ground floor
Source: software Revit

FIRST FLOOR

- CSE “Galilei”
- CDD “Autism center”

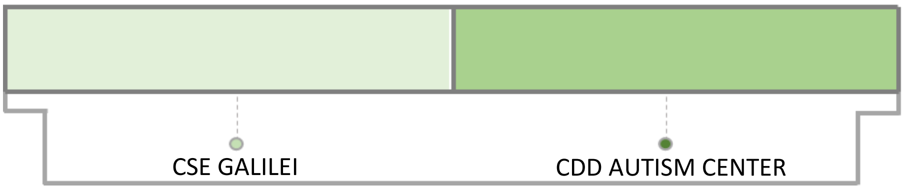


Figure 11: Space division - first floor
Source: software Revit

SECOND FLOOR

- CSE “Cardano”
- Community housing

Figure 12: Space division - second floor
Source: software Revit

The following table shows the information concerning the surface measurements for each space. This type of calculations are automatically provided by Revit software after locals insertion.

FLOOR:	SPACES NAME:	AREA Sqm:
GF	CSE BASEVI	739,48
GF	LABORATORY	228,10
GF	CSE DA VINCI	688,79
FF	CSE GALILEI	472,60
FF	CDD AUTISM CENTER	472,60
SF	CSE CARDANO	472,60
SF	COMMUNITY HOUSING	472,60
TOTAL AREA:		**3.546,77**

Table 5: Information about space surface calculations
Source: elaboration by the author

4.4 Application of spatial and technological classification system

After the graphic model has been represented in Revit, the first step made to organize information was the assignment of alphanumeric codes to each single room and to BIM objects that were modeled in the software. Also the classification work was carried out in common with the thesis concerning the construction management of the Capannone (still under realization). Once the current legislation has been studied, the main classification plans have been analyzed at international level focusing more on the OmniClass one. OmniClass is considered as a strategy tool used by construction industry. It supports the building development and its documentation in all stages, from conception to execution up to management and maintenance phases. OmniClass was chosen because allows the analysis of any intended use and also it is given by the union of several classification plans which are EPIC, MasterFormat and Uniformat II. OmniClass aims is to create a structured identification of project, to locate and manage all the relationships between entities and develop a unique communication code that guarantees consistency in the project information system in all its phases that can also be used internationally. OmniClass structures the information in 15 tables which are formulated based on a fundamental normative that is the ISO 12006-2 that provides basic structuring of the construction information grouped into three main categories that make up the process model. OmniClass, in its tables, also deals with the study of space and its relationships; in particular, Tables 13 (Spaces for function) and 14 (Spaces for form) highlight the classification made according to the intended use.

So based on Omniclass and the various regulations, the work proceeded with the identification of the elementary spaces that made up the case study. As a result they were grouped for the main functional classes:

- Circulation
- Work, study and relax
- Storage and conservation
- Technical installations

This type of organization allowed the creation of a structured space classification plan which, based on the functional groupings of the same and identifying each space according to the OmniClass methodology, led to the formulation of the Space Breakdown Structure whose acronym is SBS. Space Breakdown Structure is therefore a method of organization, hierarchy, management and identification of the spaces of a building complex. Then the SBS can be identified with a hierarchical tree structure that, based on OmniClass, organizes the information according to five levels of detail:

- **1. Functional class***:* identifies the main function performed on the analyzed building for example on residential structure, commercial structure, etc ...

- **2. Level***:* identifies the level on which the space will be analyzed compared to the ground level, for example basement, sub-basement, ground floor, etc

- **3. Class of functional spaces***:* identifies the functional class present on the analyzed plan like common areas, three-rooms / two-rooms apartment etc...
- **4. Functional space elements***:* identifies all the functional macro-categories previously analyzed.

- **5. Elementary space***:* identifies all the elementary spaces that compose the single functional category.

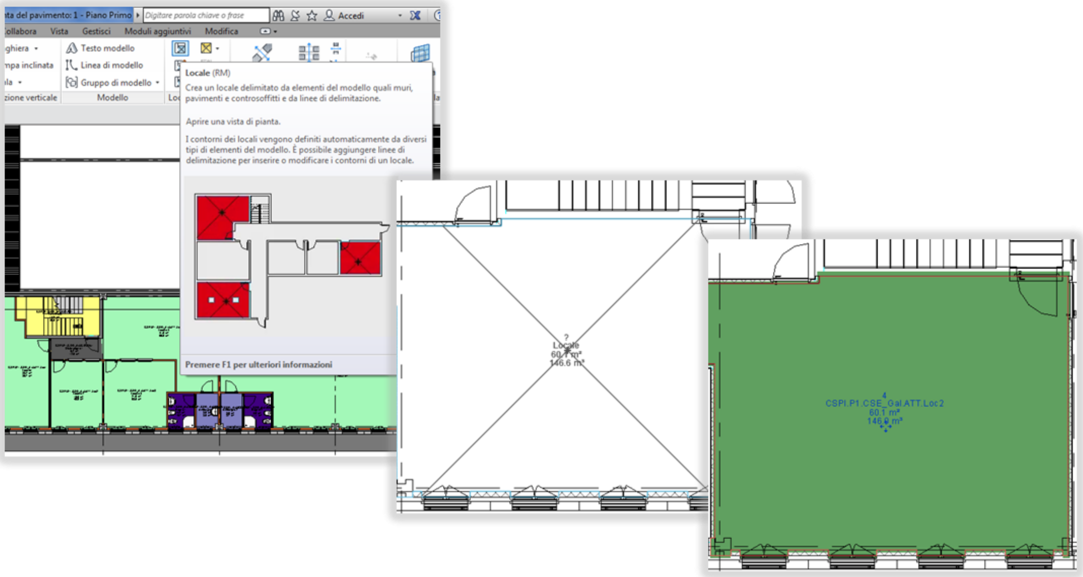
Every information is coded within the SBS through a code consisting of pairs of numbers and letters for each level of detail. In this way, a document identifying the spaces is created, then all the intangible elements that make up the project. The SBS is configured as a table of information which is always accompanied by the link to Omniclass with specific descriptions and identification codes. Inside the building the areas have been subdivided following the previous classification system so, to obtain the total code, the various partial codes have been assembled and separated by a point ".".

On the basis of the previous criterion, is provided an example of the alphanumeric coding system adopted for the local activity of the CSE Galilei placed on the first floor with the code ***CSPI.P1.CSE_Gal.CIR.LOC1*** as follow:

DESCRIPTION	ID
1. Social Center Punto d'Incontro	**CSPI**
2. First Floor	CSPI.**P1**
3. Socio educational center Galilei	CSPI.P1.**CSE_Gal**
4. Functional space for circulation	CSPI.P1.CSE_Gal.**CIR**
5. Activity room 1	CSPI.P1.CSE_Gal.CIR.**Loc1**

Table 6: Example of code composition – rooms
Source: elaboration by the author

After assigning identification codes to each respective rooms, below is shown the rooms graphic representation of CSE Galilei visible in Revit and in particular the room "activity 2" which is highlighted with its own identification code.



Locale (RM)
Crea un locale delimitato da elementi del modello quali muri, pavimenti e controsoffitti e da linee di delimitazione.

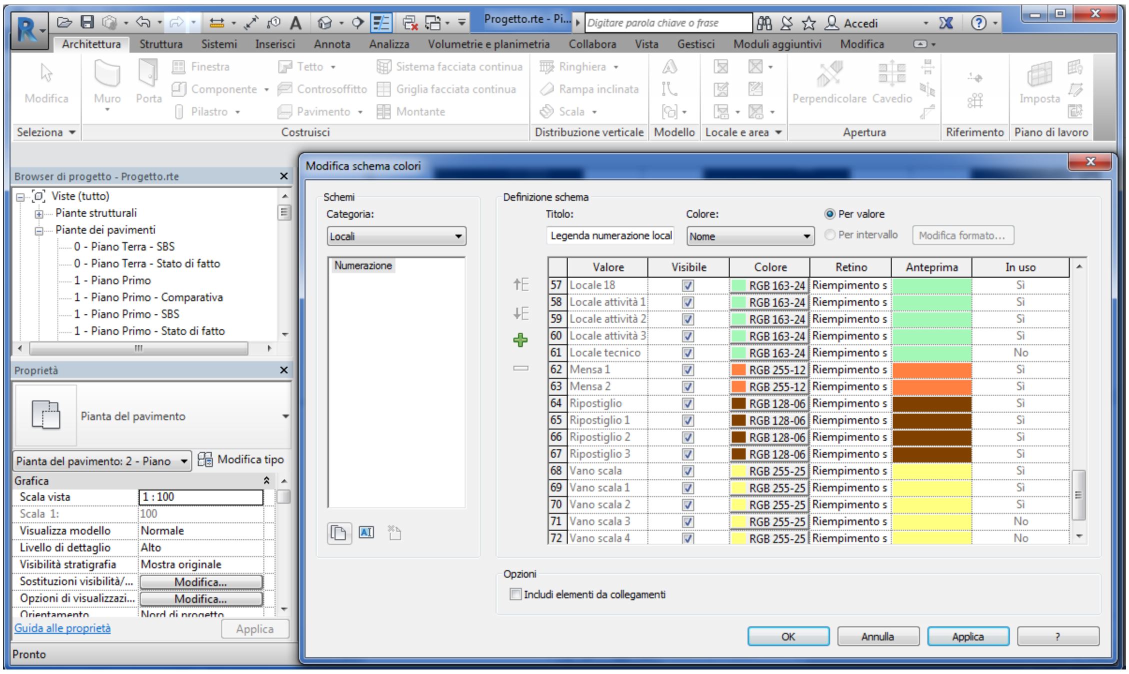
Aprire una vista di pianta.

I contorni dei locali vengono definiti automaticamente da diversi tipi di elementi del modello. È possibile aggiungere linee di delimitazione per inserire o modificare i contorni di un locale.

Premere F1 per ulteriori informazioni

Figure 13: Screenshot of local division
Source: software Revit

From the previous image it is also possible to notice how each room is identifiable with the same color according to its intended use destination. These settings are manually defined within the software thanks to the commands present in the "change color scheme" window. From here it is possible to define the desired color scales and select the various options that affect the graphic settings of the rooms.



Pianta del pavimento: 2 - Piano

Grafica	
Scala vista	1 : 100
Scala 1:	100
Visualizza modello	Normale
Livello di dettaglio	Alto
Visibilità stratigrafia	Mostra originale
Sostituzioni visibilità/...	Modifica...
Opzioni di visualizzazi...	Modifica...
Orientamento	Nord di progetto

Categoria: Locali

Titolo: Legenda numerazione local

Colore: Nome

● Per valore
○ Per intervallo

	Valore	Visibile	Colore	Retino	Anteprima	In uso
57	Locale 18	☑	RGB 163-24	Riempimento s	🟩	Sì
58	Locale attività 1	☑	RGB 163-24	Riempimento s	🟩	Sì
59	Locale attività 2	☑	RGB 163-24	Riempimento s	🟩	Sì
60	Locale attività 3	☑	RGB 163-24	Riempimento s	🟩	Sì
61	Locale tecnico	☑	RGB 163-24	Riempimento s	🟩	No
62	Mensa 1	☑	RGB 255-12	Riempimento s	🟧	Sì
63	Mensa 2	☑	RGB 255-12	Riempimento s	🟧	Sì
64	Ripostiglio	☑	RGB 128-06	Riempimento s	🟫	Sì
65	Ripostiglio 1	☑	RGB 128-06	Riempimento s	🟫	Sì
66	Ripostiglio 2	☑	RGB 128-06	Riempimento s	🟫	Sì
67	Ripostiglio 3	☑	RGB 128-06	Riempimento s	🟫	Sì
68	Vano scala	☑	RGB 255-25	Riempimento s	🟨	Sì
69	Vano scala 1	☑	RGB 255-25	Riempimento s	🟨	Sì
70	Vano scala 2	☑	RGB 255-25	Riempimento s	🟨	Sì
71	Vano scala 3	☑	RGB 255-25	Riempimento s	🟨	No
72	Vano scala 4	☑	RGB 255-25	Riempimento s	🟨	No

☐ Includi elementi da collegamenti

Figure 14: Screenshot of "modify colour scheme" window
Source: software Revit

After having breakdown the spaces and classify rooms the work proceeds with the codification of all the elements that made up the project. In this case, being the project commissioners and project managers Italian, it was preferred to refer to the Italian regulation 8290-81 implemented. The UNI 8290 prefigures a classification sequence based on the decomposition of the building into *classes of technological units*; each class of technological unit is once again decomposed into *technological units,* each technological unit is in turn breakdown into *classes of technical elements* and finally into *technical elements*.

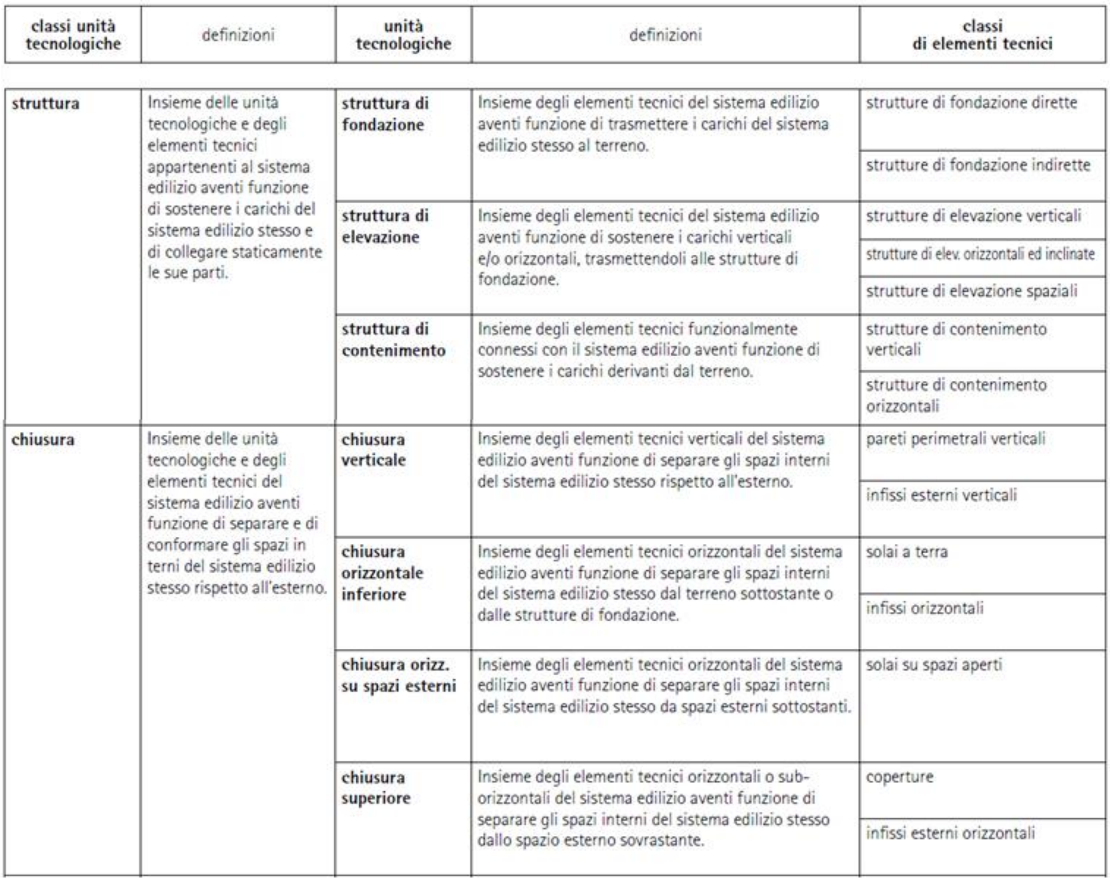
1. **Class of technological unit**: homogenous functional elements grouped by prevailing function for physical and functional continuity;

2. **Technological unit**: set of technical elements that represent functions aimed at satisfying user needs;

3. **Class of technical elements:** classes of products that perform specific functions to one or more technological classes;

4. **Technical elements:** more or less a complex building product capable of completely or partially carrying out functions of one or more technological units.

