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THE PROCESS OF CONDITION ASSESSMENT SUPPORTED WITH BIM TOOLS IMPLEMENTATION

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ABSTRACT

Since the 70s, the analysis and knowledge of buildings makes use of the Condition Assessment thanks to which it is possible to understand the condition of the building under analysis and to disclose it to the various technicians involved in the structure.

The thesis project starts from a basic idea, that is the awareness that the process of Condition Assessment is a fundamental tool for the technical management of all the activities of a built asset. This process is based on two key elements:

- *The Breakdown structure, which allows technicians to dismember the building in all its components, analyse them in more detail and track precisely*
- *The dynamic management over time of the information related to the different elements traced*

The two main characteristics of the Condition Assessment process highlighted above, have led the thesis – work to compare the tools for the digital information management in the construction sector and, in particular, to focus on tools based on the BIM methodology.

The digital tool identified is that of BIM, so building information modeling, through which is possible to simultaneously manage all the components of the Breakdown structure and the different information gathered about the elements, is always available in real time.

As a result of numerous researches, it has been hypothesized that BIM could be used as a support tool for this type of evaluation, ensuring a constant update of the state of the building under analysis.

The goal is to test and define a tool that can implement all the methodologies of Condition Assessment *with the support of the BIM model.*

The work has therefore developed in two main phases:

- *The first phase of research and analysis of all the documents and the main rules on which the condition assessment and the BIM tool are based, which has, as the main outcome, the theoretical development of this procedure born from the studies made*
- *A second practical phase in which the procedure developed by applying it to a selected case study*

The building under examination is the showroom G.Clerici Arredamenti, located in Suno (NO), in Piedmont. It is a mid – 50s building, constituted by four floors plus a basement, for a development of about 1500sqm/each.

The outcome that has been sought is, therefore, the proposal of a procedure that allows to apply the process of Condition Assessment through a digital tool such as that of BIM. In addition to the theoretical production of the new procedure, to give it more credibility and to test its effectiveness, it has been applied to an existing building to understand if, in fact, it was able to meet all the requirements.

KEYWORDS: *Condition Assessment; Breakdown Structure; Building Information Modelling; Information; Common Data Environment; Efficiency*

INDEX

INDEX OF FIGURES

ACRONYMS

AEC	ARCHITECTURE, ENGINEERING AND CONSTRUCTION
AIM	ASSET INFORMATION MODE
AIM	ARCHITECTURE INFORMATION MODEL
AIR	ASSET INFORMATION REQUIREMENTS
AM	ASSET MANAGEMENT
BCA	BUILDING CONDITION ASSESSMENT
BEP	BUILDING EXECUTION PLAN
BIM	BUILDING INFORMATION MODELING
BQ	BILL OF QUANTITIES
BSIM	BUILDING SERVICES INFORMATION MODEL
BRIM	BRIDGE INFORMATION MODEL
CAD	COMPUTER AIDED DESIGN
CAFM	COMPUTER AIDED FACILITIES MANAGEMENT
CAM	COMPUTER AIDED MANUFACTURE
CAPEX	CAPITAL EXPENDITURE
CBS	COST BREAKDOWN STRUCTURE
CDE	COMMON DATA ENVIRONMENT
CEN	EUROPEAN COMMITTEE FOR STANDARDIZATION
CPIC	CONSTRUCTION PROJECT INFORMATION COMMITTEE
DCF	DISCOUNTED CASH FLOW
DMS	DOCUMENT MANAGEMENT SYSTEM
EAM	ENTERPRISE ASSET MANAGEMENT
EIR	EXCHANGE INFORMATION REQUIREMENTS
EVA	EARNED VALUE ANALYSIS
FBA	FUNCTIONAL BREAKDOWN STRUCTURE
FIM	FACILITIES INFORMATION MANAGEMENT
FM	FACILITY MANAGEMENT

GIS	Geographic Information System
H&S	Health and Safety
HVAC	Heating, Ventilation, Air Conditioning
iBIM	Integrated Building Information Modeling
IDM	Documentation Guidelines for Information Exchange
IE	Information Exchange
IFC	Industry Foundation Class
IFD	International Framework for Dictionaries
IR	Information Requirements
IS	International Standard
ISO	International Organization for Standardization
IT	Information Technologies
KPI	Key Performance Indicator
LCC	Life Cycle Cost
LOD	Level of Definition
LOI	Level of Information
MEP	Mechanical, Electrical and Plumbing
M&O	Maintenance and Operations
MIDI	Master Information Delivery Index
MIDP	Master Information Delivery Plan
NPC	Net Present Cost
NPV	Net Present Value
O&M	Operations and Maintenance
OIR	Organizational Information Requirements
OPEX	Operational Expenditure
PAM	Property Asset Management
PEP	Project Execution Plan
PIM	Project Information Model
PPM	Planned Preventive Maintenance
QL	Quality Level
QTO	Quantity Take Off
R&S	Research and Development
RACI	Responsible, Accountable, Consulted and Informed

RBI	Risk-based Inspections
RBI	Risk-based Inspections Framework
RBIM	Risk-based Inspections and Maintenance
RFI	Request for Information
TIDP	Task Information Delivery Plan
WIP	Work In Progress
WLC	Whole Life Costing

INTRODUCTION

The study of the thesis is placed in the area of building management and in particular on the analysis of the Condition Assessment of a building. The theme of the assessment is subject to a development and evolution that began in the 70s; it has become a fundamental process, thanks to which it is possible to analyse, understand and highlight the condition of the structure through inspections and interviews addressed to the people more involved and closer to the building.

During the study, based on documents and standards related to the subject under analysis, it was realised that this process could bring many benefits, but has also some limitations that should be tried to overcome.

All the data gathered during the surveys must be clustered and recorded in reports that, in addition to being the tools with which the results are presented, it also constitutes the basis for subsequent evaluations; all new data are measured and compared to those obtained previously.

The biggest limitation that this process brings with itself, is the fact that it cannot be shared with the different technicians who work on the building, so to the various figures dedicated to the maintenance services, the owner and the managers involved.

Following further studies, the digital instrument of BIM (Building Information Modelling) has been identified as the necessary tool for overcoming this identified limit; it was also possible to identify some potential advantages that the instrument could give to people:

- It is a very practical tool, which allows to contain and catalogue as much information as possible about the study object, thus avoiding loss of information due to the transition from one software to another;
- Compared to other software, it is accessible and has different levels of visualisations and edition, in accordance with the price, depending on the particular requirements needed;
- Allows constant insertion and updating of "dynamic" information, relating to the condition of the building.

The aim of this thesis – work is, therefore, the evaluation of the condition of the building through the traditional method, so with the Condition Assessment process, and then integrate it with the new digital instrument to overcome the limitations that has arisen in the past, thus presenting a more precise, complete, and shareable with all result.

It is possible to affirm that the main objective of this process is to experiment how BIM can interact and integrate the Condition Assessment processes that are periodically carried out by building managers and technicians.

The working method adopted for the survey is therefore made up of two main parts:

- A first deductive part, based on the study of the literature on our subject and on theoretical reflections arising from the analyses made;
- A second inductive part, starting with a first practical experiment based on the notions obtained from the previous phase, the development of a BIM model for our case study building and an analytical-descriptive mapping of the various areas analysed

The development conducted seeks to demonstrate the potential coming from BIM as an instrument in the studied - field, and how can facilitate the latter periodical assessment of the conditions of the building that is being studied, of all the systems present within it and of the parts that compose it, during its entire life cycle. Furthermore, which are the outputs and benefits coming from this kind of analysis, with respect to the traditional methodologies.

Through the mapping carried out, and the utilisation of different colour's filters, which represent the status of each element, it is possible to immediately identify what are the most critical areas of the analysed building and on which it is necessary to intervene immediately.

Another very important aspect is the fact that the information is available to all the technicians who must intervene in the building; thus, everyone can be aware of the overall situation of the construction. Furthermore, the information shown can be managed by users, allowing the edition or visualisation as required by each technician.

The presence of dynamic information is also fundamental; in fact, this allows to have a continuous updated knowledge about what is the situation in which each component is, while understanding whether it is quite an ordinary maintenance or if it is necessary to plan an extraordinary one.

The main results expected to obtain from the drafting of this thesis, are the ones described below:

- The definition of the state of the art, establishing a relationship between the BIM model and the management of the built environment. The goal is therefore to be able to specify what is the stage of development that we have been able to achieve through the study and analysis of the available literature and the subsequent experimentation;
- A proposed trial, based on the analysis of the condition assessment of the building, and its study through BIM technology;
- A study and subsequent written analysis explaining, how we decided to apply BIM to the condition assessment sector, how our work was developed, and finally;
- The results we have achieved through our thesis project, and our conclusions about it.

1- BUILDING CONDITION ASSESSMENT: BACKGROUND AND PURPOSE

1.1- THE SCOPE

The main objective of this thesis project is, after understanding the assessment of the condition of a building, understand how its development and integration with the digital tool of BIM, can be of great help to a yield always updated and shareable between the various figures involved in the building of the same assessment of conditions of the facility under analysis.

1.2- THE STARTING POINT

The starting point of the study was the condition assessment and how this analysis procedure, for the evaluation of the status of a building and its individual components, was born and then evolved over years.

The designed idea arose after visiting what was then the building "case - study"; it was possible to notice, in fact, how much a structure, although apparently simple, can be made up of an infinite number of components that it is important to monitor constantly and always up to date.

The question that has arisen is how it was possible to return an always updated view of what is the state of the various components so as to facilitate both the owners of the building and the various technicians on how, when and where it is appropriate to carry out both ordinary and extraordinary maintenance.

1.3- OUR KEYWORDS

During the analysis phase, in which the most important thing was trying to learn about the condition assessment, three main key – concepts have been highlighted; these are the ones, together with the condition assessment notion, that becomes the key – words of the entire project:

- Breakdown Structure
- Single component
- Information

In addition to the study of their purest meaning, the subsequent important passage was to understand how these three concepts can interact and bond with each other.

Going into more detail, some research was done on the main themes around which the whole project would then rotate.

1.3.1- CONDITION ASSESSMENT

In the current Italian and European context, the management of the built environment has a strategic importance for socio – economic development. It requires specific skills to assess in advance, and in a synthetic way, the characteristics and values of buildings and real estate, in order to plan the activities of operation and enhancement, balancing the time – cost – quality ratio.

Analysis and assessment of the built environment are characterised by a high interdisciplinary approach and they are essential tools for checking the feasibility of rehabilitation projects concerning the built environment; in the management of the built assets, technical and performance assessment are strictly related to a context of multiple scenarios which interacts with the building itself.

To carry out a “good” assessment, it is important to provide a well – developed understanding of the demand organisation’s core business, and so, pay attention to the extent to which the existing facilities adequately support the core business activities. For this, it is important to perform a close examination of the facility to determine if it fulfils the defined needs or if action is necessary to make good any shortcoming in functionality or performance.

It is important to define the scope of the assessment, so the boundaries and the focus it would have; following the understanding of the scope, the definition of the assessment criteria has to be done through which is possible to compare the information gathered. Following is important to provide an assessment plan and in the end, when the examination comes to an end, everything has to be written down in a report which will be useful also for the next assessment.

But, in particular, what is facility condition assessment? *(Harvey H. Kaiser, 1989)*

Facility condition assessment is the process which consists in the development of a comprehensive drawing of the physical condition and functional performances of the building in real – time. Then, all the collected data can be studied to analyse the results of the collection and the observations carried out. One of the most important steps is the drafting of a final report, in which all the information found and the results obtained have to be included. Through the data – collection and the subsequent analysis it is possible to easily get information concerning the accessibility for the handicapped provisions, energy management and sustainability of the building.

Thus, the main objective of the condition assessment of a facility is the measurement of both the condition and the functionality of the building and its infrastructure, which has to be as suitable and appropriate for intended functions.

The traditional method for the assessment of existing buildings and infrastructure, which is known as “Facility Audit”, is limited to deficiency of the buildings that are physical. An evolution of this method is the one which combines:

- The Physical Condition Assessment which is carried out through a physical analysis and observation of the building by the different involved technicians. In this analysis, the purpose is the physical condition assessment
- The Functionality Assessment which comes from the users’ perspective rather than from a building perspective. Its objective is to understand “how well” the space functions works, the

suitability for the current purpose and the potential for different uses. In this new analysis, the purpose is the comprehension of the functionality of the space for its intended programmatic purpose.

As previously set, the Condition Assessment is based on three main concepts:

1. **Breakdown structure (BS):** thanks to this method it is possible to provide a description of the building as a hierarchical open structure; thus, to allocate information at different hierarchical levels, organise and extent this hierarchy to further levels (vertical extension), add new elements as the same hierarchical level (horizontal extension) and aggregate the information gathered with respect to different hierarchical levels. Therefore, using the BS it is possible to decompose the building into its singular components and analyse them in a deep way. This procedure could be applied to study different characteristics of a component; in fact, it is possible to study its functionality using the Functional Breakdown Structure (FBS), or its composition with the Product Breakdown Structure (PBS) and so on.

2. **Single component**: each single “part” in which the analysed building could be divided

3. **Information**: all gathered information, with respect to the property under examination. It can be *structural*, thus concerning the way in which the object is composed; *functional*, the function associated to it; and *economical*, which is related to the price it has during its life and for its maintenance.

The final goal of this first analysis phase is trying to understand not just the meaning of these three main concepts, but to know how they are linked to each other and in which way they can cooperate to achieve a final condition assessment.

1.4- THE USED RESOURCES

A Building Condition Assessment (BCA), also known as Facility Condition Assessment (FCA), is a systematic inspection thanks to which it is possible to collect data concerning the state of a commercial building's structure and systems; information has to be write down to allow their revision and everything has to be stored in a report to allow their use for the next assessment. *(Robert B. Green, 2016)*

BCA could stand alone or be part of a comprehensive Property Condition Assessment (PCA); with Building Condition Assessment, which is based on the inspection, is possible to obtain a lot of detailed information about the nature of the component, the issues and deficiencies which may affect in it and then provide a table of the expected costs to remedy the deficiencies previously detected.

Through BCA building owners, managers and potential buyers could forecast their costs of ownership and ensure timely and appropriate maintenance.

The analysis is often expressed through a Facility Condition Index (FCI) that summarises the assessment in just a single number used as benchmark; the used indices follow industry norms and can be compared against the condition of other comparable businesses. With the FCA it is possible to understand which are the critical components of the building and the related costs to solve the issues. Costs could be referred to restore, replace or maintenance interventions.

Therefore, through the use of clustered data and reports, it is possible to prioritise the projects for maintenance, repair or renewal. Thus, with the assessment it is possible to obtain information about:

- Real – time condition of assets;
- Estimation of the costs to solve the problems;
- Forecasting of the effective age of assets and estimate their useful life;
- Identification of code deficiencies to be corrected.

FCA it is not used to identify new opportunities, like the improvements, but it just shows the real – time status of a component. *(AkitaBox, 2018)*

The circumstances under which a condition assessment is done may differ between institutions that carry out the analysis. Firstly, a condition assessment has to be provided, and requires the support and the involvement of senior administrators of the building who have to ensure the credibility of the information found and of the conclusions provided. A precise design of the assessment helps the figure who will do it to determine in an easy way the level of information to be obtained. It is important to determine the approach used according to the nature of the organisation's facilities. This analysis could be developed by the internal staff, by consultants or by a combination of both; an internal program can produce valued results which credibility could be increased by external consultant's analysis.

This is the reason why the engagement of external consultants, even if it is more expensive, could considerably help the institutions in obtaining valued information. Through the assessment process, it is possible to enhance the overall effectiveness of the facility management by ensuring that condition inspections are a routine part of operating activities.

To carry out a Condition Assessment there are some phases to be followed:

1. **Designing the assessment**; in this phase the inspection has to be planned. The first thing to be done is the definition of the scope, so which are the goals and objectives to achieve, determine the methodology to be used, establish the intended use of results and define the report formats. Then, it is necessary to select the assessment team, which is the team number that can vary according to the complexity of the building and its components, draw a list of all the elements to inspect and review all the already available information about the building. The last thing to do is the development of an inspection plan; thus, to establish deadlines in which the assessment has to be done. Facility condition assessment has to be carried out, preferably, every three years, but this is just an indicative value.

2. **Collecting data**; all gathered data has to be collected in reports in order to be consulted during the following assessment. Data collection is based on the taxonomy of building assembly by system in Omniclass for Building Elements; classifications provide a common schema for data collection and allow to compare them between different institutions, including also Level 1 – Mayor Group Element, Level 2 – Group Element and Level 3 – individual Elements.

3. **Summarising the results**; in this third phase the inspection is evaluated. After a first analysis

of the data obtained, everything is collected in a summary report and the plan for the future assessments is prepared.

4. **Presenting the findings**; in a fourth phase, a final report is prepared and presented to all the figures interested in the building. *The presentation format is a fundamental thing to be considered before beginning the assessment process*. The report which is presented after the development of the assessment must be a brief statement of facts including graphics, description of the used methodology, all the findings and the conclusion.
5. Last but not least, it is very important **to put the assessment to work**. That means developing an ethic between the maintenance staff to inspect, observe and report deficiency with a precise time – schedule, in order to control the condition of the building and intervene if necessary.

FCA process provides the basis to determine the amount of capital needed to correct current problems and to avoid future deteriorations on the facility.

As previously said, to carry out a Condition Assessment it is necessary to develop a breakdown structure (BS). With the BS it is possible to "break" the project from the top to the bottom, in order to have specific aspects and better manage them. The total cost, duration and resources for the whole project are available and, thanks to the division given by the BS, it is possible to study the cost, the time and the resources required for each sub – activity. According to the information available, it is possible to develop different breakdowns; for the analysis of the evolution of the projects, the most important ones would be the Functional Breakdown Structure and the Cost Breakdown Structure. With the first one it is possible to associate a particular function to the different objects that constitute the building; for example, the office space, the area addressed to the show – room, the storage space and so on. Then, through the cost breakdown structure, it is possible to pair the different components to the related cost, both their life-cost and the ones coming from maintenance interventions.

It is possible to understand that there is a strong relationship between the breakdown and the single component, which characterises the building and the whole structure of the facility. Another important thing to consider is the available information relating to the building; it is fundamental to cluster all the gathered data, to analyse them continuously and compare the new results provided by the assessment with the previous ones. Information, to be considered valid, has to be clear and unique; this is necessary to allow different technicians and users to consult them and to be always informed about the status of the building in real – time.

Following the research and analysis carried out on the subject of Condition Assessment, it is therefore possible to understand and affirm the considerable importance of this process in the field of property management.

In fact, having always an up – to – date review of the situation in which the building and all its components are, in real – time, it is of fundamental importance to ensure a complete management of the situation and to understand if and where it is necessary to intervene with maintenance activities.

2- METHODOLOGIES FOR CONDITION ASSESSMENT

2.1- AN HISTORICAL BACKGROUND

Since the professions of architects and engineers were conceived and made formal, the companies of Architecture and Engineering (A&E) have evaluated the structures as part of their functions, although the works of engineering and architecture are excluded from the scope of the evaluations.

In the end, what was obtained was a story about the conditions of the building, which were observed and enriched with photographs, drawings and the proposal of a summary budget to intervene on the points most lacking.

In the 70’s they used to speak of "revision of the structures", a term replaced from 1980, period in which they began to speak of "Facility Management". Initially, the world of facility and assessment of the condition of a building were not connected to each other, but then, due to the drastic reduction in the size of computers, the increase in speed and storage space, assessments of the condition of the facilities have become very important.

What does Condition Assessment mean? *(Threnchless Pedia)*

Condition assessment is the process of inspection, thanks to which it is possible to determine whether there are any defects or leaks. It is developed through different technologies to locate the problems and understand the best way and the cost for the maintenance activity to repair/restore it. With the condition assessment, it is possible to plan and execute the rehabilitation activities.

Nowadays, many facility managers prefer to take “pro – active” steps to intervene on the problems before they could become critical for the building and the following safety for people inside it. This is possible to be done thanks to regular condition assessment performance. Through the process of condition assessment, technicians could evaluate the condition of the building in real – time and so, ensure that the asset is going to operate in the desired way fulfilling all the safety guidelines. These components, which are not fulfilling the requirements, must be indicated and repaired.

When condition assessment is developed, it is important to follow some steps. Firstly, it is important to document the condition in real – time of the building and highlight the components, which are not fulfilling the requirements in order to solve their problems. Then, when the condition assessment is developed, it is necessary to ask some questions in order to understand the status of the component and its relation with the other parts. Following, it is possible to develop a planning with all the activities and the related costs, which have also to be organised in a priority scale. *(Archibus.net)*

2.2- TRADITIONAL METHODOLOGIES

The physical condition assessment can be based on fully detailed inspections or on a predictive forecasting – model based on life – cycle expectation, or on a combination of the two.

Physical condition assessment methodology has been developed from a manual data – entry on inspection form to a more sophisticated data – gathering and analytical techniques.

Thanks to a physical condition assessment based on both building inspections and data collection from other different sources (as questionnaires to maintenance staff, maintenance records or feasibility studies) it is possible to provide a detailed cost estimating and a schedule of the project. So, the result obtained from an assessment based on field inspections can be directly converted into projects and assembled to provide a capital project plan.

The other method which can be used is the predictive model of capital renewal needs, usually through statistical methods based on a period of 10-years at minimum, thanks to which it is possible to comprehend the building and its infrastructure.

This is a forecast procedure which provides a calculation of the scheduled year for system renewal and the estimated costs associated. The total costs are evaluated on annual bases and can be averaged over a period of time to also determine the capital renewal expenditures.

The cost related to these two alternatives is an important matter in the moment of the selection, they have costs highly diverse and provide different results. In 2015, the technique based on the statistical method was 20 percent cheaper than the one requested for the performing of a full–field inspection condition assessment. There is also a saving in time; in fact, life–cycle modelling requires more or less half time to produce an accurate condition assessment. It is important to underline that both techniques depend, at different levels, on the inputs received.

2.2.1 – ASSESSMENT PHASES

The most important thing to develop a successful facility condition assessment is the cooperation among the different figures involved in the building – lifecycle (Facility Managers, Team Specialists, Users etc.). All the information which can be collected can be useful for the right assessment of the status of the property.

As already said before, condition assessment is carried out through different phases which are all fundamental to obtain an effective and accurate final result.

Drawing on the traditional methods, it is possible to obtain very useful information about the facility. Nevertheless, it is not that easy to share the resoults between all the different stakeholders involved in the different activities related to the building. All the information is delivered separately among them; thus, without having a connection to understand the relationships between components, or the project as a whole.

The overcoming of this limit is one of the main reasons that have solicited the analysis and the development of this thesis work.

2. 3 - REFERENCE STANDARDS

Nowadays, the condition assessment has four basic tools, the four main reference standards, that can be used to optimally develop the process; during the analysis it turns out that the most important ones are:

- The Dutch Standard: NEN 2767-2_2008; *(Wikipedia Italia, 2011)*
- The Norwegian Standard: NS 3424.E:2012;
- The European Standards: PD CEN/TS 17385:2019; and
- BS EN 16991-2018-RBIF that is mostly focused on the framework for risk – based inspection.

2.3.1 – THE DUTCH STANDARD: NEN 2767-2_2008

The condition assessments in the Netherlands are developed according to NEN2676, using a well – defined measurement and recording method. The registration is carried out by a certified inspector, who, for each material, component and detail, determines the possible criticalities with their respective characteristics; thus, size and intensity. *(Wikipedia Italia, 2011)*

Scores are awarded according to a six – point scale, where 1 is the best and 6 the worst scenario; for most cases, a score of 3 for the conditions is sufficient. All the characteristics are then combined together in an objective way; thus, obtaining a single value which determines and represents the condition of the whole building.

However, the fusion – matrix must be obtained with great caution. In fact, there are a lot of individual measurements that must be merged, and often, this unification could lead to a general "flatting".

Until a few years ago, it was assumed that an inspection was reliable. Nevertheless, the problem lies in the fact that there are several inspectors, with their subjective points of view and their own methods, who carry out the analysis and could provide results that differ from each other. This is the reason why it has emerged the necessity to have a unique system able to record the state of buildings in a unique, transparent and replicable way; thus, achieving results that are precise and more reliable.

Buildings need maintenance; the materials, components and all the details that constitute them "wear out" with the passing of the years; it is for this reason that the continuous recording of the conditions of the building is fundamental. The data collected from the various inspections are then compared to those collected previously in order to understand if the situation has remained univariate or if something has changed. After recording the conditions and evaluating the present situation, technicians can draw up a maintenance plan, usually multi – year, for the purpose of organising the different interventions.

After the development of maintenance activities, a condition assessment may be carried out again in order to verify whether the work has been properly performed or whether it has also managed to improve the expected conditions.

NEN 2762 describes the appropriate method for determining the maintenance conditions of the buildings and their constituent parts and often, there are visual assessments. The method proposed by the standard, aims to be simple and objective to determine the maintenance conditions of buildings.

According to this, building maintenance could be divided into:

- **Corrective**;
- **Preventive**, which can be time – based, planned or cyclic;
- **Condition – based**, thus preventive maintenance based on performance and/or parameter monitoring and subsequent actions.

Condition assessment, maintenance planning and performance control are the key – processes in condition-based maintenance; for the maintenance of the building technical data. Those are fundamental and they can be collected during the condition survey on – site when all the criticalities are registered. With the condition assessment, different results can be achieved according to the subjective perception of each inspector. Thus, if there are two or more surveyors, in the end there will be different survey decisions and the variability could be caused by different factors, such as previous experiences or the attitude to risk, influencing the different points of view.

To avoid this discrepancy, condition rating of building components could be used; thus, the technical status could be transferred between building inspectors and property managers, who have the control over maintenance performance levels and costs.

The Dutch Standard represents a standardised tool used to develop the process of condition assessment.

Researches, at National and International level, have been carried out to achieve objective inspection processes. As settled before, the process used for the condition assessment is based on a six-point scale, and a representative survey of Dutch housing associations shows that in 2003 the 90% of the building inspectors registered the type of criticalities and their extent.

Condition assessment methods are different from:

- the hierarchical classification of building components,
- the classified defects
- the use of condition parameters

Thus, even if different results are provided, there are no drawbacks and, nevertheless, it is important to underline that despite the presence of different inspectors with their own method, everyone should perform condition assessment in the same way. Therefore, the standardisation would be a tool to achieve uniformity between the different methods used for the inspections.

The assessment has both advantages and disadvantages; the biggest benefit is that objective measurement makes the results more reliable and easy to compare. The measurement method follows a very precise protocol, thus leaving no personal comments, outside the standard.

In 2022 the Dutch Government Building Agency has the initiative to standardise the condition assessment of building components and services. The aim is the objective assessment of the technical quality to provide property managers with unambiguous and reliable information about the technical status of the building based on the assessed defects.

Standard condition assessment of building:

- It is aimed to all people involved in the asset, thus to property owners, managers, tenants, consultants, contractors and inspectors;
- Its application may include the visualisation and control of physical conditions, the maintenance planning, prioritisation of maintenance budgets and the communication about the present assessed physical condition compared to the desirable one;
- It comprises three different sections: The Methodology (NEN 2006), the List of Faults (NEN

2008) and the Aggregation Methodology (NEN 2009)

The main weakness of the Standard is its limitedness to condition assessment, thus maintenance planning and priority maintenance works are not included; all the maintenance activities are not related to the condition ratings.

As previously said, the previously described scale of condition categories used in the standard allows to describe in a chronological order the occurring criticalities. The categories adopted have to be clearly defined and the data collectors well trained, in order to ensure data consistency and reliability.

A condition assessment process consists into:

1. **Assessment of criticalities**; this is the most important information because without it, it is not possible to formulate maintenance activities and to estimate the relative costs;
2. **Condition parameters** that have to be set; they are fundamental to highlight the importance, the intensity and the extent of criticalities.

To carry out a condition assessment in the right way it is necessary to develop a hierarchical classification of building components. The list of the criticalities uses the first four codes of the Dutch classification; in fact, the hierarchical classification influences in a direct way in the classification of the importance of the issues founded in the asset. The intensity of defects strongly influences the condition of building components and it deals with the degradation process. For the characteristic of the intensity, the standard follows three main intensity - classes:

- Critical which harm directly the function of building component
- Serious, so the degradation of a building component without directly damaging its function
- Minor, the ones which don’t affect the function of a building component

Another important point to highlight is the knowledge about the extent of the issue, which is necessary to assess the condition. The estimation of the extent and the choice of the appropriate class with respect to the extent of the criticality is not so easy to be defined; the standard proposes five extent classes. In the end, there is the condition rating in which the extent and the intensity of an issue are combined with its importance giving back matrices for critical, serious and minor defects. Building components may be affected by more than one criticality, and this is the reason of why the standard gives two main options to evaluate the resulting condition rating. Every defect has to be registered in order to monitor its development between condition surveys.

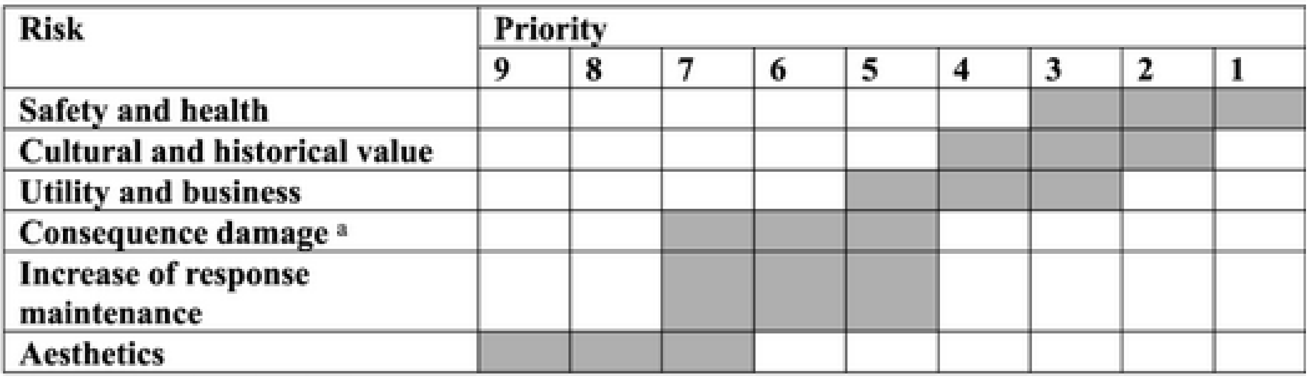
When all the data ha being collected, it is possible to develop a maintenance planning. Condition – based maintenance could be considered as a tool for the implementation of a desired differentiation of the technical quality of buildings by formulating different performance levels; the variation of performance levels is suggested when there is a different portfolio and if the maintenance management system provides the change to do it.

When maintenance planning is developed, it is necessary to distinguish the different maintenance activities according to their types, the components to which they are applied, the specification of different materials required, the quantity of work, the frequency of the activity and the nature. The maintenance managers can set condition targets of building components to forecast the condition status of the examined component after the execution of the maintenance activity. All the maintenance works have to be prioritised; the maintenance management system allows users to evaluate maintenance performance levels and set priorities of maintenance works considering the risk of failure of components.

Data gathered could be aggregated and their clustering is an important management information for property and facility managers to monitor, benchmark and allocate budget; it can be used also to set condition targets of buildings. With the aggregation rating it is possible to weigh the technical status of a building component versus other objects of a building.

Therefore, due to the standardised character of the method, the condition assessment will result in uniform and objective results for different kinds of elements in just one asset - portfolio. With this standard is possible to improve the reliability of the collected data which would bring back:

- Better and clearer maintenance plans
- Better maintenance specifications
- Improvement in transferring responsibilities
- Better contract - management



Risk	Priority								
	9	8	7	6	5	4	3	2	1
Safety and health							▨	▨	▨
Cultural and historical value						▨	▨	▨	
Utility and business					▨	▨	▨		
Consequence damage [a]			▨	▨	▨				
Increase of response maintenance			▨	▨	▨				
Aesthetics	▨	▨	▨						

Figure 1. *Risk - priority matrix (NEN 2767-2_2008)*

Finally, it is possible to underline that this standard also has some limitations. An important limitation of the NEN 2767-2_2008 standard, the impossibility to associate a precise cost to those that are the necessary maintenance interventions to solve the criticalities identified in the structure. For this reason, with this standard it is not possible to provide the annual maintenance budget and planning of the work, and, in addition, it is mostly indicated for large – scale properties. The most difficult part is to forget about the old way in which people used to think and work , in order to embrace the new method; in addition, this requires a lot of effort and time.

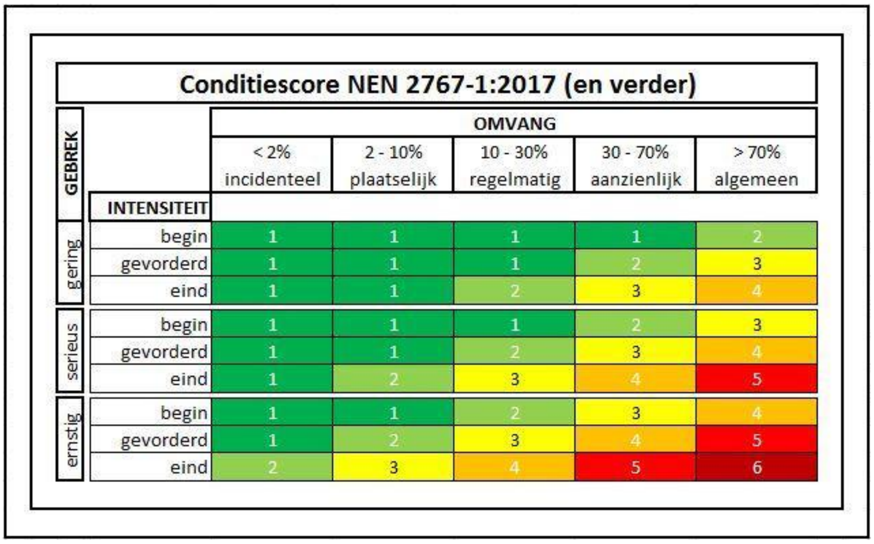
The results obtained are evaluated on the basis of some examples taken from the list of criticalities, considered “standard” for the materials, elements and details that can be found in a building. After making the comparison, a value that constitutes the score of the condition is recreated. The first characteristic considered is the “severity” of the issues, which goes from light to very serious.

The other values studied are the size and the intensity; the size could go from 2% (which is little present and visible) to 70% (so, almost totally present), while the intensity is related to its development, and it could be: early stage, advanced stage, final stage.

Combining all the information, it is possible to develop a matrix whose crossing point represents the “final score of the condition”.

After having defined a score, it is necessary to understand which type of maintenance activity has to be carried out; in fact, risks are mapped according to the condition – score.

Therefore, in the end it is possible to say that this standard describes a method to establish the technical quality of building and installation components univocally. An important part of this method are the lists of faults which are applicable to construction and building related installation of technical elements, inclusive site facilities belonging to the building. (NEN 2767-2_2008)



Conditiescore NEN 2767-1:2017 (en verder)

GEBREK	INTENSITEIT	OMVANG < 2% incidenteel	 2 - 10% plaatselijk	 10 - 30% regelmatig	 30 - 70% aanzienlijk	 > 70% algemeen
gering	begin	1	1	1	1	2
	gevorderd	1	1	1	2	3
	eind	1	1	2	3	4
serieus	begin	1	1	1	2	3
	gevorderd	1	1	2	3	4
	eind	1	2	3	4	5
ernstig	begin	1	1	2	3	4
	gevorderd	1	2	3	4	5
	eind	2	3	4	5	6

Figure 2. *Measurement of the condition of the building (Wikipedia Italia, 2011)*

2.3.2 – THE NORWEGIAN STANDARD: NS 3424.E:2012

The main objective of this standard is the specification of the requirements, necessary for the right conduction, description, assessment and documentation of a condition assessment. The standard also defines three main survey – levels, and the scope of the investigation and the assessment.

The most important activity to carry out is the clarification of the purpose and the preconditions. The process is based on different steps:

a. Definition of the task in which the construction works have to be described, according to the scope of the condition survey and the chosen level. The method, the structural design and the material usage have to be briefly described underlying the function and the physical limitation. Another important thing to be specified is the aspects that will be investigated; such as the technical condition, the environment, safety, flexibility, energy consumption and so on. The level shall be specified in accordance with the purpose, the scope and the level of detail chosen; before the selection of the scope and the survey level, it is important to carry out an assessment.

b. Selection of the reference level; the reference level which has been chosen for the basis of the description and determination of condition classes shall be specified through reference to authority, client, user and functional requirements. People involved in the survey must have the right skill to develop the best work.

c. Drawing of an execution plan which covers all activities.

d. Acquisition and assessment of underlying information, so all the relevant information about the construction works which have to be collected and reported according to the defined task; all the available information has to be reviewed and assessed.

e. Preparation of criteria for the different condition classes which are an expression of the condition of construction work with respect to the reference level. Before the registration of the condition of a component, a set of criteria has to be prepared, which would represent the framework to determine the condition class of the different components of the construction works. The criteria is defined on the basis of the purpose of the analysis and the following assessment. There are four main condition classes:
    1. CC0 – *No nonconformity*; the condition fully satisfies the chosen reference level, so there are no symptoms of nonconformity;
    2. CC1 – *Minor or moderate nonconformity;* the component shows a “normal wear” and it has been maintained, or the nonconformity is not critical with respect to the reference level;
    3. CC2 – *Essential nonconformity;* the object has suffered a major damage or has an important reduction in performance according to the reference level. Thus, it is important to intervene with local measures because of different reasons: the lack of important documentation or the remaining useful life is short, or it has been incorrectly designed or maintained, and so on;

   4. CC3 – *Major or serious nonconformity;* the construction work has suffered or is suffering a complete functional failure, or need immediate measures because it is a danger for life and health;
   5. CCNI – *Not investigated*; the component is not accessible for an inspection and there is no available documentation to verify the correct design and a possible nonconformity; is necessary to carry out more comprehensive investigations to identify a nonconformity.

f. Registration of conditions and determination of condition classes, which is usually registered directly and, linked to it and after the definition of the level and the scope, it has to be carried out an assessment. Where a condition also includes measurements, the equipment has to be balanced with respect to the product manual for the instrument concerned. In case of nonconformity, a statement has to be given of the requirements to which nonconformity relates and it must be documented with appropriate descriptions and drawings. The scope of a nonconformity can be specified as a percentage of the total quantity. When a section is not accessible, a condition class has to be determined on the basis of the adjacent parts of the construction.

g. Analysis of the causes of nonconformities.

h. Analysis of consequences with the associated probability. Consequences shall be described through the specification of consequence levels. The consequences used as a basis have to be specified in each individual case, and any assessment has to be carried out considering the probability that the specified consequence level and consequence type could arise; if an event is imminent, this shall give a special emphasis in the description of the risk.

i. Description of the risk, which shall be analysed for all components of the asset for which nonconformities have been registered. It is fundamental to analyse the risk for all parts of construction works, which have not been investigated or are not visible. The probability of the risk and consequence of its even shall be assessed on the basis of the registered condition; furthermore, the risk has to be both described (quality) and calculated (quantity). According to its quality, a risk could be classified as low, medium or high.

j. Description and prioritisation of measures, especially for condition classes CC2 and CC3.

For survey of level 1 and 2 measures could be proposed, while for level 3 the measures which are necessary and sufficient to close the nonconformity have to be determined. The measures have to be prioritised according to the purpose of the survey and, when they are recommended, a statement should be given of when the measure should be carried out. Measures could be of different nature as: organisational, technical, or change according to the scope of the condition survey or to the survey level.

k. Reporting the results. It should contain:
    - A description of the commission, which includes the purpose of the survey, the owner, the construction works, the address of the building, the client, the different parties involved, the scope and use of resources, the survey level and significant changes since year of construction;
    - A conclusion which includes a summary, an overview of parts of construction works with their consequence level;
    - A main report, which includes the reference level and criteria used as a basis for assessing condition and nonconformity, condition registration, determination of condition class and nonconformities, assessment of cause, consequence level, risk and assessment and specification of expected remaining useful life for elements of the building with CCNI;
    - An attachment to the report; thus, the conditions registered have to be verifiable. It is important to record all the observations, measurements, photographs, calculation and analysis which will be used as the foundation for determining the condition class. Also the basis for assessing the expected remaining useful life and risk have to be attached to the report; thus, the attachments are any background material which describes the construction works as a built or modified, which does not form part of the condition survey, and all the supplementary material from the condition survey which need not be included in the main report.

After the development of all these steps, it is possible to define the use of the condition survey in accordance with the purpose and preconditions.

As said before, the standard provides three main levels of analysis which are dependent of the scope and the investigations:

1. **Level 1** is the level of portfolio mapping and visual inspection, through which it is possible to acquire relevant documentation for the task. A preliminary estimation of rough costs for maintenance, repair, renovation is provided. The survey produces a statement of the causes of nonconformities where possible (for CC2 and CC3) and an analysis of the consequences; in this first level there is a proposal of measures to reduce the consequences that have arisen, then, according to the documentation requirements, the nonconformities are specified and the need for any further investigations at level 2 or 3 are determined.

2. **Level 2** is more detailed than the one before; it is connected with alterations, assessment of the extent of damage and its cause, or also with the inspection of those components where nonconformities are often registered. In this second level, a first sale – valuation is provided. The budgeting for maintenance, repairs and renovation is more detailed. The surveys carried out are more detailed with respect to level 1 and also cover a review of underlying data, like drawings, descriptions and other available documentation. In order to clarify the design and the conditions, a more comprehensive measurement is carried out when the purpose indicates a need for such measurement. Investigations are done both on the complete construction works or on parts of them and, thanks to the surveys, it is possible to conclude casual assessment and provide a qualitative risk analysis, underlying also the consequences level and the description of the risk. The measurement obtained could be proposed and prioritised in order to determine the need of any subsequent investigation done in level 3; an investigation plan for next level is developed in order to determine the measures which are sufficient to close nonconformities and could provide a basis for a detailed project planning.

3. **Level 3** is the last one and also the more detailed. The replacement or refurbishment is based on the risk assessment as part of the planning of measures, so there is also a damage valuation. The surveys done are of special nature and are focused on precise elements of the building; this registration involves an accurate measurement/test, such as laboratory tests if necessary. Furthermore, in this phase there is a conclusion of casual assessment and, the risk is analysed both from a qualitative and quantitative point of view. The measures necessary to close the nonconformities are defined and then registered.

Therefore, through NS 3424:

- It is possible to define how condition assessment has to be carried out;
- The development of the description of the condition assessment;
- The elaboration of a final report.

Then, it would also make it possible to define the condition of hidden objects; thus, components which cannot be seen as drainage, pipelines, pillars, fundament and then define the risk and the consequences associated with it showing it in a matrix, as we can see in the image below.

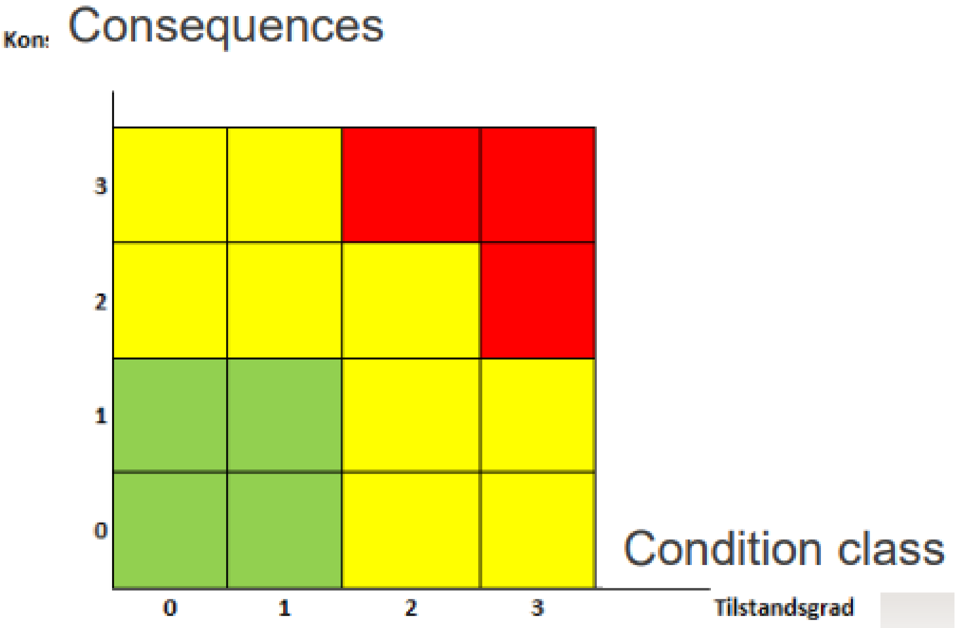


Figure 3. *A matrix of the condition survey: Consequences + Risk* (*Svein Bjoerberg, 2017*)

Finally, this standard permit to define more than technical condition, but also:

- Environmental aspects (indoor air, noise, radiation, dangerous substances);
- Functionality (accessibility, design for all, flexibility, adaptability);
- Energy consumption:
- Other aspects that could be hidden.

2.3.3 – THE EUROPEAN STANDARD: PD CEN/TS 17385:2019

According to the Standard, the condition of an immobile constructed asset is one of the factors which determine the value of the asset, which is also influenced by the quality of the maintenance performed. Maintenance actions have to be carefully weighted according to their benefits, considering that maintenance costs are a significant part of the total cost of ownership of a constructed asset.

The method presented in the standard, is based on NEN for the Dutch standard 2006 and provides an objective evaluation of the physical condition of an asset; it could be used to identify and justify a maintenance plan for the asset. Through the condition assessment process it is possible to develop non – destructive surveys for the identification of quantitative and qualitative aspects of defects, which can influence an item and determine their condition class. Thanks to them, it is possible to deliver data based on facts to the managers who have to select the right class for the criticality and choose the maintenance intervention.

This document describes a method to assess the physical condition of all types of immobile constructed assets in a uniform and objective way. This assessment results in a condition class, which expresses the technical state of maintenance of an asset at any certain moment in time on a six-point scale. It can represent either the deterioration of the asset, or the physical condition at the time of commissioning. It is also possible to monitor the degradation of the asset over time by repeating the assessment at regular intervals.

This is a very clear document which offers a uniform, objective and reproducible method, with traceable results. It also describes how to achieve the condition class on the basis of a non-destructive observation of defects of any asset (or part of it) through the use of a predefined breakdown structure, which would different from asset to asset. *(PD CEN-TS 17385-2019)*

The document is useful for:

a. The evaluation of physical condition of a single asset or portfolio of assets
b. Establishment of a maintenance strategy based on the actual condition of the asset
c. The support of financial planning

d. The encouragement and support of the communication about the actual condition versus the desired condition of an asset.

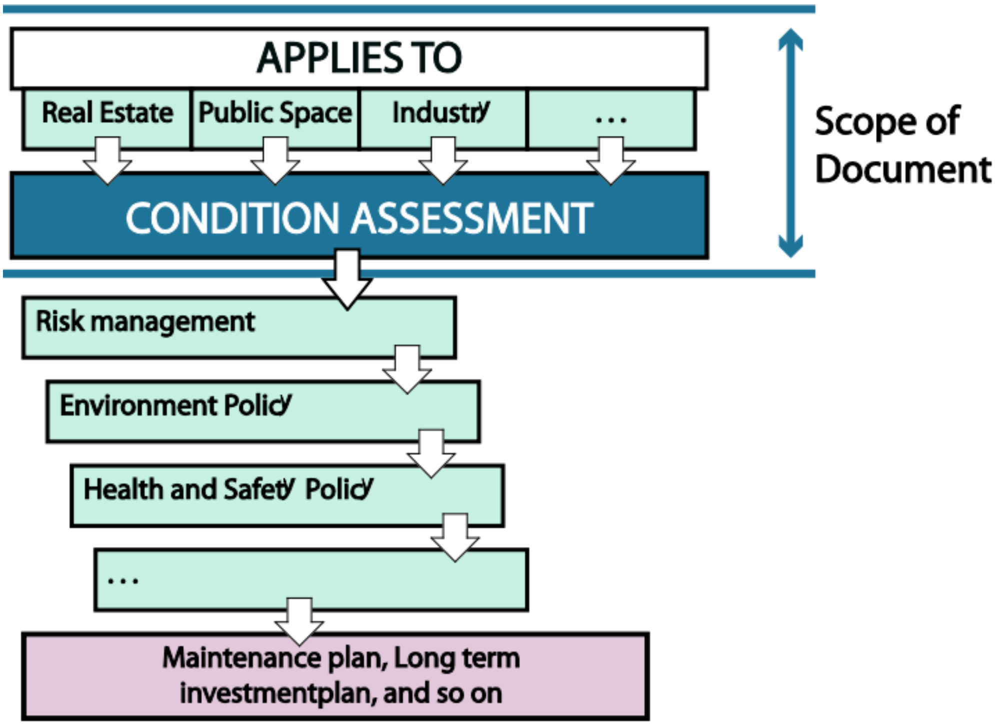


Figure 4. *Applicability of condition assessment (PD CEN-TS 17385-2019)*

The condition assessment of the asset has to be performed in relation to the requirements of a defined agreement between the asset owner and the condition assessor/assessing responsible. It also includes the objectives of the assessment with respect to identification of required maintenance or other actions.

The condition assessment has to be made according to different steps:

a. Establishment of the asset boundaries and identification of the asset breakdown structure and indenture levels. The definition of the asset boundaries is an important step, which allows the right understanding of the scope of the assessment, both by the users and the assessor. Boundaries, relationships, dependencies and interfaces between the subject of the assessment and the other involved part of the environment/system have to be defined in a clear way. This definition can also help to establish the integration of each assessment with other related studies; they have to be set from a functional point of view, in order to limit the number of connections with other items, within the scope of a specific assessment. The other important part that has to be defined is the asset breakdown structure, especially for complex assets in which the composition process and the size of each element has to be manageable in an easy way and has to be logically connected to the other objects. A particular attention has to be addressed to the interfaces between the subsystems and the elements; it is for that reason that the clear definition of boundaries is important. Therefore, all the elements must have clear functional and logical boundaries. After the definition of these particulars, a meaningful assessment can be performed. Also the elements have to be described, and they must be provided together with a reference code to aid the identification. The code has to be referred both to the element and to all the constituent materials; it has to be unique and maintenance oriented and has to provide information about the function of the item to which the element belongs and not just to its physical structure.

b. Doing visual and physical surveys to quantify defects and classify them. Thanks to surveys, it is possible to develop an analysis of defects, both from a quantitative and a qualitative point of view. The identification, quantification and following classification of the defects has to be done considering three – main condition parameters:
    1. The severity;
    2. The level of degradation;
    3. The extent of the defect.

    The methodology used does not exclude any level of detail for a condition assessment, and tries to allow the comparison between the results obtained by the assessment; in fact, the same level of detail should be applied to each part of the procedure. About the severity, it is related to its influence on the functioning of the element and the classification is based on three main levels:
    1. Critical;
    2. Serious;
    3. Minor defects.

The level of degradation, so the visible detrimental change in physical condition with time or due to an external cause, can be progressive or result of a single event. About the extent it may be assessed in relation to the area or to the volume of the element affected, and then classified according to the percentage of the total element area and volume.

c. Determine the condition classes by interpretation and combination of the identified defects and their classification. They are determined by the combination of:
    - Severity;
    - Level of degradation;
    - Extent of degradation.

According to the final matrix, there are six – condition classes:

1. Excellent condition
2. Good condition
3. Fair condition
4. Poor condition
5. Bad condition
6. Very bad condition

If more than one – type is identified for each element, individual criticalities will be located in the same section of the element, and the condition class is determined by the defect that leads to the highest condition class.

There are different situations that could happen:

- If defects have all the same severity and level of degradation, but are located in different sections of the element and the condition class, it is determined by adding the extent of all individual defects and, through the use of a given table, it is possible to define the condition class.
- If defects are in different locations and have different severity and degradation levels, it is important to divide the element into sections where the criticalities are present,

and the ones without defects. The extent of each section is defined by the issue that is described in it.

d. To do a report with the results obtained from the assessment. During the different analyses, it is possible to have different situations; in some cases, the condition class of an object can be rated low, even if a critical defect has been detected. This situation could happen when:
    - A large element is in an overall good condition and the critical defect affects just a small part of the building;
    - The condition class is calculated via aggregation.

For these reasons it is fundamental to report, next to the condition class of an element, all the critical defects, and make them clearly visible in a non – ambiguous way in the reports which contain the results obtained with the condition assessment.

2.3.4 – THE EUROPEAN STANDARD: BS EN 16991-2018-RBIF

This standard, although it is only indirectly linked to the condition assessment of a building, is nevertheless an important tool since it places considerable attention on what is the risk related to the various maintenance interventions, performed depending on the condition in which the building is located. *(BS EN 16991:2018: Risk-based inspection framework)*

Therefore, as already said, even if not directly related to the subject under analysis, it is still recommended to consider what are the possible risks related to the various interventions that can or must be performed.

Thus, this is another European Standard which specifies the framework for risk – based inspections (RBIF) and provides guidance for risk – based inspection and maintenance (RBIM) in the hydrocarbon and chemical process industries, in energy production and other sectors where RBI is applicable.

Although the RBIF includes both inspection and maintenance, this document focuses mainly on risk – based inspection (RBI) and its applicability in the context of the RBIM. The RBIF therefore supports optimisation of operations and maintenance, as well as asset integrity management.

In recent years, the RBI engineering approach is used to ensure the integrity and operation of a plant, in order to ensure smooth operation in safety; the method allows people to focus on a few critical elements that would give the maximum return on management expenses. The analysis of pressure equipment made by the RBI method provides an inspection program with the aim of reducing risks to health, safety and environment, to maximise the use of resources.

This approach could be used to program structural integrity checks, assigning priorities based on the assessment of risks related to the individual plant component, contrary to traditional systems (to which the current regulation also refers) in which the controls are programmed on a regular basis, depending on the design of the apparatus and its operating conditions. The risk assessment shall take into account possible failure, severity of consequences and probability of occurrence.

RBIF has some general requirements:

- Firstly, it is important to clearly define the objectives and the risk criteria;
- Then, the assessment and the applied procedure shall follow legal and regulatory requirements;
- For the assessment it is necessary to have an adequate level of information;
- The assessment should be performed by a multidisciplinary team composed by skilled and qualified people and it has to represent the real – status of the building;
- The final results shall be realistic (but they have to consider also uncertainties and assumptions) and representable in a risk – matrix, verifiable and coherent with both the objectives of the analysis and the risk criteria used;
- If is necessary to change something in management, it has to be done according to accepted and recognized standards;

- If computer models and tools are used during the inspection, they have to be validated and must provide documentation authorised by risk managers.

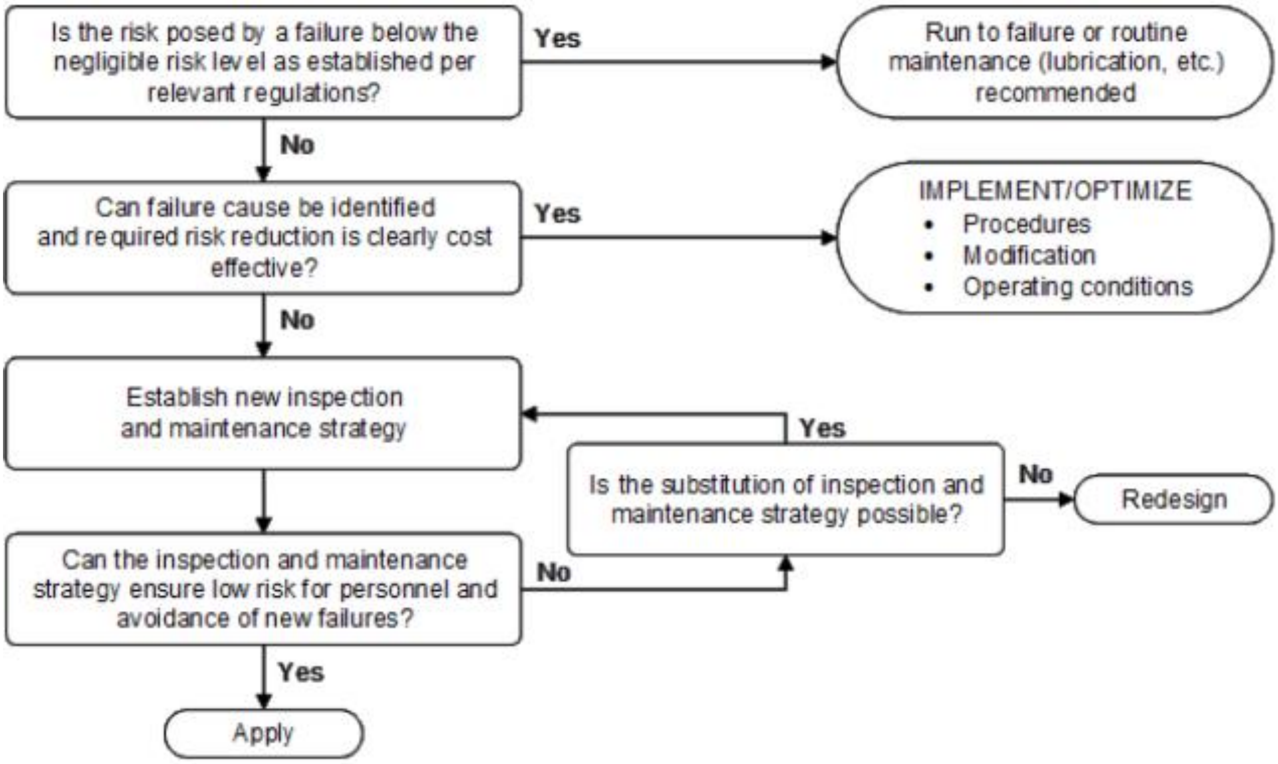


Figure 5. *Main RBI application level and decision tree (BS EN 16991:2018)*

The process is divided into different application levels and an inspection – maintenance strategy level; the main levels are showed in the image above, and takes into account the factors below:

- Level of risk;
- Opportunity to;
- The risk to personnel during execution of inspection and maintenance;
- The risk of introducing new failure cases while trying to eliminate the existing ones.

A decision tree is developed, providing three main purposes:

- To present a systematic evaluation of needs for inspection and maintenance activities;
- Consistency of the evaluation between different units, plan system and similar units located in different areas;
- Simplification of the documents of reached conclusions .

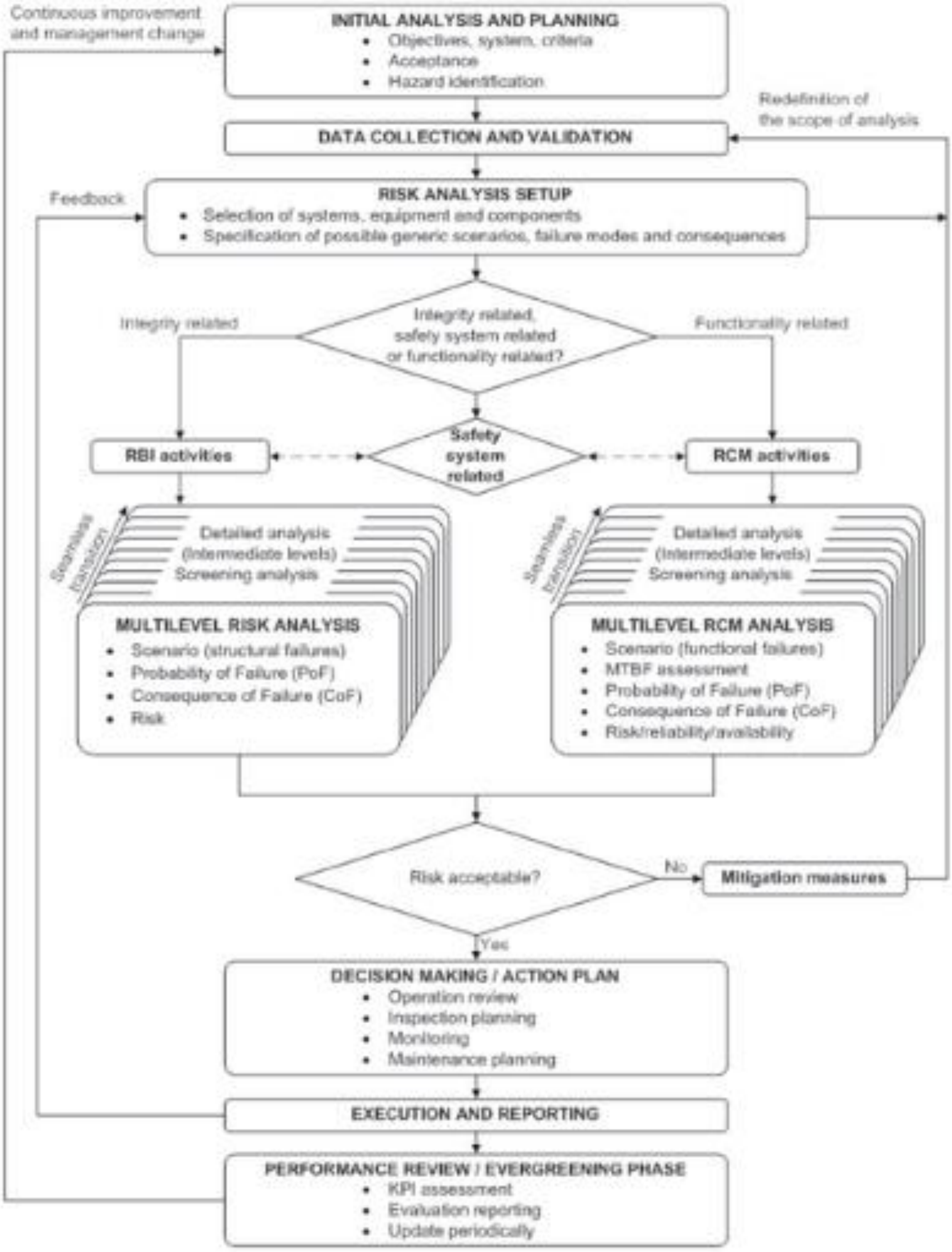


Figure 6. *Example for the development of a risk analysis* (BS EN 16991:2018)

2.3.5– REFERENCE STANDARDS: FINAL CONSIDERATIONS

Therefore, at the end of the research, what has been possible to affirm is the existence of three main instruments (plus one related to the risks), on which the whole process of condition assessment is based. These standards have both common characteristics and discordant points (especially at the organisational and development levels); nevertheless, at the end, the aim is for all the same, thus to reinforce and support the whole process of the condition assessment of a building.

One of the most important aspects is that all standards are based on the two cornerstones of condition assessment; thus, the need to develop a breakdown structure of the building, in order to study its single components and the acquisition of the dynamic information about them. The evaluation of condition is therefore a dynamic process to be performed at a certain rate at the time level.

Moreover, every evaluation developed and all the data obtained are fundamental for the analyses that will be developed in a later period; it is possible therefore to say that, among all the investigations that were carried out, there is a strong link.

For the three main standards it is possible to identify some key – features; the BS EN 16991-2018-RBIF will not be inserted in the comparison, because, even if, as already said before, it is very important, the framework to which it is dedicated is a particular one. Thus, it has been decided to make a parallel just between the other three main standards.

NEN 2767-2_2008	**NS 3424.E:2012**	**PD CEN/TS 17385:2019**
It describes the appropriate method to determine the maintenance conditions of a building and the constituent parts; the method proposed aims to be simple and objective.	It describes the requirements necessary for the right conduction, description, assessment and documentation of a Condition Assessment	The method presented is based on NEN for the Dutch standard 2006 and provides an object evaluation of the physical condition of an asset; it is used to identify and justify a maintenance plan for the asset in a uniform and objective way.
Scores are awarded according to a 6 – point scale.	It defines three main survey – levels and the scope of the investigation and the assessment.	The assessment results in a condition class which expresses the technical state of maintenance of an asset in a specific moment in time; it is based on a 6 – point scale.
The standard represents a standardized tool used to develop the process of Condition Assessment.	The process is based on different steps: - Definition of the task - Selection of the reference level - Drawing of an execution plan - Acquisition and Assessment of underlying information	The standard is useful for: - Evaluate the physical condition of a single/portfolio asset - Establish a maintenance strategy based on the actual condition of the asset - Support the financial planning

	- Preparation of criteria - Registration of condition - Analysis of the causes of nonconformities - Analysis of consequences - Description of the risk - Description and prioritization of measures - Reporting	- Encourage and support the communication about the actual condition vs the desired ones of an asset. According to the standard, the condition assessment has to be made following different steps: - Establish the asset boundaries and identify the asset BS and levels - Perform visual and physical surveys to quantify and classify defects; with inspections is possible to analyse defects both from a quantitative and a qualitative point of view (based on three main condition parameters: the severity, the level of degradation and the extent of the defect). - Determine the condition classes by interpretation and combination of the identified defects and their classification - Develop a report in which there are the assessment results
The standard is: - Aimed to all people involved in the building - The application includes the visualization and control of physical conditions, maintenance planning, prioritization of maintenance budgets and the communication about the present assessed physical condition compared to the desirable one - It includes different sections	So, with the standard is possible to define: - How condition assessment has to be done - How Condition Assessment must be described and assessed - How report shall be written - The condition of hidden objects, the related risks and their consequences	The standard pays great attention of the maintenance actions which have to be carefully weighed according to their benefits considering that maintenance costs are a significant part of the total cost of ownership of a constructed asset.
The standard also presents some limitations: - condition assessment is not able to prepare the annual maintenance budget and planning of the work	The standard permits to define not just technical conditions, but also: - Environmental aspects - Functionality - Energy consumption	According to the Standards, the condition of an immobile constructed asset is one of the factors which determine the value of the asset which is influenced

- all the maintenance activities are not related to the condition ratings - it is mostly indicated for large – scale properties - the results are evaluated on the basis of some examples taken from the “standard” list of defects	- Other important aspects	by the quality of the maintenance performed.

2.4- KEY CONCEPT IN THE CONDITION ASSESSMENT: BREAKDOWN STRUCTURE AND DATA MANAGEMENT

As a result of the research developed on the topic of Condition Assessment, it is possible to identify two solid elements on which this is based:

- Breakdown structure
- Data management

A key thing is that these two must constantly work in parallel; if something changes in the Breakdown structure of the building, it is important that also the data related to these is managed and controlled in real - time.

The relation between these two key concepts is at the basis of the whole development of the condition assessment; moreover, it is fundamental that the procedure of the condition assessment can give back feedback regarding the analysed elements which have to be always updated in real - time.

As it has been highlighted by the analysis previously done, by using the traditional method there are some limitations that are important to get over.

2.4.1 - RESEARCH HYPOTHESIS: THE INTEGRATION OF THE CONDITION ASSESSMENT WITH BIM

Thus, to overcome the limit imposed by the traditional methods for the condition assessment, different analyses have been developed, concluding that the integration of the condition assessment with BIM instruments could be one of the best paths to follow.

So, it has been decided to focus the development of the master thesis on the relationship that exists between BIM tool and condition assessment, highlighting on how this instrument can significantly facilitate the development of continuous assessment of the building conditions, the systems present in it and all the elements that make it up.

In the early days, BIM was associated with 3D design, but it is not just this; there is a digital visualisation and models which are fundamental parts of the BIM process, but this perspective misses the wider benefits provided by the tool.

The primary advantage that BIM brings is the collaboration among different experts to foster innovation; at the basis of this cooperation there is high-quality project information that is allowed by the BIM data environment, through which project stakeholders can communicate and collaborate from the beginning of the work.

Thus, BIM provides the necessary instrument to share quality information in a very meaningful way and cluster different disciplinary expertise to drive improved project outcomes.

It is also important to highlight that all the data related to the project (both current and historical) are available in the cloud and they can be consulted and used by all the project stakeholders, whenever they need or want. *(BSI group, 2019)*

2.4.2 – THE POTENTIAL SUPPORT OF BIM SYSTEM TO BREAKDOWN STRUCTURE AND DATA MANAGEMENT

The Building Information Modelling is a way for the management of the information during the whole lifecycle of a building, starting from the initial design, through the construction phases, maintenance, coming to the final dismantling with the use of a digital model of the facility, so, its digital twin.

This instrument aims at collaboration between the different figures involved in the building, so the different technicians, the professional figures and the final users; this cooperation is possible thanks to the presence of a CDE (Common Data Environment) in which all the information is clustered and shared among people. With the use of BIM, different teams for the design and the construction of the building can coordinate all the information through different levels; in fact, the information provided is linked to the design phase before the beginning of the construction for all the duration and they can be also useful for the analysis of potential impact.

From April 2016, the UK asked the providers of the construction sector who are involved in tender management at "central level" to work following the BIM Asset Life – Cycle. BSI (British Standard Institution) supports the sector providing a wide range of solutions able to satisfy all the different requirements.

By the using of BIM and BIM certification is possible to get different benefits:

- An increase in process speed and efficiency
- An increase in the productivity and speed in delivery
- A decrease of uncertainty
- A better control on cost during the whole life-cycle
- A decrease of the environmental impact
- A saving in re-work costs
- Higher level of security
- More opportunities to guarantee public procurement in accordance with the BIM Asset Life-Cycle
- A decrease in the quantity of waste produced
- A better error prevention

So, BIM is transforming the construction industry and changing the way in which multidisciplinary teams can cooperate at the different stages of the asset life-cycle in order to deliver significant efficiency and cost – saving benefits.

The control of the state of a building and all its components is very important; thanks to the 3D model it is also possible to plan in the most suitable way the necessary interventions of both ordinary and extraordinary maintenance.

This possibility of control and planning turns out to be a facilitation not only from the organisational point of view, but also from the economic point of view; In fact, having a precise picture of the state of the building allows you to prepare a plan of interventions as clear and precise as possible, thus avoiding having to act at the last minute or after the damage has already occurred. Taking action to repair a failure can be much more expensive (both economically and time-wise) than a previous intervention.

With the development of a BIM model of the building under analysis it is possible to know in detail every single component of the construction and analyse its real state of "health". Thanks to the 3D modelling tool, all evaluations can be constantly updated and shared with the different technicians who take care of the building and its maintenance. Everyone is therefore aware of the current condition of the construction and can compare it, at any time, with the previous one to verify the evolution of the "health" of the different components.

Thus, for all the reasons listed above, has been tried to develop the thesis project on the interaction between these two worlds to be able to make it more known, because, although very strong is at its first developments and therefore not well known.

3- DATA MANAGEMENT IN THE CONSTRUCTION PROCESS: INFORMATION SYSTEMS AND BIM

As it has said before, the scope of this thesis is to develop a condition assessment, improving, if it's possible, the procedure and integration of the outcomes. Therefore, to merge the breakdown structure, thus the identification of each element composing our asset, and the dynamic information coming from each of these items.

It is important to consider that there are several software solutions available in the market to perform the task of building information modelling and enable the owner and other involved parties, to manage the assets for all aspects, including the operation and maintenance of facilities. (*Mamdouh Al-Gendy, Hesham Osman, Mahmoud Taha, 2012)*

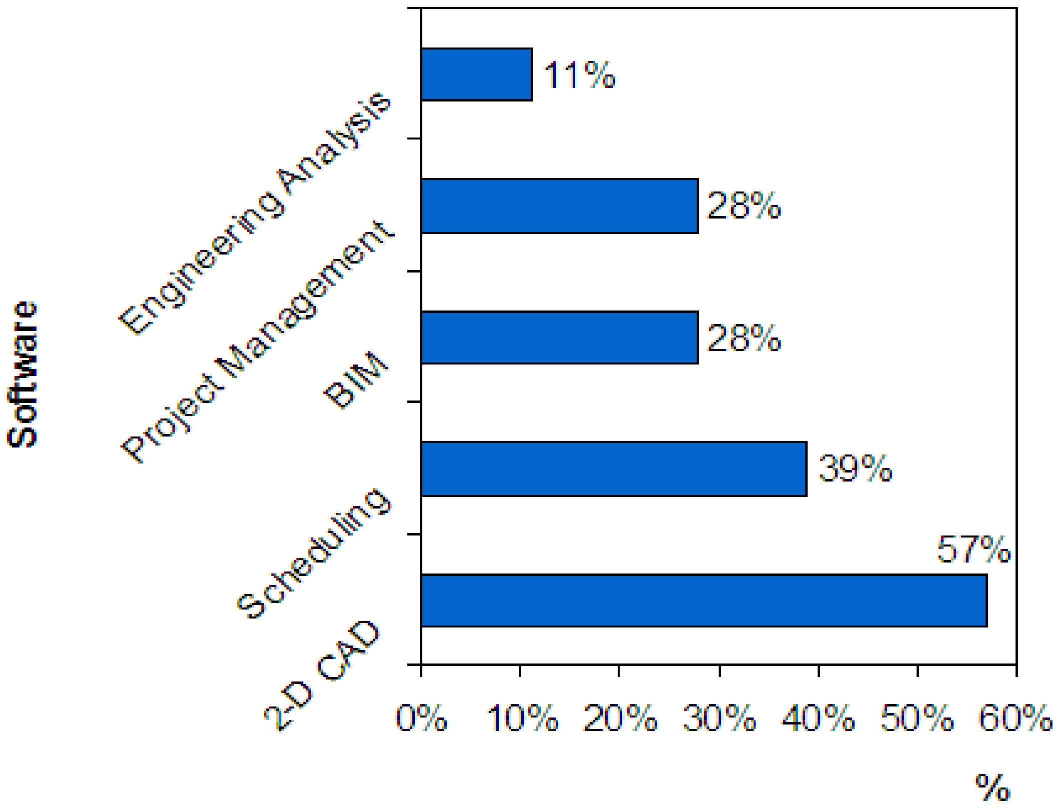


Figure 7. *Software types used most frequently in construction (Mamdouh Al-Gendy, Hesham Osman, Mahmoud Taha, 2012)*

Thus, why to use Building Information Modelling?