The purpose of the work is to articulate a list of items, according to the logic of the completed works, in order to allow analytical estimatation (see the cost per unit of measurement of the individual interventions necessary for the realization of a work) and elementary estimatation (see cost per unit of measurement of technological units). The products were then classified with their own identification code according to the following scheme:



classi unità tecnologiche	definizioni	unità tecnologiche	definizioni	classi di elementi tecnici
struttura	Insieme delle unità tecnologiche e degli elementi tecnici appartenenti al sistema edilizio aventi funzione di sostenere i carichi del sistema edilizio stesso e di collegare staticamente le sue parti.	**struttura di fondazione**	Insieme degli elementi tecnici del sistema edilizio aventi funzione di trasmettere i carichi del sistema edilizio stesso al terreno.	strutture di fondazione dirette
				strutture di fondazione indirette
		struttura di elevazione	Insieme degli elementi tecnici del sistema edilizio aventi funzione di sostenere i carichi verticali e/o orizzontali, trasmettendoli alle strutture di fondazione.	strutture di elevazione verticali
				strutture di elev. orizzontali ed inclinate
				strutture di elevazione spaziali
		struttura di contenimento	Insieme degli elementi tecnici funzionalmente connessi con il sistema edilizio aventi funzione di sostenere i carichi derivanti dal terreno.	strutture di contenimento verticali
				strutture di contenimento orizzontali
chiusura	Insieme delle unità tecnologiche e degli elementi tecnici del sistema edilizio aventi funzione di separare e di conformare gli spazi in terni del sistema edilizio stesso rispetto all'esterno.	**chiusura verticale**	Insieme degli elementi tecnici verticali del sistema edilizio aventi funzione di separare gli spazi interni del sistema edilizio stesso rispetto all'esterno.	pareti perimetrali verticali
				infissi esterni verticali
		chiusura orizzontale inferiore	Insieme degli elementi tecnici orizzontali del sistema edilizio aventi funzione di separare gli spazi interni del sistema edilizio stesso dal terreno sottostante o dalle strutture di fondazione.	solai a terra
				infissi orizzontali
		chiusura orizz. su spazi esterni	Insieme degli elementi tecnici orizzontali del sistema edilizio aventi funzione di separare gli spazi interni del sistema edilizio stesso da spazi esterni sottostanti.	solai su spazi aperti
		chiusura superiore	Insieme degli elementi tecnici orizzontali o sub-orizzontali del sistema edilizio aventi funzione di separare gli spazi interni del sistema edilizio stesso dallo spazio esterno sovrastante.	coperture
				infissi esterni orizzontali

Table 7: Classification of technological system

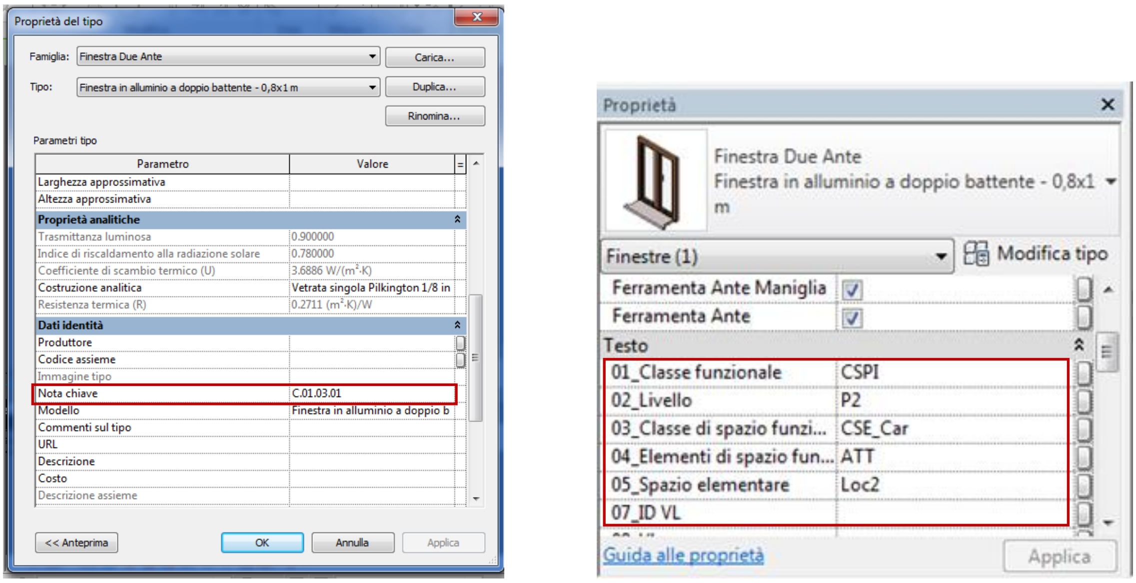
Source: UNI 8290

Following this type of classification system the work proceeds with the codification of the elements. Below is presented the passage for the creation of the unique product code "aluminum double-leaf window" placed in the external closure of the structure.

DESCRIPTION	ID
*1.*Closures:	C
*2.*Vertical closures:	C.**01**
*3.*Transparent vertical closures (windows):	C.01.**03**
*4.*Aluminum double-leaf window - 0,80x100cm	C.01.03.**01**

Table 8: Example of code composition – products
Source: elaboration by the author

At this point, every single element that will be selected in the 3D model on Revit will be able to provide us information regarding their precise identification with the ID code present in the "keynote" line on “type properties” window. The same type of information about the localization code, previously composed, is provided in the “property” window.



Famiglia: Finestra Due Ante
Tipo: Finestra in alluminio a doppio battente - 0,8x1 m

Parametro	Valore
Larghezza approssimativa	
Altezza approssimativa	
Proprietà analitiche	
Trasmittanza luminosa	0.900000
Indice di riscaldamento alla radiazione solare	0.780000
Coefficiente di scambio termico (U)	3.6886 W/(m²·K)
Costruzione analitica	Vetrata singola Pilkington 1/8 in
Resistenza termica (R)	0.2711 (m²·K)/W
Dati identità	
Produttore	
Codice assieme	
Immagine tipo	
Nota chiave	C.01.03.01
Modello	Finestra in alluminio a doppio b
Commenti sul tipo	
URL	
Descrizione	
Costo	
Descrizione assieme	

Finestra Due Ante
Finestra in alluminio a doppio battente - 0,8x1 m

Finestre (1)

Ferramenta Ante Maniglia	☑
Ferramenta Ante	☑
Testo	
01_Classe funzionale	CSPI
02_Livello	P2
03_Classe di spazio funzi...	CSE_Car
04_Elementi di spazio fun...	ATT
05_Spazio elementare	Loc2
07_ID VL	

Figure 15: Screenshots of “type of properties” and “properties” windows containing the information about product and localization codes
Source: software Revit

In this way Revit is ables to associate the two types of codes at each single typology of product present in the model. This typology of information makes every element unique and quickly identifiable within the structure and allows maintenance technician, or any other figure working on the project, to quickly found a product that could be demolished, replaced or simply maintained. Below it is present an example of the total code formed by the union of the product ID plus the localization code. The table refers to the same product "aluminum double-leaf window" placed at the first floor of CSE Galilei.

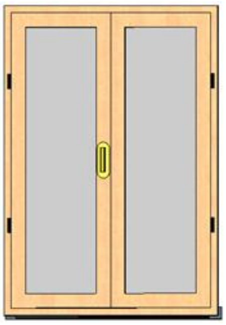
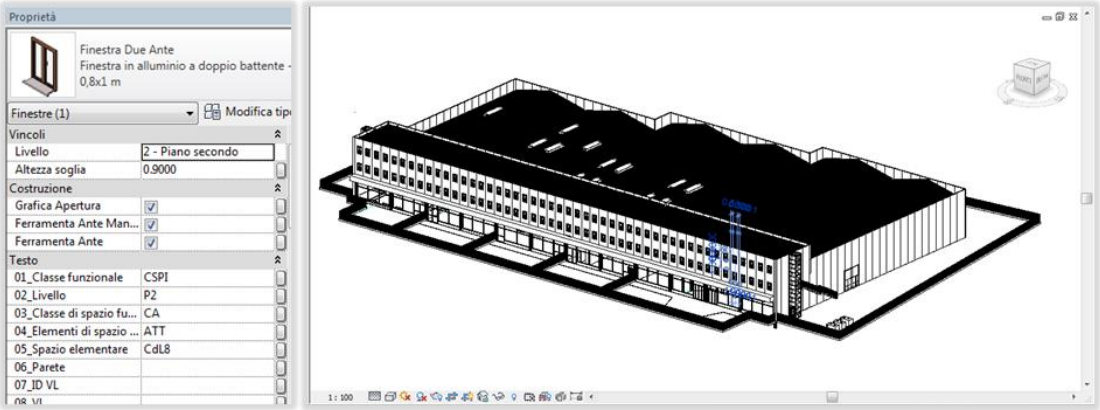
Product ID + Localization code	C.01.01.01
	C.01.03.01_**CSPI**
	C.01.03.01_CSPI.**P1**
	C.01.03.01_CSPI.P1.**CSE_Gal**
	C.01.03.01_CSPI.P1.CSE_Bas.**CIR**
	C.01.03.01_CSPI.P1.CSE_Bas.CIR.**Loc1**

Table 9: Example of product ID plus Localization code
Source: elaboration by the author

Also graphically, Revit allows us to quickly identify the product within the 3D model view and know all the information associated with it by simply clicking on the element.



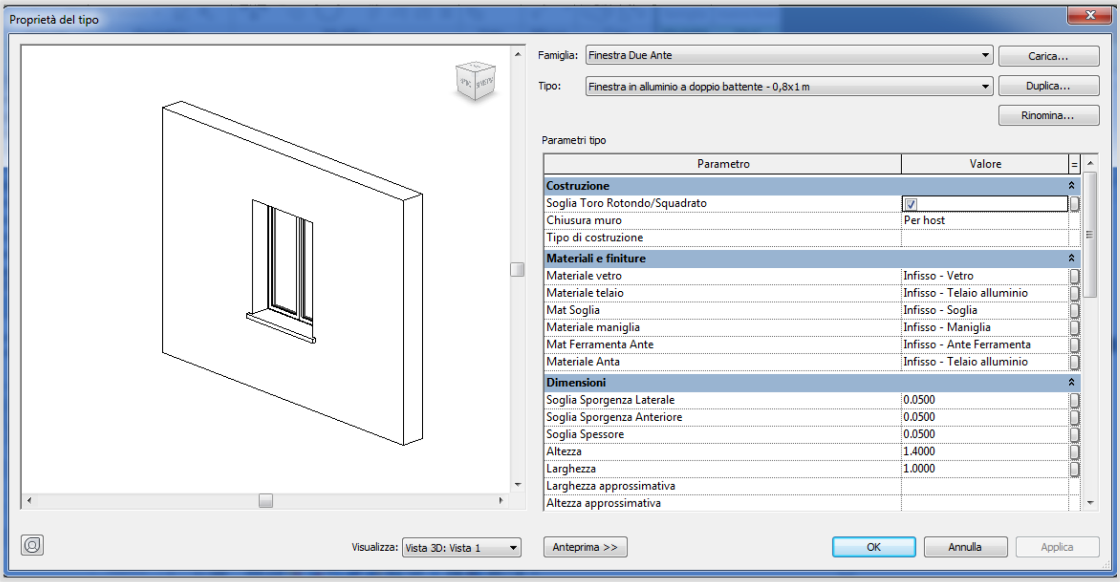
Finestra Due Ante
Finestra in alluminio a doppio battente - 0,8x1 m

Finestre (1)

Vincoli	
Livello	2 - Piano secondo
Altezza soglia	0.9000
Costruzione	
Grafica Apertura	☑
Ferramenta Ante Man...	☑
Ferramenta Ante	☑
Testo	
01_Classe funzionale	CSPI
02_Livello	P2
03_Classe di spazio fu...	CA
04_Elementi di spazio ...	ATT
05_Spazio elementare	CdL8
06_Parete	
07_ID VL	

Figure 16: Screenshot of the product display within the 3D model
Source: software Revit

From the same "type properties" window is possible to visualize other typology of information, of the selected product, about dimensions or materials and finishes. The lines that regard the dimensional data are automatically provided by the software while the explanation of how to add materials and finishes will be addressed specifically in the next chapter.



Famiglia: Finestra Due Ante
Tipo: Finestra in alluminio a doppio battente - 0,8x1 m

Parametri tipo

Parametro	Valore
Costruzione	
Soglia Toro Rotondo/Squadrato	☑
Chiusura muro	Per host
Tipo di costruzione	
Materiali e finiture	
Materiale vetro	Infisso - Vetro
Materiale telaio	Infisso - Telaio alluminio
Mat Soglia	Infisso - Soglia
Materiale maniglia	Infisso - Maniglia
Mat Ferramenta Ante	Infisso - Ante Ferramenta
Materiale Anta	Infisso - Telaio alluminio
Dimensioni	
Soglia Sporgenza Laterale	0.0500
Soglia Sporgenza Anteriore	0.0500
Soglia Spessore	0.0500
Altezza	1.4000
Larghezza	1.0000
Larghezza approssimativa	
Altezza approssimativa	

Visualizza: Vista 3D: Vista 1

Figure 17: Screenshot of "type properties" windows
Source: software Revit

CHAPTER 5

TECHNOLOGICAL ANALYSIS

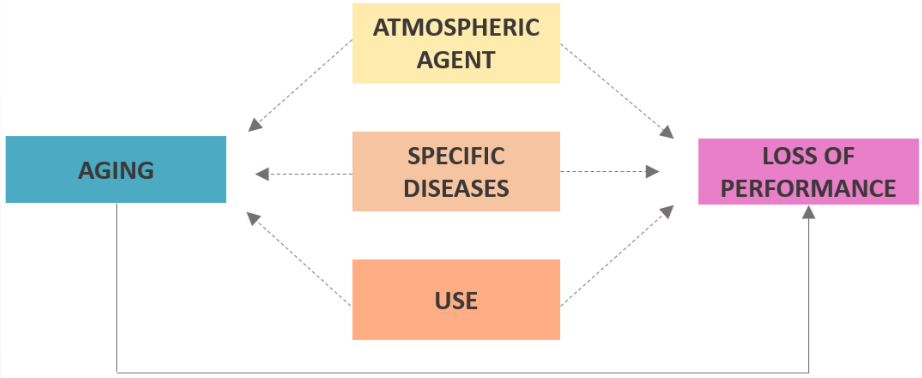
5.1 Control of the building status

For every artefact, simultaneously with its completion and at the beginning of his useful life, an entropic transformation process begins whose speed varies with the physical characteristics of the building itself, with the environmental context in which it is inserted and with the use to which it is subjected. The tendency to move from a stage of minimum complexity is typical of this process, proportionally to the decrease in the entropy level of the system. However, slow the transformations may appear, buildings don't escape from this process intended to extend progressively the "non-operating" conditions of the entire building system parts. Then the problem consists, on the one hand, in succeeding or evaluate the times and the modalities with which the building system loses its original entropy and its ability to function; on the other, to understand and evaluate the possibilities - where they exist- to resist to the transformation process reconstituting the lost operating capacity (entropy). The physical characteristics, the environment and the methods of use are therefore the factors that condition the ways and the speed of this transformation.

5.1.1 Verify the degradation and obsolescence condition

The phenomena that characterize the building transformation belong to the category of physical degradation and obsolescence. When the transformation process concerns the demand, obsolescence can be define as *functional obsolescence*; when the transformation process concerns the response (the condition of the object), it can be defined as *physical obsolescence.* The degradation of the building derives from evaluations of a mainly technical nature that take into account the consequences of the aging of the individual parts of the building and of the whole, taking into account the economic aspect. The two assessments, of obsolescence and degradation, are linked but conceptually and methodologically distinct. They are connected when the costs of the intended interventions, for the functional adaptation of the housing and the costs of extraordinary maintenance activity, must be compared with the value of the building once the renovation works and extraordinary maintenance have been carried out. Reconnecting the reflections on the two concepts of degradation and obsolescence to the transformation process, it can be defined the characteristics of this process. In it coexist phenomena of:

- PHYSICAL DEGRADATION. These phenomena can be determined by the wear to which the technical elements are subjected, from the action of external atmospheric agents, from specific origin defects or from the coexistence of all these factors. The degradation of the building derives from evaluations of a mainly technical nature, taking into consideration the consequences of the aging of the individual parts of the building and of the whole, keeping in mind the economic aspect;



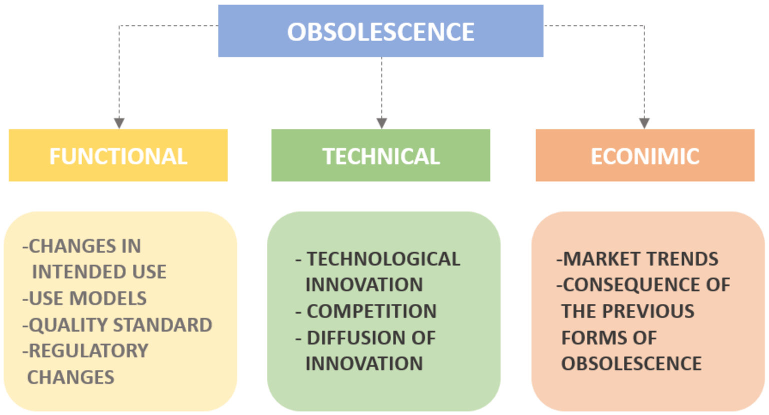
Charts 4: The action of physical degradation
Source: Molinari C. (2005) – "Procedimenti e metodi della manutenzione edilizia"

- OBSOLESCENCE. From what has been said, at least three forms of obsolescence can be imagined:

- *Functional obsolescence*. These types of phenomena are linked to the change arising in the application of the building product, for example variations in the intended use of buildings or environments. Regulatory changes are always functional in nature and capable to transform the requirements framework or to impose new constraints on the technical solutions previously adopted (changes in the legislative framework, standards or technical standards);

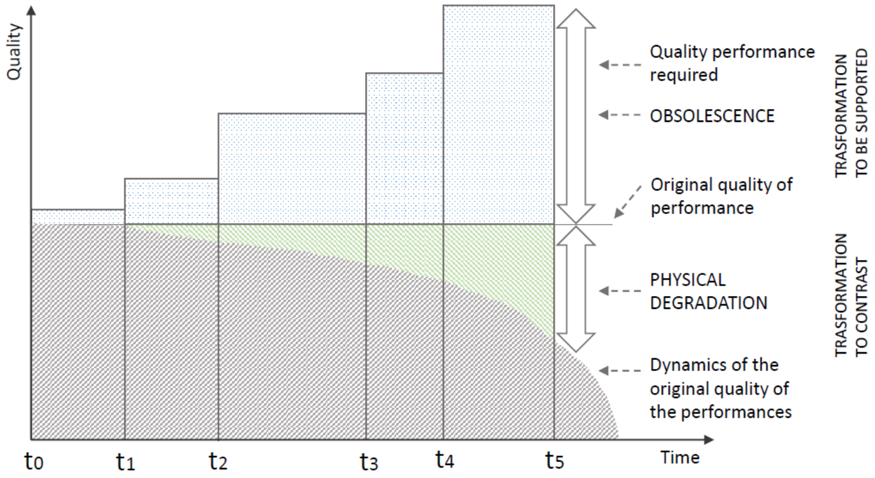
- *Technical obsolescence*. Changes in demand due to intolerance towards products considered technologically outdated;

- *Economic obsolescence*. Phenomena linked to physical degradation, to the two previous forms of obsolescence and also to other specific factors of a strictly economic nature such as, for example, the trend of the housing market or discount rates.