Building Information Modelling could be introduced in this field of study, not as a new technique or as a response, but as an evolution of the instruments already used for the traditional methodologies. It would be possible to introduce BIM as a tool that allows future professionals to integrate, in a standardised manner, the information and the data related to the status of each component. In order to analyse the condition of the asset in a dynamic way, would this tool also permit to study the condition evolution, during the entire life cycle of the asset?

The final aim of this study is to develop a BIM-enabled building condition assessment tool, in order to ensure and facilitate a consistent and cost-effective inspection of building components, during the entire life-cycle of the project, based on the use of Autodesk Revit architect software as our principal tool.

This will allow both to managers and to technicians, to simplify the communication, having all the information in a unique and simplified platform; to avoid losing information, coming from the use of different softwares; and to have a control on both the entire building and all its particular elements, without losing the idea of the building as a whole.

Technically speaking, this system would provide to the user with the following advantages:

- The collection of all the necessary information about building components, thus allowing decision-makers to have a quick action upon defects;
- Saving both time and money, for its quick response and for the clear communication;
- Providing accurate maintenance information, specially using the tool of attachment of pictures of the different status for assessment grades;
- Saving inspection records by date, enabling a good monitoring for the building element history;
- Unification of criterions for different inspectors, since the comparison between current status and stored graded images becomes much easier.

If we have into consideration that the asset management phase of a building represents the 60% of its total lifecycle cost *(Maha Al-Kasasbeh, Osama Abudayyeh, Hexu Liu, 2020)*, the fact of searching for an instrument that allows specialists and technicians to develop a more efficient condition assessment on buildings could not be considered as a minor goal.

3.1- BUILDING INFORMATION MODELLING: A FIRST APPROACH - STRENGTHS AND WEAKNESSES

During the development of the analysis different documents and sources have been used to know in a better and deeper way the topic dealt. It has been possible to notice that, even if the argument was the same for all the documentations, they treat it in many ways the information and give back results which are not perfectly in line with each other.

All the sources for the analysis on the relation between BIM and Condition Assessment also provides some weaknesses and some strengths related to this connection.

Comparing the different sources analysed is possible to provide some points, which describes the importance of the use of BIM, in the best way:

- BIM software and its data – base system is able to collect and develop all the different aspects of the building, and, for this reason, it represents a perfect platform for an assessment tool that can control the inspection activities which are necessary for the building maintenance. *(Mamdouh Al-Gendy, Hesham Osman, Mahmoud Taha; 2012)*
- BIM can help in solving problems of facility inspection through the generation and the management of digital representation of the physical and functional characteristics of a facility.
- The integration of a BIM in the coordination process in complex scale projects can decrease clashes and improve progress of work during the construction phase. *(Mohab Mohamed Abotaleb, Elisabeth Saab, Mohamed AbdelZaher; 2020)*
- BIM is a rich information – based platform with a lot of data required and it is integrated with the WBS – based DBMS to achieve an effective integrated building asset management. *(Maha Alkasasbeh; 2020)*

From the sources also arise some strengths related to the use of BIM in the Condition Assessment:

- The coverage of a considerable parts of the inspection tasks.

- The possibility for the inspector to estimate (in a quite precise way) the urgent maintenance tasks of each building component.
- Time – saving in the assessment of the defects thanks to the standardisation of the assessment process and the verification of the judgement with a standard deterioration images for each component of the building.
- The enhancement of the communication between managers and the inspectors of the different fields.
- Higher precision in the definition of repair cost because the inspection – defect cost is estimated before by the inspector.
- Great help in solving problems of facility managers by generation and management of digital representation of the physical and functional characteristics of a facility.
- The proposed decision support system facilitated a wide range of functionalities, including the accurate acquisition, storage, processing and reporting of asset information promptly.
- The increase of the operational efficiency by aiding in the planning, execution and coordination of maintenance operations.
- The provision of an inventory system which covers all types of buildings along with their life – cycle information.
- The possibility to create a flexible asset accounts which can be defined at any WBS level, depending on the desired details and the availability of resources.

On the other hand, the greatest weaknesses emerged are:

- The requirement of the presence of a 3D – Revit for each inspected building.
- The inclusion of 15 building – components which covers just the most visible architectural components of the building, but it doesn't cover maintenance for structural ones (like Slabs, columns, beams).

- The difficult to form standardised deterioration images for the component deterioration stages especially when the building is a new construction.
- The possibility to work just in a single application and the data cannot be shared among the whole maintenance staff .

3.2- A CLEAR AND EFFECTIVE DATA COLLECTION

BIM could be defined as «a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward». *(Deke Smith; 2009)*

In the complex process of a condition assessment, it is a key aspect to take into consideration that several stakeholders will be involved. How to ensure that all participants are up to date, and using the latest information provided? Would it be possible to guarantee the coordination between interested parties, with the intent of creating best practices that enhance the flow of information?

All condition assessment projects start with data collection, and often this data ends up being inaccurate because of time and communication failures. Moreover, it is important to highlight that the related information is dynamic.

In a condition assessment developed through traditional methods, the information related to each item was recorded through a breakdown structure. Nevertheless, with this approach we would have several stakeholders, managing different kinds of information, depending on their area of interest, to then share and coordinate the data collected in a unique analysis (*Figure 8*).

Could it be that the key to perform an effective information recording is to ensure a single file that would include all the spatial components with its related information, to then be distributed among the different stakeholders (*Figure 9*)? Or in other words, is it possible to conceive BIM as the repository for change management information?

Could it be that the key to perform an effective information recording is to ensure plans include a spatial component that uses BIM as the repository for change management information.

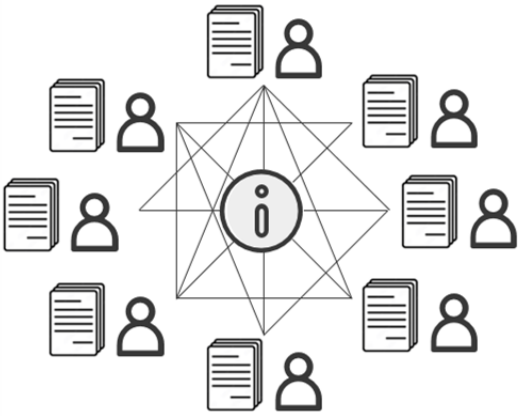


Figure 8. *Several sources of information*

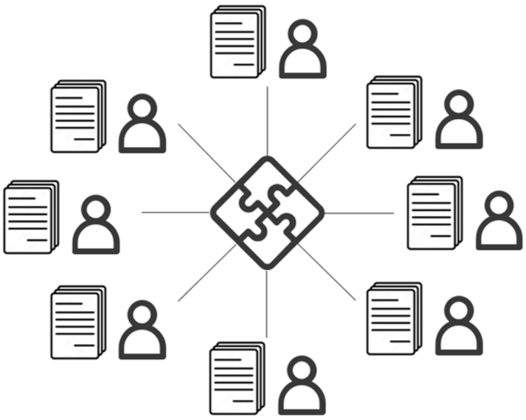


Figure 9. *Single source of information*

Using BIM can reduce inefficiencies and deliver significantly higher-quality data in a quicker way. The use of this tool would allow more activities to be accomplished in parallel and the reduction of re-work activities. *(Deke Smith; 2009)*

This approach proposes to link the breakdown structure codes, in order to identify each component of the asset, in a common, coordinated and shared BIM model, to the information recorded during time. If the hypothesis of this thesis is confirmed, it would be possible to develop an analysis of the evolution of the recorded data, with the aim of understanding the whole life cycle of the project. The outputs would have several benefits, such as the prevention of future costs, performed thru the historical data recorded, and the comprehension of the entire asset and its systems as a whole.

3.3- BIM DIMENSIONS

Thus, we can say that BIM is a tool that facilitates the creation and managing of information during the life cycle of a project. But, to understand it in a more practical manner, what are the scopes, and to what extent can we use the benefits of the Building Information Modelling? Thus, to categorise and organise these possibilities, we can present the **BIM dimensions**. *(Stephen Hamil; 2021)*

- **2D BIM**: It is a digital geometric model that constitutes an X and a Y axis associated with further information. Early CAD systems were 2D models, where plans and sections could be developed on computers more quickly and more accurately than manually on a drawing board.

- **3D BIM:** It could be considered as the most popular BIM dimension that all construction companies are familiar with. It is also referred to as a coordinated model. It represents the three-dimensional geographical structures of a building. BIM 3D models are employed to schematic designs, design development and documentation, construction documentation, and record drawings. This dimension brings several benefits compared to the 2D BIM, such as:
    - A 3D visualisation throughout the entire project;
    - Helpful in checking possible collision of elements during design and execution phases;
    - Enhance of the communication among stakeholders;
    - Ensuring transparency during the entire life cycle project;
    - Creation of a detailed model, from which it could be studied the impact that the project would have on the environment. *(James Ocean; 2020)*

- **4D BIM:** This dimension implies scheduling information to model construction sequences. Adding a dimension of time allows the project team to better visualise how the construction will be sequenced. Traditional methods used in construction, such as Gantt and Pert chart have some limitations and problems:
    - Loss of information in the transmission of data;
    - Lack of communication between the construction manager and the suppliers;
    - Insufficient monitoring of the process and lack of a global vision of the consequences.
- To avoid these problems, BIM has the possibility to build a “WBS – Work Breakdown Structure”, and to connect this WBS to a digital twin.

- **5D BIM:** It is considered to be the activity of cost estimation and analysis. It is possible to create a direct link between the elements of the digital model, the calculation of quantities and the estimation of costs.

  This technology determines greater accuracy and predictability of estimates of project costs, variances in quantities, materials, equipment, and labour. It also provides methods for extraction and cost analysis and methods for evaluating different scenarios. Furthermore, allows you to see the progress of activities and related costs over time (BIM 4D).

- **6D BIM:** It is associated with the energy efficiency and sustainable development of a new or existing building. Sustainability concept can be examined from three different points of view:
    - Environmental, in terms of the ability to reproduce and maintain natural resources;
    - Economic, understood as the right to generate income and work;
    - Social, as a generator of well-being for man.

  The 6D BIM simulation allows an exhaustive analysis in terms of sustainability of the asset.

- **7D BIM:** It is the operational management and maintenance of the building and its components throughout the whole life cycle of the project. When we talk about the life cycle, we cannot ignore the aspects of maintenance and closure or renovation of the building. 7D BIM software extracts and keeps track of all data related to components, specifications, maintenance and installation manuals, warranties, etc.

  Thanks to this technology, it is possible to optimise the operational management of the building throughout its life cycle:
    - Allowing an easy and efficient management of the assets, replacement and maintenance of its parts;
    - Facilitating audits and ensuring efficiency, safety and compliance with construction regulations throughout its life cycle;
    - Optimising resources and maintenance costs, thanks to continuous and updated monitoring systems.

This would be the dimension on which we will focus throughout the development of this thesis *(BibLus)*. Of course, we understand that a quality analysis of an asset should be performed thinking in the project as a whole; therefore, even if it won't be the focus of this study, the other dimensions will be part of the collaborated data studied and taken into consideration.

Therefore, BIM dimensions have evolved from a need to differentiate between modelling geometry in two or three dimensions. This has been part of the modelling evolution, moving from drawing boards to the first 2D CAD systems, to 3D modelling packages. Adding further aspects to this modelling can help project teams understand what information they are setting out to model.

Nevertheless, it is important to highlight that in the international standards, these dimensions are not typically referred to. If specific information is required to be modelled, this should be identified clearly in the information requirements that are issued to the project team. Furthermore, they should state precisely which information fields are required, and in which format, instead of using terminology such as 5D, 6D, 7D, …

Thus, these dimensions allow to the interested parties to understand in a simplified manner which would be the scope of the project; nevertheless, the process and the specific information required in order to achieve the objectives should be clearly specified in the contract, and it could vary from project to project.

3.4- EVOLUTION OF THE DATA RECORDING

Another main challenge in applying asset management strategies to buildings is the timely availability of quality asset information *(Maha Alkasasbeh and Hexu Liu; 2020)*. This comes from the fact that asset data is provided at different moments of the project life cycle. For example, as built data is generated during the design and construction phases, whereas condition assessment data is collected throughout the operation and maintenance phase of a facility. Furthermore, during the condition assessment, the data collection is not always

This fragmentation could lead to delays in building management tasks and cost overruns, resulting in wasted time and money on nonvalue added tasks. The lack of data integration during the lifecycle of a building makes information flow more difficult and ineffective. Integrating building lifecycle information would facilitate information flow and improve the availability, reliability, and consistency of asset information, resulting in reduced time and cost in asset management *(Maha Alkasasbeh and Hexu Liu; 2020)*.

In this regard, is it possible to use BIM as a tool that helps us, not only integrating the asset's information, but also analysing the evolution of each item's information during its entire life cycle? And which would be advantages compared with other similar softwares?

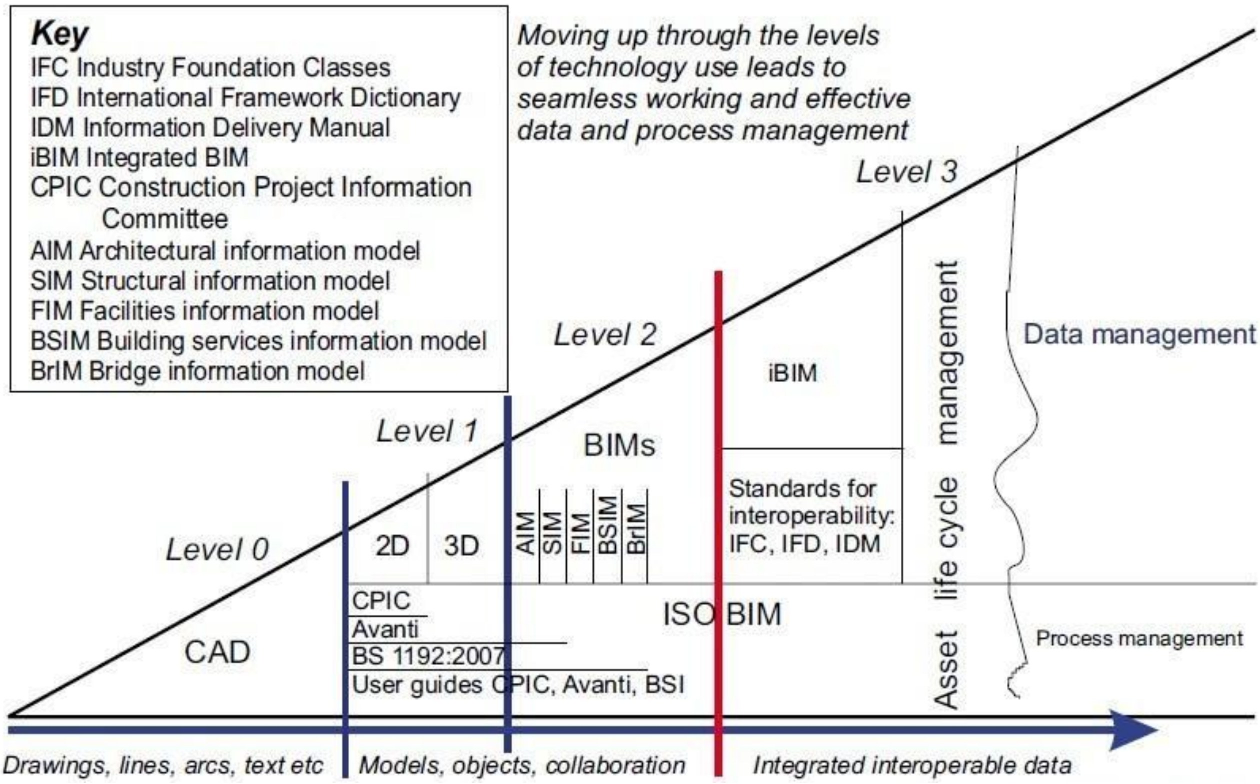


Figure 10. *BIM Levels – Softwares and requirements (PAS 1192-2:2013)*

First of all, it would be crucial to understand the concept of «digital maturity», coming from UK standard «PAS 1192-2:2103». This framework sets out the requirements for the level of model detail (the graphical content), model information (non-graphical content, such as specification data), model definition (its meaning) and model information exchanges *(Richard McPartland; 2017)*. This concept will help us to understand which are the possibilities that different softwares has to offer us, depending on our needs (*Figure 10*), and the standards that regulate each stage (*Figure 11*).

Thus, as is possible to observe from these figures, until stage 2 the management of information is focused in the analysis of files, while after it is allowed the management of the data. Therefore, the analysis of collaborated and integrated information coming from the facility.

Furthermore, from stage 3 it is conceived the use of a Common Data Environment (CDE) based on query/modeller/container, which is different from the CDE conceived before, that allows the management not of data, but just of files. This means that the information is not integrated as a whole, there would be different stakeholders managing its own information, such as it has been already seen in the previous *Figure 8*. On the other hand, from stage 3 it is possible to have a single source of information, a single model, that would provide clear, unique and coordinated data, as it has been already seen in the previous *Figure 9*.

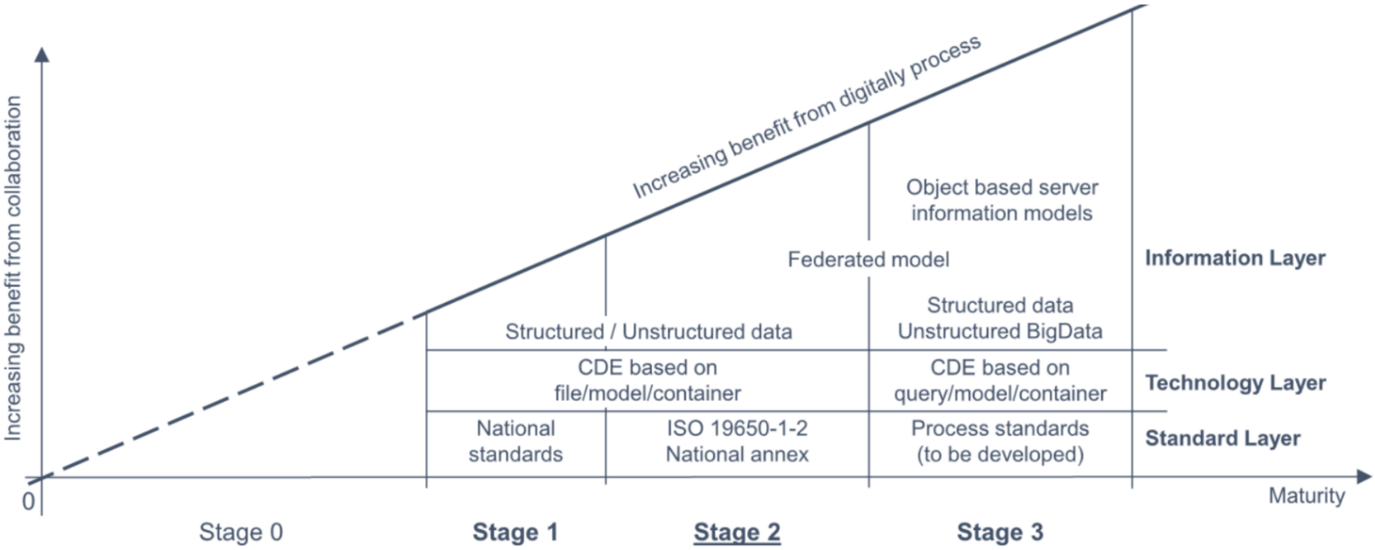


Figure 11. *BIM Levels – Standards and information required* (PAS 1192-2:2013)

If we translate these standards stages and processes into practical procedures where it is also possible to observe the evolution in the complexity of information provided and the collaboration between the different stakeholders, as is possible to see in *Figure 12* (*Emirates BIM User Group; 2016*):

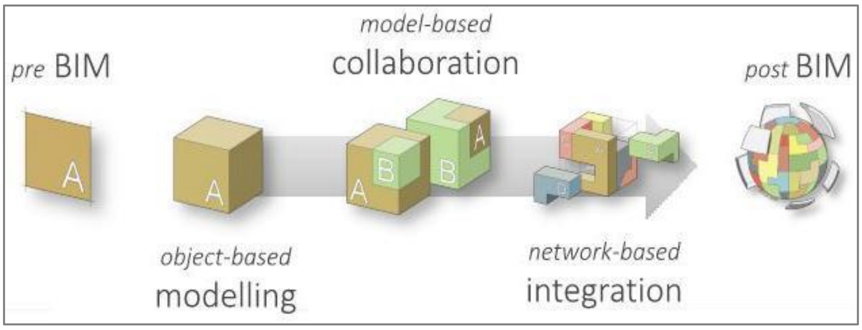


Figure 12. *BIM Collaboration stages*

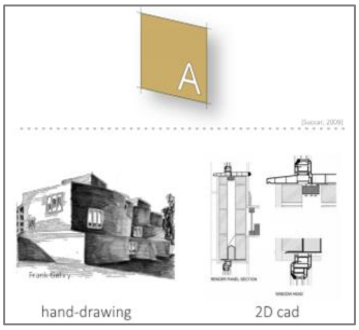


Figure 13. *Pre-BIM status*

1. <u>Pre-BIM status</u>: Before the implementation of BIM, organisations were dependent on manual and 2d CAD tools and processes. This type of tools, such as AutoCAD, are used to generate drawings and details that are a great improvement with respect to drawings made by hand, saving time and providing a high precision. Nevertheless, as they are not an «object-based software tools», there could be discrepancies between different drawings. This risk increases even more if we are coordinating information coming from plans provided by different clients. Please refer to *Figure 13*.

2. <u>BIM Stage 1</u>: BIM capability is acquired through the successful implementation of an «object-based software tool» such as Revit, Archicad and Tekla. These tools can generate model-based deliverables, and represent an improvement for the coordination between the different components of an asset. Nevertheless, this object didn't contain information. Thus, it represents an advance from the coordination point of view, but just from a geometric point of view. Furthermore, there is a limitation from the point of view of the different languages, since not all the files are readable for the different stakeholders. Please refer to *Figure 14 (Emirates BIM User Group; 2016)*.

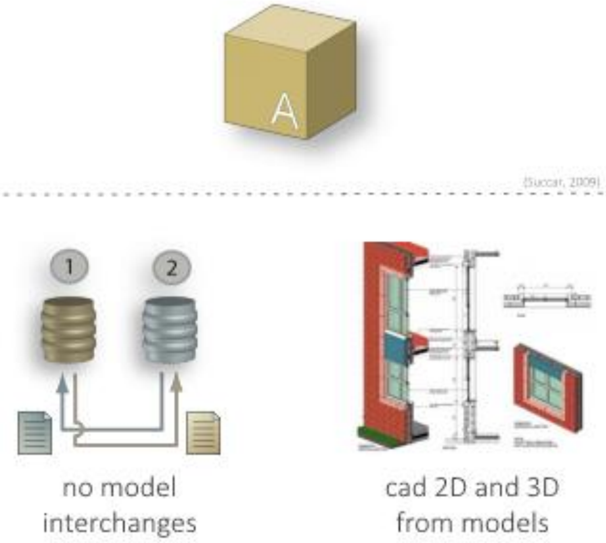


Figure 14. *BIM Stage 1*

3. <u>BIM Stage 2</u>: Players acquire the ability to collaborate with other disciplinary players. The collaboration of information between stakeholders occurs through an interchange (interoperable exchange) of models through «proprietary» formats (e.g. RVT and NWD) and non-proprietary formats or «open formats» (e.g. IFC). Nevertheless, this collaboration between different disciplines is file-based and one-to-one, which means that the stakeholders are still isolated in their silos with disjointed supply chains. workflows. Please refer to *Figures 15 and 16 (Emirates BIM User Group; 2016)*.

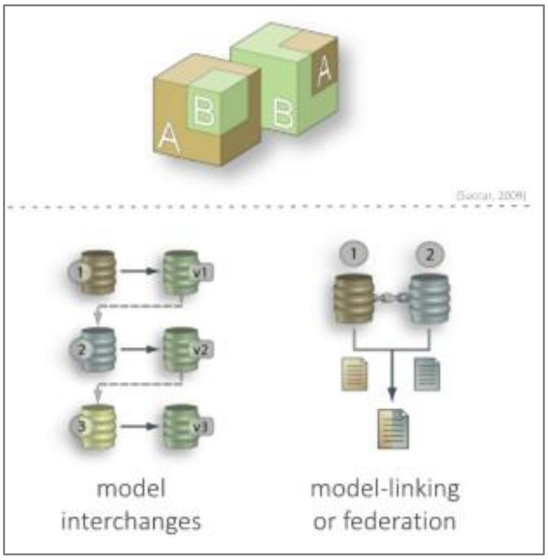


Figure 15. *BIM Stage 2*

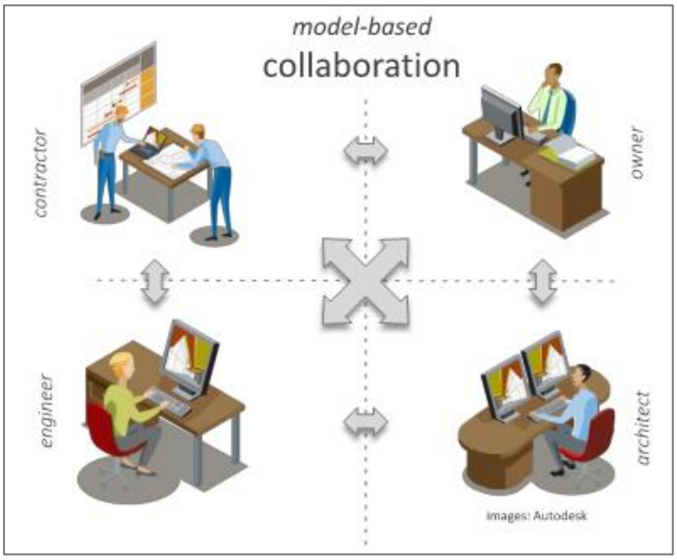


Figure 16. *BIM Stage 2*

4. <u>BIM Stage 3</u>: At this capability stage, data-rich models are created, shared and maintained collaboratively across Project Lifecycle Phases. This integration can be achieved through «model servers» (using proprietary, open or non-proprietary formats), Cloud Computing, or SaaS (Software as a Service).
   At this state the models are interdisciplinary, allowing complex analyses at early stages of virtual design, construction and maintenance of the asset. (*Emirates BIM User Group; 2016)*

   At this stage the collaboration between disciplines start from a CDE, improving the transparency of the processes and allowing a high level of fluidity in the transmission of information. All the interested parties have guaranteed the shared knowledge of the approval documentation. Please refer to *Figure 17 (Emirates BIM User Group; 2016).*

5. <u>Post BIM</u>: In this phase we conceive a virtually integrated Design, Construction & Operation (viDCO).
   This process and all its components are conceived as a whole. This phase is still in development, it will allow to study the project, and its digital twin, as the information centre from which data is collaboratively constructed and extracted. The disciplines are not developed as disjointed supply chains, but based on a digital construction. Please refer to *Figure 18 (Emirates BIM User Group; 2016).*

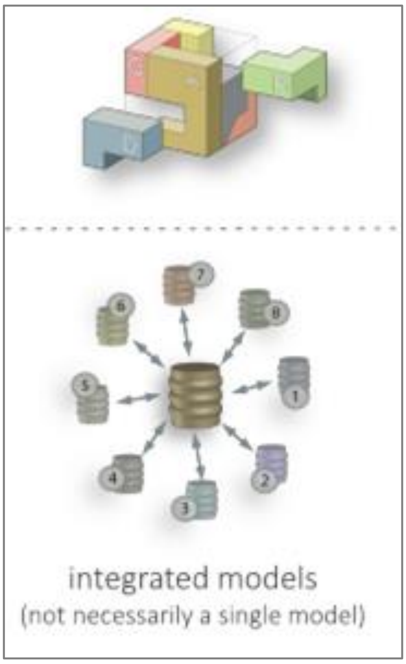


Figure 17. *BIM Stage 3*

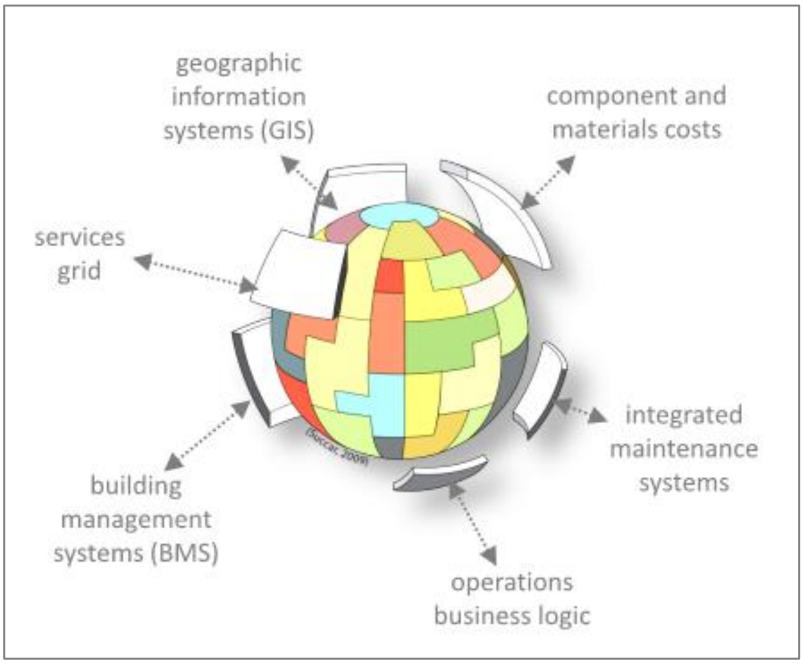


Figure 18. *Post BIM*

Nevertheless, the developed methodologies used nowadays to perform a condition assessment analysis are not far in essence from traditional methods. The contribution of BIM to this field could be studied not as a change of paradigm, but a new instrument that could help professionals to achieve efficient and reliable results.

The greatest contribution could be, in the first place, the transparency of the data collection, and secondly the reliability in the continuous collaboration and communication of the results obtained.

Furthermore, harnessing the potential of the Building Information Modelling, it is possible to conceive not just an analysis of the data, but also to perform an analysis of the evolution of this data, in order to understand and prevent the asset components from future risks situations.

3.5- A COST-EFFECTIVE APPROACH

Thus, it is clear that Building Information Modelling could be a powerful tool from a cost-efficient point of view, most of all in the earliest phases of the project, where the previous coordination and prevention of clashes of disciplines could represent a major impact during the construction.

Nevertheless, **which would be the impact of BIM during a condition assessment process?**

Starting from the possibility of storing large amounts of data, even after the project completion, there is the possibility of transferring this digital record into already existing building maintenance software and using it for a variety of purposes during the entire service life of the building. *(Anna Liza Montenegro; 2021)*

With BIM, condition assessment analysis moves towards data driven planning and scheduling, with data flows on actual equipment specifications, manuals and warranties, installation and engineering records forming the basis for a far more cost-effective approach to managing large, complex structures. *(Juliana Hill; 2015)*

Analysing the situation from a practical point of view, how is that Building Information Modelling could reduce costs during a condition assessment process?

- **Saving time**: One of the two most important terms in construction are «time» and «cost». Being able to reduce both would be the major aim for project managers. It's no wonder then, that one of the major reasons for the existence of BIM is to reduce these elements and improve the efficiency of projects. Using this tool in a correct way would represent not only a free up collaboration, but also a saving of time and a reduction costs by becoming more efficient.

- **Sustainability**: Besides the obvious benefits to the environment of not overrunning on time and materials the project processes, BIM is a powerful tool to optimise the entire life cycle management for minimal environmental impact.

- **Collaboration**: The way that BIM can improve the collaboration of your projects is by opening up channels of communication, making it easier for you to work effectively with other parties involved with your projects. *(Julia Valentine; 2018)*
  What has improving collaboration got to do with your projects' efficiency and cost saving? Teams have the possibility of working together on the same platform to ensure everyone involved plays their part in effectively planning out and considering the project. All stakeholders in the project can give input no matter where they are in the world. Thus, being able to more easily communicate together is one of the main reasons our projects are becoming more efficient. Developing a condition assessment on the basis of a more transparent and reliable data collection, would represent a higher quality of the analysis.
  Furthermore, in case of future issues, the traceability of data would represent a critical aspect from the cost point of view. AS an example, if there would be a case in which the glue that was used to seal the glasses of a curtain wall has been reported or detected as defective, if it's possible to track and control which would be the glasses affected through the Breakdown Structure developed in a BIM model, this would represent not only a time saving, but also a cost saving, coming from the fact that the maintenance should be performed only to the glasses detected, instead of the entire curtain wall.

In conclusion, a higher quality of data, a more efficient process and a higher traceability of information would be translated into a major cost-efficient process.

3.6- COMMUNICATIONAL IMPROVEMENT

As discussed before, even if the methodologies utilized in the development of a condition assessment would be strongly aligned with the traditional methodologies, the great contribution of the Building Information is the improvement in a clear, efficient and reliable communication and collaboration among the different stakeholders involved in a project. Improving the communication between stakeholders, the entire construction process is streamlined and made more efficient.

Thus, when well implemented, the use of BIM as a tool for communication and collaboration can lead to a higher design quality and quality of the realized building, as well as increased efficiency and costs savings. *(Bel Mirjam; 2018)*

BIM can be used for integrated communication and collaboration between different stakeholders, from the same as well as from different project phases. For a good collaboration with BIM, clear objectives should be communicated between stakeholders. But the highest improvement is the possibility of working together in a «shared environment ». The project stakeholders can be architects, engineers, subcontractors, but also new roles that emerge due to BIM, such as BIM managers and BIM designers. Furthermore, end-users can be included in the communication. A shared environment represents a major improvement from the point of view of condition assessment.

The Common Data Environment (CDE) requirements have been defined in the PAS1192 and BS1192 documentation in the past, and more recently, in the ISO 19650. These documents outline what organisations working in the AEC, that is the Architecture, Engineering and Construction domains need to do in order to reach a BIM Level 2 compliance on their projects. *(Viraj Voditel; 2020)*

BIM involves the development of an asset in a virtual environment. It is extremely beneficial as different stakeholders can deduce possible conflicts between disciplines and incoming information, also reducing at the same time the costs from of rework or from preventing issues.

A CDE provides a platform for these changes to be recorded, distributed and resolved, usually on a connected system like the internet or intranet, nowadays mostly on the cloud. This would result in a more efficient way of delivering projects, and in a more transparent process. *(Viraj Voditel; 2020)*

It could be defined as the single source of information used to collect, manage and disseminate documentation, more specifically all the graphical model and non-graphical data for the whole project team (i.e. all project information whether created in a BIM environment or in a conventional data format). Creating this single source of information facilitates collaboration between all the interested and helps avoid duplication and mistakes. *(BIM Wiki; 2021)*

The data sharing platform is for the first time proposed, in an organic and defined way, in the British technical standards: the standards of the PAS 1192 series, where it takes the name of Common Data Environment. Please refer to *Figure 19.*

This concept was subsequently taken up in our regulatory sector within the Ministerial Decree 560/2017 on public procurement (BIM Decree) and in the Italian standards of the UNI 11337 series, where it took on the name of data sharing environment, synthetically indicated with ACDat . In particular, it is discussed extensively within UNI 11337-5 and UNI / TR 11337-6, rules dedicated to specifying the methods of drafting the information specifications. As is known, in fact, in the Information Specifications the contracting authority must specify its requirements for the information management of the entire order and, therefore, also of the ACDat.

The following aspects must be met:

- Accessibility, according to pre-established rules, by all the actors involved in the process;
- Traceability and historical succession of the revisions made to the data contained;
- Support of a wide range of types and formats and their processing;
- High query flows and ease of access, recovery and extrapolation of data (open data exchange protocols);
- Conservation and updating over time;
- Guarantee of confidentiality and security. *(BibLus BIM; 2019)*

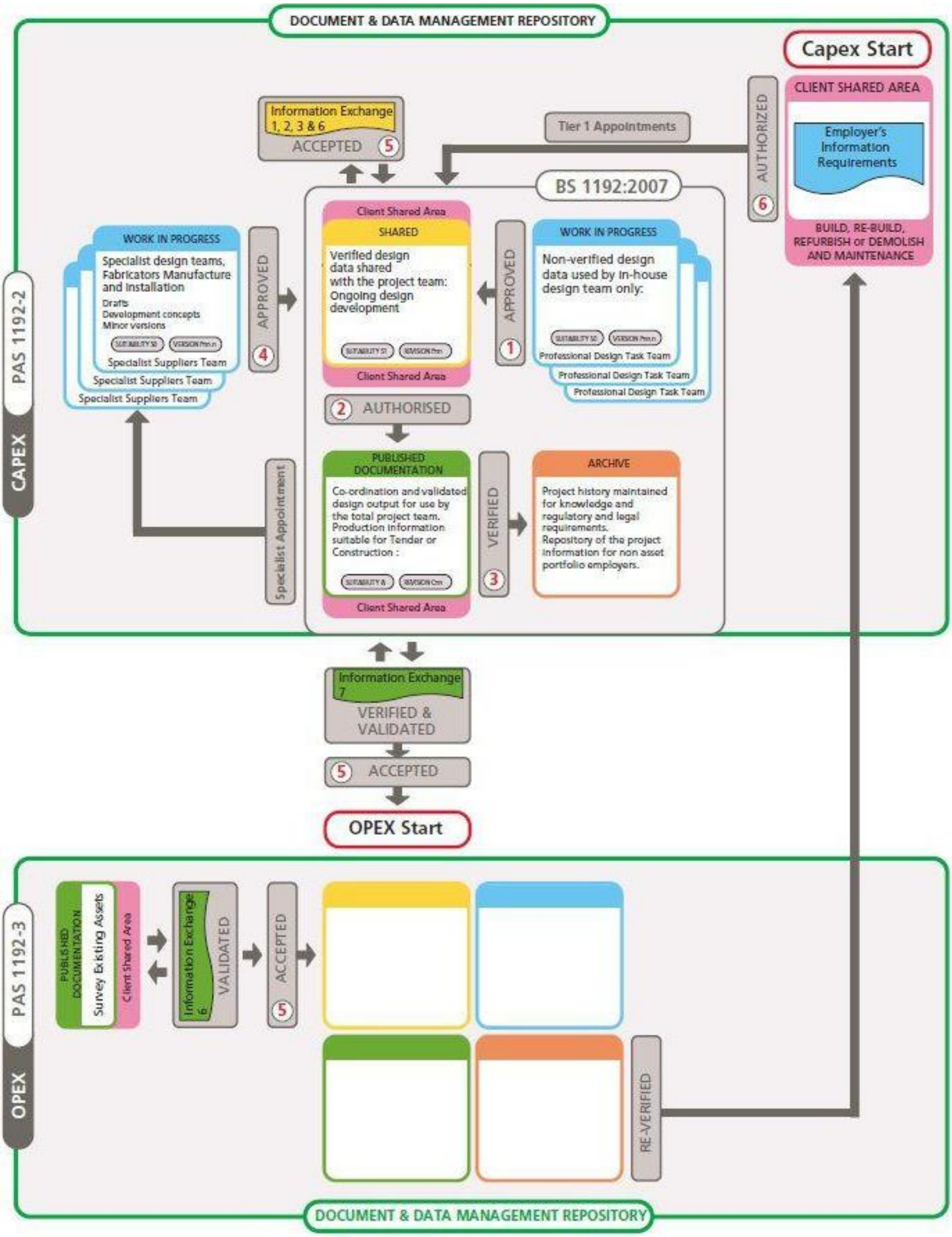


Figure 19. *Common Data Environment (PAS 1192)*

«PAS 1192 2: Specification for information management for the capital/delivery phase of construction projects using Building Information Modelling» proposes that the advantages of using a CDE are:

- Ownership of information remains with the originator, although it is shared and reused, only the originator shall change it;
- Shared information reduces the time and cost in producing co-ordinated information, and
- Any number of documents can be generated from different combinations of model files.

Giving a greater control over revisions and versions of that data. *(BIM Wiki; 2021)*

Information within the CDE can have a wide variety of status levels. However, there will generally be four main areas of information, with a sign-off process allowing information to pass from one area to the next (Please refer to *Figure 20*):

- **Work in progress** (WIP): There could be several areas of WIP, one per stakeholder involved in the project. These areas are used to hold and elaborate still unapproved information;
- **Shared area**: This information has been already checked, reviewed and approved in order to be shared with other organisations, perhaps including the client;
- **Published**: In this area is stored all the data that has been already authorised or accepted by the client;
- **Archive**: It is used to create a constant record of progress throughout the lifecycle of the asset, as well as all transaction and change orders.

The information flow is described graphically highlighting the evolution of the processing and approval states, and with an indication of the moments relating to checks and coordination. Also for the state of approval four levels are defined:

- **A0:** To be approved. In this case, the information content has not yet gone through the approval process;
- **A1:** Approved. This means that the information content has undergone the approval process with positive results;
- **A2:** Approved with comment. Despite having passed the approval process, inadequacies were found such as to require punctual interventions for usability for the intended purposes
- **A3:** Unapproved. The approval process has failed, requiring a thorough rework of the information content.

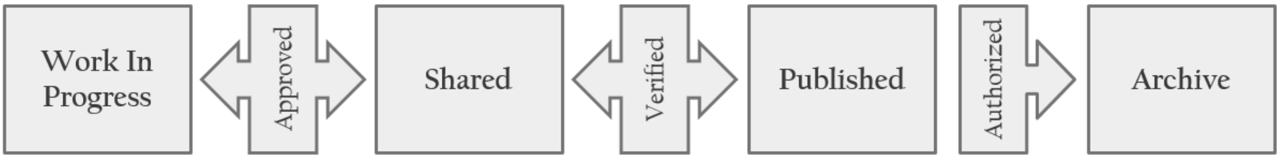


Figure 20. *Sign-off process*

Each passage between one area and the next one foresees a moment for assessing the fulfilment of the requirements. In this case, UNI 11337-4 and UNI 11337-5 help us to define evaluation and verification methods to be used by clarifying the main aspects to be verified, the moments in which these verifications will be performed and proposing appropriate indicators to be used. *(BibLus; 2019)*

The use of this tool in a condition assessment would improve immeasurably the transparency, reliability and traceability of the data.

Nowadays there is a wide range of Common Data Environment available in the market. The most known and used would be BIM 360. The biggest benefits coming from using this CDE are that it provides great traceability and verification tools, it proposes different levels of visualisation and approval for each interested party, and finally, it is an Autodesk tool, making it compatible with the most used BIM softwares, such as Revit or Navisworks. On the other hand, there are also its bigger weaknesses, since it is a very monopolistic situation, and the cost of the licences are getting more and more expensive.

3.7- A COMMON LANGUAGE

This sharing and collaboration of information brings another new subject to analyse, that is the language in which the documents are shared. These are processes in which several stakeholders are involved, and not all will be using the same softwares.

Each particular software produces a file in a particular format that will be shared in the CDE, such as

PDF, RVT, NWD, XLM, TXT, and so on and so forth. Thus, it is fundamental to guarantee that all the stakeholders could open and use these files. Therefore, the shared information must be provided in an **open language**.

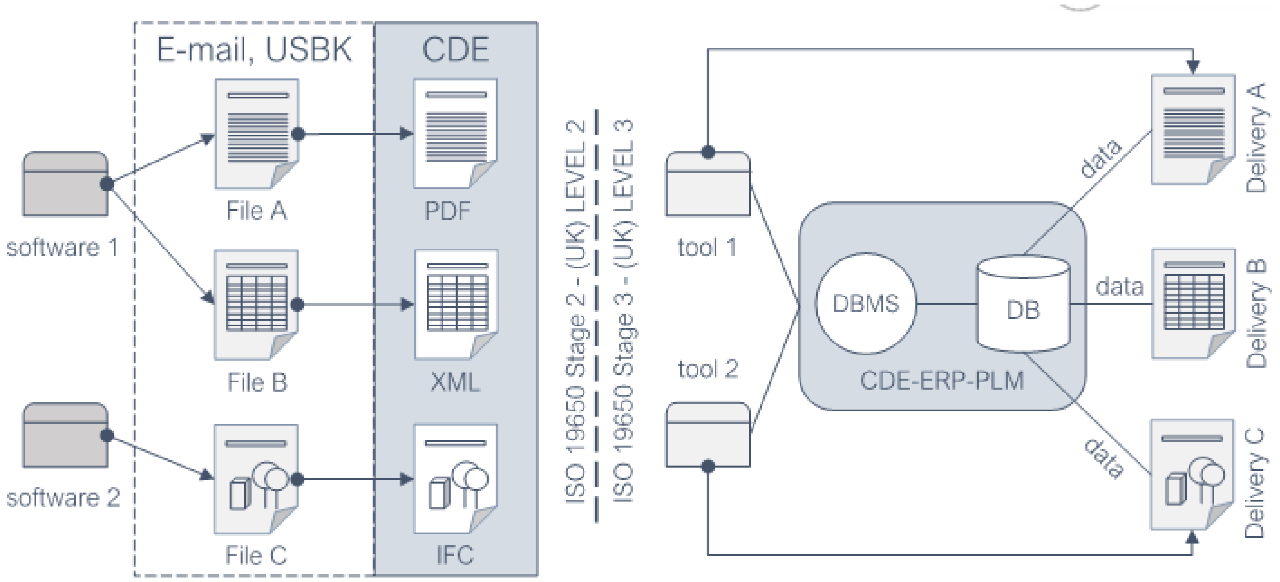


Figure 21. *BIM Environment (Alberto Pavan; 2021)*

Thus, **closed BIM,** also known as «lonely BIM», is a working approach based on the use of proprietary formats. This presupposes that in a working team it is necessary to use a single BIM software to be able to exchange information, and sometimes even the same software version. Consequently, the use of open and non-proprietary interchange files is not envisaged. The result is a closed and restrictive process that makes collaboration with professionals using different tools, applications and software difficult.

On the contrary, **open BIM** is based on methods and workflow in which all participants collaborate and exchange project information, using open, non-proprietary and neutral formats, regardless of the BIM tools and applications used.

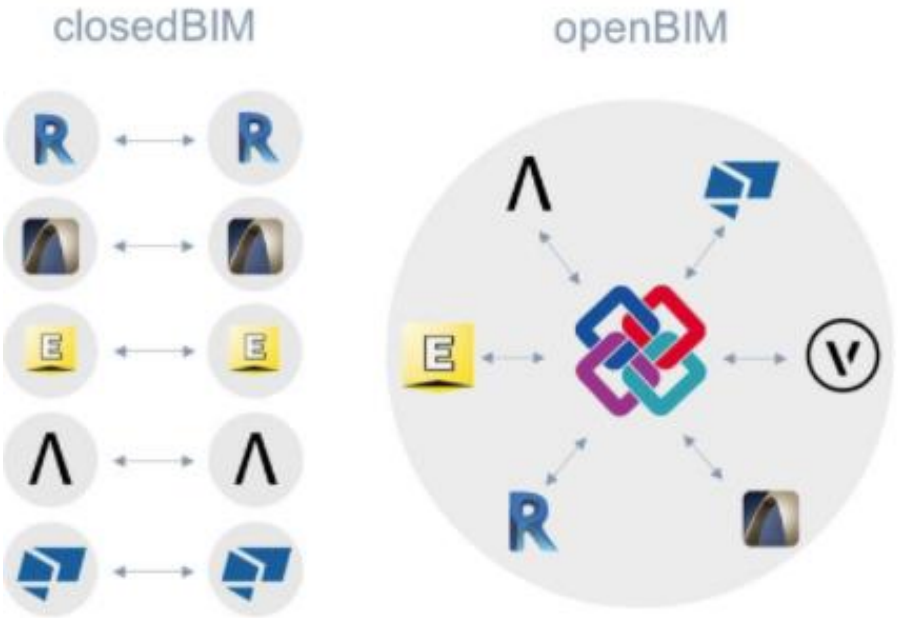


Figure 22. *Closed BIM vs. Open BIM (BibLus)*

The open BIM approach provides significant advantages for construction professionals, ensuring a smoother workflow and quality of the final result. Digital collaboration supports decision-making processes, reduces fragmentation of workflows, promotes transparency, and improves multidisciplinary team collaboration. In practice, it is certainly convenient for professionals to switch to open BIM to ensure:

- A more efficiency in internal processes;
- Effectiveness in achieving quality objectives;
- Continuous growth;
- More competitiveness;
- More effective communication;
- Shared procedures;
- Environmental sustainability;
- Constant accessibility to data;
- Greater collaboration and interoperability. *(BibLus)*

Therefore, open file formats can be read and edited by anyone. The IFC – **Industry Foundation Classes**, format is an open and neutral file format, designed by buildingSMART International to support interoperability between individual applications operating within the construction industry and **registered as an official international standard ISO 16739:2013**. It allows the interchange of an information model, without loss or distortion of data and/or information.

The IFC gives also the possibility to define the relationships between the building elements and therefore:

- Reports describing the components of an asset;
- The relationships that enclose the spatial configuration;
- Other reports linking the position of elements in systems, which is extremely useful for operation and maintenance of the building.

The IFC schema itself can be expressed in various file formats, most commonly as IFC-SPF but also as XML or a ZIP file:

- **IFC-SPF**: A text format in the modelling language of express data. It has compact dimensions and is the most used IFC format;
- **IFC-XML:** Although XML is a more common programming language, IFC-XML has a larger file size than IFC-SPF and is less used;
- **IFC-ZIP:** Is compressed format of the IFC-SPF file. A. ifcZIP file usually compresses between a 60% and an 80% .ifc and a 90-95%. ifcXML.

4- PROPOSAL FOR BIM BASED CONDITION ASSESSMENT PROCESS

Thus, taking into consideration what has been previously settled, how is it planned to be developed for the study project?

The process has been divided into two parts:

First of all, the work has been focused in a more deductive phase, searching and studying deeply all the related bibliography arising from the analyses made.

Of course, it is important to highlight the fact that this approach derived from technologies that could be considered as relatively new or at least innovative. Therefore, attempts have been made not to pigeonhole the study objective only in the bibliography that is strictly related, but also to broaden our search framework towards more traditional methods, in order to be able to take the strengths and weaknesses of the different options, with the aim of to provide a new approach that can be overcoming and at the same time more efficient for all professionals involved in the matter.

At the same time, we understand that the method can be very different depending on the context in which it was conceived, and the objective for which it is proposed. Thus, we have developed this case study into the Italian legislation, but having as references also international approaches. Is in this way that our main sources are:

- D.lgs. 9 aprile 2008, n. 81; Testo coordinato con il D.Lgs. 3 agosto 2009, n. 106 (Italian)
- D.lgs. 8 giugno 2001, n. 213 (Italian)
- NEN 2726-2 (Danish)

Secondly, it was created the practical bases that will be needed, in order to develop the case study. Based on an investigation carried out on different previous case studies, a flow chart matrix has been developed in which it is possible to identify the different roles and responsibilities of the people involved in the process. It has been also defined the technical bases that would be needed in order to develop the project in an accurate way.

4.1- FIRST STAGE: RESEARCH AND STUDY OF PREVIOUS CASE STUDIES

In order to have a framework in which to found and set the case study proposed in this thesis, we will develop two previous case studies, with bases and objectives similar to ours:

4.1.1- LIFECYCLE MANAGEMENT IN EUROPARCO REAL ESTATE COMPLEX

The project was developed using BIM softwares, such as Revit and Navisworks, and a web-based platform named Archibus. *(Immobiliare Real Estate; 2018)*

Archibus is an advanced tool for the management of the whole life-cycle of real estate. It is constituted of a Central Module of Control and different applicative modules:

- Asset management;
- Space management and planning;
- Management of the real estate portfolio;
- Management of capital projects;
- Management of resources;
- Maintenance;
- Services for the working – place.

It has been launched in 1983 in Boston; during the last years, its use has been matched with BIM methodology which has increased the management of real estate. It is an extension for AutoCad and

Revit, creating a link to the elements modelled in BIM; then, the Web central 3D Navigator extension allows people to view the 3D model of the building. *(BIM portale; 2022)*

The Europarco real estate case study was "Selected for the exemplary integration between BIM implementation tools and real estate management systems". With this motivation, the jury of the Digital & Bim Award 2017 included the Europarco project of the company eFM among the finalists in the "Large-scale construction" category, which involves the construction and management of two office buildings in Rome.

BNP Paribas REIM SGR, manager of the "U-Turn" real estate investment fund, has commissioned eFM to implement the BIM for the Europarco project, which involves the construction of two buildings, for office use, for approximately 60 thousand square metres. BIM was used in the project starting from the executive design phase up to the management phase.

Starting from the two-dimensional executive projects, parametric BIM models were created by preparing a federated model, divided by disciplines, which through the analysis of clash detection highlighted about 80 design interferences, whose resolution led to a saving of 1, 5 times the cost of modelling the executive project in BIM.

The models of the buildings were integrated with the management tools to make a forecast of the future management costs of the buildings, with particular attention to the technological components and the planned maintenance plans. This has ensured a better understanding of the properties of the properties, allowing the development of accurate and detailed service specifications, the basis for the future activation of monitoring and control methods for the performance of services. During the implementation phase, the methods for updating and checking the models were also defined. The updating of these is guaranteed through the collection of information on the installed components and also thanks to the back-office activity, verifying and validating the information entered, associating the technical documentation with the components.

For the management part, it was used the Archibus software. The model of the work was then integrated into the IWMS management platform: the application of BIM specifications that makes it possible to use all the information assets of the management software, reducing the traditional times for making the property known, estimated in about 3 months for complexes of this size.

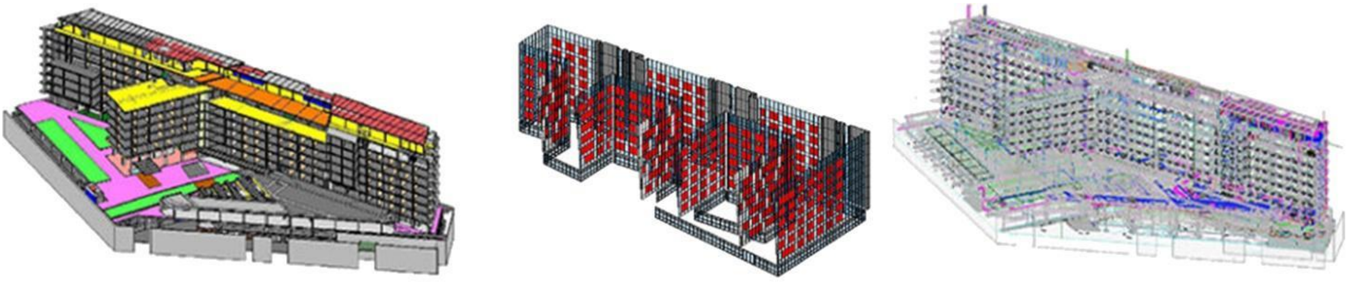


Figure 23. *Coordination models (Immobiliare Real Estate; 2018)*

4.1.2- BIM-ENABLED CONDITION ASSESSMENT TOOL

The large amounts of data that are created and required by various stakeholders through the lifecycle of a building creates a daunting information management task The use of Building Information Models (BIM) aims to simplify this task by creating a single unified information repository that can serve various disciplines at different stages of the facility lifecycle. *(Mamdouh Al-Gendy, Hesham Osman, Mahmoud Taha, 2012)*

The case study main objective is to develop a BIM-enabled building condition assessment tool to ensure consistent and cost-effective inspection of building components based on the use of Autodesk Revit architect software as the tool platform. The developed BIM tool will enhance the capabilities of the condition assessment of facilities.

The authors of this case study have developed, in addition to the existing Revit parameters, an assessment tool added its own inspection data fields:

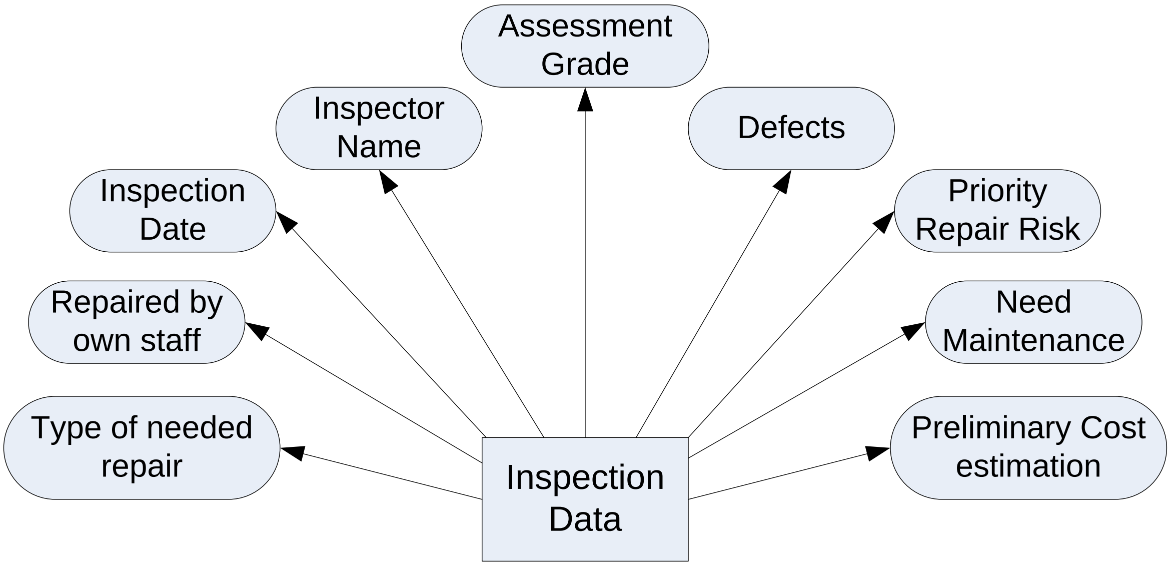


Figure 24. *Added inspection data fields (Mamdouh Al-Gendy, Hesham Osman, Mahmoud Taha; 2012)*

These inspection fields have some stored values from which users can select. For example, the type of needed repair field has three values as shown in *Figure 25*.

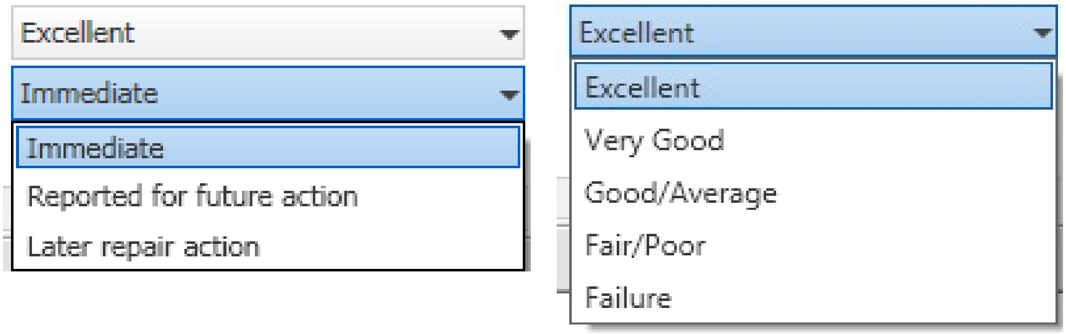


Figure 25. *Options of the assessment tool data input of some fields (Mamdouh Al-Gendy, Hesham Osman, Mahmoud Taha; 2012)*

It was also possible to apply an image to the selected component: first of all, it is the original picture, and secondly, a set of standard images of different types of deterioration.

Figure 26. *Standard deterioration images (Mamdouh Al-Gendy, Hesham Osman, Mahmoud Taha; 2012)*

The developed assessment tool was tested by eleven experts in the field of operating and maintenance of educational facilities. The tested experts are classified into two categories:

i. Maintenance department Managers of eight surveyed universities.
ii. Three consultant engineers in the field of maintenance and construction in general.

The assessed strengthen point of this case study were:

- The tools covers a considerable parts of the inspection tasks
- It allows inspectors to roughly estimate the cost for the urgent maintenance tasks of each building component individually.
- The tool saves time consumed in the assessment of defects since it standardises the assessment process and verifies the judgement through a standard deterioration images for each building component.

- It enhances the communication between managers and field inspectors.
- The tool makes the repair cost more determined since each inspection defect cost is preliminary estimated by the inspector.

On the other hand, the tool has shown some limitations, such as:

- The tool requires the existence of 3D-Revit model for each inspected building. The inspection data are added to building component within Revit architect. Construction of Revit models represents a big obstacle especially for old buildings.
- The tool included fifteen building components only which covers most of the visible architectural components. It doesn't cover maintenance of the structural components such as columns, beams, slabs and foundations. Structural elements can be included using Revit structure software.
- There are some difficulties in forming the standardised deterioration images for the components deterioration stages especially when the building components are new. The element manufacturers can supply such images.
- The tool is working in a single user application. In other words, data can't be shared among the whole maintenance staff. *(Mamdouh Al-Gendy, Hesham Osman, Mahmoud Taha; 2012)*

The case study asset is two stories classrooms buildings with a single entrance gate.

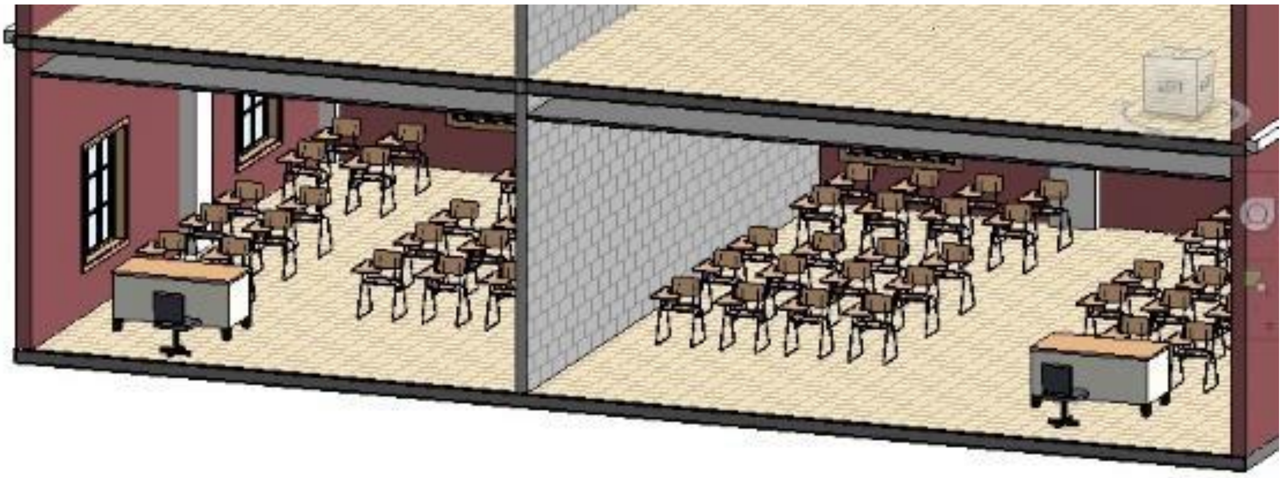


Figure 27. *Case study: Architectural Revit model (Mamdouh Al-Gendy, Hesham Osman, Mahmoud Taha; 2012)*

Thus, the final aim of this case study was to develop an BIM-enabled integrated tool for the inspection and condition assessment of building components that can overcome the drawbacks of the manual traditional practices of such processes.

The authors of this case studied had concluded that the presence of preliminary estimated cost for the defect repair makes it easier to assign more definite budgets.

Furthermore, the option to perform reports coming from these kinds of analysis have helped for a better repair decision making, and a greater traceability of the life-cycle of each component, and also of the building as a whole.

4.2- SECOND STAGE: DEVELOPMENT OF THE TECHNICAL PROPOSAL

The final aim of this thesis is to develop a condition assessment using BIM softwares as a tool, in order to verify the original assumption that it would become the process more transparent, efficient and reliable.

It was developed an integration of the searched bibliography and the previous cases study analysed, with the real case study of the «G. Clerici Arredamenti showroom», located in Suno, Piedmont. To do this, it was created a Building Execution Plan, or BEP.

The intent of the BIM Execution Plan (BEP) is to define a foundational framework to ensure successful deployment of advanced design technologies on your BIM enabled project. The BEP is about optimising work and model flow across the project, as contrasted with optimising siloed interests *(GSA; 2019)*. Thus, it is a comprehensive document that helps project participants move forward with clear roles and expectations.

A BIM Implementation Plan can provide a number of key benefits. As a guiding document that helps different members of the team identify and execute the function BIM provides in the various phases of the project, it can help everyone stay on the same page and present a clear plan of goals and targets every step of the way.

- **Stronger communication**: Having a plan in place encourages early communication. It also establishes who is responsible for communicating information along different stages of production, while prescribing responsibilities in certain areas.
- **Alignment on standards and collaboration**: This is particularly important for large or international projects, where different regions might have different protocols, standards or regulations. International teams can collaborate via a single plan, preventing the creation of silos and multiple plans or ideas on how to do things that might not all fit together.
- **Save a lot of time**: It might take time to put the plan together, but once it is up and running, it will set out key deliverables, procedures and other information that will streamline the BIM process and keep everyone moving forward. This can save a lot of time in the long run. *(Matt Ramanage; 2022)*

During the process development of the Condition Assessment, these key benefits could be seen reflected in a more **fluid communication** and an **alignment of goals** with the technicians and specialists who will be responsible for each activity, with a considerable **time saving**, due to a more efficient search of information, data verification, and share of the results obtained.

Above all, these benefits will be exploited during the follow-up phase, where it will be possible to make much more efficient the evolution analysis of the asset and its components.

4.2.1 – PURPOSE

All the requirements and recommendations coming from this analysis apply to all the parties involved in the condition assessment process. This document reflects the current proposal for the project, which could be review and amended in line with each project requirement.

Thus, the purpose of this project is to support the Condition Assessment process of an asset, using BIM implementation techniques.

4.2.2 – ROLES AND RESPONSIBILITIES: RACI MATRIX

1. Roles
    a. **Client [C]:** It is the appointing party, thus the owner or responsible of the asset that will be analyzed.
    b. **Building Manager [M]:** It is the lead appointed party, thus the Condition assessment responsible.
    c. **BIM Coordinator [B]:** Appointed party. It is a BIM specialist that will be in charge of all the activities related the manage, programming and updates of the BIM tool proposed, in order to develop the condition assessment prosses, leaded by the PM.
    d. **Specialist [S]:** Appointed party. These are the technicians and professionals responsible of developing the activities carried out during the condition assessment process, for each particular discipline.
    e. **Law [L]:** Appointed party. It is the regulatory entity that will give a legal framework to the works that will be carried out through the condition assessment, and the one in charge of approving them.

2. Responsibilities
    a. **Responsible [R]:** Those who do the work to achieve the task. There is a least one role with a participation type of responsible, although others can be delegated to assist in the work required.
    b. **Accountable [A]:** Also considered as the approver or the final approving authority: The one ultimately answerable for the correct and thorough competition of the deliverable or task, and the one who delegated the work to the responsible.
    c. **Consulted [C]:** Those whose opinions are sought, typically subject matter experts; and with whom there is two-way communication.
    d. **Informed [I]:** Those who are kept up to date on progress, often only on competition of the task or deliverable; and with whom there is just one-way communication.