Charts 5: Focus on forms of obsolescence
Source: Molinari C. (2005) – "Procedimenti e metodi della manutenzione edilizia"

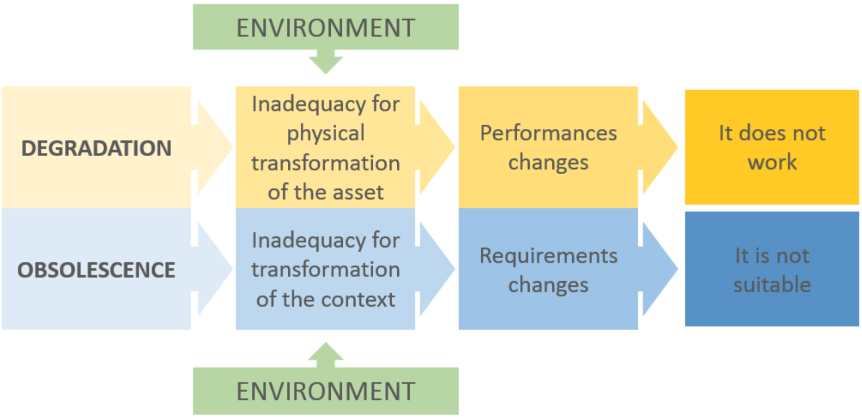
The difference between the performance quality provided by the building system and the required one is represented in the chart 5 with increasing trend. It is presumed that the quality required tends constantly, even if in a discontinuous way, to increase over time. If this may be true in most cases, it is necessary to underline the existence of frequent exceptions for which a given quality standard can be stabilized at a lower level than the previous one. It is therefore possible to verify a condition that renders a system obsolete because it is inadequate to respond to a new situation in which the required quality standards change in a negative sense.



Charts 6: Process of transforming the requested quality in relation to the technical elements performances inside the building.

Source: Molinari C. (2005) – "Procedimenti e metodi della manutenzione edilizia"

We can therefore state that degradation is an intrinsic process to the building product and it depends on modifications that occur also due to the impact with the external environment. Therefore, it concerns the transformations of the specific technical elements and their consequent losses of efficiency. Obsolescence is linked to external modifications exogenous to the product that concerns the social, cultural, technological and economic context of which the product is an integral part. The transformations, that are originate in the context, determine a change in the required operating quality independently from the services level provided by the technical elements (see chart 6).



Charts 7: The origin of results about the two transformation processes
Source: Molinari C. (2005) – "Procedimenti e metodi della manutenzione edilizia"

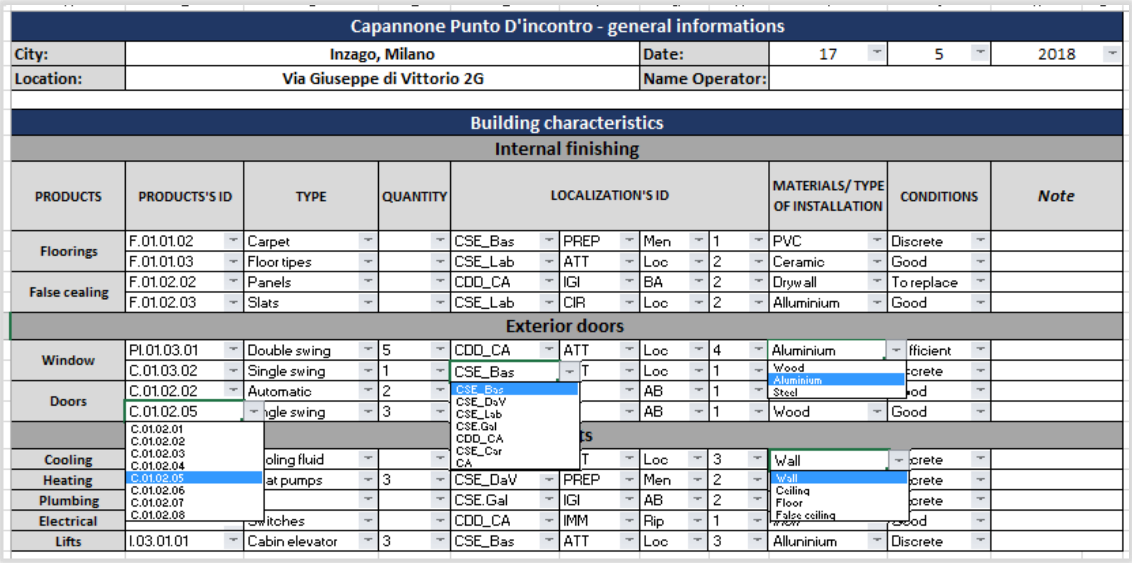
The general objective to manage the consequences of these processes, on the quality of building systems, is to maintain a high building availability to the requirements at operating levels. In particular, in the case of physical degradation, it is about opposing the transformation: this can be achieved through repair and replacement work or using technical elements that are less easily deteriorable. In the case of obsolescence, on the other hand, it's about to comply with the accelerating transformation procedures for adaptation to the new levels of quality required.

These objectives can be pursued in the building management phase through appropriate maintenance policies even if the technical-economic effectiveness depends on the decisions taken at the design stage. The strategies with which to operate, to achieve the two different objectives, are related to the degree of predictability or, conversely, of uncertainty with respect to the occurrence of transformation phenomena. A first strategy, based on the predictability of degradation phenomena, is to built using technical elements of which is known its reliability over time. It allows to respond to the transformations of physical degradation by contrasting, through substitutions or preventive repairs, the occurrence of malfunctions or failures. In fact, acting in advance reduces operating times below the required performance levels and therefore the increase of the system overall availability.

In construction a large margin of uncertainty, on this first category of phenomena, will always remain unbridgeable. To determine this gap also contributes the difficulty in collecting and processing information and, especially, a situation of uncertainty linked to the unpredictability of the use conditions about the technical elements which made up the building and act decisively on their behavior over time. Unpredictability is the condition that characterizes the transformation phenomena included in obsolescence for which changes, that modify the quality required, are linked to events not related to the technical characteristics of the building. In this case is not possible to act with any form of preventive and programmable intervention. The only possible strategy, to facilitate the adaptation to new quality levels, is to facilitate maintenance operations reducing intervention times, costs and an increase in the level of system availability. It is about operate in the design phase to raise the level of building maintainability and its parts. It expresses the suitability of a technological unit to be easily subjected to maintenance interventions (repair or replacement). The role of maintenance is outlined as a system of activity that avoid inconveniences induced by the two forms assumed by the transformation processes: degradation and obsolescence.

5.1.2 Collection and management of information through a digital database

Before being able to organize maintenance and management activities of the building products, it was necessary to carry out a detailed analysis to know which elements are located inside each space, the materials of which they are made and their state of consistency. For this purpose a computerized data-collecting board has been designed on excel spreadsheet. Thanks to this table it will be easily to insert all useful information about building locals and products by selecting options from the various "drop-down menus"(see figure 19). Therefore this database will allow to have a real and faithful graphic representation of the existing building taking into account the state of consistency of the structure and its parts. This type of information are important especially for the implementation and updating of the maintenance plan.



Capannone Punto D'incontro - general informations

City:	**Inzago, Milano**	**Date:**	17	5	2018
Location:	**Via Giuseppe di Vittorio 2G**	**Name Operator:**			

Building characteristics

Internal finishing

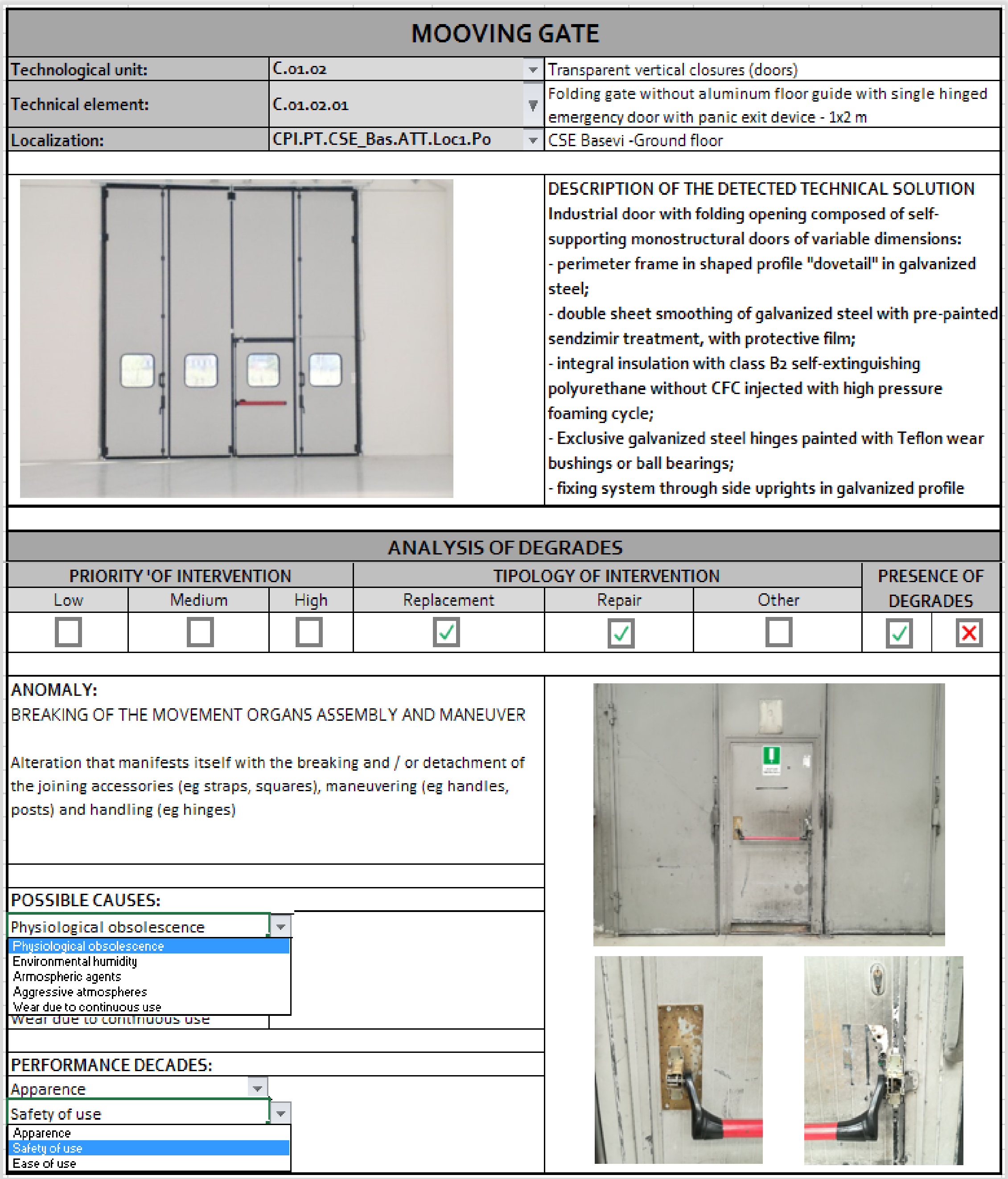
PRODUCTS	PRODUCTS'S ID	TYPE	QUANTITY	LOCALIZATION'S ID				MATERIALS/ TYPE OF INSTALLATION	CONDITIONS	*Note*
Floorings	F.01.01.02	Carpet		CSE_Bas	PREP	Men	1	PVC	Discrete	
	F.01.01.03	Floor tipes		CSE_Lab	ATT	Loc	2	Ceramic	Good	
False cealing	F.01.02.02	Panels		CDD_CA	IGI	BA	2	Drywall	To replace	
	F.01.02.03	Slats		CSE_Lab	CIR	Loc	2	Alluminium	Good	
Exterior doors										
Window	PI.01.03.01	Double swing	5	CDD_CA	ATT	Loc	4	Aluminium	fficient	
	C.01.03.02	Single swing	1	CSE_Bas	T	Loc	1		crete	
Doors	C.01.02.02	Automatic	2			AB	1		od	
	C.01.02.05	ngle swing	3			AB	1	Wood	Good	
ts										
Cooling		oling fluid			T	Loc	3	Wall	crete	
Heating		at pumps	3	CSE_DaV	PREP	Men	2		crete	
Plumbing				CSE.Gal	IGI	AB	2		crete	
Electrical		witches		CDD_CA	IMM	Rip	1		od	
Lifts	I.03.01.01	Cabin elevator	3	CSE_Bas	ATT	Loc	3	Alluninium	Discrete	

Figure 18: Screenshot of the digital database with "drop-down menus"
Source: elaboration by the author with Excel

The decision to create a database for the collection of digitized information guarantees, to the operators, speed in finding data and especially it allow to have a direct connection of all the selected information with the Revit model.

5.2 Technological analysis and cataloging of elements

After collecting all the information concerning the materials and the products conditions, inside the building, it was possible to organize this data elaborating diagnostic cards for all those elements that show degradation conditions. For this elements is possible to schedule a plan of maintenance interventions which purpose is to replace or repair it. Below is presented an example cards concerning the replacement of the panic exit device of an emergency exit door.



MOOVING GATE

Technological unit:	C.01.02	Transparent vertical closures (doors)
Technical element:	C.01.02.01	Folding gate without aluminum floor guide with single hinged emergency door with panic exit device - 1x2 m
Localization:	CPI.PT.CSE_Bas.ATT.Loc1.P0	CSE Basevi -Ground floor

DESCRIPTION OF THE DETECTED TECHNICAL SOLUTION

Industrial door with folding opening composed of self-supporting monostructural doors of variable dimensions:
- perimeter frame in shaped profile "dovetail" in galvanized steel;
- double sheet smoothing of galvanized steel with pre-painted sendzimir treatment, with protective film;
- integral insulation with class B2 self-extinguishing polyurethane without CFC injected with high pressure foaming cycle;
- Exclusive galvanized steel hinges painted with Teflon wear bushings or ball bearings;
- fixing system through side uprights in galvanized profile

ANALYSIS OF DEGRADES

PRIORITY 'OF INTERVENTION			TIPOLOGY OF INTERVENTION			PRESENCE OF DEGRADES	
Low	Medium	High	Replacement	Repair	Other		
☐	☐	☐	☑	☑	☐	☑	☒

ANOMALY:

BREAKING OF THE MOVEMENT ORGANS ASSEMBLY AND MANEUVER

Alteration that manifests itself with the breaking and / or detachment of the joining accessories (eg straps, squares), maneuvering (eg handles, posts) and handling (eg hinges)

POSSIBLE CAUSES:

Physiological obsolescence

Wear due to continuous use

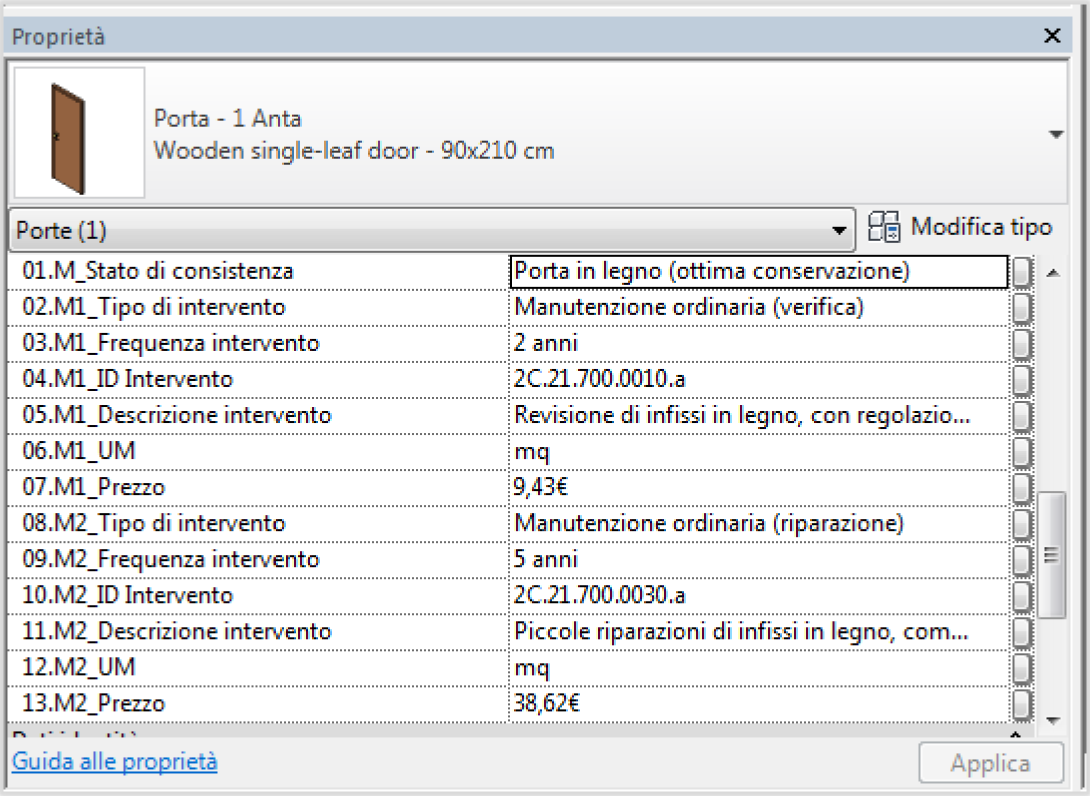
PERFORMANCE DECADES:

Apparence

Safety of use

Figure 19: Screenshot of a digital user manual
Source: elaboration by the author with Excel

After entering this type of information inside the diagnostic cards, for all those elements that show degradation, the same data have been added to the affected items in Revit model. In this way each product will be made up of data concerning the state of consistency (which can be excellent, good or degraded) and a description of the maintenance operations to be performed with different frequencies based on the intervention priorities.



Porta - 1 Anta
Wooden single-leaf door - 90x210 cm

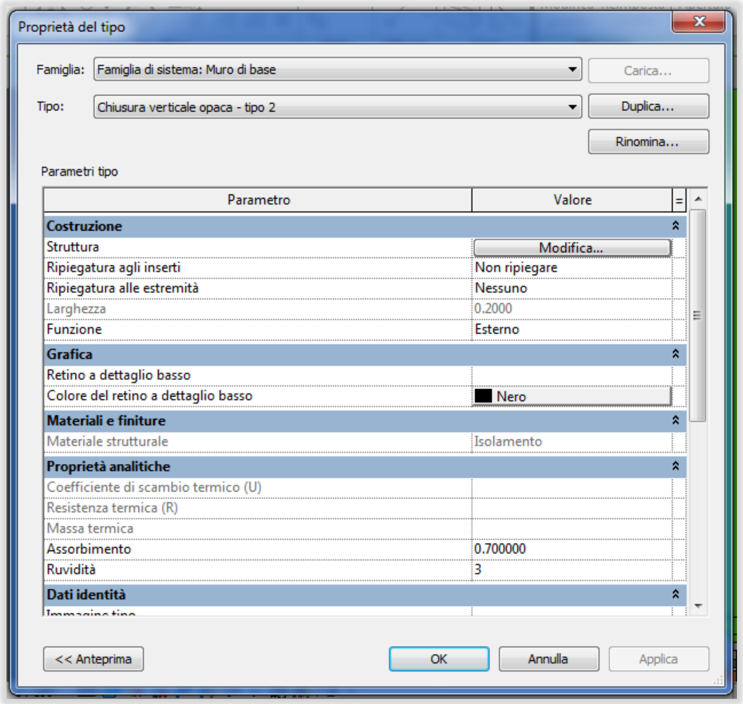
Porte (1)

01.M_Stato di consistenza	Porta in legno (ottima conservazione)
02.M1_Tipo di intervento	Manutenzione ordinaria (verifica)
03.M1_Frequenza intervento	2 anni
04.M1_ID Intervento	2C.21.700.0010.a
05.M1_Descrizione intervento	Revisione di infissi in legno, con regolazio...
06.M1_UM	mq
07.M1_Prezzo	9,43€
08.M2_Tipo di intervento	Manutenzione ordinaria (riparazione)
09.M2_Frequenza intervento	5 anni
10.M2_ID Intervento	2C.21.700.0030.a
11.M2_Descrizione intervento	Piccole riparazioni di infissi in legno, com...
12.M2_UM	mq
13.M2_Prezzo	38,62€

Figure 20: Screenshot of the product maintenance information
Source: software Revit

5.2.2 Management of parametric information with a BIM model

Is repeatedly discussed about how BIM represents a crucial step towards the digitalization of the construction industry, a process that for years has happened in many other sectors; in addition, are also frequently mentioned the reasons why this tool represents a keystone in order to reach efficiency towards improvements in the design phase, in terms of increased quality, decreased costs and subsequently in the management and control phases. Now it's time to see concretely how this system works and what is its real potential linked to the management phase of a building. One of the features that characterizes BIM models is principally bound to the ability to store and assign parameters and information to the various objects that compose the building structure. But in practice, what does it means and how much in deep is it possible to go in attributing parameters to objects? To give an answer, it's necessary to understand the real content of parametric data and its mode of management within the model. In this way is possible to define, according to the initial input of economic management, the actual effectiveness of using BIM software among the various stages that characterize the life cycle of a building. Starting from a simple element, such as an opaque vertical closure, the tool firstly allows to personalize it and so to edit components, materials, thicknesses and their intrinsic characteristics, in order to realistically show it.



Famiglia: Famiglia di sistema: Muro di base

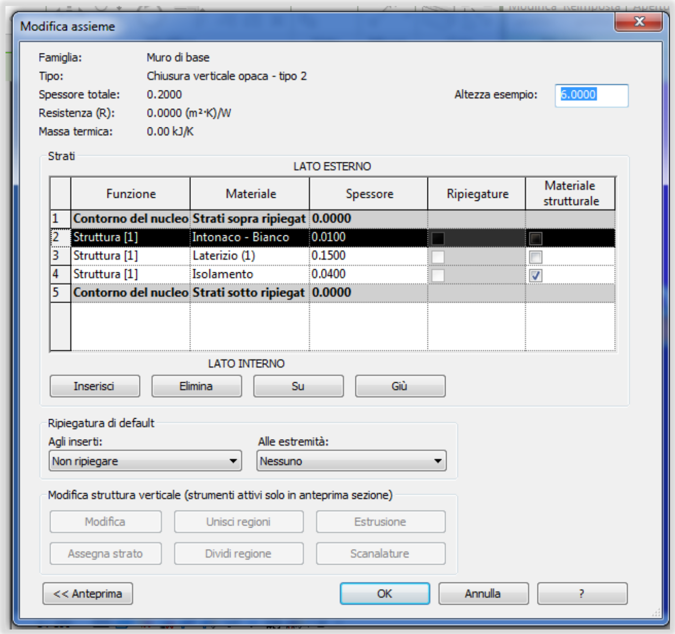
Tipo: Chiusura verticale opaca - tipo 2

Parametri tipo

Parametro	Valore
Costruzione	
Struttura	Modifica...
Ripiegatura agli inserti	Non ripiegare
Ripiegatura alle estremità	Nessuno
Larghezza	0.2000
Funzione	Esterno
Grafica	
Retino a dettaglio basso	
Colore del retino a dettaglio basso	■ Nero
Materiali e finiture	
Materiale strutturale	Isolamento
Proprietà analitiche	
Coefficiente di scambio termico (U)	
Resistenza termica (R)	
Massa termica	
Assorbimento	0.700000
Ruvidità	3
Dati identità	

Figure 21: Screenshot of detailed information refer to a single wall *setting*
Source: software Revit

The software also allows to insert all the layers (if they exist) of a building product assigning each their own characteristics. By entering the data correctly, the software is also able to provide automatically information regarding the physical performance of the product useful for an energy assessment or product management.



Famiglia: Muro di base
Tipo: Chiusura verticale opaca - tipo 2
Spessore totale: 0.2000
Resistenza (R): 0.0000 (m²·K)/W
Massa termica: 0.00 kJ/K
Altezza esempio: 6.0000

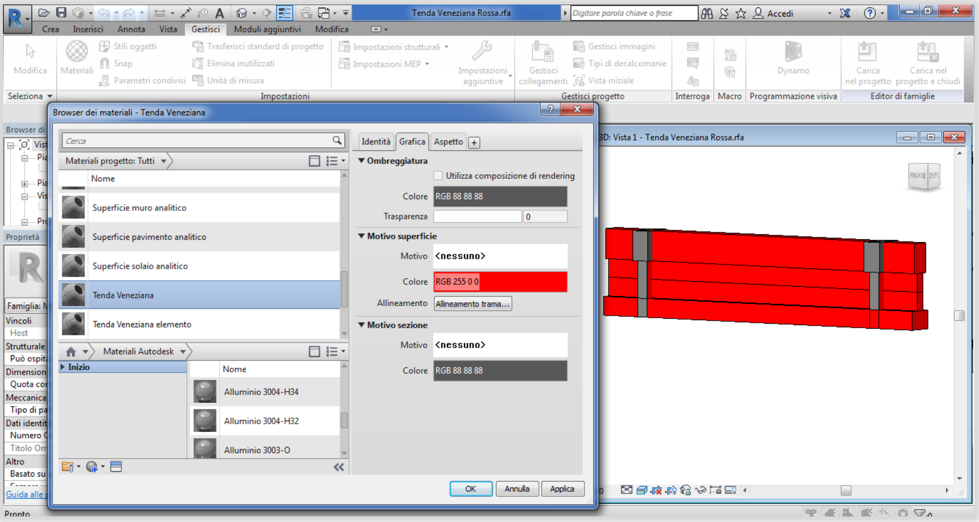
	Funzione	Materiale	Spessore	Ripiegature	Materiale strutturale
1	Contorno del nucleo	Strati sopra ripiegat	0.0000		
2	Struttura [1]	Intonaco - Bianco	0.0100	☐	☐
3	Struttura [1]	Laterizio (1)	0.1500	☐	☐
4	Struttura [1]	Isolamento	0.0400	☐	☑
5	Contorno del nucleo	Strati sotto ripiegat	0.0000		

Ripiegatura di default
Agli inserti: Non ripiegare
Alle estremità: Nessuno

Modifica struttura verticale (strumenti attivi solo in anteprima sezione)

Figure 22: Screenshot of the product layouts
Source: software Revit

Among other information that is possible to insert, Revit allows also to add those that refer to the type of material that makes up the object. Through the "materials browser" window, the designer can select the type of surface from the drop-down menu or add new ones if they do not already exist. Through this window is also possible to enter information regarding the color of the material visible in the 3D model or in other views.



Browser dei materiali - Tenda Veneziana

Materiali progetto: Tutti

Nome
Superficie muro analitico
Superficie pavimento analitico
Superficie solaio analitico
Tenda Veneziana
Tenda Veneziana elemento

Materiali Autodesk

Nome
Alluminio 3004-H34
Alluminio 3004-H32
Alluminio 3003-O

Ombreggiatura
☐ Utilizza composizione di rendering
Colore: RGB 88 88 88
Trasparenza: 0

Motivo superficie
Motivo: <nessuno>
Colore: RGB 255 0 0
Allineamento: Allineamento trama...

Motivo sezione
Motivo: <nessuno>
Colore: RGB 88 88 88

Figure 23: Screenshot of the material browser
Source: software Revit

CHAPTER 6

MAINTENANCE

6.1 Introduction to maintenance activities

The management process is the most significant step of a building's useful life, both in terms of temporal development and economic investment. The management phase consists in the execution of planned maintenance operations for the proper functioning of the building exercise. The management activity concerns all building organisms but it plays an absolutely central role in the field of large real estate, public and private assets. To make it more effective is necessary refer to an integrated process, which is a complex and articulated operation, that offers considerable opportunities for an intelligent use of data that affect buildings. It is a multidisciplinary collaborative process which analyzes and integrates different aspects and knowledge during all the phases of building analysis. The final objective is to reach the performance targets defined by the client (zero energy balance, high internal comfort, economy savings, functionality, etc.) through a participatory process which leads to determine the most advantageous solution. This approach necessarily requires the use of an information platform, coordinated with the different systems, in order to optimize activities, produce efficiency and especially evaluate the economic interests.

6.2 Determination of the priority criteria and definition of maintenance strategies.

The definition of the priority criteria is essential to acquire, during the plan process, the necessary principle references to define the priority levels of interventions. The priority framework allows to:

- order the interventions to be carried out;
- distribute planned interventions over the validity period of the plan;
- evaluate the urgency level for unplanned interventions.

In the presence of a failure or based on the inspections and monitoring results:

- verify the possibility of postponing some interventions because it is considered more convenient to wait the concomitance of other planned interventions. It also could be a useful strategy if there is not economic availability in that precise moment.

The priority criteria are established:

- in relation to the presence of binding legislation provisions;
- in relation to situations that may generate safety, health or environment risks;
- in relation to the presence of contractual provisions;
- on the basis of critical aspects that interest technical elements, assessed in relation to the performed functions;
- on the basis of needs expressed by the property.

PRIORITY LEVELS	TYPES OF CRITICALITY	TYPES OF INTERVENTION
HIGH	Impaired safety; Main functional block; Trasmission of faults; Regulatory requirements.	Emergency intervention (immediate action required) or planned intervention in relation to regulatory provisions.
MEDIUM	Disregardin of the basic requirements; Hinder main functions	Urgent or planned intervention according to plan indications
LOW	Causes future problems; High maintenance costs; Conservation of aesthetic quality .	Not urgent intervention or not planned intervention according to plan indications (possibly postponed)

Table 10: Priority levels in relation to the types of criticality and intervention
Source: elaboration by the author

The maintenance plan operations are referred to a medium-long term time scale. Depending on the characteristics of the building and the specific maintenance service contract, the types of intervention could have different time frame for buildings in operation. The definition of the possible operations (maintenance strategy) to be adopt for the organization of maintenance is a fundamental decision for the subsequent prediction of characteristics, methods of execution and time sequence of activities to be performed. First of all it is important to define if is necessary to intervene in a planned preventive way or in the presence of a failure. The definitions of ordinary and extraordinary maintenance are presented in the standard UNI 11063:2003.

- **Ordinary maintenance.** Type of maintenance interventions during the building life cycle, suitable for:

- maintain the original integrity of the building;
- maintain or restore the efficiency of the assets;
- contain normal use degradation;
- guarantee the useful life of the asset;
- face up to accidental events.

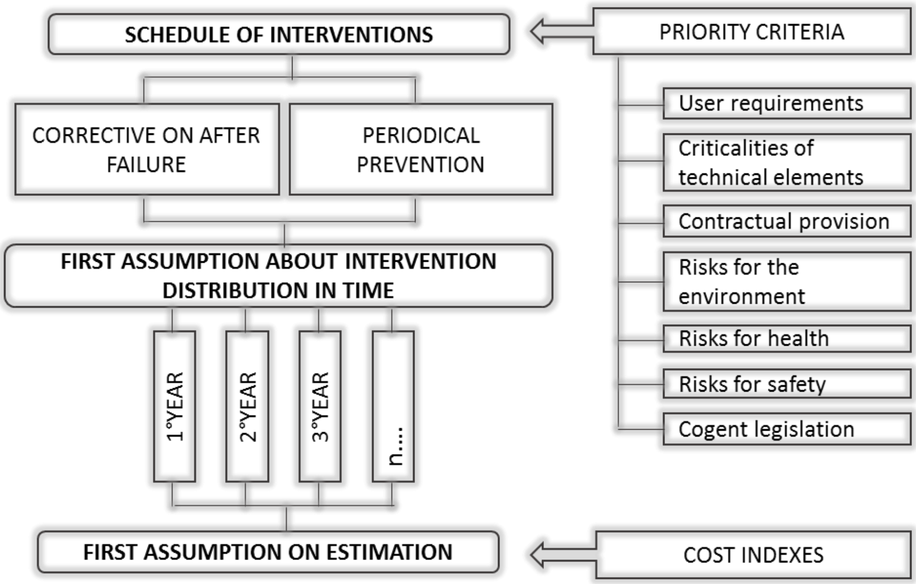
Generally, interventions are required in presence of:

- failures detection (maintenance after failure or corrective);
- implementation of maintenance policies (preventive maintenance, cyclical, under condition), need to optimize the availability of the asset and improve efficiency (improvement interventions or small change which do not involve an increase in the asset value).