	Activity	C	M	B	S	L
1	Request for a Condition Assessment. The client asks to a building manager the development of a condition assessment.	R	A	-	-	-
2	Compilation of existing information. The building manager is the responsible to collect all the data related to the asset, in order to understand the whole state of the building.	C	R	-	C	C
3	Detection of criticalities present in the building and its components. The building manager, assessed by specialist and informed of existing condition by the client, is the responsible of carrying out an analysis of the degradations, obsolescence and criticalities that could be founded in the building.	I	R	-	C	C
4	Establish the BIM Execution Plan. The BIM coordinator must to develop this contractual document, in which all the BIM project information requirements must be settled out for all the parties involved.	I	A	R	C	C
5	Compilation of the necessary information in relation to current regulations.	I	R	-	C	A
6	Development of BIM model. All the collected data must be uploaded/updated in the BIM model.	-	A	R	-	-
7	Condition assessment development. The Building Manager develops the condition assessment, according to the visible information collected in the BIM model, and adding the corresponding notes/comments to each item. The client must to approve the condition assessment activities.	A	R	C	-	I
8	Analysis of the status of the items and the asset as a whole thought the BIM model	C	R	A	C	-
9	Analysis for several improvement proposals	A	R	I	C	C
10	Budget presentation, analysis and approval. This budget will be carried out from the information that could be extracted from the model, having into consideration both the quantities, and the near affected elements.	A	R	-	C	-

11	Professional approval of improvements	I	A	I	R	-
12	Approval of the modifications by the regulatory entity	I	A	-	C	R
13	Update of the model. The new state of the object will be updated on the BIM software. Furthermore, it must be updated the date of the new inspections and the related comments that must have being into consideration for future assessments.	-	A	R	-	-
14	Update the information to the CDE. In this manner, all the technicians and stakeholders involved will be updated about the status of the asset, the considerations for future assessments, and the dates of future inspections.	I	A	R	I	-
15	Periodical check of the calendar of inspections. Such as the elevators, that must be checked each month.	A	R	C	A	-
16	Monitoring of the evolution. A new condition assessment must be carried out periodically, in order to check: - The status of the elements that have been intervened because of its criticality - The status of those elements in «yellow», that have not been intervened - The status of degradation and obsolescence of all items	A	R	I	C	C

In order to understand how these roles and responsibilities are related to each other, and how s the flow if the information, it has been developed a flow chart matrix, as you can see in the figure below:

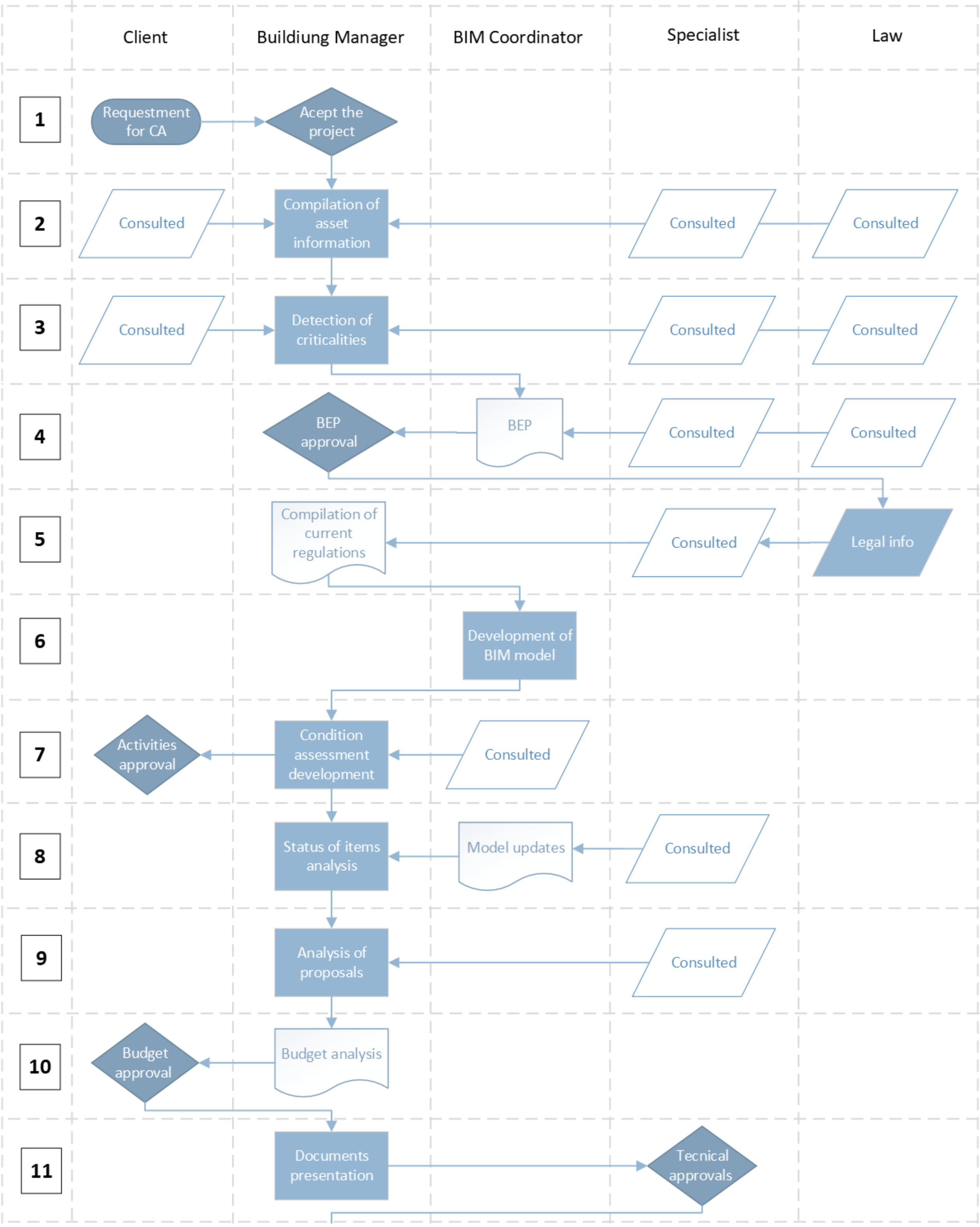


Figure 28. *Project parameters – Selected categories (1st part)*

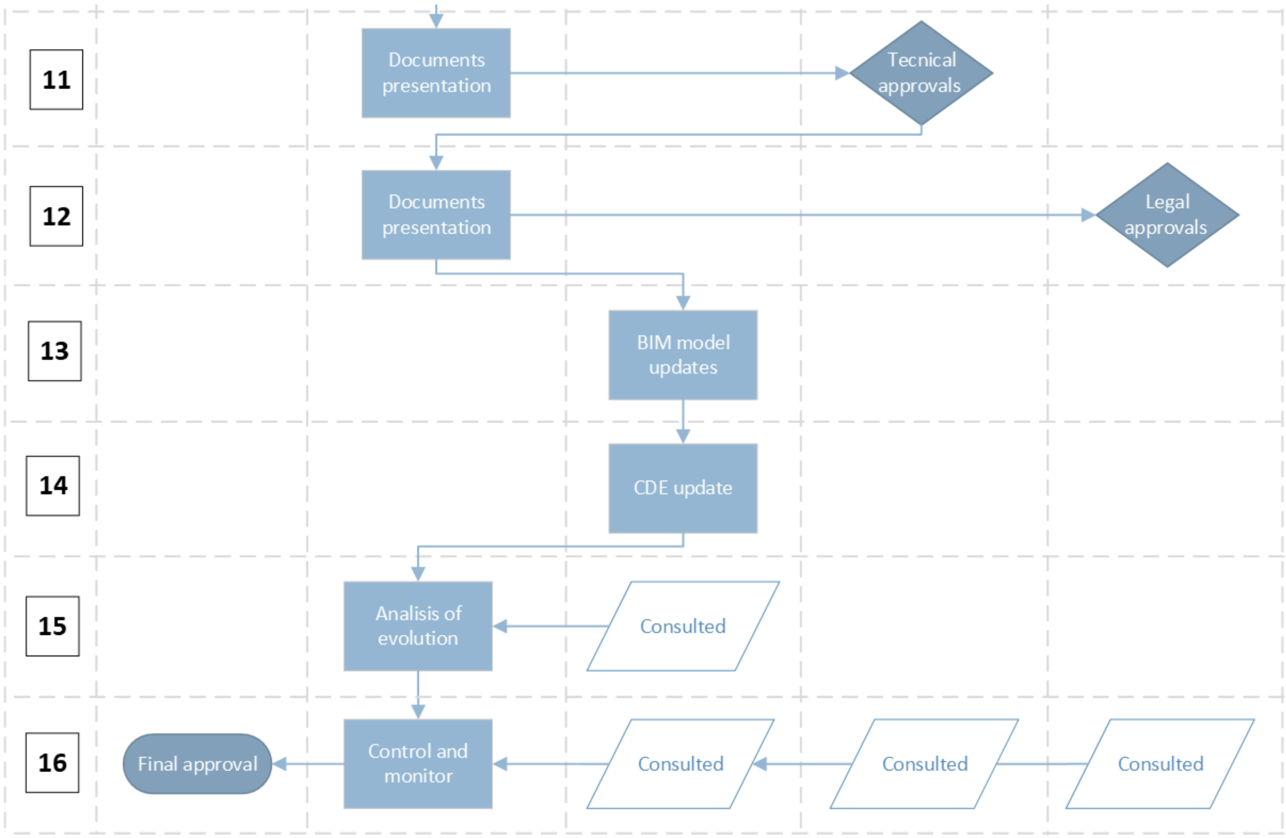


Figure 28. *Project parameters – Selected categories (2nd part)*

4.2.3 – SOFTWARE PLATFORMS

For the optimal development of this thesis, it was proposed that all 2d and 3d graphical information will to be managed using the software and formats as indicated in the table below. Nevertheless, this could be updated depending on the nature and particular requirements of the project:

Use	Software Platform	Version
Design	Autodesk Revit Autodesk AutoCAD Autodesk Navisworks Archibus	To verify

Condition Assessment	Autodesk Revit Autodesk Navisworks Microsoft Excel	To verify
Time Management	Autodesk Navisworks Microsoft Excel Microsoft Project Primavera	To verify
Cost Management	Autodesk Revit Autodesk Navisworks Microsoft Excel	To verify
Document Review	Microsoft Word Microsoft Excel Adobe Acrobat Reader	To verify

4.2.4 – DATA STORAGE

It is extremely important to define the CDE of the project, in order to guarantee a correct flow of information, and an efficient condition assessment.

In this case, it is proposed the utilization of BIM360 managed by the BIM coordinator as Common Data Environment. Furthermore, the access to project information will be controlled collaboratively by the Project Manager.

4.2.5 – LEVEL OF DEFINITION (LOD) AND LEVEL OF INFORMATION (LOI)

It is important to define the level of detail that is required for the good development of a condition assessment thru BIM. This not only ensures that the design is developing in sufficient detail, but also that the information required to operate the task efficiently, is actually provided. It also gives an indication of the reliance that can be placed on information. (BIM Wiki; 2022)

It is important at this point to highlight the difference between Level of Detail and Level of Information. PAS 1192-2, now replaced by BS EN ISO 19650, defines these two components to the 'level of definition':

1. **Levels of model detail (LOD)**: It is related to the graphical content of models; thus, the geometrical complexity of the components.
2. **Levels of model information (LOI)**: It is related to the non-graphical content of models; thus, the information contained in its components.

Therefore, thinking in a as-built project, it would be possible to have a not that complex geometrical element, but it would be required an extremely high level of information.

It is important therefore to define the LOD and LOI that would be required for the optimization of the condition assessment proposed in this thesis. This not only ensures that the work is been developed with a sufficient level of detail, but also that the information required to operate the condition assessment process efficiently is actually provided.

Below it will be possible to see the proposed scale of LOD and LOI required for this thesis:

Discipline	LOD	LOI
Civil	200	400
Architecture	300	400
Structure	300	400
Mechanical	350	400
Plumbing	350	400
Electrical	350	400
Lighting	350	400
Fire	350	400
Security	350	400

4.2.6 – NAMING CONVENTION

It is important to develop a naming convention for all the elements composing the asset, at the beginning of the condition assessment. For the scope of this thesis, it was proposed a system composed both by the category of the element, thus the Breakdown Structure, and an identity number:

1° LEVEL Breakdown Structure Code	2° LEVEL		
	Category	Level	ID Number
21-41 51 13 11	WI	2	03
	WI2.03		

5- CASE STUDY

5.1- DESCRIPTION OF THE CASE STUDY

The building we have chosen is the G.Clerici Arredamenti showroom, located in Suno (NO), Piedmont; it is around 1500 square metres/each floor. The construction was built in the 50s, by Giuseppe G.Clerici with the help of his father; they were two carpenters and they realised the shop in very few time. Nowadays the building is managed by Giuseppe's daughters and his grandchildren. According to the fact that they were two carpenters, in the courtyard behind the building there is also a carpentry where they made custom furniture.

The construction is made up of three floors and one basement which is used as a warehouse for the furniture which are not exposed in the showroom or are waiting to be delivered to the clients. The ground floor is composed of a showroom of modern furniture, especially here you can find kitchens and the furniture dedicated to the living room; there are also three small offices and the services which can be used both from the staff and from the clients. From this point people can also find the circulation core composed by an elevator, stairs and lift-track, this last one is mostly used by the staff in order to move the furniture.

In the mezzanine it is possible to find the main office which is also connected with a new part of the building in which, a few weeks ago, has been inaugurated a new gym and a co-working space; here you can also find a bathroom which can be used both by the people using the gym and the ones working in the other offices.

The first floor is composed of another showroom, the accounting office and another bathroom.

Then, continuing to climb the stairs, you reach the second floor where you can find another showroom dedicated for the bedrooms' furniture; there are both furniture for double room and for children's bedrooms. On the third and last floor there are the apartments of Giuseppe and his daughters.


Arrediamo il tuo Spazio
CLERICI

5.2- BREAKDOWN STRUCTURE

The initial phase of the analysis was to develop a Breakdown Structure of the case study, in order to have both a global knowledge of the functioning of the building as a whole, and the identification of all its components. To do the work it was followed the OmniClass Code.

1. The first analysis was developed using Table 11, that describes the Construction Entities by Function which "are significant, definable units of the built environment consisting of interrelated spaces and elements and characterised by function". The case study was identified as a *Commercial Facility* in the first level, and more specifically as an Office Showroom. Please refer to *Figure A-01* in the Annex.

2. Secondly, it was developed the breakdown structure of the building, according to the functions of its spaces. To this work it was followed the OmniClass Code, more specifically, Table 13. This table describes the Spaces by Function which "are basic units of the built environment delineated by physical or abstract boundaries and characterised by their function or primary use". To visualise the breakdown by spaces, please refer to *Figures A-02.A/B/C/D* in the Annex.

   Moreover, the breakdown developed in order to identify the spaces was translated into our BIM model, in order to see reflected in our digital representation of the asset, and in a global manner, all the spaces and its relationships. It will allow us in the possibility to develop a due diligence and a future monitoring of the asset in a more controlled and clean manner. To visualise the floor plans with its respective codification, please refer to *Figures A-03.A/B/C/D* in the Annex.

3. And lastly, the asset was analysed technically, guided by the OmniClass Table 21. This table describes the Elements, which is a major component, assembly, or "construction entity part which, in itself or in combination with other parts, fulfills a predominating function of the construction entity" (ISO 12006-2). To visualize the breakdown by elements, please refer to *Figure A-04.S/B/C* in the Annex.

   This last classification will allow us to study the technical aspects of the building, and to monitor all its elements in a global manner, controlling all of them in a 3d visualization.

The breakdowns structures developed will allow us to identify clearly all the components of the asset. This is a powerful tool in technical assessment.

It is important to highlight that in this kind of study several stakeholders will be involved in the process. All these actors usually do not use the same type of language, and even more, usually the communication flow is developed in different channels. The possibility of using the several features of BIM as unique language and as a CDE, will prevent the several stakeholders from possible misunderstandings of missing information.

5.3- DESCRIPTION OF THE ANALYSED AREAS

As said before, the analysed building is located in Suno, Piedmont and was built in the mid – 1950s; it is an imposing structure, developed on four floors above ground and one semi – basement that serves as a warehouse area. Each floor has a rectangular shape with a development of about 1500sqm.

The entire construction is made up of two big parallel volumes A and B; volume B is under construction and renovation and for this reason we have decided to omit the study of the latter and focus our analysis on volume A and in particular with the renovation of the office area and the first floor where customers are welcomed.

Please refer to the *Figure A-05* the Annex to see the floor plan of the analysed area.

5.3.1 – OFFICES AREA

The area in consideration is located both on the first floor and on the mezzanine – floor, and it is composed by three offices:

1. **Office 1 – Mezzanine**: about 44 square metres, it is dedicated to the meetings and with customers;
2. **Office 2**: about 10 square metres, is dedicated to the document's management;
3. **Office 3**: about 10 square metres, is also dedicated to the projects and the consultations with clients.

Office 1 - Description

The attention has been focused on the area of office 1 for its particular central position between the two volumes that causing problem in temperature due to the presence of an empty and open area below (please refer to Figures 9, in page 10 of the Annex), for the passage of vehicles for loading and unloading goods in the ground floor's warehouse.

Being this an area of continuous passage of means of transport, both working trucks and private cars, it is not possible to create a closure as it would obstruct the transit; this is the reason why, during the analysis we have tried to understand which alternatives could be taken to increase thermal comfort at this point.

During the condition assessment of the building, it was therefore understood the criticality that this point brings with it; for this, the area in consideration has been reported as a critical node to which technicians must pay particular attention during the development of the maintenance plan.

In *Figure A-06* from the Annex you can see the section of the building, where it is possible to identify the specific location of the office.

Structural part:

1. The office is located on the mezzanine floor, 5.56 m from the ground, and rests on a floor the concrete brick internally covered by a granite floor, and vertically closed by walls in reinforced concrete mixed with bricks covered with taupe – coloured plaster.

2. Natural lighting comes from both sides: two rows of ribbon windows that can be opened, respectively with eyelash heights of 60 cm and 240 cm; and two single-leaf windows with an edge height of 100 cm. The largest windows, located on the north side of the building, are equipped with an internal curtain necessary especially for the summer season, so as to limit the entry of the sun and its heat. These are roller – blinds by means of a rope system and the structure is fixed on the ceiling.
3. With regard to artificial lighting, the office is equipped with a light band that runs along its entire length and two lamps hanging above the desk, so as to ensure a correct and constant lighting on the workstations. Please refer to *Figure A-07* to see a picture of this area.

Internal Furniture:

1. Inside the office there are two main workstations, necessary for the design development phase and then, both for the preparation and for the comparison with the customers for the various projects and estimates – proposed; moreover, each desk is equipped with a PC workstation. In this environment there are several cupboards, two located behind the desks (dark – wood) and one, white, below the windows; in these all the main catalogues are preserved.

Heating system

1. The heating system in this room is that of convectors; there are two units located on the south – wing of the office, adjacent to the desks, through which it is possible to heat the room in the winter. As already said, however, having an open area below, this system is not very efficient, and, therefore, it will be necessary to provide for a replacement/improvement of what is now present.

Office 2 - Description

The office indicated as “office 2” has an area of about 10sqm and it is mostly used as an administration area, in which it is possible also to find the checkout with which receipts are made to customers. In this room it is also possible to find an armoury which contains all the documents related to the various estimates and the delivery – notes necessary for the organisation and the delivery of the material. Please refer to *Figure A-08* to see a picture of the analysed area.

Structural part:

1. The office is located on the first floor, 3,87m from the ground; as for the structure of this office, here too is possible to find an external structure, realized of concrete bricks internally painted with green and white plaster and a floor covered in granite.
2. The entrance of natural light is guaranteed by the presence of a window located above the radiator on the wall on the west side; it is a hinged opening, also equipped with a white curtain that ensures an improved comfort by limiting the entry of solar heat in the summer.
3. With regard to artificial lighting, the office is equipped with a light band that runs along its entire length and two lamps hanging above the desk, so as to ensure a correct and constant lighting on the workstations.

Internal Furniture:

1. As for the furniture, inside the office is possible to find a wooden desk, some shelves, a wardrobe which contains all the necessary sales and delivery documents and an additional cupboard on which is placed the cash – register.

Heating system

1. The heating system in this room is that of a single radiator located under the window.

Office 3 - Description

The office indicated as “office 3” has an area of about 10sqm and it is used, as office 1, to develop the projects and to consult with clients; it is a small, but comfortable office. The organisation of the office is very simple, but designers can find here everything they need. Please refer to *Figure A-09* to see a picture of the analysed area.

Structural part:

1. The office is located on the first floor, 3,87m from the ground; as for the structure of this office, as already said for Office 2, here too is possible to find an external structure, made of concrete bricks internally painted with grey plaster and a floor covered in granite. The South, East and North walls of the room consist of stained-glass windows, with wrought iron structure that give the office a great visual permeability, allowing designers to immediately notice the entry of a new customer in the showroom.
2. The entrance of natural light, in this environment, is allowed by a hinged window located on the west wall, and, also in this case, it is equipped with a curtain (sliding) that allows to regulate the entry of the sun and its heat.
3. For the artificial light, a light source (current lamp) has been set up above the desk area, ensuring constant lighting during work.

Internal Furniture:

1. As for the furniture, inside this office it is possible to find a large wooden desk located centrally from the room where designers develop their projects and then discuss them with customers. Adjacent to the desk, placed under the window in the room, there is a low wooden - cupboard that occupies the entire east wall and ends in a wardrobe of the same material and colour. A particular element that you can find in the room is the “tecnigrafo”; it is a structure with a blackboard, illuminated by an adjacent lamp, where designers developed their projects.

Heating system

1. The heating system in this room is that of a single radiator located next to the wardrobe in the entrance area.

5.3.2 – SHOWROOM AREA

Another fundamental area which must be analysed is the one situated on the first floor, where it is possible to find a part of the exposition of the furniture, two offices and a service area with toilets. Here customers are welcomed, in the area used as a hall and they can view part of the furniture that are sold in the show – room.

This floor has a total extension of about 110sqm and in the façade it is almost totally covered by large windows alternated by iron pillars; the presence of so much glass obviously brings with it both benefits and problems.

Thanks to these, the show – room is perfectly visible also from the external road, therefore, the customers have the possibility to understand, already from the outside, if they are interested in something or not.

This, however, also creates the most important thermal bridges, due to the fact that the façade is not perfectly insulated, therefore going to cool the environment which represents a major problem especially in the winter season.

5.3.3 – FAÇADE

The façade is made up of walls in reinforced concrete mixed with bricks covered with grey plaster for a total extension of about 1100 square meters. Its peculiarity lies in the vertical wall cuts that decorate the facade itself with a play of shadows and lights (please refer to Figure 14 in page 11 of the Annex and please refer to Figure 15 in page 12 from the Annex to see Analysed façade – Elevation). The entire facade, as was previously said, consists of a large window that allows people to observe from the outside the furniture in the exhibition. This solution has some positive aspects, but also some negative results; it allows the environment to be constantly illuminated, a fundamental aspect for a show – room and creates a strong connection with the outside world, arousing greater interest; on the other hand, one of the most negative aspects that can be found is the thermal bridge that these surfaces are prone to create, moreover, since glass is not an insulating material, it allows both summer heat and winter cold to penetrate the indoor area more easily.

5.4- CRITICALITIES

5.4.1 – VERTICAL CLOSURES

Since the building dates back to the 50s, of course it suffers from lack of proper thermal insulation layers inside the walls and the quality of other layers in terms of technology they used in that period is not as good as the materials nowadays'. Seen from another way round, during these years, the building and its outside layers have been faced with degradation and decrease in their efficiency.

This is an issue that is harmful both during the cold seasons, when the heating system is not efficient because of the loss of heat, but also during the warm seasons, when the unappropriated insulation makes the air conditioning system less efficient too.

If we speak more specifically of the area of the offices, this is a critical point, since it is located as a bridge, connecting the two major buildings, avoiding the direct radiation of the sun for the whole time of the day. This is an advantage during the warm seasons, but during the cold seasons it will intensify the problem of heating of the building.

Another important point to be considered are the windows which bring with them both positive and critical aspects; they are composing a large area of the external closure (approximately 35-45% of the area), they are important in terms of natural lighting and they constitute a very important filter between the internal and the external of the building.

On the other hand, for the showroom façade, and more specifically the ground floor, the presence of the courting walls in the entire façade represents a major not insulated area which creates thermal bridges, and incurs in a lower efficiency of the heating and air conditioning systems.

Considering all the facts that are explained above, the composition of the exterior walls, and more specifically its insulation, and the exposed glazed areas are one of the sources of issues.

5.4.2 – HEATING AND COOLING SYSTEMS

It is clear that the technology of these systems is going to be updated as time goes, and the technology of these systems used in the building is out of date and does not have the proper level of efficiency in terms of power consumption.

Also, if we do not modify the building itself and increase its construction technology in terms of walls, windows, floors and roofs; changing the heating and cooling system will be useless.

Considering the proposals to solve the above-mentioned issues, changing the cooling and heating systems that have better efficiency in power consumption and are in more accordance with sustainability and environmental issues could be a useful solution.

This change, in the heating and cooling systems, could especially affect the thermal comfort that could be found in offices; for the show – room area, the “simple and only” change of the heat source may not be enough (whereas it is an open space of about 1100sqm).

5.5- DEVELOPMENT OF THE CONDITION ASSESSMENT THRU BIM

This last phase of the thesis has been dedicated to the practical development of our study, having as base point the notions obtained in previous phases. Thus, it has been built the BIM model in Revit Architecture of the case study, to then develop an analytical-descriptive mapping of the various areas analysed.

This information would be reflected also on a 3D view, in which it would be visible thru different colours the criticality situation of each component, thus allowing decision-makers to have a quick action upon degradations, depending its criticalities.

Thus, the proposal is to include in one unique software all this data collection, and also make this available to all the technicians. Of course, to allow the information to all the professionals involved, could become a double-edged sword. Is in this way that our proposal is to maintain the control of the model with the Facility Manager, which will manage the level of information provided to each technician, and if this information will be just visible or also editable.

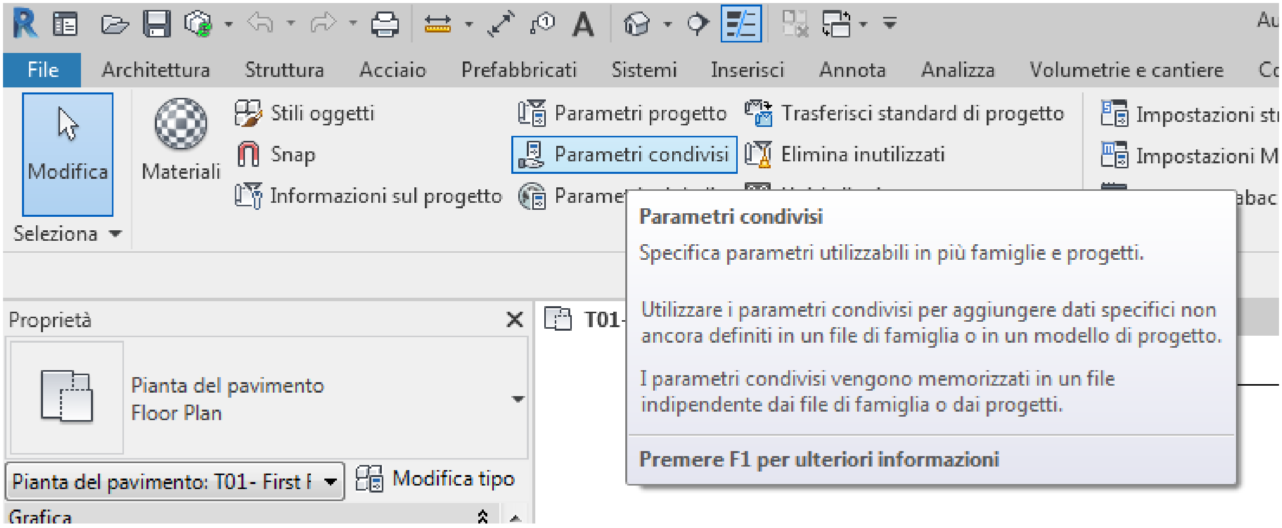
In this way, we are reducing the risk of loss of information in communication between parties, allowing the global vision of the project by all the professionals involved, as well as keeping the general management of the project in the hands of one person.

To do this, firstly, and in order to guarantee that this could be a standardised system, it was created a set of shared parameters, that will allow to identify each element of the asset according to the Breakdown Structure, and to monitor and study its life cycle in a standardised manner.

The shared parameters are parameters that could be applied to families or projects and then been shared with other families and projects. Thus, we can say that it gives us the possibility to standardise the type of attributes included in our models. They give you the ability to add specific data that is not already predefined in the family file or the project template. *(Revit Architecture 2011 User Assistance)*

In *Figure 29* is shown how to insert these standardised parameters, and in *Figure 30* is the list of shared parameters created for the purposes of this project. It has been divided into different groups, depending on the number of inspections. Thus, after each inspection, it will be possible to see all the data and to monitor the process of each item.

Once the shared parameters have been inserted on the model, they become project parameters, and could be applied to all the category elements that would be affected by the condition assessment analysis, as it is shown in the *Figure 31*.



Parametri condivisi

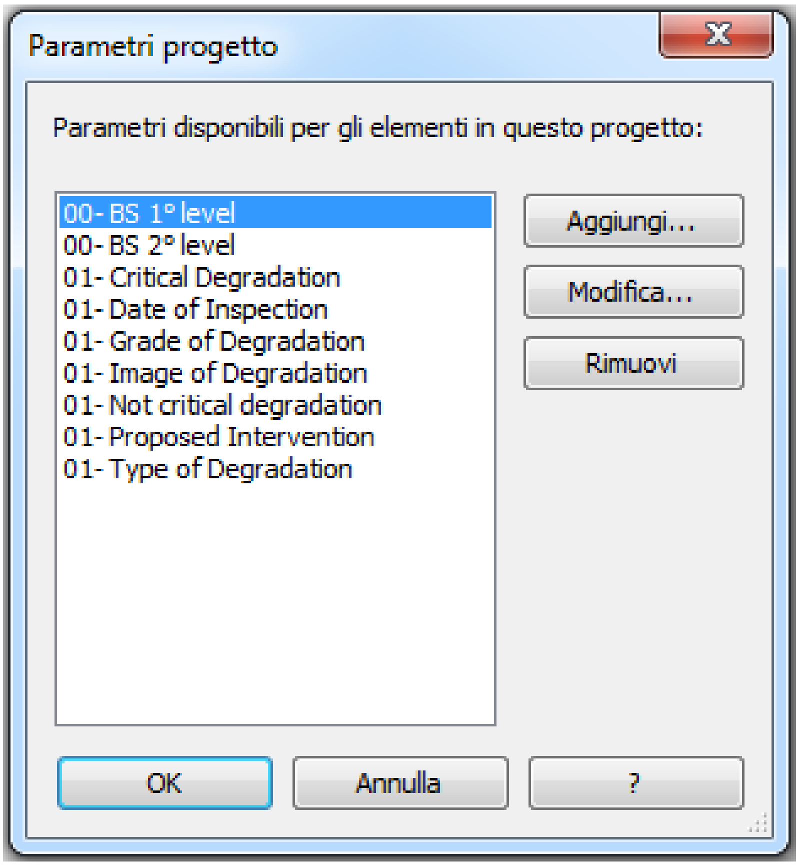
Specifica parametri utilizzabili in più famiglie e progetti.

Utilizzare i parametri condivisi per aggiungere dati specifici non ancora definiti in un file di famiglia o in un modello di progetto.

I parametri condivisi vengono memorizzati in un file indipendente dai file di famiglia o dai progetti.

Premere F1 per ulteriori informazioni

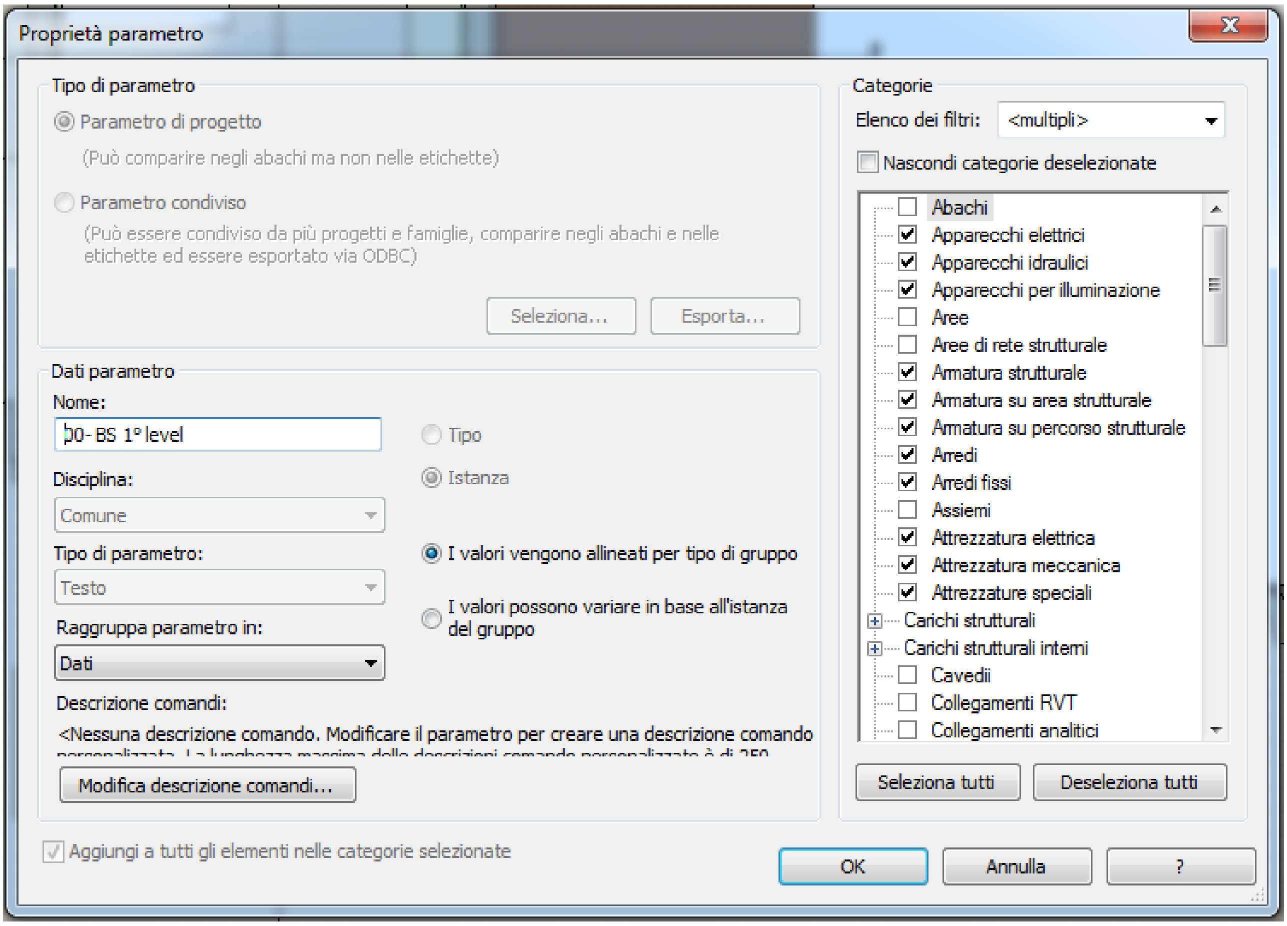
Figure 29. *Shared parameters upload*



Parametri disponibili per gli elementi in questo progetto:

00- BS 1° level
00- BS 2° level
01- Critical Degradation
01- Date of Inspection
01- Grade of Degradation
01- Image of Degradation
01- Not critical degradation
01- Proposed Intervention
01- Type of Degradation

Figure 30. *Shared parameters list*



Proprietà parametro

Tipo di parametro

● Parametro di progetto
(Può comparire negli abachi ma non nelle etichette)

○ Parametro condiviso
(Può essere condiviso da più progetti e famiglie, comparire negli abachi e nelle etichette ed essere esportato via ODBC)

Seleziona... Esporta...

Dati parametro

Nome: 00- BS 1° level

Disciplina: Comune

Tipo di parametro: Testo

Raggruppa parametro in: Dati

○ Tipo
● Istanza

● I valori vengono allineati per tipo di gruppo
○ I valori possono variare in base all'istanza del gruppo

Descrizione comandi:
<Nessuna descrizione comando. Modificare il parametro per creare una descrizione comando

Modifica descrizione comandi...

Categorie

Elenco dei filtri: <multipli>

☐ Nascondi categorie deselezionate

☐ Abachi
☑ Apparecchi elettrici
☑ Apparecchi idraulici
☑ Apparecchi per illuminazione
☐ Aree
☐ Aree di rete strutturale
☑ Armatura strutturale
☑ Armatura su area strutturale
☑ Armatura su percorso strutturale
☑ Arredi
☑ Arredi fissi
☐ Assiemi
☑ Attrezzatura elettrica
☑ Attrezzatura meccanica
☑ Attrezzature speciali
Carichi strutturali
Carichi strutturali interni
☐ Cavedii
☐ Collegamenti RVT
☐ Collegamenti analitici

Seleziona tutti Deseleziona tutti

☑ Aggiungi a tutti gli elementi nelle categorie selezionate

OK Annulla ?

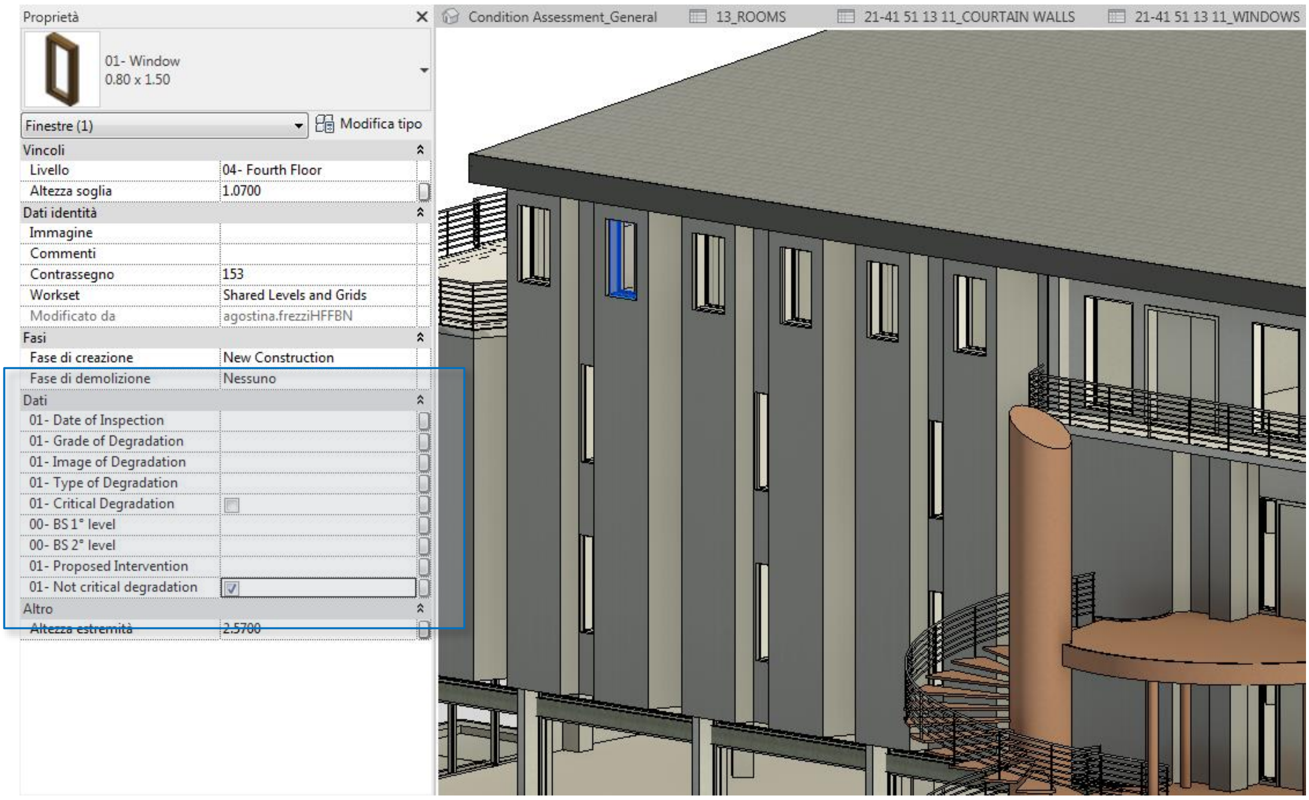
Figure 31. *Project parameters – Selected categories*

This procedure will allow that each particular elements of the model could be:

- Firstly, identified according the WBS already developed;
- And secondly, available to add all the needed information, required to the development of a condition assessment.