The fore mentioned interventions do not modify the original characteristics of the asset, the essential structure and their intended use. Relative costs must be foreseen in the maintenance budget and attribute to the financial year in which the activities were carried out.

- **Extraordinary maintenance.** Type of non-recurring interventions with high cost, compared to the replacement value of the asset and the annual costs of ordinary maintenance of the same. The interventions also:

- may prolong the useful life and / or improve its efficiency, reliability, productivity, maintainability and inspectability;
- they do not modify the building characteristics and the essential structure;
- they do not involve changes in the property use.



Charts 8: Definition process about assumption on estimation
Source: Molinari C. (2005) – "Procedimenti e metodi della manutenzione edilizia"

6.2.1 Evaluation criticalities and frequencies of intervention

The criticality of an element can be evaluated on the basis of failure severity or from the probability of its decay. The main phases of the decision-making process that lead to the strategies identification, applicable to the various technical elements in relation to their criticality's degree, are:

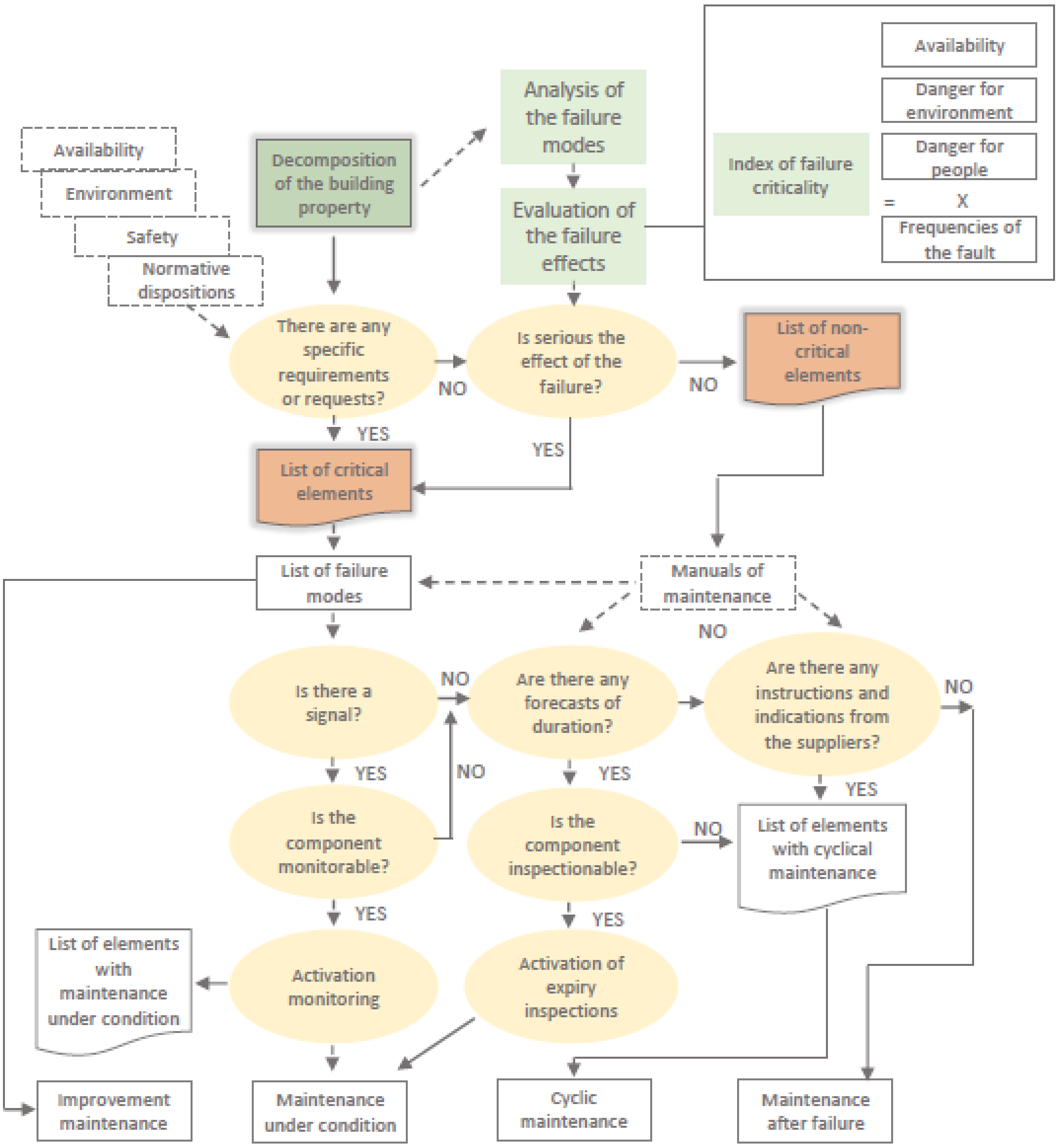
- **The decomposition of the building organism into its constituent elements**

- **The recognition of the criticality degree.** For not critical elements a minimal base knowledge can be collected in relation to the growth of return information; for critical or highly critical items, the information to be collected and surveys of their status must be accurate as the predictions on their behavior with respect to predetermined time frames. In the evaluation of an entity's criticality it must be considered:

- the direct and indirect risks of personal injury;
- the environment risks;
- the regulatory requirements;
- the propagation of faults to other critical entities;

- the risks of property damage;
- the availability required of the building property in relation to the performed functions;
- the assumed requirements for the quality references definition of the building asset;
- the existence or absence of redundant systems;
- other effects.

To arrive to an overall criticality assessment it must be considered the degree of difficulty that is encountered to maintain or improve an entity in relation to its replacement costs. The determination of the criticality degree allows to define a list of critical elements. The outcome of information and the analytical activities on it leads to a series of decisions which directs the assumption of different maintenance strategies in consideration of the level and type of criticality.



Charts 9: Schematic process for the definition of the different maintenance interventions

Source: UNI standard 10366

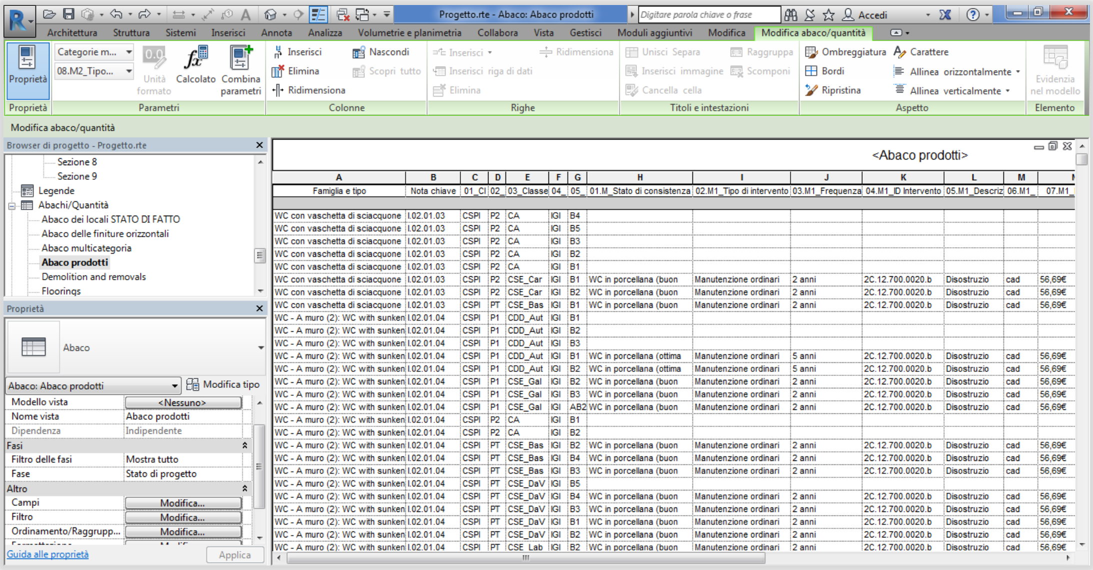
6.3 Maintenance plan

The elaboration of the maintenance plan provides the preparation of interventions organized by technical elements classes according to the established maintenance strategies. A preliminary action for the acquisition of building information is the adoption of a unique classification system and the organization of the building that allows to:

- decompose the building into technological units and technical elements (updating with new elements or components);
- identify, with a univocal code, the localization of technical elements (compared to the functional spatial system) .

Regarding the technological system this classification and coding system must allow to write the building organism and to allocate information, that can be assumed from different sources, to technical elements. This composition must represent the single and common basis of reference for the various actions concerning the acquisition and storage of information. The decomposition and classification must therefore be the same adopted by the various subjects that will investigate the technical and consistency characteristics of the building (documentary audits, surveys, diagnostic investigations, etc.) both by the editors of the manual, plan and schedule of maintenance.

Regarding the practical application and specifically the maintenance of the shed Punto d'Incontro, a ten-year plan has been drawn up which provides cleaning operations, verification and renewal of the elements with periodic frequency scanned by the priorities that have been assigned to each product. The maintenance plan was organized in order to allows easier management, control and freedom in any change of the project. Before proceed with the preparation of the maintenance plan it was necessary to extract the data from the list of products present in Revit abacus views and export all information to an Excel file. The schedules allow to filter the data and organize the information according to the requested order. In this case the products were ordered by family and type, key-note, localization, state of consistency and data relating to maintenance.



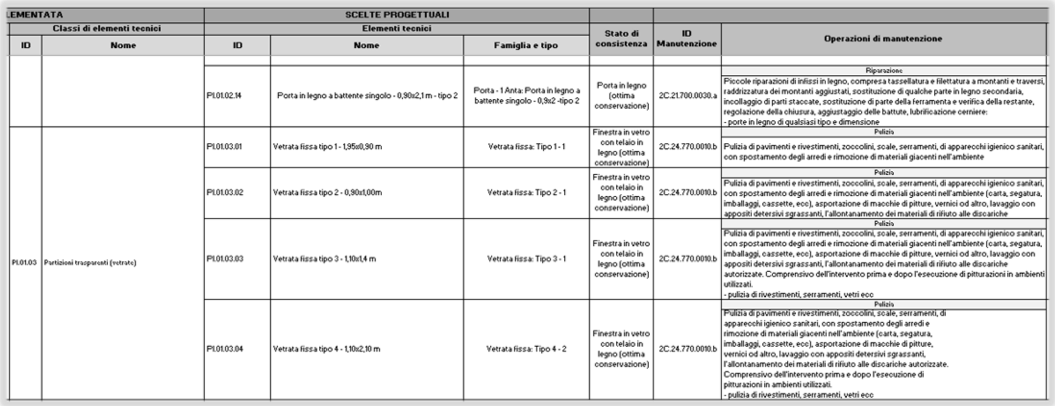
Abaco: Abaco prodotti
Modello vista <Nessuno>
Nome vista Abaco prodotti
Dipendenza Indipendente
Filtro delle fasi Mostra tutto
Fase Stato di progetto

<Abaco prodotti>

A	B	C	D	E	F	G	H	I	J	K	L	M	
Famiglia e tipo	Nota chiave	01_Cl	02_	03_Classe	04_	05_	01.M_Stato di consistenza	02.M1_Tipo di intervento	03.M1_Frequenza	04.M1_ID Intervento	05.M1_Descriz	06.M1_	07.M1_
WC con vaschetta di sciacquone	I.02.01.03	CSPI	P2	CA	IGI	B4							
WC con vaschetta di sciacquone	I.02.01.03	CSPI	P2	CA	IGI	B5							
WC con vaschetta di sciacquone	I.02.01.03	CSPI	P2	CA	IGI	B3							
WC con vaschetta di sciacquone	I.02.01.03	CSPI	P2	CA	IGI	B2							
WC con vaschetta di sciacquone	I.02.01.03	CSPI	P2	CA	IGI	B1							
WC con vaschetta di sciacquone	I.02.01.03	CSPI	P2	CSE_Car	IGI	B1	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC con vaschetta di sciacquone	I.02.01.03	CSPI	P2	CSE_Car	IGI	B2	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC con vaschetta di sciacquone	I.02.01.03	CSPI	PT	CSE_Bas	IGI	B1	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P1	CDD_Aut	IGI	B1							
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P1	CDD_Aut	IGI	B2							
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P1	CDD_Aut	IGI	B3							
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P1	CDD_Aut	IGI	B1	WC in porcellana (ottima	Manutenzione ordinari	5 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P1	CDD_Aut	IGI	B2	WC in porcellana (ottima	Manutenzione ordinari	5 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P1	CSE_Gal	IGI	B2	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P1	CSE_Gal	IGI	B3	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P1	CSE_Gal	IGI	AB2	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P2	CA	IGI	B1							
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	P2	CA	IGI	B2							
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	PT	CSE_Bas	IGI	B2	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	PT	CSE_Bas	IGI	B4	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	PT	CSE_Bas	IGI	B3	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	PT	CSE_DaV	IGI	B5							
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	PT	CSE_DaV	IGI	B4	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	PT	CSE_DaV	IGI	B3	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	PT	CSE_DaV	IGI	B1	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	PT	CSE_DaV	IGI	B2	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€
WC - A muro (2): WC with sunken	I.02.01.04	CSPI	PT	CSE_Lab	IGI	B2	WC in porcellana (buon	Manutenzione ordinari	2 anni	2C.12.700.0020.b	Disostruzio	cad	56,69€

Figure 24: Screenshot of the products list in an abacus view
Source: software Revit

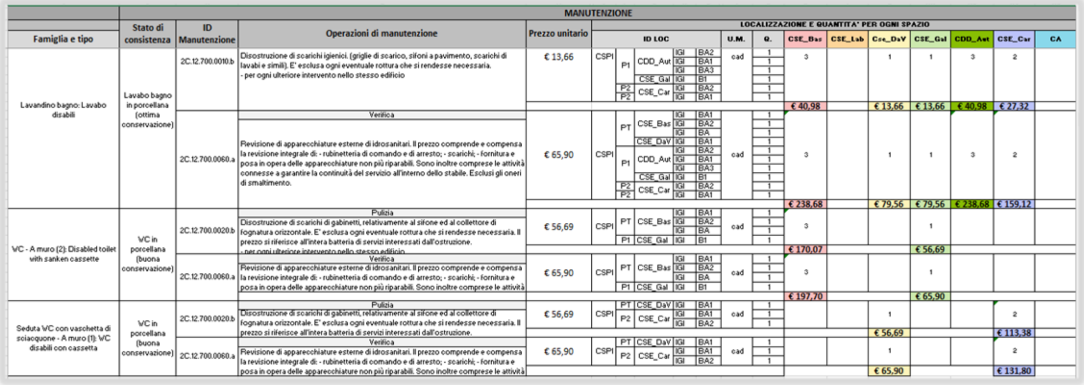
After extrapolating data and inserted it into an Excel spreadsheet, the information were organized following the classification of the standard UNI 8290-81 implemented, previously used for coding building products. For each element is present the state of consistency, the maintenance interventions and the unitary price corresponding to the price list of Milan 2018 for the maintenance operations. For each type of intervention has been associated the identification code, taken from the price list, in order to have correspondence and ease in finding the sources from which the data were taken. Conversely, some of the unit prices have been calculated through an estimation resulting from the comparison of other items belonging to other price lists.