Thus, in other words, allowing the objective of integrating the **BS** with the **information** coming from the building components.

In *Figure 32* it is shown how this is possible in a window belonging to the elaborated Revit model. The parameters already uploaded and adjusted are editable, allowing to add particular information to each element of the model. Of course, this information is also recorded and allows the analysis of its evolution throughout the whole life cycle of the project, but we will see it later more in detail.



01- Window
0.80 x 1.50

Vincoli	
Livello	04- Fourth Floor
Altezza soglia	1.0700
Dati identità	
Immagine	
Commenti	
Contrassegno	153
Workset	Shared Levels and Grids
Modificato da	agostina.frezziHFFBN
Fasi	
Fase di creazione	New Construction
Fase di demolizione	Nessuno
Dati	
01- Date of Inspection	
01- Grade of Degradation	
01- Image of Degradation	
01- Type of Degradation	
01- Critical Degradation	☐
00- BS 1° level	
00- BS 2° level	
01- Proposed Intervention	
01- Not critical degradation	☑
Altro	
Altezza estremità	2.5700

Figure 32. *WBS + Information in Revit software*

As it is possible to see in the previous figure, each element has two levels of Breakdown Structure that must be provided:

1. **BS 1° level**: This code it is common to all the projects. It is **standardized** and obtained from the breakdown structure, which is based on the OmniClass Code, and it will be the same for all elements belonging to the same category.

   For example, in the case of **all windows** components included in the model, the BS 1° level code **will be** *21-41 51 13 11*.
2. **BS 2° level**: This code it is customized in each different project, and it is unique for each element. It is composed by two parts:
   a. The category code of Revit, plus the number of levels in which the element is located. Please refer to chapter 4.2.6 to see the naming convention developed in this project, and proposed for future developments.
   b. The identity number of the component. Please refer to chapter 4.2.6 to see the naming convention developed in this project, and proposed for future developments.

   It is important to highlight that the BS 2° level code is **not standardised** by a regulation;

therefore, the final decision about this codification will fall on the BIM Coordinator in charge of the project

For example, in the case of a particular window component included in the model, the BS 2° level code **could be** WI2.03.

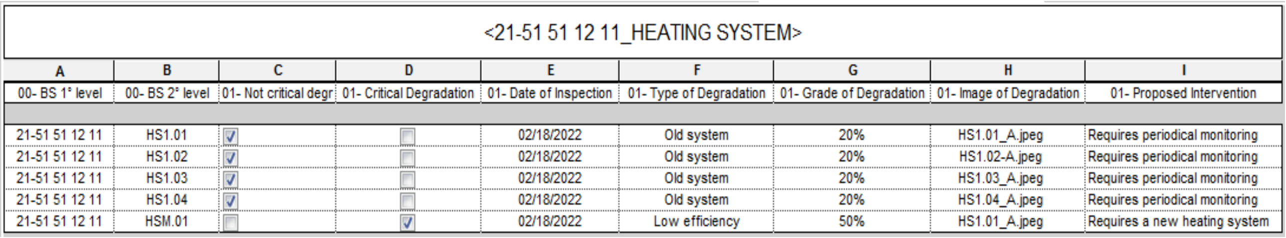
Please refer to the tables below for the nomenclature used per level and category of each element, in order to be used for the naming convention:

NAMING CONVENTION		
LEVELS		
Ground Floor	**G**	-3,32mts
First Floor	**1**	0,00mts
Mezzanine	**M**	+1,55mts
Second Floor	**2**	+3,10mts
Third Floor	**3**	+6,42mts
Fourth Floor	**4**	+9,75mts
Roof	**R**	+13,16mts

NAMING CONVENTION		
CATEGORIES		SAMPLES
Beam	**BE**	BE1.01
Ceiling	**CE**	CE1.01
Columns	**CO**	CO1.01
Cooling System	**CS**	CS1.01
Courtain Wall	**CW**	CW1.01
Door	**DO**	DO1.01
Electrical System	**ES**	ES1.01
Elevator	**EL**	EL1.01
Finish Floor	**FF**	FF1.01
Fixed Furniture	**FX**	FX1.01
Foundations	**FO**	FO1.01
Furniture	**FU**	FU1.01
Heating system	**HS**	HS1.01
Lighting System	**LS**	LS1.01
Mechanical System	**MS**	MS1.01
Plumbing System	**PS**	PS1.01
Railings	**RA**	RA1.01
Ramp	**RP**	RP1.01
Roof	**RF**	RF1.01
Rooms	**RO**	RO1.01
Signals	**SG**	SG1.01
Slabs	**SL**	SL1.01
Stair	**ST**	ST1.01
Wall	**WA**	WA1.01
Walls Finish	**WF**	WF1.01
Window	**WI**	WI1.01

Using this method, it was possible to identify each singular element in the building, with an unique code. This code will have the final aim of tracking the evolution of the asset, during it entire life cycle. Please refer to Figures XX, in the page XX of the annex, in order to see the codification of the floor plans.

In the sample below, it is possible to see the schedule developed to analyse the heating system of the analysed area:



<21-51 51 12 11_HEATING SYSTEM>

A	B	C	D	E	F	G	H	I
00- BS 1° level	00- BS 2° level	01- Not critical degr	01- Critical Degradation	01- Date of Inspection	01- Type of Degradation	01- Grade of Degradation	01- Image of Degradation	01- Proposed Intervention
21-51 51 12 11	HS1.01	☑	☐	02/18/2022	Old system	20%	HS1.01_A.jpeg	Requires periodical monitoring
21-51 51 12 11	HS1.02	☑	☐	02/18/2022	Old system	20%	HS1.02-A.jpeg	Requires periodical monitoring
21-51 51 12 11	HS1.03	☑	☐	02/18/2022	Old system	20%	HS1.03_A.jpeg	Requires periodical monitoring
21-51 51 12 11	HS1.04	☑	☐	02/18/2022	Old system	20%	HS1.04_A.jpeg	Requires periodical monitoring
21-51 51 12 11	HSM.01	☐	☑	02/18/2022	Low efficiency	50%	HS1.01_A.jpeg	Requires a new heating system

Figure 33. *Data collection in the model*

During the condition assessment, one of the most critical issues detected was the low efficiency of the heating system. Even when it was maintained during the years, the life cycle of the system is has become obsolete, and it is not enough to heat the office area.

Therefore, the involved elements were checked as critical, with a percentage of 50%, which means that it should be addressed as soon as possible.

This situation it is also reflected in a 3d view, were all the elements are in halftone with a grade of transparency, while the critical assets are automatically coloured in red.

The “critical check” is the tool that converts the elements in red, due to a filter that is applied in the 3d view of the condition assessment. Once the asset has been intervened, the “critical check” will be removed, and the element will become automatically white again.

In order to make this tool clearer for all the stakeholders, it is possible to add a tag in the 3d views to all the critical elements, that will allow a quick understanding of the issue, the ID code of the affected asset, and a representative image.

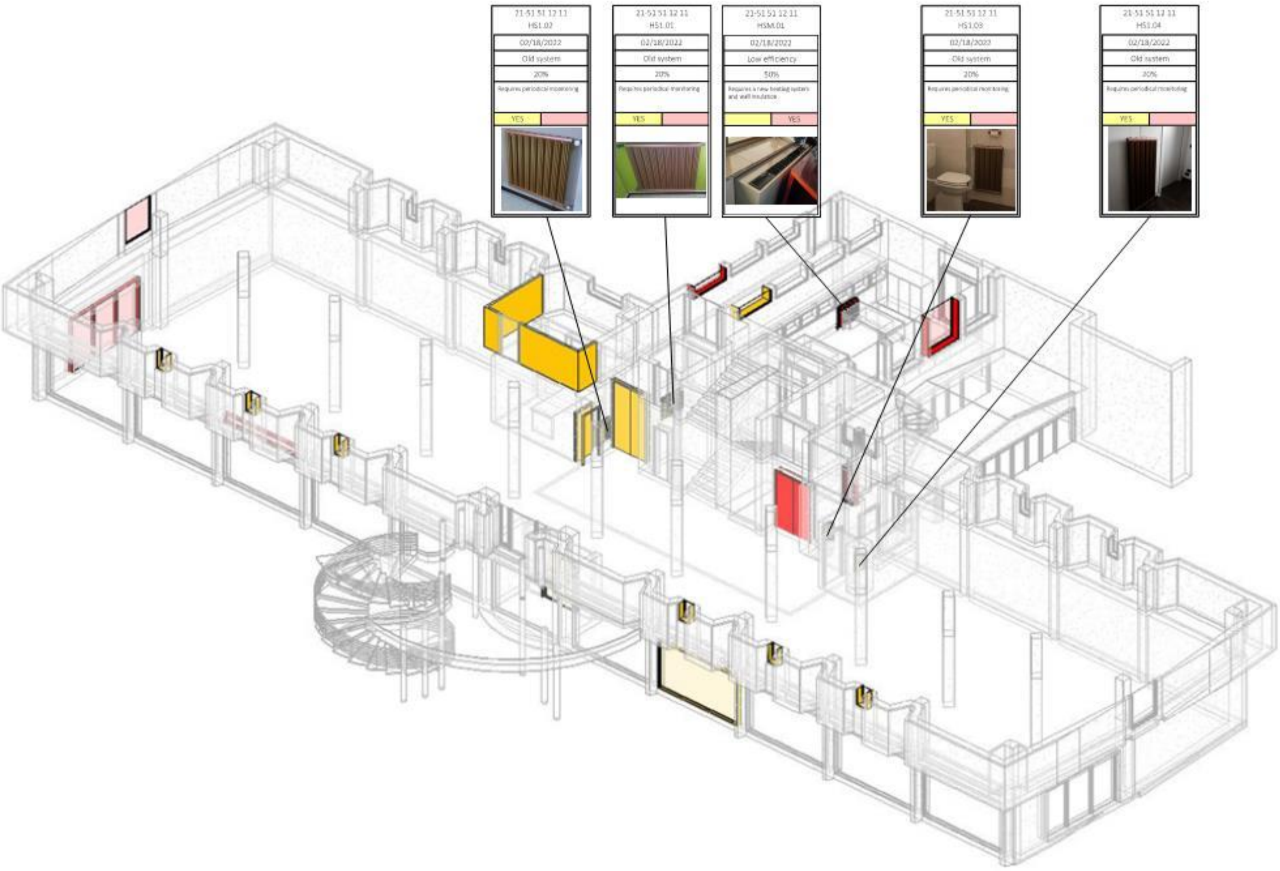


Figure 34. *3d view of data collection*

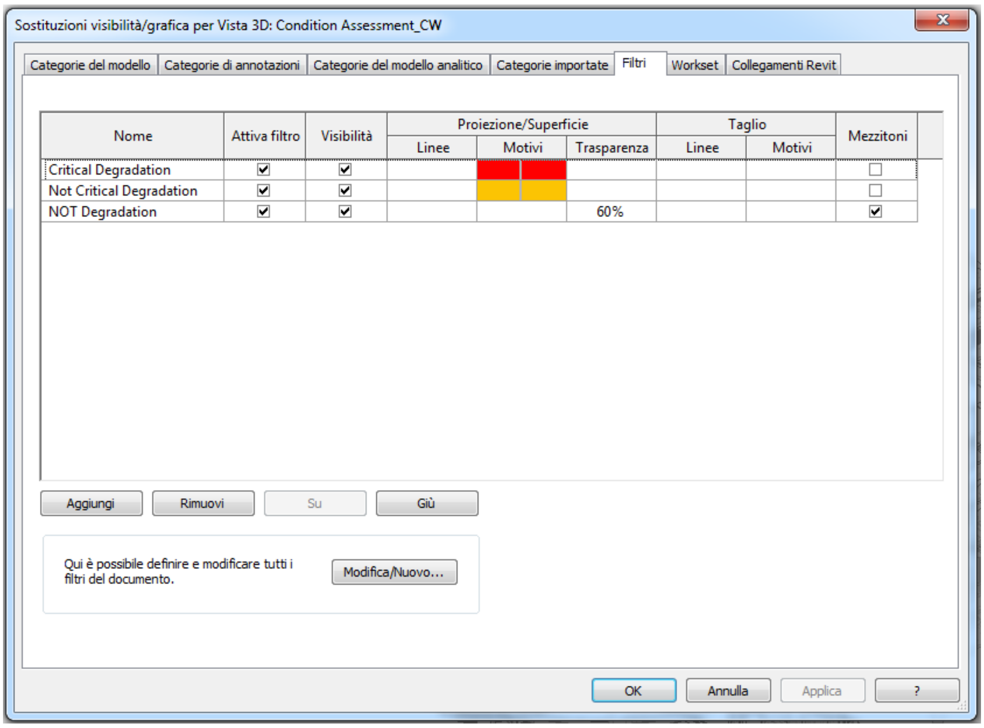
The condition assessment analysis tables and its corresponding 3d views are all available in the Annex, in *Figures A-10*, *A-11*, *A-12*, *A-13*, *A-14*, *A-15* and *A-16*.

Finally, how to integrate all this information, in order to have a global view of the project? It is possible to have a kick understanding of the criticalities, and its impact in the whole project?

To do this, it was created a set of templates with visible filters that will coloured in red **automatically** all the components that represent a critical issue.

Thus, to do this, it was created three different types of filters:

1. **Critical degradation**: All the elements that have been checked as a critical issue will be automatically coloured in red;
2. **Not critical degradation**: All items that contain a level of degradation or obsolescence that not represent a critical situation, but need to be controlled and monitorized;
3. **NOT degradation**: The rest of the components will have a halftone visibility, with a transparency of 60%. This visualization will allow greater visibility of critical components, which will be opaque and red.



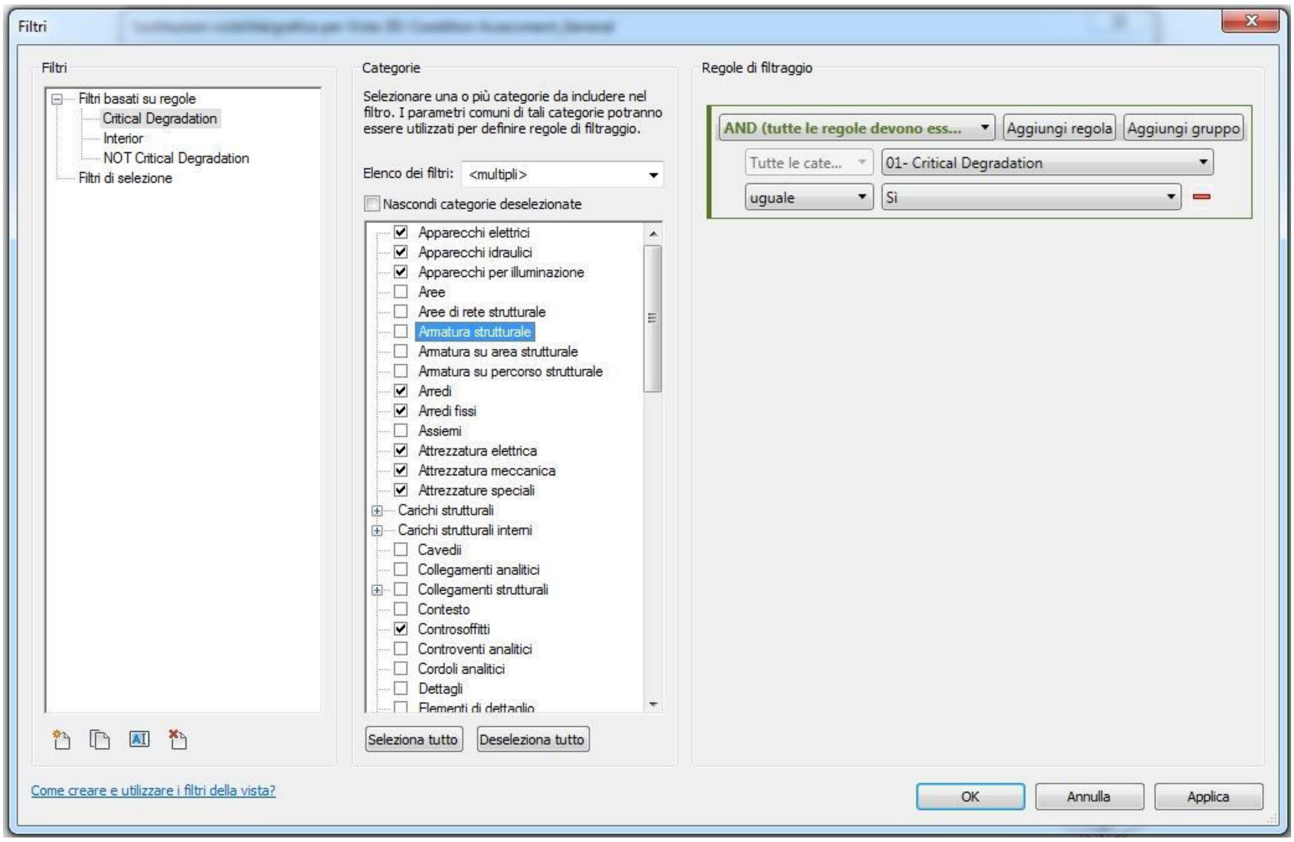
Sostituzioni visibilità/grafica per Vista 3D: Condition Assessment_CW

Nome	Attiva filtro	Visibilità	Proiezione/Superficie			Taglio		Mezzitoni
			Linee	Motivi	Trasparenza	Linee	Motivi	
Critical Degradation	☑	☑		🟥				☐
Not Critical Degradation	☑	☑		🟧				☐
NOT Degradation	☑	☑			60%			☑

Qui è possibile definire e modificare tutti i filtri del documento.

Figure 35. *Filters created to automatically detect critical issues*

For each filter it has been made a selection of the components that will be affected in the model, as it is shown in the image below:



Filtri basati su regole
- Critical Degradation
- Interior
- NOT Critical Degradation

Filtri di selezione

Selezionare una o più categorie da includere nel filtro. I parametri comuni di tali categorie potranno essere utilizzati per definire regole di filtraggio.

Elenco dei filtri: <multipli>

☐ Nascondi categorie deselezionate

- ☑ Apparecchi elettrici
- ☑ Apparecchi idraulici
- ☑ Apparecchi per illuminazione
- ☐ Aree
- ☐ Aree di rete strutturale
- ☐ Armatura strutturale
- ☐ Armatura su area strutturale
- ☐ Armatura su percorso strutturale
- ☑ Arredi
- ☑ Arredi fissi
- ☐ Assiemi
- ☑ Attrezzatura elettrica
- ☑ Attrezzatura meccanica
- ☑ Attrezzature speciali
- Carichi strutturali
- Carichi strutturali interni
- ☐ Cavedii
- ☐ Collegamenti analitici
- ☐ Collegamenti strutturali
- ☐ Contesto
- ☑ Controsoffitti
- ☐ Controventi analitici
- ☐ Cordoli analitici
- ☐ Dettagli
- ☐ Elementi di dettaglio

AND (tutte le regole devono ess...

Tutte le cate... | 01- Critical Degradation

uguale | Sì

Come creare e utilizzare i filtri della vista?

Figure 36. *Elements affected in the 3d condition assessment analysis*

Finally, it is possible to quickly and efficiently find all the components that represent a degree of criticality for the asset, also understanding the relationship of the component with the whole building.

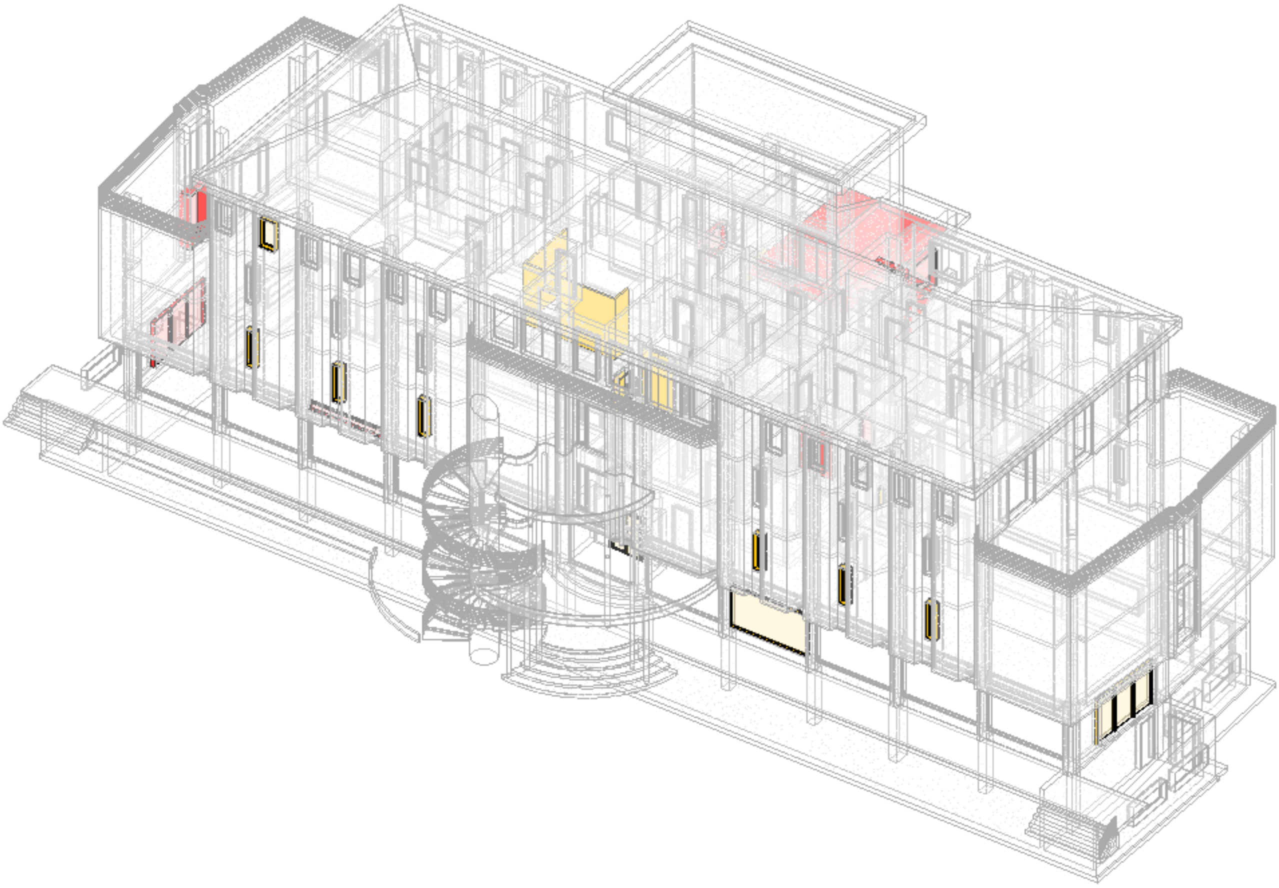


Figure 37. *Highlighted elements on a 3D view according its criticality*

In order to make it more visible and clearer for all the stakeholders, it is recommended to divide the information; thus, the 3d view in areas and by analysed elements. Please refer to *Figure 34* to see an example of the 3d view of the First Floor.

5.4- FOLLOW-UP AND COMMUNICATION BETWEEN DISCIPLINES

Therefore, it is clear to see how this procedure would help to the Building Manager in understanding the real situation of the whole asset, in an easy way that is always up-to-date, when making a condition assessment. Nevertheless, how would be the follow up of this situation? And moreover, which would be the improvement for the several parties involved?

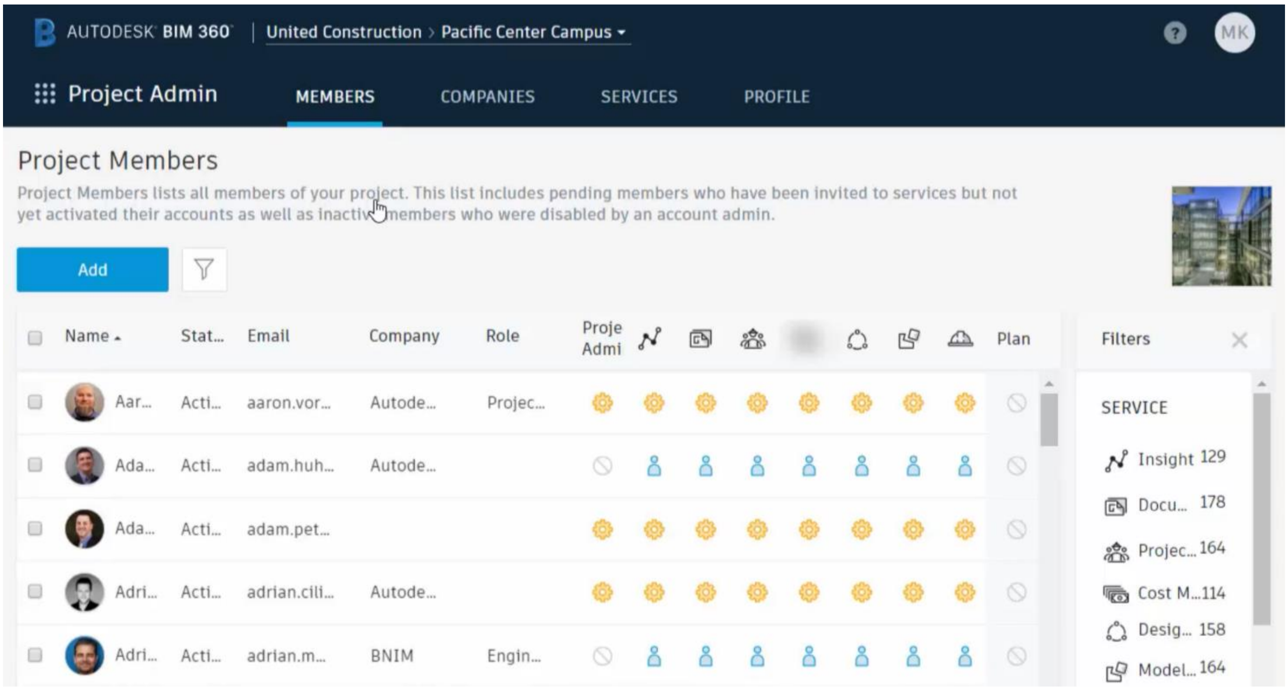
For both questions, the response is a **simple and transparent communication process**. In order to achieve this final objective, the key tool is the already known **Common Data Environment**. Thus, a shared point where the information could be visible for all the stakeholders, depending on their responsibilities.

Speaking in a more practical way, the two more known CDE used nowadays on the market are:

1. **SharePoint**: It works like a shared folder (such as DropBox), but gives the possibility of manage the permits of different folders. This would give to the Building Manager the possibility of having the configuration below:
    - ➢ *Project Clarici Arredamenti*
        - ***00. Coordination****: This folder would be visible for all the parties involved. Once each responsible has an approval document, ithis document will be copied from the Work in Progress folders, to this shared folder, following a proposed structural organization, such as:*
            1. *Condition Assessment*
            2. *Legal framework*
            3. *Interventions*
            4. *Permissions*
        - ***01. WIP_Condition Assessment****: Work in Progress folder, that will be visible just for the Building Manager and his/her team;*
        - ***02. WIP_Heating System****: Work in Progress folder, that will be visible for the responsible of the heating system;*
        - ***03. WIP_Cooling System****: Work in Progress folder, that will be visible for the responsible of the cooling system;*

- ***04. WIP_Enclosures****: Work in Progress folder, that will be visible for the responsible of the enclosures;*
- ***05. WIP_XXX: ….***

2. **BIM 360**: This platform gives the same possibilities of managing the visibility permissions of the folders, but it also allows to any person with access to the account, a visualization of certain 2D and 3D views. These views would be the approved final versions, and will contain in a simple way all the information needed. Therefore, the criticalities that have been analysed in the asset, and all its updated and evolution over the time could be visible for all the stakeholders involved in the project. Moreover, it is also possible to assigned the issue to a specific responsible. Thus, once the Building Manager has detected a criticality on the building, it could be assigned to the specialist, who will receive an email of the issue. This will allow to have a tracker of the issues, the time to response, the time to solve, and the actual status of each element at all times.



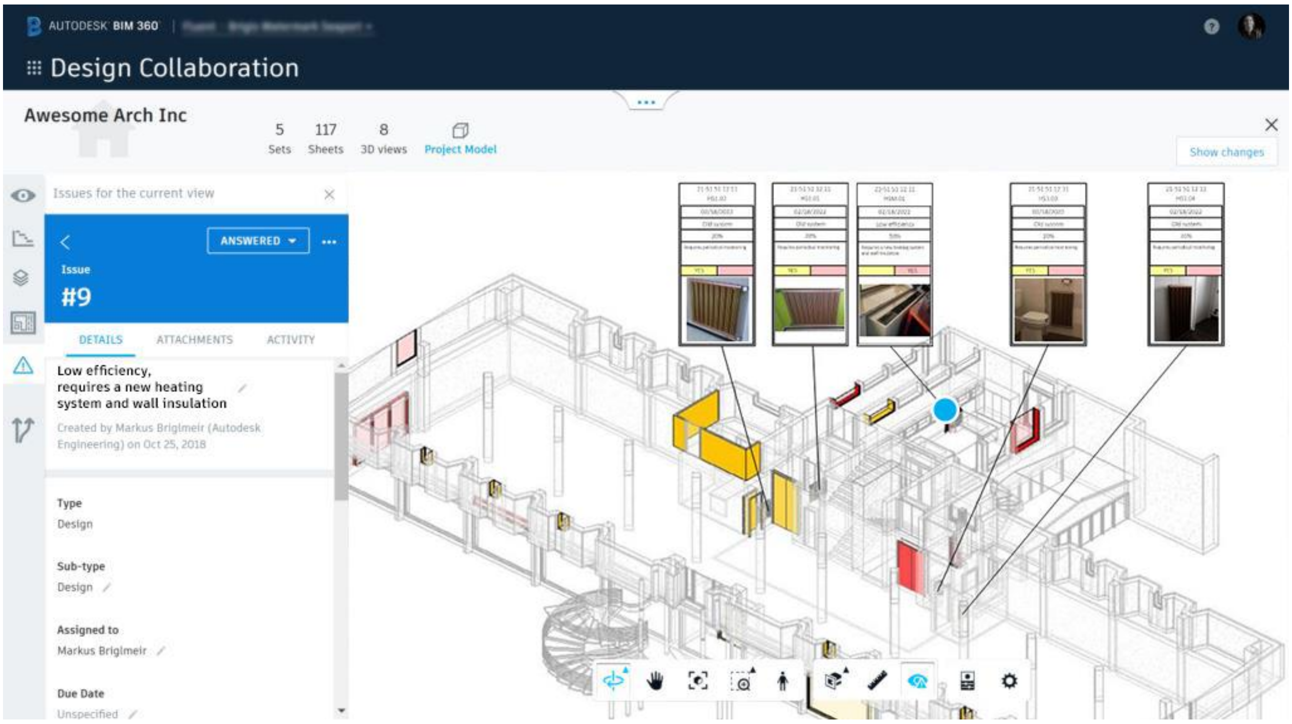
Project Members

Project Members lists all members of your project. This list includes pending members who have been invited to services but not yet activated their accounts as well as inactive members who were disabled by an account admin.

☐	Name ▴	Stat...	Email	Company	Role	Proje Admi								Plan
☐	Aar...	Acti...	aaron.vor...	Autode...	Projec...	⚙	⚙	⚙	⚙	⚙	⚙	⚙	⚙	⊘
☐	Ada...	Acti...	adam.huh...	Autode...		⊘	👤	👤	👤	👤	👤	👤	👤	⊘
☐	Ada...	Acti...	adam.pet...			⚙	⚙	⚙	⚙	⚙	⚙	⚙	⚙	⊘
☐	Adri...	Acti...	adrian.cili...	Autode...		⚙	⚙	⚙	⚙	⚙	⚙	⚙	⚙	⊘
☐	Adri...	Acti...	adrian.m...	BNIM	Engin...	⊘	👤	👤	👤	👤	👤	👤	👤	⊘

Insight	129
Docu...	178
Projec...	164
Cost M...	114
Desig...	158
Model...	164

Figure 38. *BIM 360: Sample of the permissions granted, depending on the role of each responsible*



Issue
#9

Low efficiency, requires a new heating system and wall insulation

Created by Markus Briglmeir (Autodesk Engineering) on Oct 25, 2018

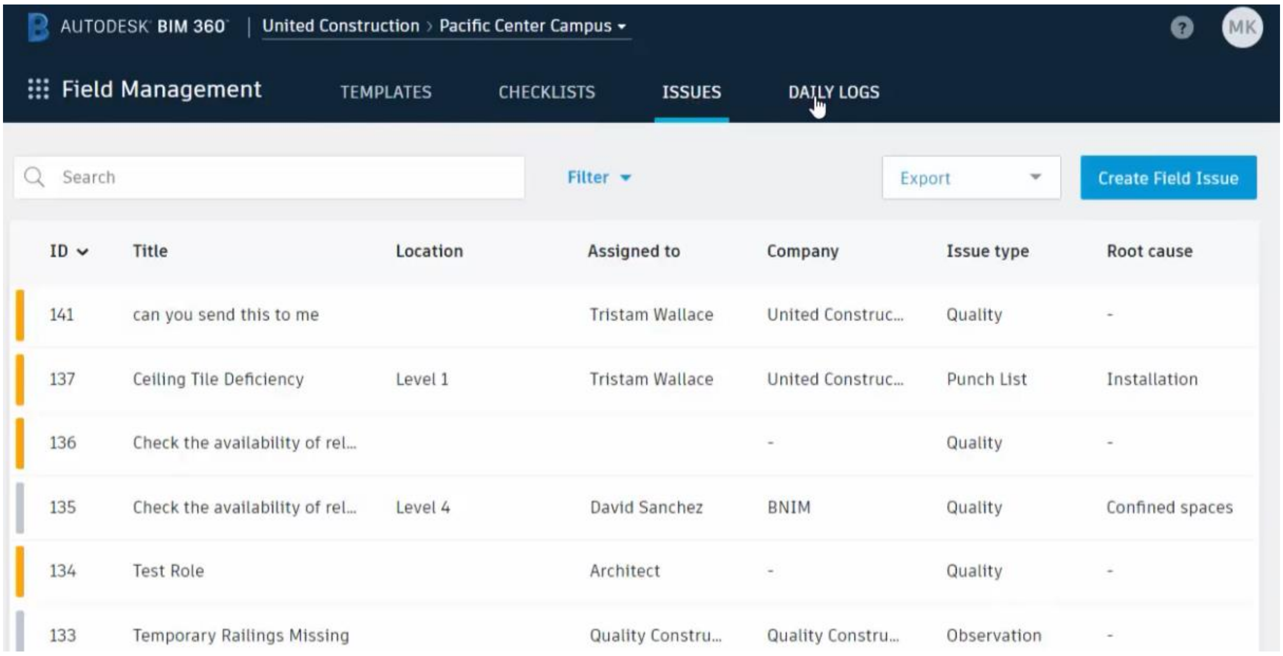
Type
Design

Sub-type
Design

Assigned to
Markus Briglmeir

Due Date
Unspecified

Figure 39. *BIM 360: Sample of a status 3D view visible for all the stakeholders*



ID	Title	Location	Assigned to	Company	Issue type	Root cause
141	can you send this to me		Tristam Wallace	United Construc...	Quality	-
137	Ceiling Tile Deficiency	Level 1	Tristam Wallace	United Construc...	Punch List	Installation
136	Check the availability of rel...			-	Quality	-
135	Check the availability of rel...	Level 4	David Sanchez	BNIM	Quality	Confined spaces
134	Test Role		Architect	-	Quality	-
133	Temporary Railings Missing		Quality Constru...	Quality Constru...	Observation	-

Figure 40. *BIM 360: Sample of the assigned issues*

Therefore, with these tools it would be possible to solve one of the biggest limitations coming from traditional approaches: to **conceive the information of all the components of the asset as a whole**.