LEMENTATA		SCELTE PROGETTUALI					
Classi di elementi tecnici		Elementi tecnici			Stato di consistenza	ID Manutenzione	Operazioni di manutenzione
ID	Nome	ID	Nome	Famiglia e tipo			
		P1.01.02.14	Porta in legno a battente singolo - 0,90x2,1 m - tipo 2	Porta - 1 Anta: Porta in legno a battente singolo - 0,9x2 -tipo 2	Porta in legno (ottima conservazione)	2C.21.700.0030.a	Riparazione Piccole riparazioni di infissi in legno, compresa tassellatura e filettatura a montanti e traversi, raddrizzatura dei montanti aggiustati, sostituzione di qualche parte in legno secondaria, incollaggio di parti staccate, sostituzione di parte della ferramenta e verifica della restante, regolazione della chiusura, aggiustaggio delle battute, lubrificazione cerniere: - porte in legno di qualsiasi tipo e dimensione
P1.01.03	Partizioni trasparenti (vetrate)	P1.01.03.01	Vetrata fissa tipo 1 - 1,95x0,90 m	Vetrata fissa: Tipo 1 - 1	Finestra in vetro con telaio in legno (ottima conservazione)	2C.24.770.0010.b	Pulizia Pulizia di pavimenti e rivestimenti, zoccolini, scale, serramenti, di apparecchi igienico sanitari, con spostamento degli arredi e rimozione di materiali giacenti nell'ambiente
		P1.01.03.02	Vetrata fissa tipo 2 - 0,90x1,00m	Vetrata fissa: Tipo 2 - 1	Finestra in vetro con telaio in legno (ottima conservazione)	2C.24.770.0010.b	Pulizia Pulizia di pavimenti e rivestimenti, zoccolini, scale, serramenti, di apparecchi igienico sanitari, con spostamento degli arredi e rimozione di materiali giacenti nell'ambiente (carta, segatura, imballaggi, cassette, ecc), asportazione di macchie di pitture, vernici od altro, lavaggio con appositi detersivi sgrassanti, l'allontanamento dei materiali di rifiuto alle discariche
		P1.01.03.03	Vetrata fissa tipo 3 - 1,10x1,4 m	Vetrata fissa: Tipo 3 - 1	Finestra in vetro con telaio in legno (ottima conservazione)	2C.24.770.0010.b	Pulizia Pulizia di pavimenti e rivestimenti, zoccolini, scale, serramenti, di apparecchi igienico sanitari, con spostamento degli arredi e rimozione di materiali giacenti nell'ambiente (carta, segatura, imballaggi, cassette, ecc), asportazione di macchie di pitture, vernici od altro, lavaggio con appositi detersivi sgrassanti, l'allontanamento dei materiali di rifiuto alle discariche autorizzate. Comprensivo dell'intervento prima e dopo l'esecuzione di pitturazioni in ambienti utilizzati. - pulizia di rivestimenti, serramenti, vetri ecc
		P1.01.03.04	Vetrata fissa tipo 4 - 1,10x2,10 m	Vetrata fissa: Tipo 4 - 2	Finestra in vetro con telaio in legno (ottima conservazione)	2C.24.770.0010.b	Pulizia Pulizia di pavimenti e rivestimenti, zoccolini, scale, serramenti, di apparecchi igienico sanitari, con spostamento degli arredi e rimozione di materiali giacenti nell'ambiente (carta, segatura, imballaggi, cassette, ecc), asportazione di macchie di pitture, vernici od altro, lavaggio con appositi detersivi sgrassanti, l'allontanamento dei materiali di rifiuto alle discariche autorizzate. Comprensivo dell'intervento prima e dopo l'esecuzione di pitturazioni in ambienti utilizzati. - pulizia di rivestimenti, serramenti, vetri ecc

Table 11: Information about maintenance activities
Source: elaboration by the author with Excel

After defining the unit price for each maintenance operation to be carried out, the cost has been multiplied by the quantity of the product present inside each room. In this way it was possible to calculate the total cost for each space without taking into account the frequencies of the intervention. (See attachments of the Excel tables at the end of the thesis pages).



	MANUTENZIONE													
					LOCALIZZAZIONE E QUANTITA' PER OGNI SPAZIO									
Famiglia e tipo	Stato di consistenza	ID Manutenzione	Operazioni di manutenzione	Prezzo unitario	ID LOC	U.M.	Q.	CSE_Bas	CSE_Lab	Cse_DaV	CSE_Gal	CDD_Aut	CSE_Car	CA
Lavandino bagno: Lavabo disabili	Lavabo bagno in porcellana (ottima conservazione)	2C.12.700.0010.b	Disostruzione di scarichi igienici. (griglie di scarico, sifoni a pavimento, scarichi di lavabi e simili). E' esclusa ogni eventuale rottura che si rendesse necessaria. - per ogni ulteriore intervento nello stesso edificio	€ 13,66	CSPI P1 CDD_Aut IGI BA2 IGI BA1 IGI BA3 CSE_Gal IGI B1 P2 CSE_Car IGI BA2 P2 IGI BA1	cad	1 1 1 1 1 1	3		1	1	3	2	
								€ 40,98		€ 13,66	€ 13,66	€ 40,98	€ 27,32	
		2C.12.700.0060.a	Verifica Revisione di apparecchiature esterne di idrosanitari. Il prezzo comprende e compensa la revisione integrale di: - rubinetteria di comando e di arresto; - scarichi; - fornitura e posa in opera delle apparecchiature non più riparabili. Sono inoltre comprese le attività connesse a garantire la continuità del servizio all'interno dello stabile. Esclusi gli oneri di smaltimento.	€ 65,90	CSPI PT CSE_Bas IGI BA1 IGI BA2 IGI BA CSE_DaV IGI BA1 P1 CDD_Aut IGI BA2 IGI BA1 IGI BA3 CSE_Gal IGI B1 P2 CSE_Car IGI BA2 P2 IGI BA1	cad	1 1 1 1 1 1 1 1 1 1	3		1	1	3	2	
								€ 238,68		€ 79,56	€ 79,56	€ 238,68	€ 159,12	
WC - A muro (2): Disabled toilet with sanken cassette	WC in porcellana (buona conservazione)	2C.12.700.0020.b	Pulizia Disostruzione di scarichi di gabinetti, relativamente al sifone ed al collettore di fognatura orizzontale. E' esclusa ogni eventuale rottura che si rendesse necessaria. Il prezzo si riferisce all'intera batteria di servizi interessati dall'ostruzione. - per ogni ulteriore intervento nello stesso edificio	€ 56,69	CSPI PT CSE_Bas IGI BA1 IGI BA2 IGI BA P1 CSE_Gal IGI B1	cad	1 1 1 1	3			1			
								€ 170,07			€ 56,69			
		2C.12.700.0060.a	Verifica Revisione di apparecchiature esterne di idrosanitari. Il prezzo comprende e compensa la revisione integrale di: - rubinetteria di comando e di arresto; - scarichi; - fornitura e posa in opera delle apparecchiature non più riparabili. Sono inoltre comprese le attività	€ 65,90	CSPI PT CSE_Bas IGI BA1 IGI BA2 IGI BA P1 CSE_Gal IGI B1	cad	1 1 1 1	3			1			
								€ 197,70			€ 65,90			
Seduta WC con vaschetta di sciacquone - A muro (1): WC disabili con cassetta	WC in porcellana (buona conservazione)	2C.12.700.0020.b	Pulizia Disostruzione di scarichi di gabinetti, relativamente al sifone ed al collettore di fognatura orizzontale. E' esclusa ogni eventuale rottura che si rendesse necessaria. Il prezzo si riferisce all'intera batteria di servizi interessati dall'ostruzione.	€ 56,69	CSPI PT CSE_DaV IGI BA1 P2 CSE_Car IGI BA1 IGI BA2	cad	1 1 1			1			2	
										€ 56,69			€ 113,38	
		2C.12.700.0060.a	Verifica Revisione di apparecchiature esterne di idrosanitari. Il prezzo comprende e compensa la revisione integrale di: - rubinetteria di comando e di arresto; - scarichi; - fornitura e posa in opera delle apparecchiature non più riparabili. Sono inoltre comprese le attività	€ 65,90	CSPI PT CSE_DaV IGI BA1 P2 CSE_Car IGI BA1 IGI BA2	cad	1 1 1			1			2	
										€ 65,90			€ 131,80	

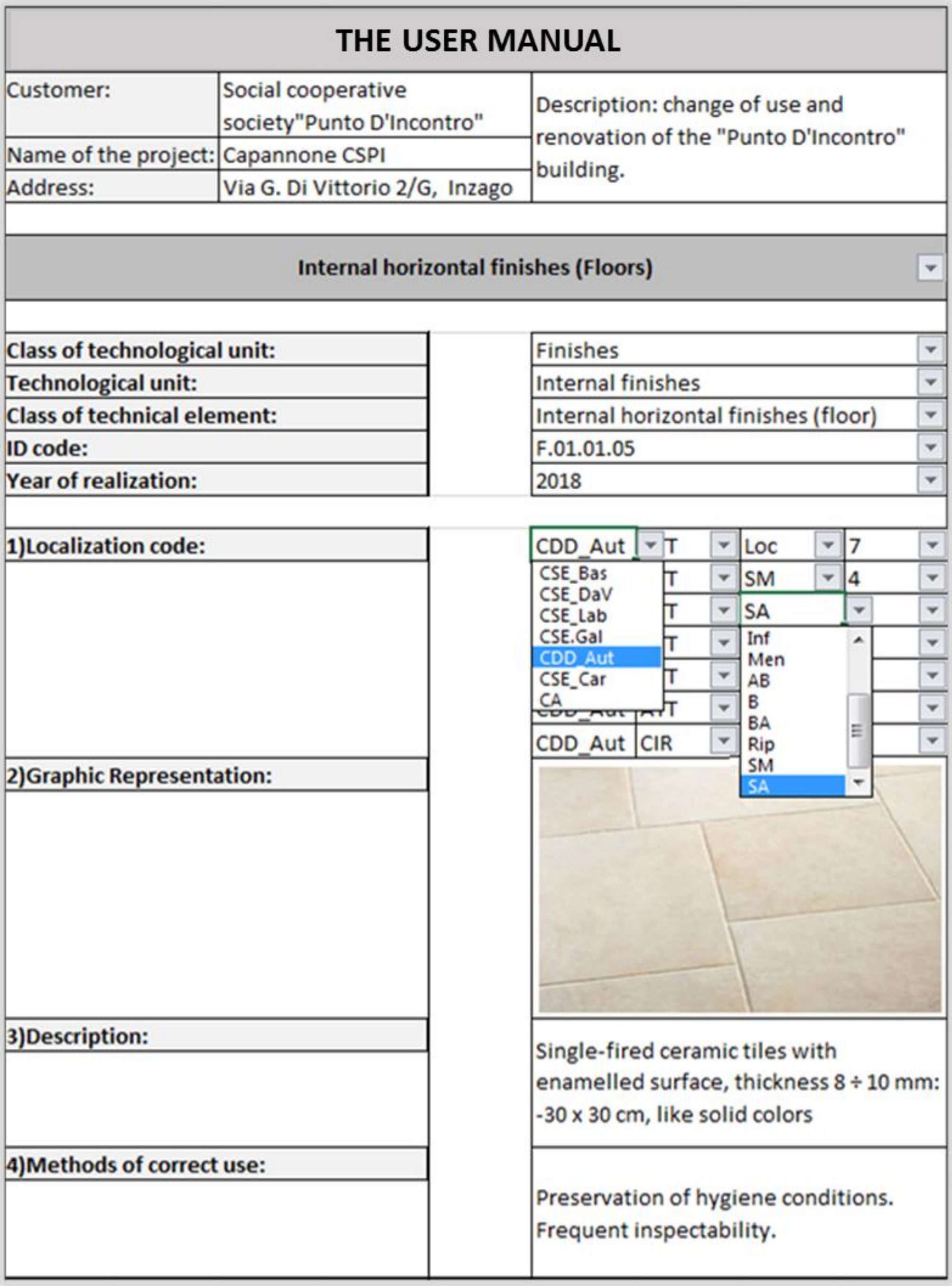
Table 12: Screenshot of a part of the maintenance plan
Source: elaboration by the author with Excel

6.3.1 The user manual

This manual refers to the use of the most important parts of the building and in particular to the technological systems. The table contains all the necessary information that allow user to know the property use, as well as all the elements useful to limit damage as a result of improper use. The user manual contains the following information:

- intervention placement of the mentioned parties;
- graphic representation;
- description;
- methods of correct use.

Since the purpose of this work is to provide a complete project that is interoperable and therefore entirely computerized, also the user manual and the maintenance manual have been digitalized so as to allow easy finding, organization and exchange of information with the Revit model. An example sheet of the digitialized user manual is shows below, it provides information for the correct use of the floors. In this table is possible to select all the specifications concerning the product inside the shed through the drop-down menus corresponding to each item.



THE USER MANUAL

Customer:	Social cooperative society"Punto D'Incontro"	Description: change of use and renovation of the "Punto D'Incontro" building.
Name of the project:	Capannone CSPI	
Address:	Via G. Di Vittorio 2/G, Inzago	

Internal horizontal finishes (Floors)

Class of technological unit:	Finishes
Technological unit:	Internal finishes
Class of technical element:	Internal horizontal finishes (floor)
ID code:	F.01.01.05
Year of realization:	2018

1)Localization code:

CDD_Aut	T	Loc	7
	T	SM	4
	T	SA	
	T		
	T		
	T		
CDD_Aut	CIR		

2)Graphic Representation:

3)Description:

Single-fired ceramic tiles with enamelled surface, thickness 8 ÷ 10 mm: -30 x 30 cm, like solid colors

4)Methods of correct use:

Preservation of hygiene conditions. Frequent inspectability.

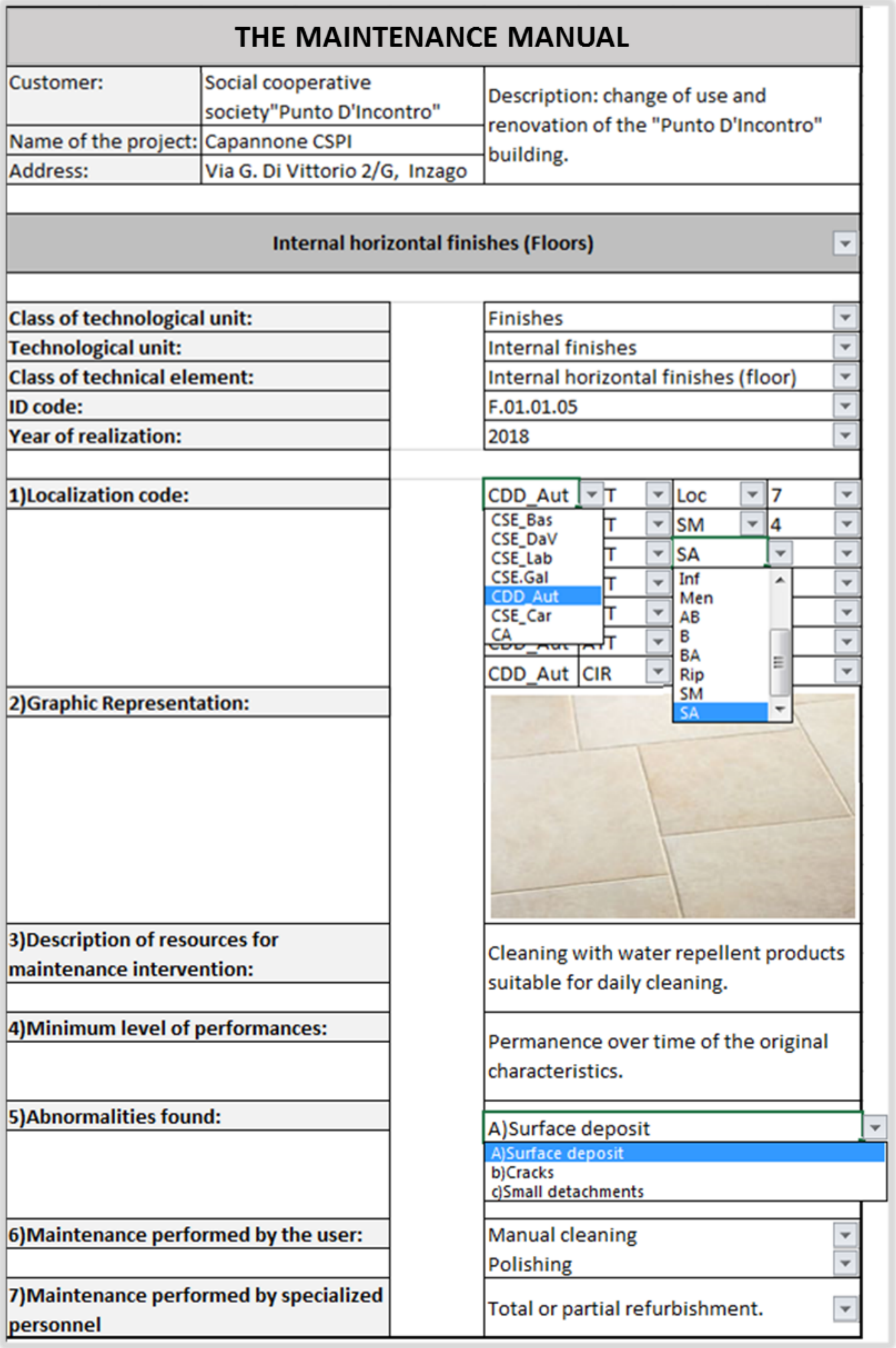
Table 13: Screenshot of the digital user manual
Source: elaboration by the author with Excel

6.3.2 The maintenance manual

The maintenance manual is a tool that must provide, to technical operators, the necessary indications for the execution of a correct building maintenance plan. The paragraph 6 of article n° 38 of the draft regulation, in the text transmitted by minister of the high council for public works, defines that: *"the maintenance manual refers to the most important parts of the building and in particular about technological systems".* It provides, in relation to the different technological units, the characteristics of the materials or components involved, the necessary indications for a correct maintenance as well as the recourse to assistance or service centers. The paragraph 7 of the article n°38 it normally contains the following information:

- location;
- graphic representation;
- description of the needed resources for maintenance operations;
- minimum level of performance;
- anomalies that can be found;
- maintenance operations that can be performed directly by the user;
- maintenance interventions to be carried out by specialized personnel.