Finally, the Building Manager will be the responsible of having this information updated. Thus, during the process of **monitoring the evolution**, the information of the status of each component will be bring up-to-date and published, in order to have a transparent visualization of the whole functioning of the asset.

In this particular thesis, as an example, some glasses shown as red have a criticality coming from a broken glass, which must to be solved with urgency. The Building Manager will assign this task to the specialist. Once the problem has being solved, the Building Manager will upload the status of the element, that will be shown as transparent in the 3D view.

Therefore, the process of a Condition Assessment will maintain the same stakeholders and the same traditional steps working as usual. Nevertheless, the biggest improvement of this process comes from a more transparent process, and the conception of the asset of a whole, and not as the sum of parts to be analysed by specialists independently.

6- CONCLUSIONS

The development of this thesis - project has developed following two main phases: a first analytical phase and a second experimental in which everything that has been understood has been applied to a case study to give more concreteness to the hypothesis developed.

First it has been tried to understand the real meaning of the process of Condition Assessment, on which key points base all its development and how these must constantly interact with each other.

After having identified and analysed the fundamental standards that underlie the Condition Assessment, a comparison was developed between these to try to understand which points shared them and on which, instead, were discordant.

Later, realising that the two strong key - points, so the Breakdown structure and the Data management, of the Condition Assessment appeal in all the standards on which the process is based, it has been tried to understand how they could interact continuously and give the technicians involved in the study of the building feedback on the condition of the building, always updated in real - time.

At this point, after understanding all the qualities that condition assessment has and the advantages it offers, it is possible to understand this process also has limits.

In fact, it does not allow the interaction between all different figures involved in the process, it takes a rather long time and the update of the data is not automatic.

Thus, understanding this, it has been tried to comprehend what was the best tool to overcome the limitations presented by traditional methods for Condition Assessment.

The answer was found in the digital tool of BIM, Building Information Modelling, thanks to which, the traditional methods of condition assessment could be integrated, obtaining a more precise and effective result.

At the end of both phases of the project it was possible to highlight the real usefulness of the thesis - work.

The main objective was to emphasise the strength and improvements that the digital tool of BIM can give to the process of Condition Assessment; what is important to know is that BIM is just a tool and its utility is strictly connected with the project and the needs coming from it. It is fundamental to use it to its full potential, otherwise, it could represent a major loss of time with lower benefits, nevertheless, if the mechanism is understood in the right way, the benefits coming from the correct use of BIM are immeasurable, in economic, coordination and communicative terms between the different parties involved.

Thence, it is possible to point out that the critical points towards a success project are:

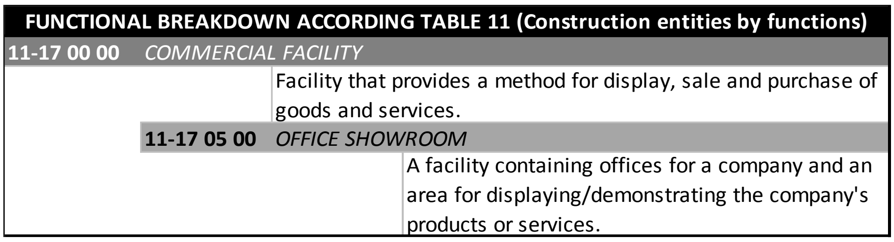
1. Try to use BIM as a means, instead of a goal in itself: the reasons why BIM is used should be well defined upfront, and good agreements should be made about it;
2. BIM is not only a way to resolve design errors, but also to involve different stakeholders, including the client. The interests and competences of different actors should be defined upfront;
3. If the client does not have extensive knowledge of BIM, or does not know exactly why and how to use BIM, it is also up to the design team to help the client sort this out.
4. BIM and digital communication should not replace real life communication, as it stays important to meet face to face. *(Bel Mirjam; 2018)*

For the reasons listed above, it is hoped that, in future projects, the use of BIM as an integration for Condition Assessment procedures is an automatic and a matter of course.

This is especially for all the advantages that this tool has managed to bring to new projects, giving them more precision and speed in updating their data, allowing all the people involved in the same work to consult at any time, information about the building.

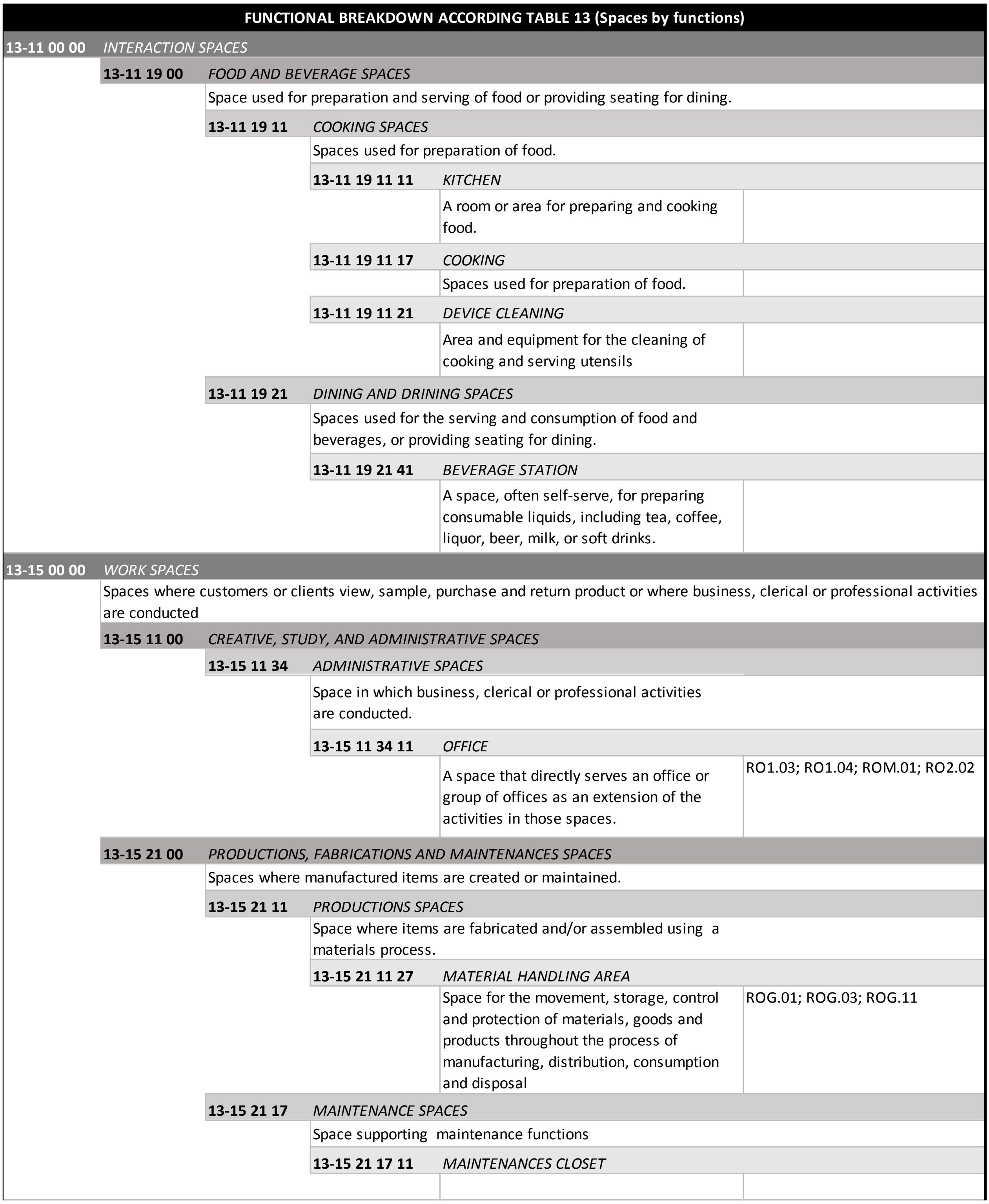
Thus, to conclude, the hope is that technicians can begin to have more detailed information and knowledge about this powerful tool so as to implement it in their works.

INDEX OF FIGURES



FUNCTIONAL BREAKDOWN ACCORDING TABLE 11 (Construction entities by functions)		
11-17 00 00	*COMMERCIAL FACILITY*	
	Facility that provides a method for display, sale and purchase of goods and services.	
	11-17 05 00	*OFFICE SHOWROOM*
		A facility containing offices for a company and an area for displaying/demonstrating the company's products or services.

Figure A-01. *Breakdown Structure from OmniClass Table 11*



FUNCTIONAL BREAKDOWN ACCORDING TABLE 13 (Spaces by functions)					
13-11 00 00	*INTERACTION SPACES*				
	13-11 19 00	*FOOD AND BEVERAGE SPACES*			
		Space used for preparation and serving of food or providing seating for dining.			
		13-11 19 11	*COOKING SPACES*		
			Spaces used for preparation of food.		
			13-11 19 11 11	*KITCHEN*	
				A room or area for preparing and cooking food.	
			13-11 19 11 17	*COOKING*	
				Spaces used for preparation of food.	
			13-11 19 11 21	*DEVICE CLEANING*	
				Area and equipment for the cleaning of cooking and serving utensils	
		13-11 19 21	*DINING AND DRINING SPACES*		
			Spaces used for the serving and consumption of food and beverages, or providing seating for dining.		
			13-11 19 21 41	*BEVERAGE STATION*	
				A space, often self-serve, for preparing consumable liquids, including tea, coffee, liquor, beer, milk, or soft drinks.	
13-15 00 00	*WORK SPACES*				
	Spaces where customers or clients view, sample, purchase and return product or where business, clerical or professional activities are conducted				
	13-15 11 00	*CREATIVE, STUDY, AND ADMINISTRATIVE SPACES*			
		13-15 11 34	*ADMINISTRATIVE SPACES*		
			Space in which business, clerical or professional activities are conducted.		
			13-15 11 34 11	*OFFICE*	
				A space that directly serves an office or group of offices as an extension of the activities in those spaces.	RO1.03; RO1.04; ROM.01; RO2.02
	13-15 21 00	*PRODUCTIONS, FABRICATIONS AND MAINTENANCES SPACES*			
		Spaces where manufactured items are created or maintained.			
		13-15 21 11	*PRODUCTIONS SPACES*		
			Space where items are fabricated and/or assembled using a materials process.		
			13-15 21 11 27	*MATERIAL HANDLING AREA*	
				Space for the movement, storage, control and protection of materials, goods and products throughout the process of manufacturing, distribution, consumption and disposal	ROG.01; ROG.03; ROG.11
		13-15 21 17	*MAINTENANCE SPACES*		
			Space supporting maintenance functions		
			13-15 21 17 11	*MAINTENANCES CLOSET*	

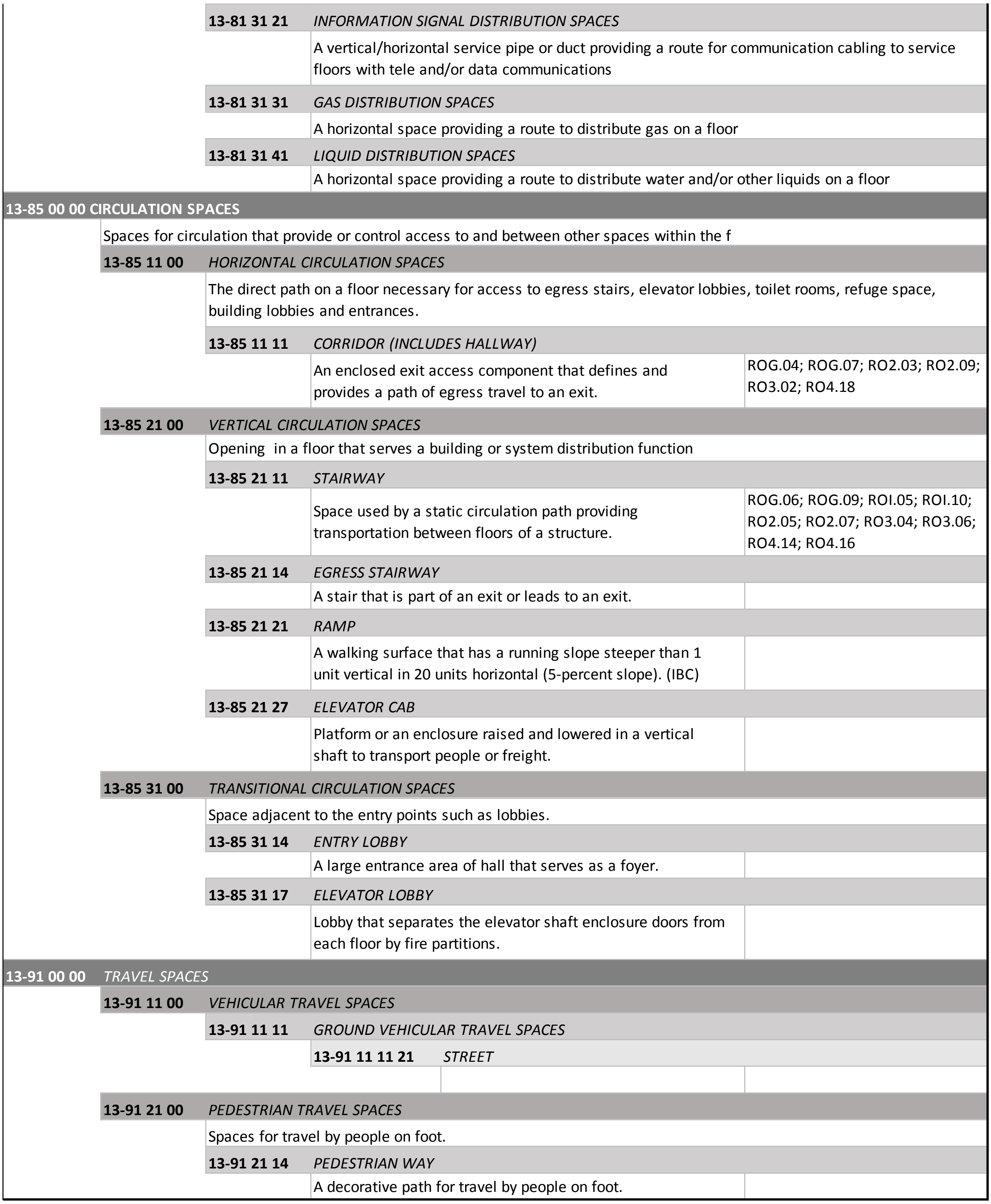
Figure A-02.A. *Breakdown Structure from OmniClass Table 13*

13-25 00 00				*COMMERCIAL SPACES*	
	13-25 11 00			*BUYING AND SELLING SPACES*	
				Space where customers or clients can view or purchase product.	
		13-25 11 11		*GENERAL RETAIL SPACE*	
			13-25 11 11 14	*CHECKOUT SPACE*	
				Space with counters and product sales/returns equipment	ROG.10
		13-25 11 27		*SHOWROOM*	
				Space used to display articles for sale including associated circulation area.	RO1.02; RO2.01; RO3.08
		13-25 11 31		*DEMOSTRATION SPACE*	
				Space where the product is demonstrated in an operational setting; often for large and/or complex operations and products.	
13-31 00 00				*RECREATION SPACES*	
				A space for any leisure activity, such as play, that diverts, amuses or stimulates.	
	13-31 11 00			*NON-ATHLETIC RECREATION SPACES*	
				Spaces for recreation and entertainment that do not include athletic activity or sports.	
		13-31 11 14		*PLEASURE GARDEN*	
				A garden that is opened to the public for recreation, differentiated from other public gardens by containing entertainments in addition to the planting; for example, concert halls or bandstands, rides, zoos or menageries.	RO4.01; RO4.02; RO4.34
	13-31 31 00			*FITNESS SPACES*	
				Space that is related to medical and other wellness services provided to the personnel in a facility; such as first aid stations.	
		13-31 31 21		*TRAINING SPACE*	
				Spaces for exercise and fitness activities.	
13-41 00 00				*CARE SPACES*	
				Space for conducting commercial activities and those in support of personal needs.	
	13-41 11 00			*GROOMING SPACES*	
				Spaces for cleaning, grooming, or maintaining parts of the body, including primping, hair dressing, shaving, and providing manicures and pedicures.	
		13-41 11 14		*CLEANING SPACES*	
			13-41 11 14 14	*SHOWER*	
				A space in which one bathes underneath a spray of water.	
			13-41 11 14 17	*TOILET SPACE*	
				A space containing a toilet or similar fixture that disposes of human waste by using water to flush it through a drainpipe to another location.	RO1.07;
			13-41 11 14 21	*RESTROOM*	
				A space with washing and toilet facilities.	ROG.08; RO1.08; RO2.08; RO3.07
13-51 00 00				*RESTING SPACES*	
				A space where one can rest.	
	13-51 24 00			*LIVING SPACES*	
		13-51 24 11		*GENERAL RESIDENTIAL SPACE*	
				Space used to provide accommodation for people when not at work. The accommodation provides facilities for sleeping and relaxation and usually cooking, eating, cleaning.	RO4.03; RO4.04; RO4.05; RO4.06; RO4.07; RO4.08; RO4.09; RO4.10; RO4.11; RO4.12; RO4.19; RO4.20; RO4.21; RO4.22; RO4.23; RO4.24; RO4.25; RO4.26; RO4.27; RO4.28; RO4.29; RO4.30; RO4.31; RO4.32; RO4.33

Figure A-02.B. *Breakdown Structure from OmniClass Table 13*

13-65 00 00			*PROTECTION SPACES*	
			Spaces to provide shelter or keep someone safe from harm or discomfort.	
	13-65 11 00		*SPACES FOR PROTECTION FROM THE ELEMENTS*	
			Spaces to provide shelter or keep someone safe from environmental harm or discomfort.	
		13-65 11 14	*ENTRY PORCH*	
			A covered entrance to a vestibule or doorway attached to a building.	RO1.01
		13-65 11 17	*COVERED WALKWAY*	
			A sidewalk or path with a cover to provide shelter from weather or sunlight.	RO1.10
13-75 00 00			*STORAGE SPACES*	
	13-75 11 00		*FIXED LOCATION STORAGE SPACES*	
		13-75 11 11	*STORAGE ROOM*	
			A room that is used to store equipment or materials and that serves multiple room use categories, organizational units, or buildings.	RO4.13
		13-75 11 14	*CLOSET*	
			Small room used for containment of work-related items.	
		13-75 11 31	*WAREHOUSE SPACE*	
			Space specifically designed for the storage of raw material, in process materials or finished goods.	ROG.02
		13-75 11 37	*VEHICULAR STORAGE SPACE (INCLUDES GARAGE, PARKING LOT)*	
			Outdoor area used for transient storage of motor vehicles, not including loading docks, sally ports and building service areas such as enclosed auxiliary lobbies used to enter a building from parking areas.	
		13-75 11 47	*CUPBOARD*	
		13-75 11 51	*STORAGE SHELF*	
		13-75 11 54	*DRAWER*	
	13-75 21 00		*NON-FIXED LOCATION STORAGE SPACES*	
			Spaces, which do not have a fixed location, used for the storage of goods and materials for long and short terms.	
		13-75 21 14	*PORTABLE BIN*	
			Movable storage container, used for relocation or temporary storage purposes	
13-81 00 00 FACILITY SERVICE SPACES				
			Portion of a building that provides services that enable occupants to work in a building	
	13-81 21 00		*FACILITY EQUIPMENT SERVICE SPACES*	
		13-81 21 31	*ELEVATOR SHAFT*	
			An enclosed space extending through one or more stories of a building connecting vertical openings in successive floors, or floors and the roof used to enclose an elevator.	ROG.05; RO1.06; RO1.09; RO2.04; RO2.06; RO3.04; RO3.05; RO4.15; RO4.17
	13-81 31 00		*SERVICE DISTRIBUTION SPACES*	
			Space used to accommodate intra-floor and horizontal distributions services such as flues, fire towers, fire hose cabinets (because of the pipes attached to them), stacks, pipe shafts, electricity, vertical/horizontal air conditioning ducts and other vertical/horizontal ducts.	
		13-81 31 11	*POWER DISTRIBUTION SPACES*	
			A vertical/horizontal service pipe or duct providing a route for electrical cabling to service floors with electricity.	

Figure A-02.C. *Breakdown Structure from OmniClass Table 13*



		13-81 31 21		*INFORMATION SIGNAL DISTRIBUTION SPACES*	
				A vertical/horizontal service pipe or duct providing a route for communication cabling to service floors with tele and/or data communications	
		13-81 31 31		*GAS DISTRIBUTION SPACES*	
				A horizontal space providing a route to distribute gas on a floor	
		13-81 31 41		*LIQUID DISTRIBUTION SPACES*	
				A horizontal space providing a route to distribute water and/or other liquids on a floor	
13-85 00 00 CIRCULATION SPACES					
	Spaces for circulation that provide or control access to and between other spaces within the f				
	13-85 11 00			*HORIZONTAL CIRCULATION SPACES*	
		The direct path on a floor necessary for access to egress stairs, elevator lobbies, toilet rooms, refuge space, building lobbies and entrances.			
		13-85 11 11		*CORRIDOR (INCLUDES HALLWAY)*	
				An enclosed exit access component that defines and provides a path of egress travel to an exit.	ROG.04; ROG.07; RO2.03; RO2.09; RO3.02; RO4.18
	13-85 21 00			*VERTICAL CIRCULATION SPACES*	
		Opening in a floor that serves a building or system distribution function			
		13-85 21 11		*STAIRWAY*	
				Space used by a static circulation path providing transportation between floors of a structure.	ROG.06; ROG.09; ROI.05; ROI.10; RO2.05; RO2.07; RO3.04; RO3.06; RO4.14; RO4.16
		13-85 21 14		*EGRESS STAIRWAY*	
				A stair that is part of an exit or leads to an exit.	
		13-85 21 21		*RAMP*	
				A walking surface that has a running slope steeper than 1 unit vertical in 20 units horizontal (5-percent slope). (IBC)	
		13-85 21 27		*ELEVATOR CAB*	
				Platform or an enclosure raised and lowered in a vertical shaft to transport people or freight.	
	13-85 31 00			*TRANSITIONAL CIRCULATION SPACES*	
		Space adjacent to the entry points such as lobbies.			
		13-85 31 14		*ENTRY LOBBY*	
				A large entrance area of hall that serves as a foyer.	
		13-85 31 17		*ELEVATOR LOBBY*	
				Lobby that separates the elevator shaft enclosure doors from each floor by fire partitions.	
13-91 00 00	*TRAVEL SPACES*				
	13-91 11 00			*VEHICULAR TRAVEL SPACES*	
		13-91 11 11		*GROUND VEHICULAR TRAVEL SPACES*	
			13-91 11 11 21	*STREET*	
	13-91 21 00			*PEDESTRIAN TRAVEL SPACES*	
		Spaces for travel by people on foot.			
		13-91 21 14		*PEDESTRIAN WAY*	
				A decorative path for travel by people on foot.	