The maintenance manual is configured as a support tool for the execution of scheduled maintenance activities and its essential aim is to provide the necessary information to make rational, economic and efficient maintenance of building assets. The maintenance manual must also contain all relevant basic information for the maintenance service and provide the registration and the updating of return information as a result of maintenance operations performed. Also in this case, the maintenance manual has been digitalized keeping the information from the user manual and adding new ones to the floor maintenance methods.



THE MAINTENANCE MANUAL

Customer:	Social cooperative society"Punto D'Incontro"	Description: change of use and renovation of the "Punto D'Incontro" building.
Name of the project:	Capannone CSPI	
Address:	Via G. Di Vittorio 2/G, Inzago	

Internal horizontal finishes (Floors)

Class of technological unit:	Finishes
Technological unit:	Internal finishes
Class of technical element:	Internal horizontal finishes (floor)
ID code:	F.01.01.05
Year of realization:	2018

1)Localization code:

CDD_Aut	T	Loc	7
	T	SM	4
	T	SA	
	T		
	T		
CDD_Aut	ATT		
CDD_Aut	CIR		

2)Graphic Representation:

3)Description of resources for maintenance intervention: Cleaning with water repellent products suitable for daily cleaning.

4)Minimum level of performances: Permanence over time of the original characteristics.

5)Abnormalities found: A)Surface deposit

6)Maintenance performed by the user: Manual cleaning
Polishing

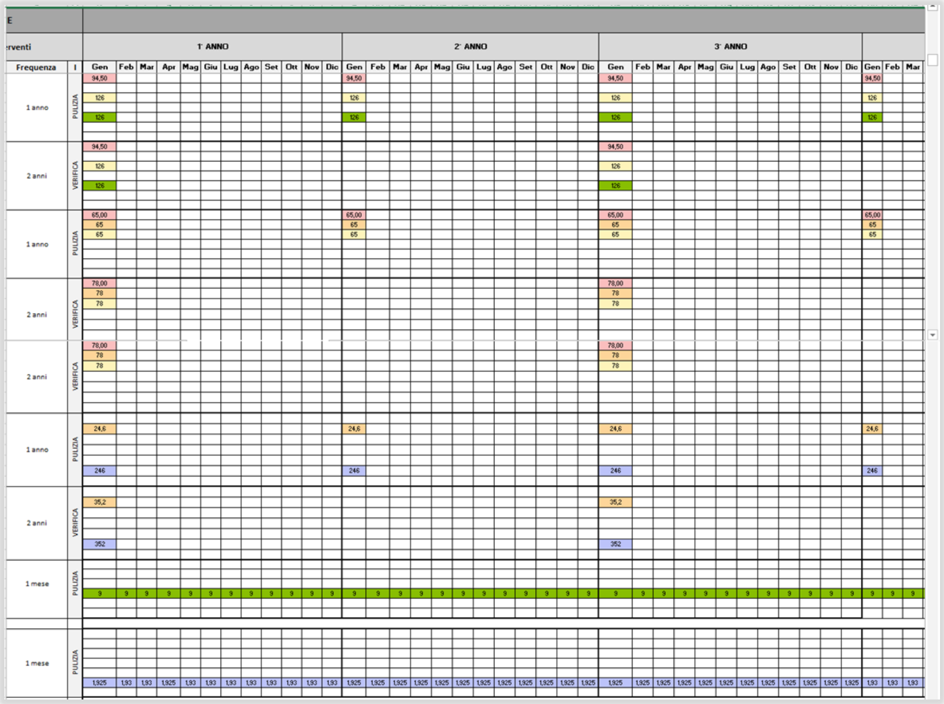
7)Maintenance performed by specialized personnel Total or partial refurbishment.

Table 14: Screenshot of digital maintenance manual

Source: elaboration by the author with Excel

6.3.3 The maintenance schedule

The maintenance schedule consists in the organization of intervention frequencies on an monthly or annual time period. It provides a system of check interventions to be performed, at times that are temporally or otherwise fixed, in order to properly manage the asset and its parts over the years. When there is the presence of a operative building, is important be able to know a series of aspects regarding his behavior over time and the events that interested it. If the information of the building technical elements can not be found or consider themselves reliable, it is possible to use knowledge from various sources such as database and technical literature. Based on the information entered in the maintenance plan, the maintenance schedule has been developed starting from prefixed activities with different frequencies in the total time of ten years. The maintenance activities has been distributed with monthly or annual frequency based on the priority degrees. After the scheduling of intervention divided by each space, it has been calculated the annual and the total cost of maintenance over a period of ten years, that is the shed rental time.



E																																								
rventi		1' ANNO												2' ANNO												3' ANNO														
Frequenza	I	Gen	Feb	Mar	Apr	Mag	Giu	Lug	Ago	Set	Ott	Nov	Dic	Gen	Feb	Mar	Apr	Mag	Giu	Lug	Ago	Set	Ott	Nov	Dic	Gen	Feb	Mar	Apr	Mag	Giu	Lug	Ago	Set	Ott	Nov	Dic	Gen	Feb	Mar
1 anno	PULIZIA	94,50												94,50												94,50												94,50		
		126												126												126												126		
		126												126												126												126		
2 anni	VERIFICA	94,50																								94,50														
		126																								126														
		126																								126														
1 anno	PULIZIA	65,00												65,00												65,00												65,00		
		65												65												65												65		
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2 anni	VERIFICA	78,00																								78,00														
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2 anni	VERIFICA	78,00																								78,00														
		78																								78														
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1 anno	PULIZIA	24,6												24,6												24,6												24,6		
		246												246												246												246		
2 anni	VERIFICA	35,2																								35,2														
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1 mese	PULIZIA	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
1 mese	PULIZIA	1,925	1,93	1,93	1,925	1,93	1,93	1,93	1,93	1,93	1,93	1,93	1,93	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,925	1,93	1,93	1,93

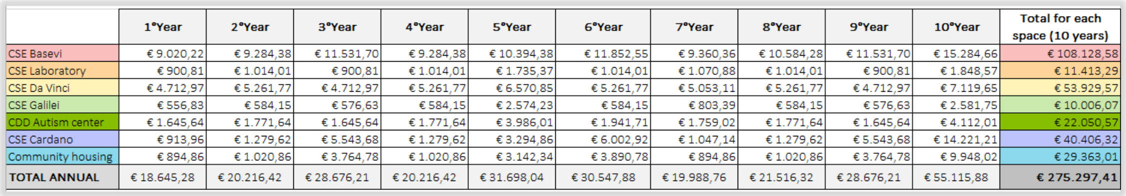
Table 15: Screenshot of maintenance schedule
Source: elaboration by the author with Excel

CHAPTER 7

ECONOMIC MANAGEMENT OF THE ASSET

7.1 Cost analysis and reflections on the results

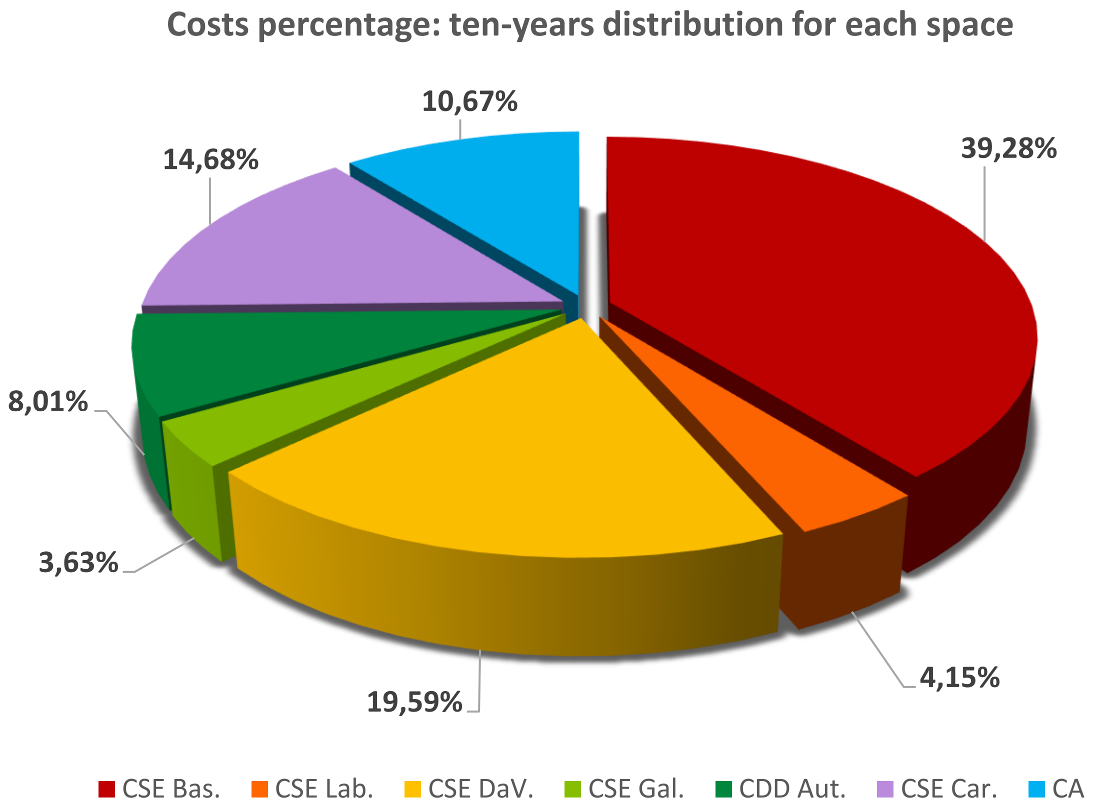
After the maintenance plan and the consequent setting up of all the interventions have been worked out, it was possible to have an annual and ten-years costs estimation that affect the scheduled maintenance operations. The obtained value allows to know the total cost of maintenance work which is equal to: 275.297,41€.



	1°Year	**2°Year**	**3°Year**	**4°Year**	**5°Year**	**6°Year**	**7°Year**	**8°Year**	**9°Year**	**10°Year**	**Total for each space (10 years)**
CSE Basevi	€ 9.020,22	€ 9.284,38	€ 11.531,70	€ 9.284,38	€ 10.394,38	€ 11.852,55	€ 9.360,36	€ 10.584,28	€ 11.531,70	€ 15.284,66	€ 108.128,58
CSE Laboratory	€ 900,81	€ 1.014,01	€ 900,81	€ 1.014,01	€ 1.735,37	€ 1.014,01	€ 1.070,88	€ 1.014,01	€ 900,81	€ 1.848,57	€ 11.413,29
CSE Da Vinci	€ 4.712,97	€ 5.261,77	€ 4.712,97	€ 5.261,77	€ 6.570,85	€ 5.261,77	€ 5.053,11	€ 5.261,77	€ 4.712,97	€ 7.119,65	€ 53.929,57
CSE Galilei	€ 556,83	€ 584,15	€ 576,63	€ 584,15	€ 2.574,23	€ 584,15	€ 803,39	€ 584,15	€ 576,63	€ 2.581,75	€ 10.006,07
CDD Autism center	€ 1.645,64	€ 1.771,64	€ 1.645,64	€ 1.771,64	€ 3.986,01	€ 1.941,71	€ 1.759,02	€ 1.771,64	€ 1.645,64	€ 4.112,01	€ 22.050,57
CSE Cardano	€ 913,96	€ 1.279,62	€ 5.543,68	€ 1.279,62	€ 3.294,86	€ 6.002,92	€ 1.047,14	€ 1.279,62	€ 5.543,68	€ 14.221,21	€ 40.406,32
Community housing	€ 894,86	€ 1.020,86	€ 3.764,78	€ 1.020,86	€ 3.142,34	€ 3.890,78	€ 894,86	€ 1.020,86	€ 3.764,78	€ 9.948,02	€ 29.363,01
TOTAL ANNUAL	€ 18.645,28	€ 20.216,42	€ 28.676,21	€ 20.216,42	€ 31.698,04	€ 30.547,88	€ 19.988,76	€ 21.516,32	€ 28.676,21	€ 55.115,88	**€ 275.297,41**

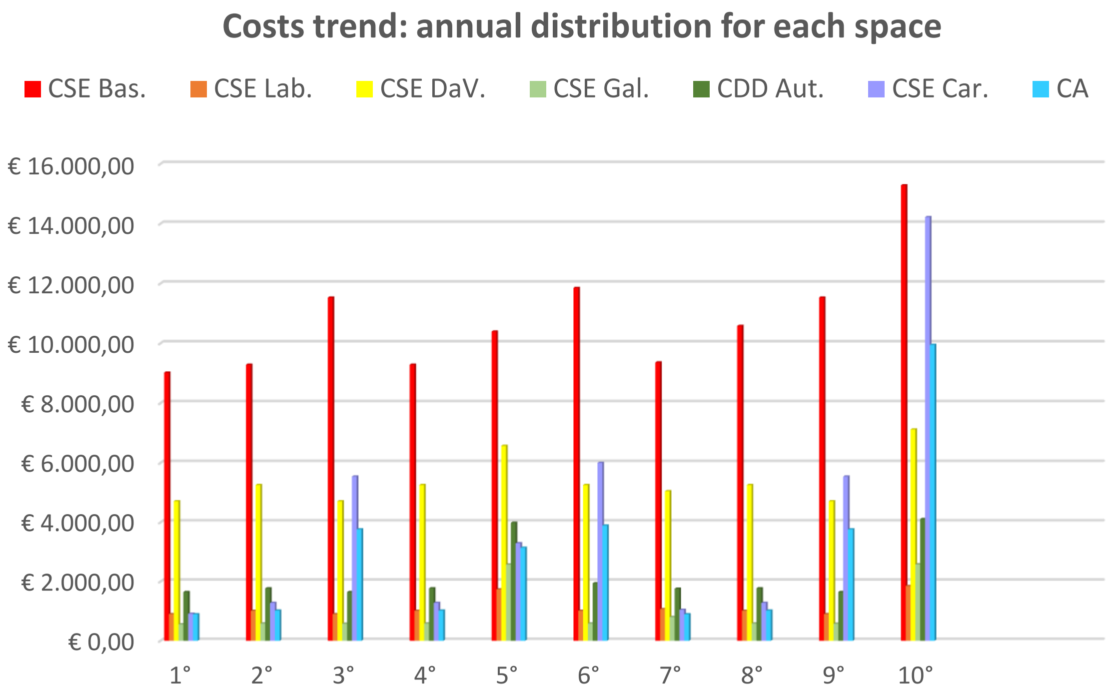
Table 16: Screenshot of maintenance cost estimation
Source: elaboration by the author with Excel

Subsequently the achieved results were organized in a pie chart illustrating the incidence of percentages on the total cost for each space (see chart 10). The cost percentage of maintenance operations, distributed in a period of ten-years, reveals significantly greater expenses for the locals of CSE Basevi (39,28%) because this space presents the largest surface equal to 739,48 sqm followed by the space of CSE Da Vinci (19,59%) that is 688,79 sqm.



Charts 10: Ten-year distribution for each space
Source: elaboration by the author with Excel

Focusing on annual expenses it is easy to understand the costs trend over the years thanks to the construction of a histogram (chart 11). From a first observation it is possible to notice a constant trend except for the third, sixth and tenth year that present peaks. This result is due to some maintenance interventions that will be carried out in specific periods. The highest peak is presented at the tenth year from all spaces, this result is due to the presence of activities which are more frequent in these year because the structure it is brought to age. The managers of the structure will consider whether to keep this distribution of costs or anticipate/postpone some of these expenses in order to avoid the peaks and have a regular cost trend during years. These kinds of decisions depend especially from the economic availability that the organization will have at the moment.

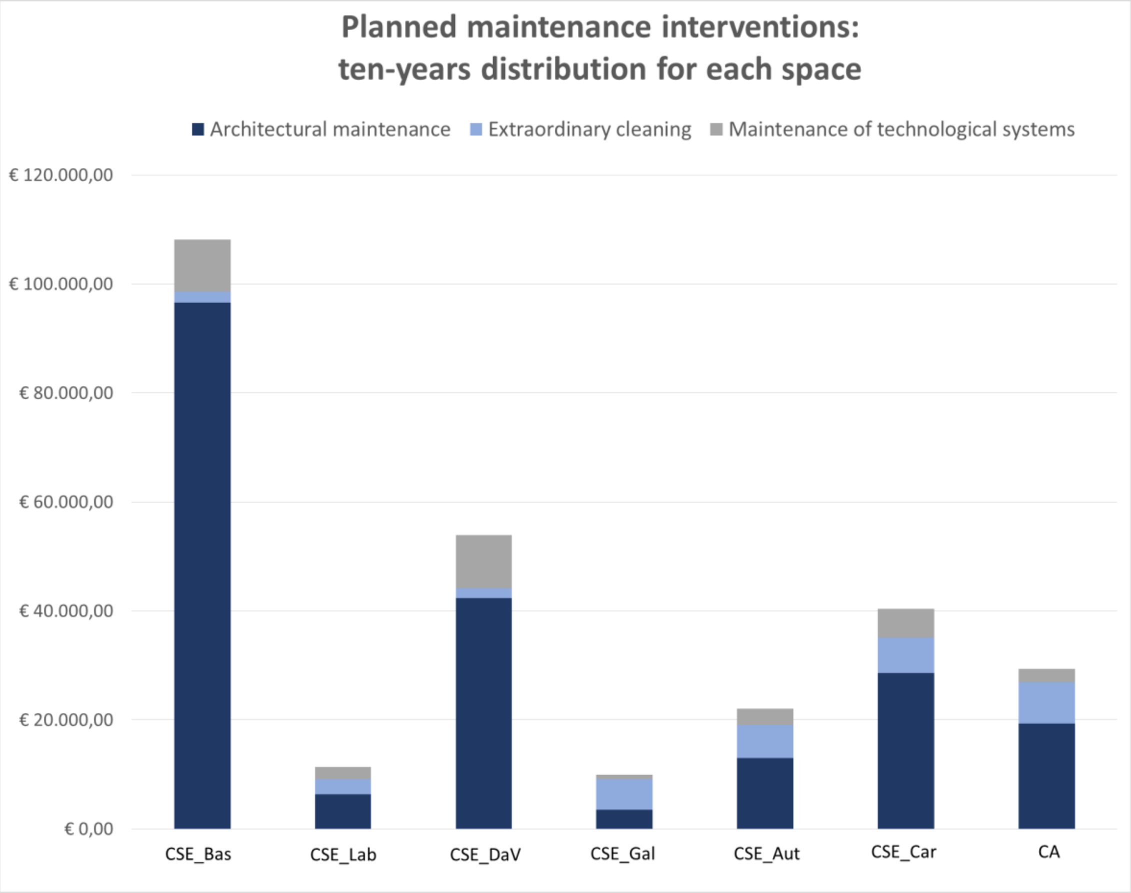


Charts 11: Annual distribution for each space
Source: elaboration by the author with Excel

A further analysis was carried out to better understand which type of maintenance interventions have higher costs within every space. To deal with this type of analysis it was necessary to group all maintenance interventions into three macro-categories that are:

- ARCHITECTURAL MAINTENANCE. This category includes all the operations that concern the checking of internal partitions like windows, generic and fire doors, the maintenance of the roof, gutters and downpipes.
- EXTRAORDINARY CLEANING. It refers to all the cleaning interventions which require the presence of specific equipment (chemical products, ladder etc..) and more execution time. Among this activities are included the cleaning of the curtain wall on the ground floor, windows, venetian blinds and railings on the first and second floor.

- MAINTENANCE OF TECHNOLOGICAL SYSTEMS. In this section are grouped all the operations aimed to maintain the terminals of technological systems like air conditioning, hydraulic, electrical and lifting.



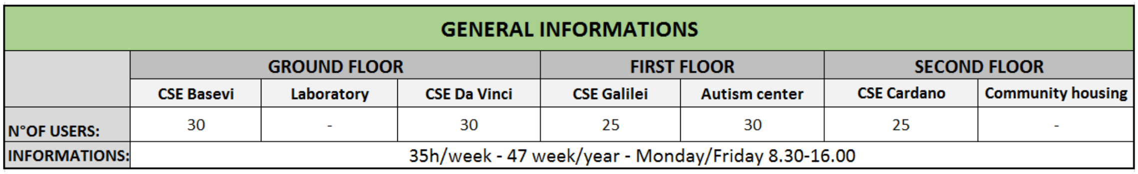
Charts 12: Cost distribution for each planned maintenance intervention
Source: elaboration by the author with Excel

The chart above provides useful information regarding the impact that each type of intervention has on the total cost of maintenance of each space over a total period of ten years. Specifically, it is easy to see how the higher costs are due to architectural maintenance interventions especially in the rooms of CSE Basevi. This result is due to cleaning activities of the skylights and of the shed covering which includes gutters and downpipes for which is required the presence of specific products, heavy vehicles and specialized workers. It should also be remembered that this space has a greater extension than the other areas inside the building, this is the reason why it has such high costs. In addition, the locals within this space have not been subjected to renovation, so the products present degradations and this is why is required a greater frequency of interventions over the years.

For the same principles also the spaces of the CSE Cardano, on the second floor, presents considerable expenses while in the CSE Da Vinci are request constant maintenance interventions about checking of internal partition especially for the numerous presence of fire doors.

7.1.2 The organization of services

The daytime services offered by the facility welcome people from around 25 municipality of the Martesana area, from the city of Milan and from the district of Treviglio. The centers are structured to accommodate a total of 140 people, in relation of 1:5 with the staff as required by regional standards. The shed is open from Monday to Friday from 9:00 to 16:00 for 47 weeks/year.



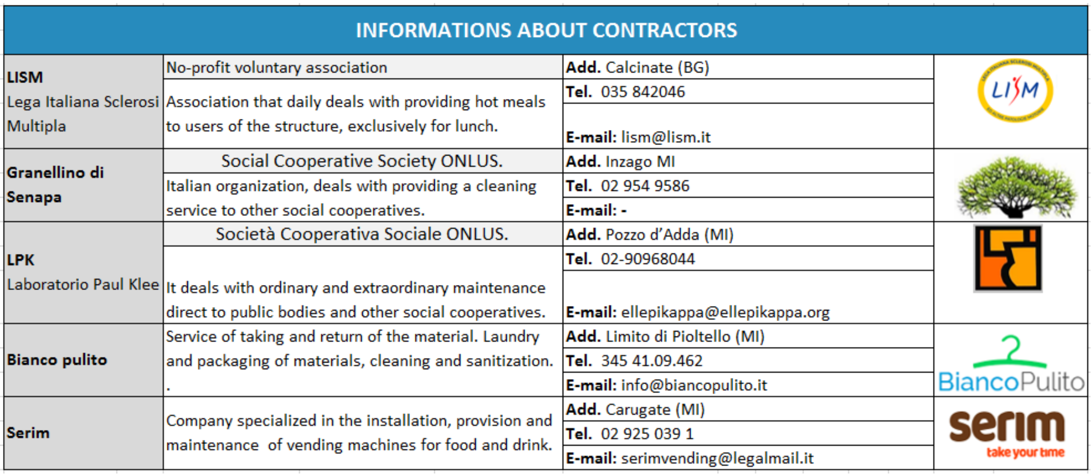
GENERAL INFORMATIONS							
	GROUND FLOOR			FIRST FLOOR		SECOND FLOOR	
	CSE Basevi	Laboratory	CSE Da Vinci	CSE Galilei	Autism center	CSE Cardano	Community housing
N°OF USERS:	30	-	30	25	30	25	-
INFORMATIONS:	35h/week - 47 week/year - Monday/Friday 8.30-16.00						

Table 17: General information about users flow
Source: elaboration by the author with Excel

Within the structure there are several services that is necessary to manage, these concern:

- the preparation of hot daily meals for five days a week only for lunch;
- the weekly cleaning of all the rooms inside the shed, including the toilets;
- the washing of the room sheets in the community housing with a weekly frequency or on request ;
- the management of the foods and drinks vending machines placed on the various floors of the structure;
- the ordinary and extraordinary maintenance of the building.

To manage the previous services, have been identified companies including three no-profit social cooperatives. The costs estimation for the services management has been calculated doing an average price present on the market. Below it is shows a table with a list of the various contractors and their useful information.



INFORMATIONS ABOUT CONTRACTORS		
LISM Lega Italiana Sclerosi Multipla	No-profit voluntary association Association that daily deals with providing hot meals to users of the structure, exclusively for lunch.	**Add.** Calcinate (BG) **Tel.** 035 842046 **E-mail:** lism@lism.it
Granellino di Senapa	Social Cooperative Society ONLUS. Italian organization, deals with providing a cleaning service to other social cooperatives.	**Add.** Inzago MI **Tel.** 02 954 9586 **E-mail:** -
LPK Laboratorio Paul Klee	Società Cooperativa Sociale ONLUS. It deals with ordinary and extraordinary maintenance direct to public bodies and other social cooperatives.	**Add.** Pozzo d'Adda (MI) **Tel.** 02-90968044 **E-mail:** ellepikappa@ellepikappa.org
Bianco pulito	Service of taking and return of the material. Laundry and packaging of materials, cleaning and sanitization. .	**Add.** Limito di Pioltello (MI) **Tel.** 345 41.09.462 **E-mail:** info@biancopulito.it
Serim	Company specialized in the installation, provision and maintenance of vending machines for food and drink.	**Add.** Carugate (MI) **Tel.** 02 925 039 1 **E-mail:** serimvending@legalmail.it

Table 18: Information about contractors
Source: elaboration by the author with Excel

For companies that provide canteen, cleaning and laundry services the annual and total expenses have been calculated for the period of rent of the shed. In the calculations has been taken into account the average presence of 140 daily users for 47 weeks/year that is the opening period of the structure. The total estimated expenditure fot this type of services is equal to 1.752.160,48 € (see table 19).

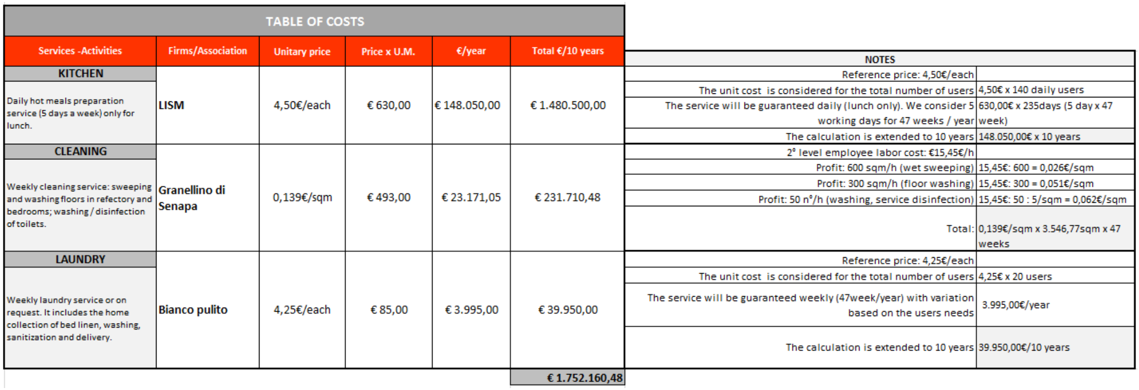
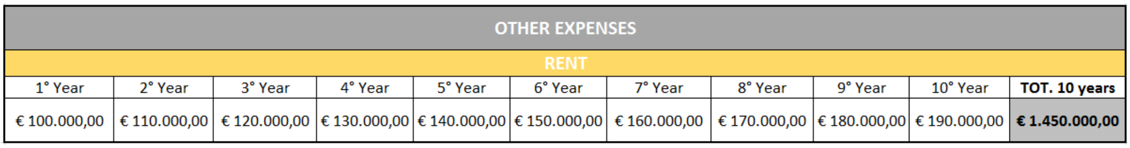


TABLE OF COSTS					
Services -Activities	Firms/Association	Unitary price	Price x U.M.	€/year	Total €/10 years
KITCHEN Daily hot meals preparation service (5 days a week) only for lunch.	**LISM**	4,50€/each	€ 630,00	€ 148.050,00	€ 1.480.500,00
CLEANING Weekly cleaning service: sweeping and washing floors in refectory and bedrooms; washing / disinfection of toilets.	**Granellino di Senapa**	0,139€/sqm	€ 493,00	€ 23.171,05	€ 231.710,48
LAUNDRY Weekly laundry service or on request. It includes the home collection of bed linen, washing, sanitization and delivery.	**Bianco pulito**	4,25€/each	€ 85,00	€ 3.995,00	€ 39.950,00
					€ 1.752.160,48

NOTES	
Reference price: 4,50€/each	
The unit cost is considered for the total number of users	4,50€ x 140 daily users
The service will be guaranteed daily (lunch only). We consider 5 working days for 47 weeks / year	630,00€ x 235days (5 day x 47 week)
The calculation is extended to 10 years	148.050,00€ x 10 years
2° level employee labor cost: €15,45€/h	
Profit: 600 sqm/h (wet sweeping)	15,45€: 600 = 0,026€/sqm
Profit: 300 sqm/h (floor washing)	15,45€: 300 = 0,051€/sqm
Profit: 50 n°/h (washing, service disinfection)	15,45€: 50 : 5/sqm = 0,062€/sqm
Total:	0,139€/sqm x 3.546,77sqm x 47 weeks
Reference price: 4,25€/each	
The unit cost is considered for the total number of users	4,25€ x 20 users
The service will be guaranteed weekly (47week/year) with variation based on the users needs	3.995,00€/year
The calculation is extended to 10 years	39.950,00€/10 years

Table 19: Calculation for the total cost estimation
Source: elaboration by the author with Excel

Other expenses to take into consideration are those relating to the rental of spaces within the building. The agreement foresees a rent payment equal to 100.000 €/ year, equivalent about to € 8.340,00 per month. The agreement provides an increase in rent about €10,000.00 for each additional year because the cooperative has carried out extraordinary expenses for the renovation of the structure (see table 20).



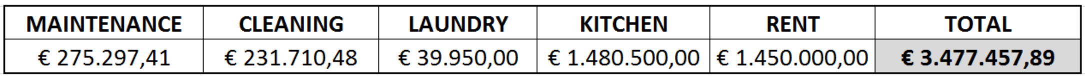
OTHER EXPENSES

RENT

1° Year	2° Year	3° Year	4° Year	5° Year	6° Year	7° Year	8° Year	9° Year	10° Year	**TOT. 10 years**
€ 100.000,00	€ 110.000,00	€ 120.000,00	€ 130.000,00	€ 140.000,00	€ 150.000,00	€ 160.000,00	€ 170.000,00	€ 180.000,00	€ 190.000,00	**€ 1.450.000,00**

Table 20: Other expenses take into account
Source: elaboration by the author with Excel

Finally, in the table below are presented all the maintenance, service and rent expenses to take into account for the cost estimation. The total expense calculation in the overall period of ten years is equal to: €3.477.452,89.



MAINTENANCE	CLEANING	LAUNDRY	KITCHEN	RENT	TOTAL
€ 275.297,41	€ 231.710,48	€ 39.950,00	€ 1.480.500,00	€ 1.450.000,00	**€ 3.477.457,89**

Table 21: Total cost estimation in a period of 10 years
Source: elaboration by the author with Excel

CHAPTER 8

CONCLUSIONS

The crisis in the construction world brought with him a source of change which saw one of its main guidelines in Building Information Modeling. Outside the Italian construction world, this methodology is increasingly requested leading to a directive, at European level, which provides the obligation to use the BIM methodology by the member states for projects financed with public funds starting from 2016. The use of these work methods by the various teams working simultaneously on a project, provides, towards all the actors involved in the process, a clearer view of the whole and allows all the figures involved, to make decisions in a more effective and quick way already from the preliminary phase of the project, avoiding making mistakes. This approach involves the need to put more attention, from the early design stages, to the objectives and needs that must be developed in the execution phase of the work. The major commitment is amply repaid by the increase in the quality of the project and the consequent reduction in corrections and variations, leading to significant cost containment. Therefore, BIM should not be more understood as a 'simple' 3D modeling which leads to the realization of the 'only' architectural model of the project. Unfortunately, the evolution towards the global conception of the model is, at national level, still very backward due to widespread of incorrect information.

The thesis work treated the subject, in the building process and within the "Building Information Modeling", the development of a maintenance plan, service management and economic expenditure during the years of use of the asset. It was therefore necessary to conceive a technological-spatial coding, with the aim of simplifying the reading, analysis, management and attribution of the spatial and technological information of each object within the model. This coding was a fundamental component in the integration of information into the design processes. The coding has been applied to a real case through the use of Revit software showing, in a practical way, how the BIM approach can optimize the work of all the actors of the building process, starting from the decisional and preliminary phase, passing from the execution up to the management of the building organism. Through the use of the codification developed, a concrete possibility has been identified to optimize the interoperability between the most used software, with the aim of showing the potentiality offered by the BIM methodology for managing the information associated with the objects.

The studies carried out have been fundamental in order to analyze a topic which is discussed in Italy but which is still full of disagreements and misunderstandings, although it has a high potential, especially in the face of a fragmented and sometimes obsolete process. With a view to the future development of BIM, it will be possible to arrive in the near future to improve the whole process necessary for constructions with useful tools for a more accurate planning and timing. In conclusion, the thesis shows that BIM generates multiple benefits in the sphere of competence of Facility Management, both in terms of design and management, inducing at the economic level the optimization of costs and their control and monitoring during the useful life of the building .

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