Figure A-02.D. *Breakdown Structure from OmniClass Table 13*

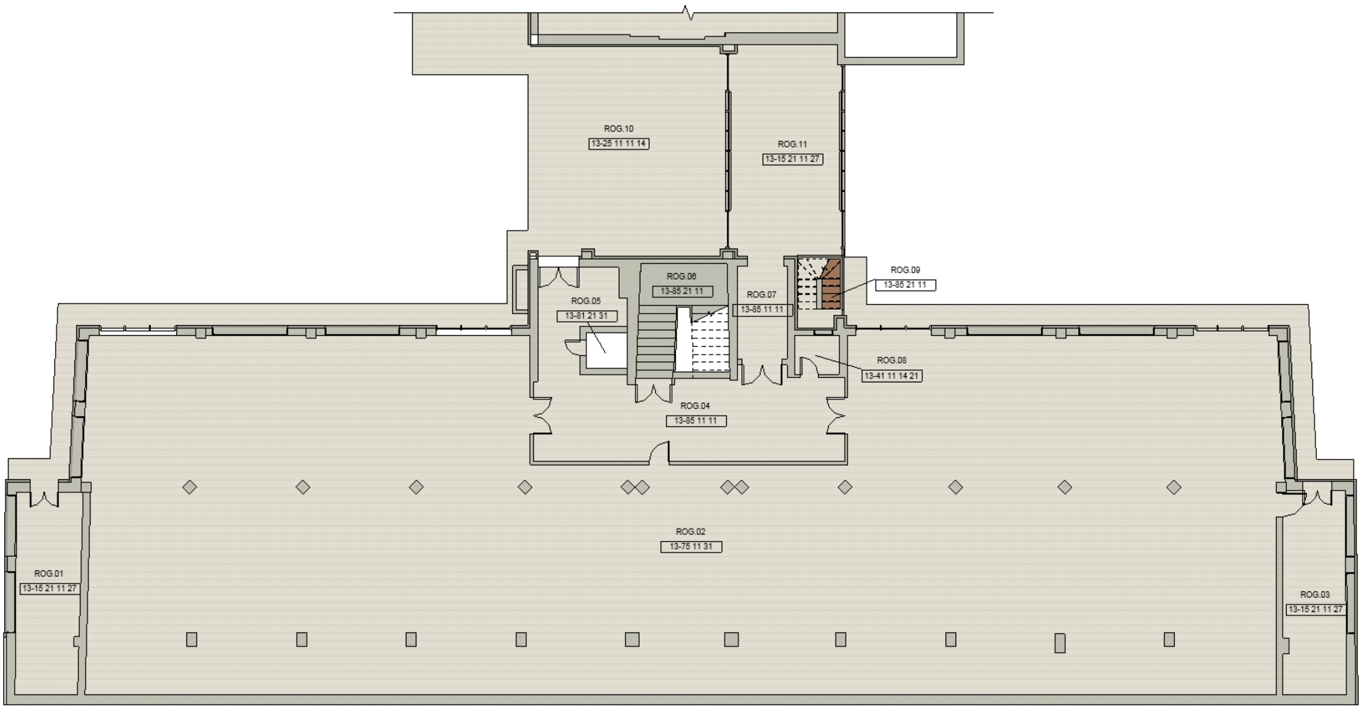


Figure A-03.A. *Ground Floor*

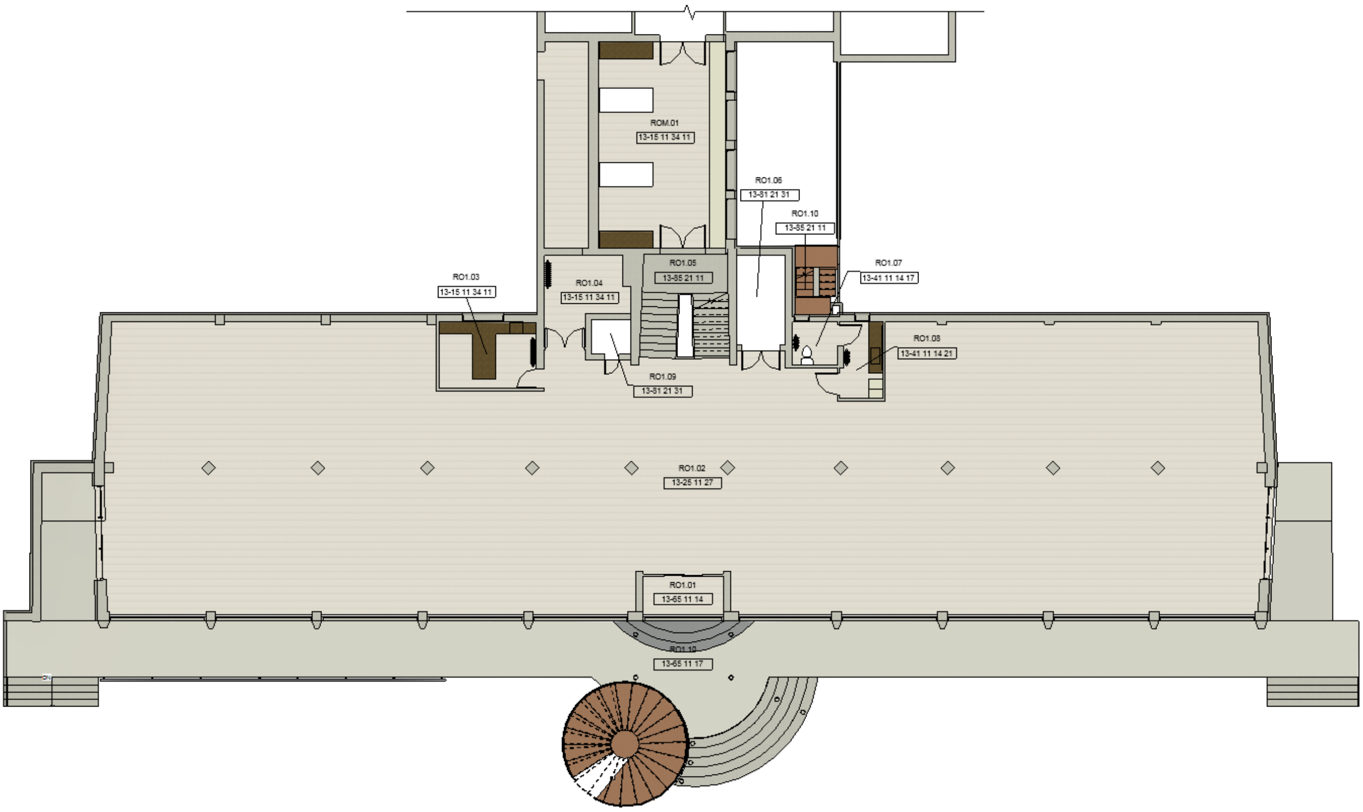


Figure A-03.B. *First Floor*

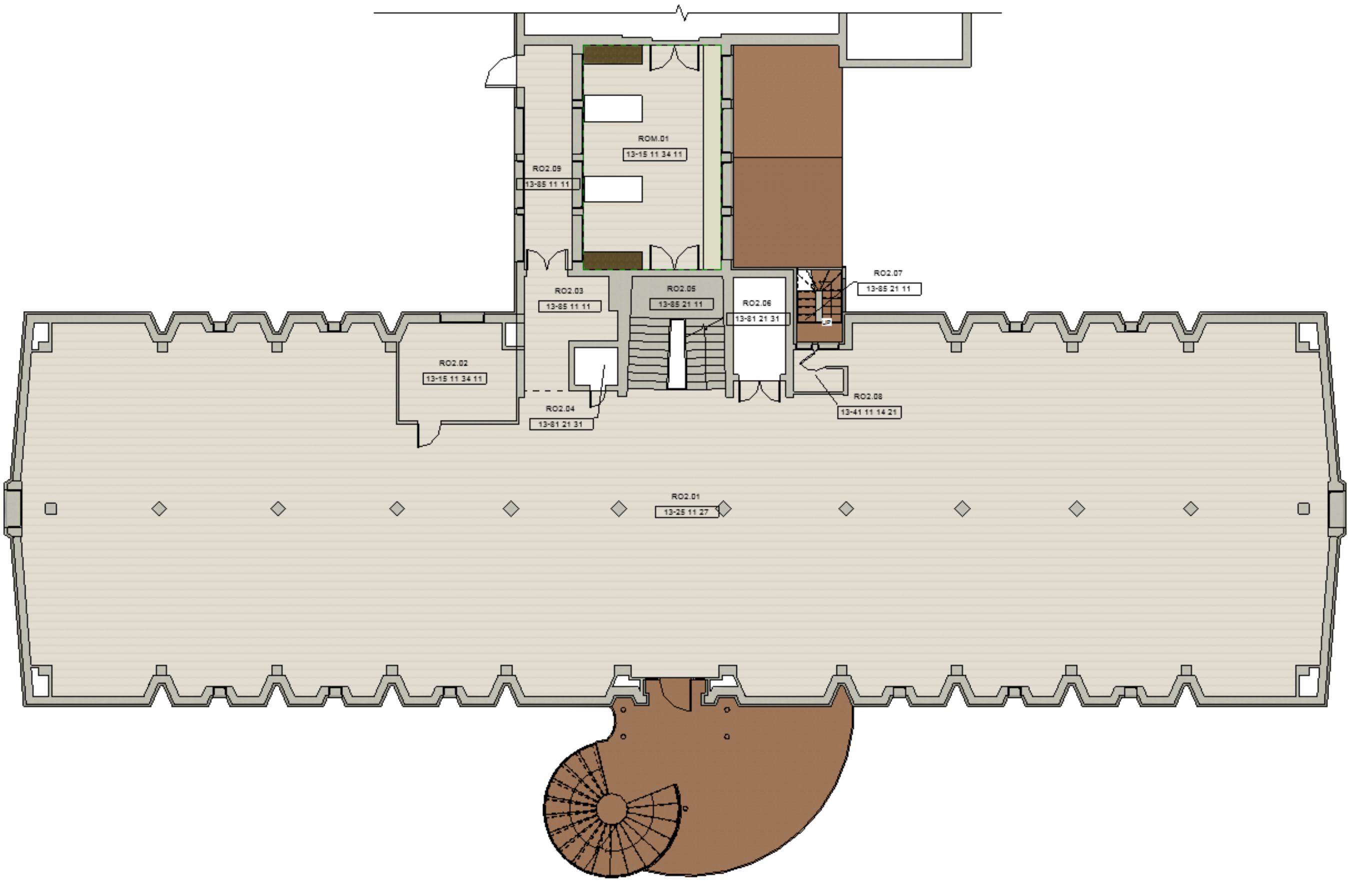


Figure A-03.C. *Second Floor*

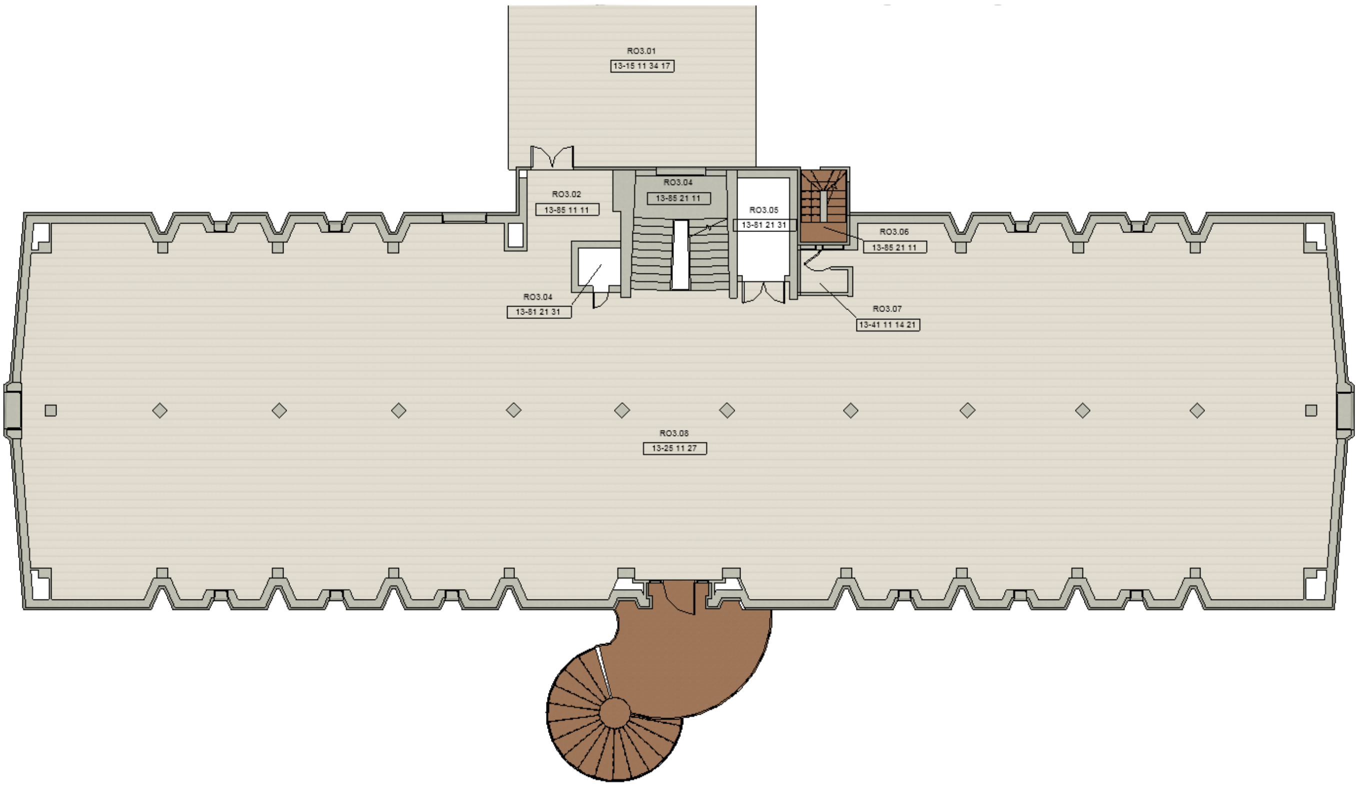


Figure A-03.D. *Third Floor*

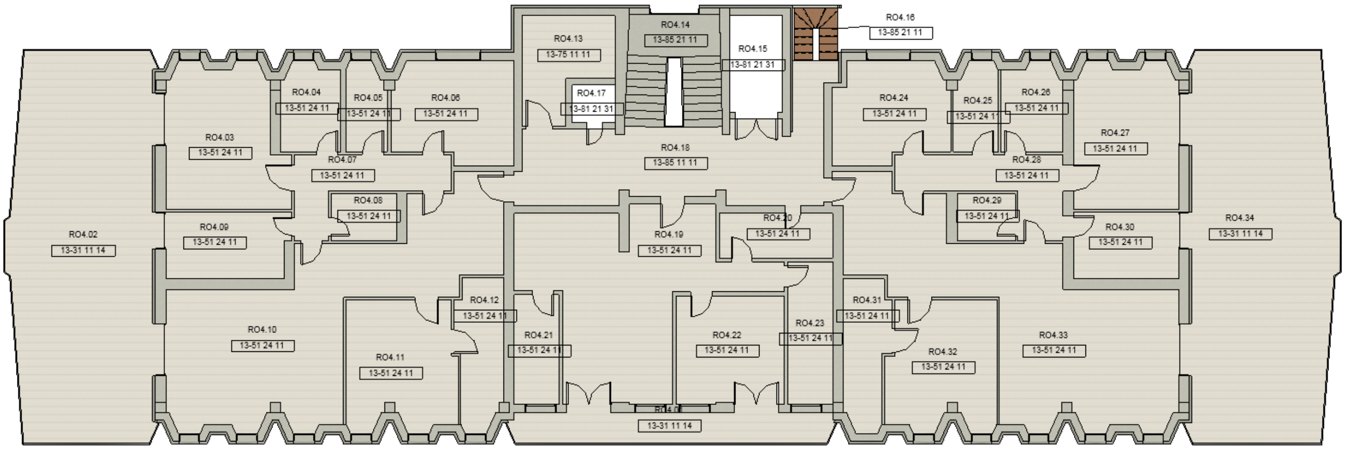
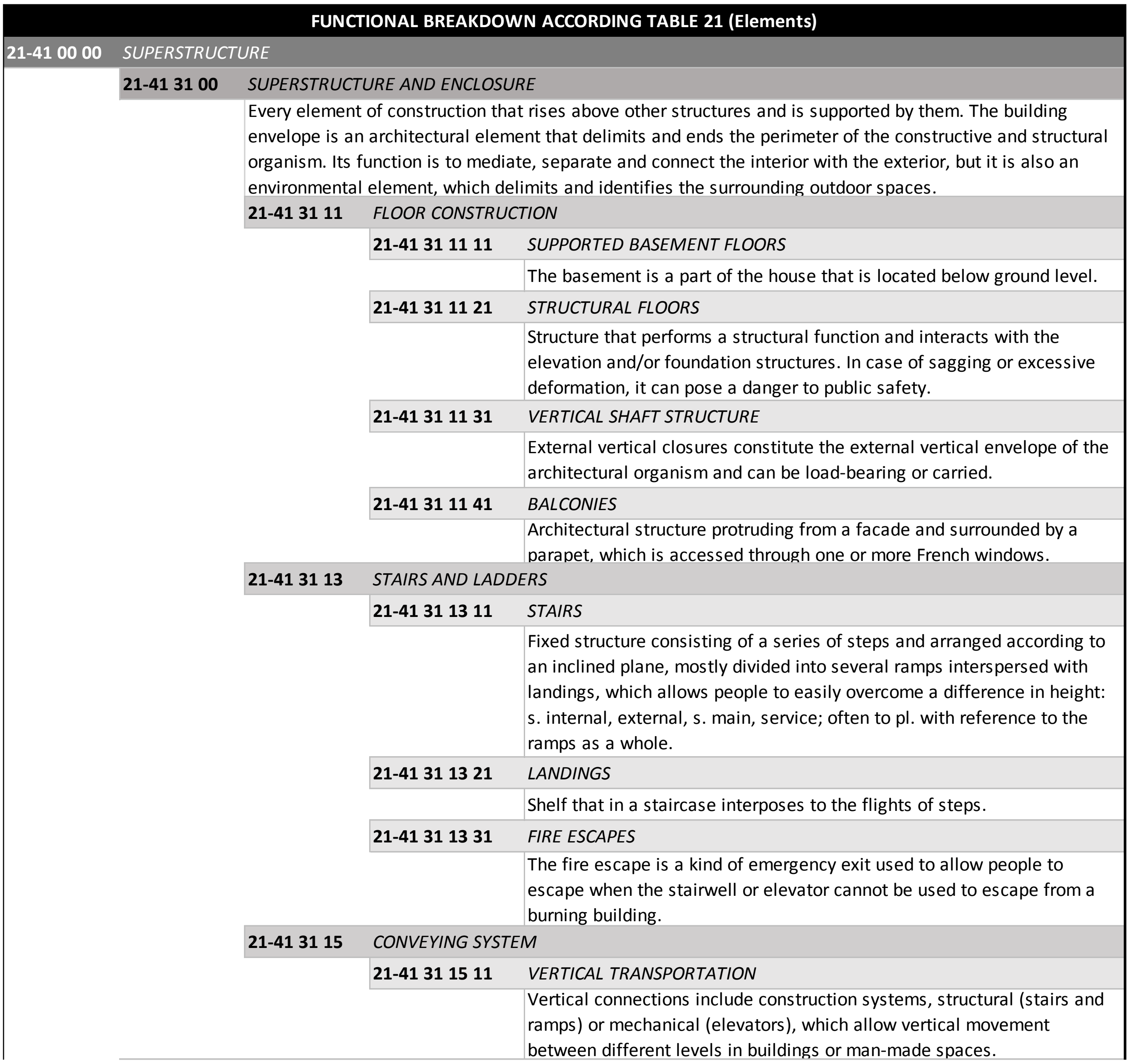


Figure A-03.E. *Fourth Floor*



FUNCTIONAL BREAKDOWN ACCORDING TABLE 21 (Elements)				
21-41 00 00	*SUPERSTRUCTURE*			
	21-41 31 00	*SUPERSTRUCTURE AND ENCLOSURE*		
		Every element of construction that rises above other structures and is supported by them. The building envelope is an architectural element that delimits and ends the perimeter of the constructive and structural organism. Its function is to mediate, separate and connect the interior with the exterior, but it is also an environmental element, which delimits and identifies the surrounding outdoor spaces.		
		21-41 31 11	*FLOOR CONSTRUCTION*	
			21-41 31 11 11	*SUPPORTED BASEMENT FLOORS*
				The basement is a part of the house that is located below ground level.
			21-41 31 11 21	*STRUCTURAL FLOORS*
				Structure that performs a structural function and interacts with the elevation and/or foundation structures. In case of sagging or excessive deformation, it can pose a danger to public safety.
			21-41 31 11 31	*VERTICAL SHAFT STRUCTURE*
				External vertical closures constitute the external vertical envelope of the architectural organism and can be load-bearing or carried.
			21-41 31 11 41	*BALCONIES*
				Architectural structure protruding from a facade and surrounded by a parapet, which is accessed through one or more French windows.
		21-41 31 13	*STAIRS AND LADDERS*	
			21-41 31 13 11	*STAIRS*
				Fixed structure consisting of a series of steps and arranged according to an inclined plane, mostly divided into several ramps interspersed with landings, which allows people to easily overcome a difference in height: s. internal, external, s. main, service; often to pl. with reference to the ramps as a whole.
			21-41 31 13 21	*LANDINGS*
				Shelf that in a staircase interposes to the flights of steps.
			21-41 31 13 31	*FIRE ESCAPES*
				The fire escape is a kind of emergency exit used to allow people to escape when the stairwell or elevator cannot be used to escape from a burning building.
		21-41 31 15	*CONVEYING SYSTEM*	
			21-41 31 15 11	*VERTICAL TRANSPORTATION*
				Vertical connections include construction systems, structural (stairs and ramps) or mechanical (elevators), which allow vertical movement between different levels in buildings or man-made spaces.

Figure A-04.A. *Breakdown Structure from OmniClass Table 21*

	21-41 51 00	*ENCLOSURE*		
		The building envelope is an architectural element that delimits and ends the perimeter of the building and structural organism. Its function is to mediate, separate and connect the interior with the exterior, but it is also an environmental element, which delimits and identifies the surrounding outdoor spaces.		
		21-41 51 11	*VERTICAL ENCLOSURE*	
			21-41 51 11 11	*Exterior Walls*
				The perimeter walls are common parts of a condominium building that delimit the spaces included in them.
		21-41 51 11	*VERTICAL OPENINGS*	
			21-41 51 13 11	*TRANSPARENT OPENINGS*
				Opening in the external wall of a building to give light and air inside, generally also allowing the view to the outside; it can be one or more lights, and is equipped with a mobile frame, equipped with glass and shutters, so that it can be opened or closed as desired.
		21-41 51 15	*HORIZONTAL/SLOPED PROTECTION*	
			21-41 51 15 41	*Waterproofing*
				A waterproofing membrane is a thin layer of material used to prevent water from contacting another material that it is placed over.
	21-41 71 00	*INTERIOR*		
		The whole of the enclosed spaces, of the rooms of a building, in contrast to its external parts		
		21-41 71 11	*INTERIOR CONSTRUCTION*	
			21-41 71 11 11	*FIRE WALLS*
				A fire-resistant wall is a structure designed to slow the spread of heat, smoke and flame during an emergency. Properly built firewalls give occupants more time to safely exit the building during a fire and can help reduce total damage to the property.
			21-41 71 11 31	INTERIOR PARTITIONS
				The vertical interior partitions are made up of the set of technological units designed to separate the interior spaces and to regulate communications between them.
		21-41 71 12	*OPENINGS AND DOORS*	
			21-41 71 12 21	*INTERIOR DOORS*
				Doors inside the building that connect different rooms.
		21-41 71 15	*INTERIOR FINISHES*	
			21-41 71 12 21	*FLOOR FINISHED*
				Finished floor level **(FFL)** refers to the uppermost surface of a floor once construction has been completed but before any finishes have been applied.
			21-41 71 15 31	*WALL FINISHES*
				As the name “Wall Finishes” itself suggests that it is finish given to the wall to enhance the interior or exterior look of the structure. Wall finishes used for the interiors are quite delicate and need maintenance.
			21-41 71 15 11	*STAIR FINISHES*
				Cladding material and finishing of stairs
21-51 00 00	*FACILITY SERVICES*			
		Facilities service requests are defined as work outside of routine maintenance that does not involve a change in space use or space classification, require professional engineering, or permitting. Facilities services are performed on a re-bill basis for actual charges incurred.		
	21-51 51 00	*HEATING, VENTILATING AND AIR CONDITIONING (HVAC)*		
		21-51 51 12	*HEATING*	
			Equipment or devices used to provide heat, especially to a building.	
			21-51 51 12 11	Heat Generation for Single Facility

Figure A-04.B. *Breakdown Structure from OmniClass Table 21*

	21-51 71 00	*ELECTRICAL*		
			An electrical system, within the context of a building, is a network of conductors and equipment designed to carry, distribute and convert electrical power safely from the point of delivery or generation to the various loads around the building that consume the electrical energy	
		21-51 71 11	*ELECTRICAL POWER*	
			Electric power is the rate, per unit time, at which electrical energy is transferred by an electric circuit	
			21-51 71 11 14	Electrical Service and Distribution for Single Facility
		21-51 71 15	*LIGHTNING*	
			Artificial Light is any light source that is not naturally occurring. Artificial Light includes things like flash/strobes, of course, but also any street lights, indoor lighting, or other man-made light sources.	
			21-51 71 15 11	Interior Lightning
21-61 00 00	*FACILITY EQUIPMENT AND FURNISHING*			
	21-61 11 00	*EQUIPMENT AND FURNISHING*		
		Equipment and furnishings means any equipment or furnishings that are portable and of standard manufacture.		
		21-61 11 21	*WORK ENVIRONMENT EQUIPMENT AND FURNISHING*	
			21-61 11 21 61	*OFFICE EQUIPMENT AND FURNISHINGS*
		21-61 11 24	*FURNITURE AND FITTINGS*	
			21-61 11 24 31	*SHOP FURNITURE AND FURNISHINGS*

Figure A-04.C. *Breakdown Structure from OmniClass Table 21*

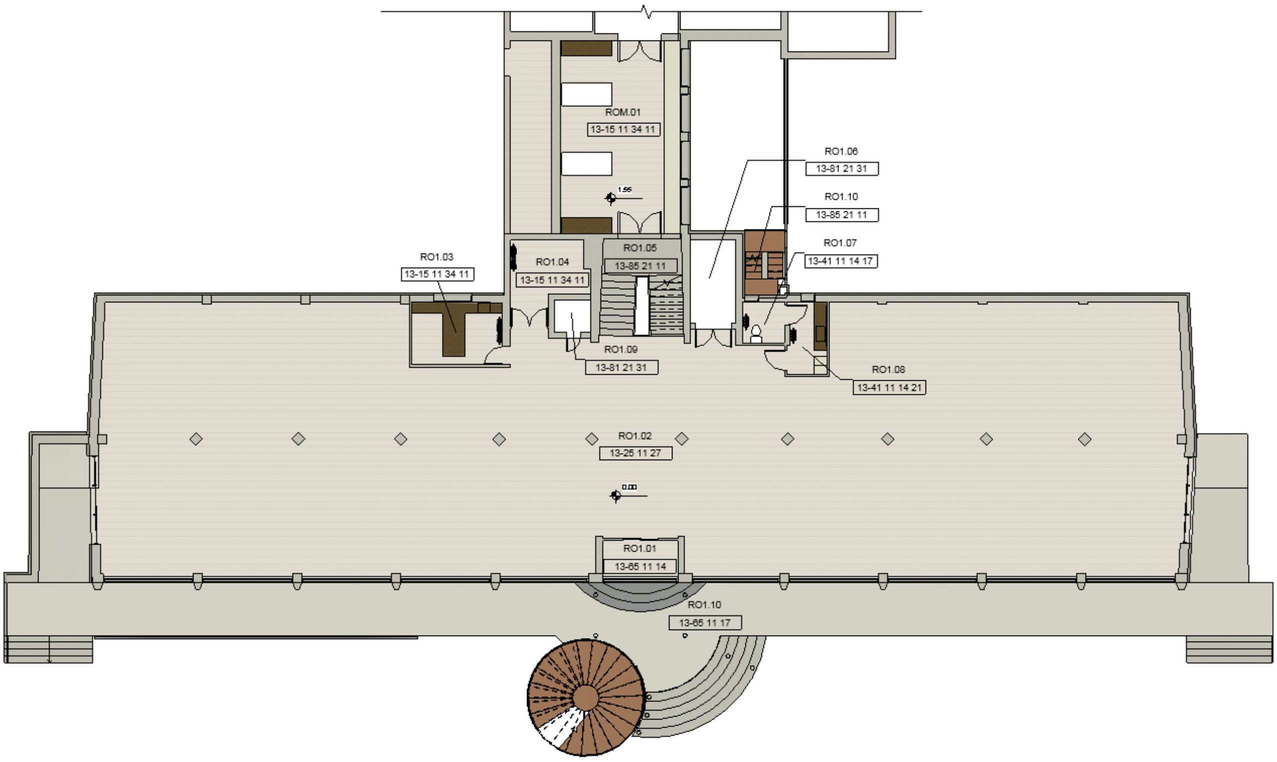


Figure A-05. *Analysed Area: First Floor and Mezzanine*

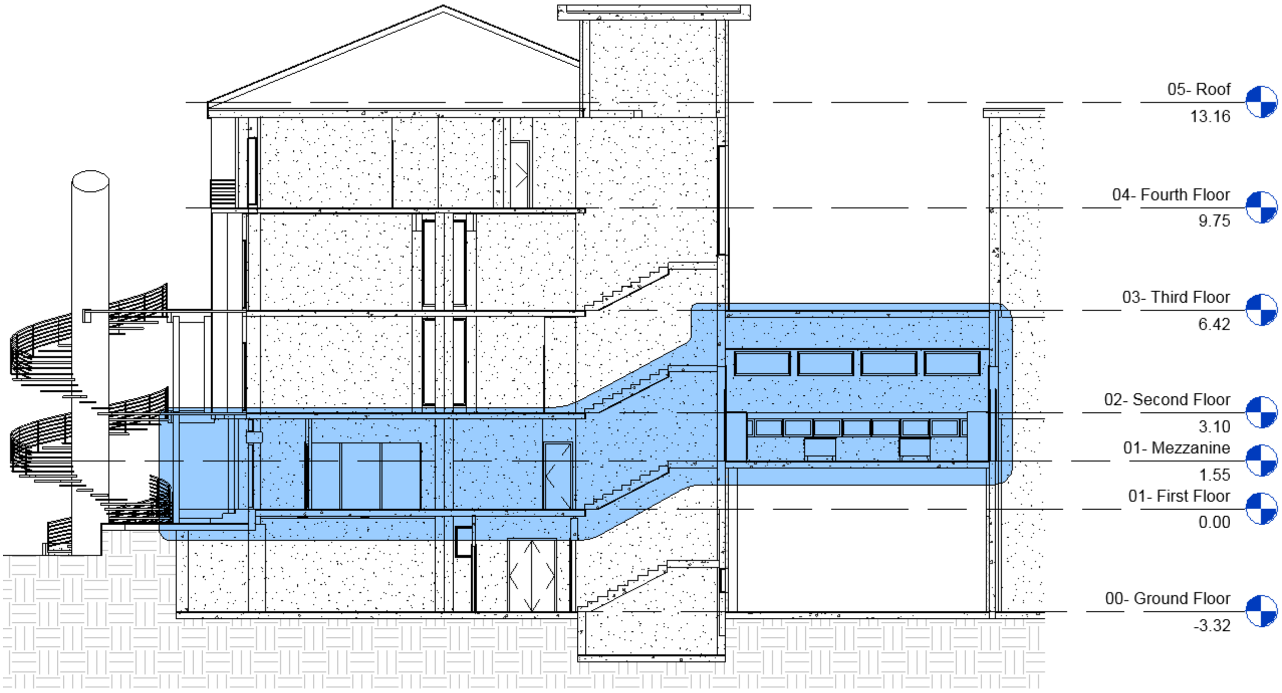


Figure A-06. *Analysed Area: Section*

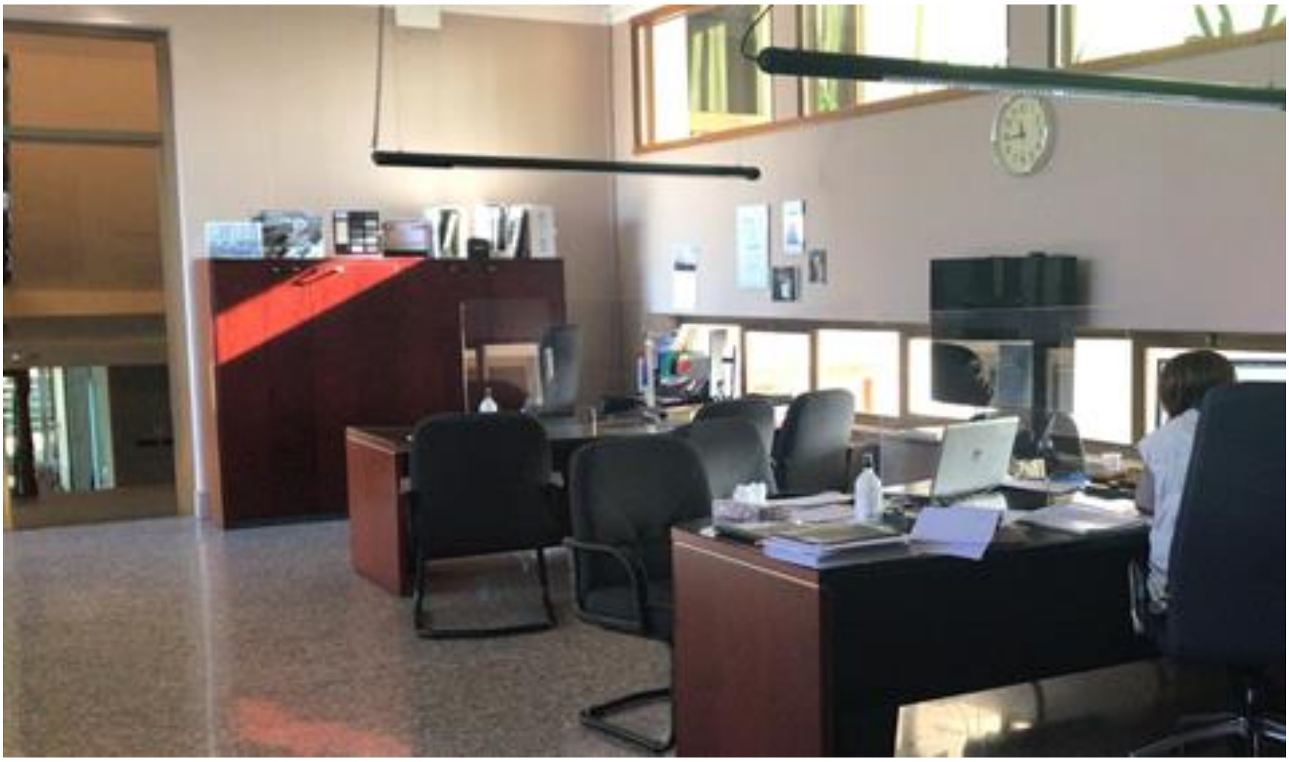


Figure A-07. *Case Study: Office's artificial lighting and furniture*

Figure A-08. *Case study: Office 2*

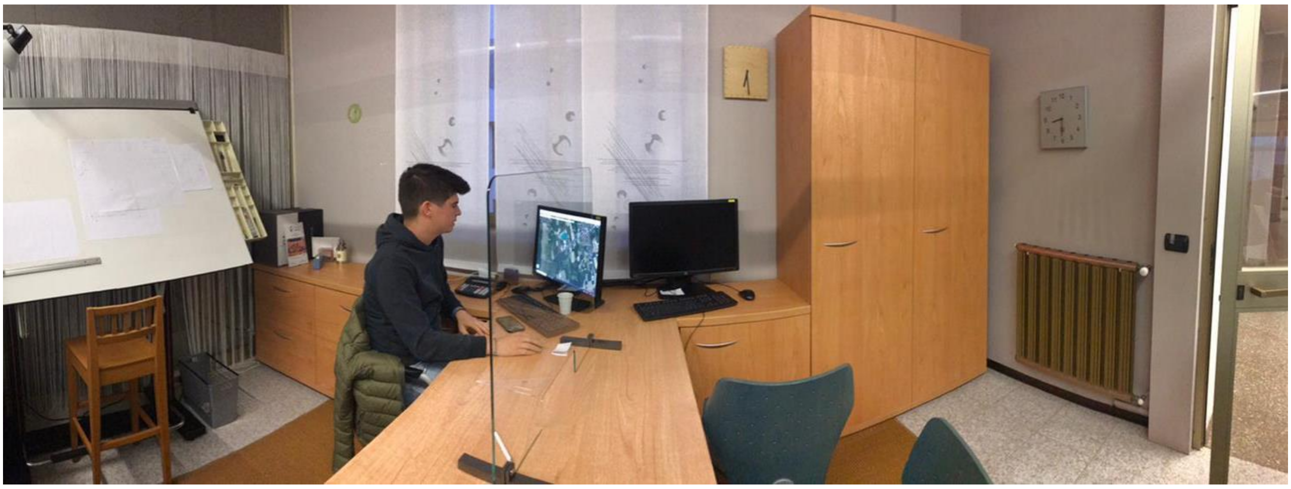
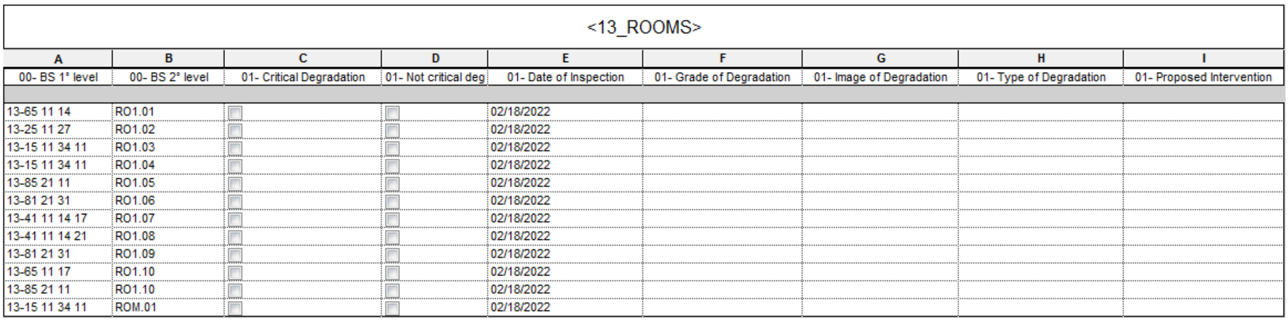


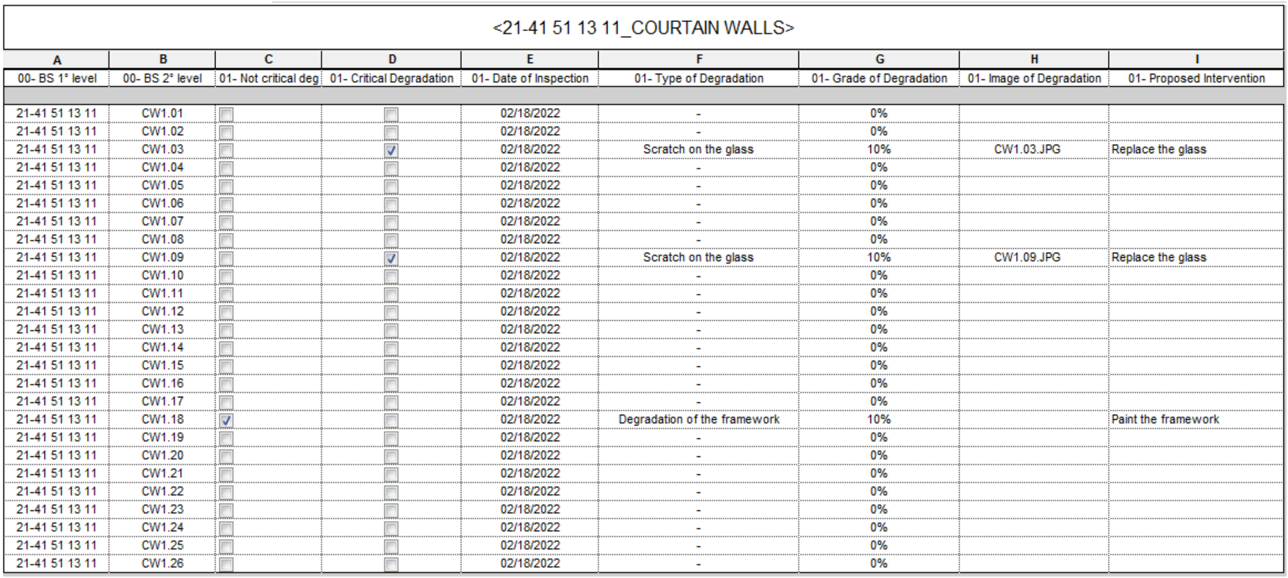
Figure A-09. *Case study: Office 3*



<13_ROOMS>

A	B	C	D	E	F	G	H	I
00- BS 1° level	00- BS 2° level	01- Critical Degradation	01- Not critical deg	01- Date of Inspection	01- Grade of Degradation	01- Image of Degradation	01- Type of Degradation	01- Proposed Intervention
13-65 11 14	RO1.01	☐	☐	02/18/2022				
13-25 11 27	RO1.02	☐	☐	02/18/2022				
13-15 11 34 11	RO1.03	☐	☐	02/18/2022				
13-15 11 34 11	RO1.04	☐	☐	02/18/2022				
13-85 21 11	RO1.05	☐	☐	02/18/2022				
13-81 21 31	RO1.06	☐	☐	02/18/2022				
13-41 11 14 17	RO1.07	☐	☐	02/18/2022				
13-41 11 14 21	RO1.08	☐	☐	02/18/2022				
13-81 21 31	RO1.09	☐	☐	02/18/2022				
13-65 11 17	RO1.10	☐	☐	02/18/2022				
13-85 21 11	RO1.10	☐	☐	02/18/2022				
13-15 11 34 11	ROM.01	☐	☐	02/18/2022				

Figure A-10. *Condition Assessment schedule - Mezzanine and First Floor rooms*



<21-41 51 13 11_COURTAIN WALLS>

A	B	C	D	E	F	G	H	I
00- BS 1° level	00- BS 2° level	01- Not critical deg	01- Critical Degradation	01- Date of Inspection	01- Type of Degradation	01- Grade of Degradation	01- Image of Degradation	01- Proposed Intervention
21-41 51 13 11	CW1.01	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.02	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.03	☐	☑	02/18/2022	Scratch on the glass	10%	CW1.03.JPG	Replace the glass
21-41 51 13 11	CW1.04	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.05	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.06	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.07	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.08	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.09	☐	☑	02/18/2022	Scratch on the glass	10%	CW1.09.JPG	Replace the glass
21-41 51 13 11	CW1.10	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.11	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.12	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.13	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.14	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.15	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.16	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.17	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.18	☑	☐	02/18/2022	Degradation of the framework	10%		Paint the framework
21-41 51 13 11	CW1.19	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.20	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.21	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.22	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.23	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.24	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.25	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	CW1.26	☐	☐	02/18/2022	-	0%		

Figure A-11. *Condition Assessment schedule – Mezzanine, First and Second Floors curtain walls*

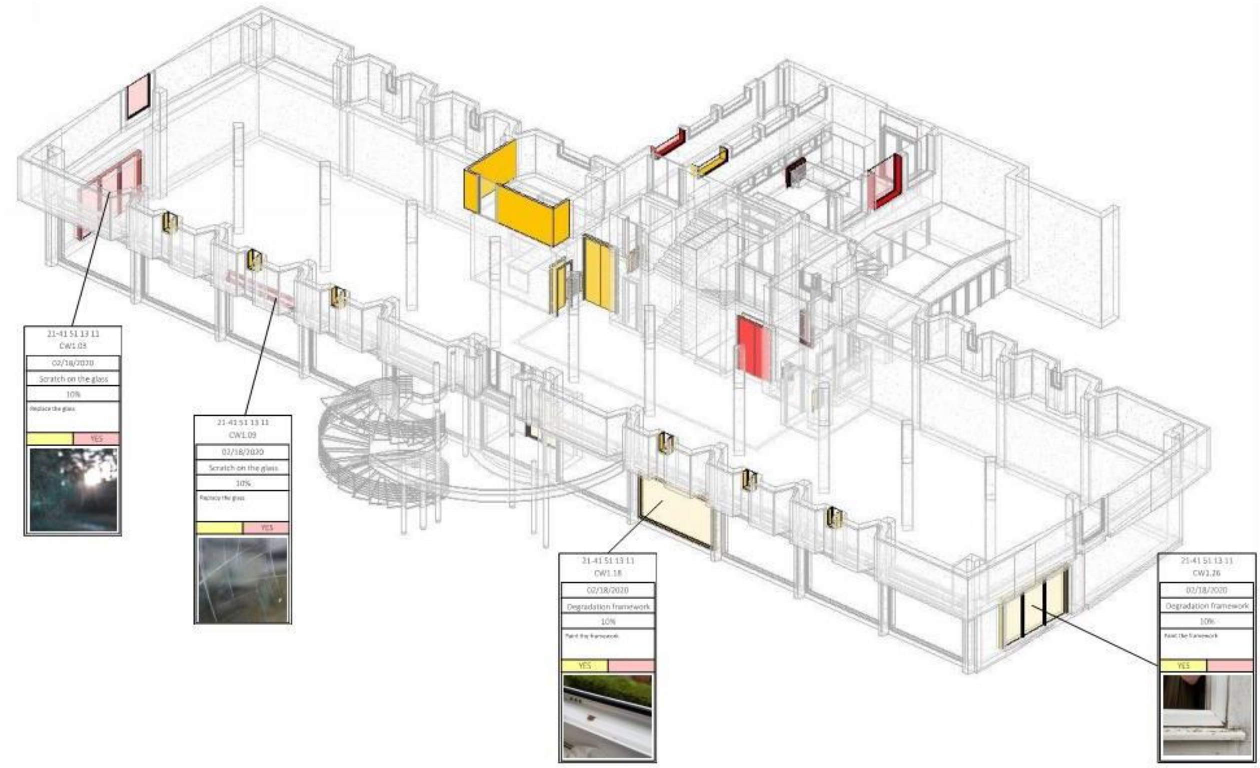
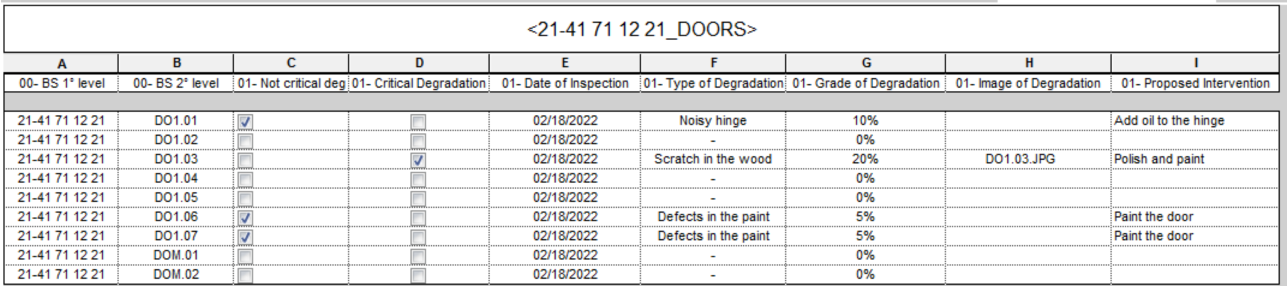


Figure A-12. *Condition Assessment 3D - Mezzanine and First Floor curtain walls*



<21-41 71 12 21_DOORS>

A	B	C	D	E	F	G	H	I
00- BS 1° level	00- BS 2° level	01- Not critical deg	01- Critical Degradation	01- Date of Inspection	01- Type of Degradation	01- Grade of Degradation	01- Image of Degradation	01- Proposed Intervention
21-41 71 12 21	DO1.01	☑	☐	02/18/2022	Noisy hinge	10%		Add oil to the hinge
21-41 71 12 21	DO1.02	☐	☐	02/18/2022	-	0%		
21-41 71 12 21	DO1.03	☐	☑	02/18/2022	Scratch in the wood	20%	DO1.03.JPG	Polish and paint
21-41 71 12 21	DO1.04	☐	☐	02/18/2022	-	0%		
21-41 71 12 21	DO1.05	☐	☐	02/18/2022	-	0%		
21-41 71 12 21	DO1.06	☑	☐	02/18/2022	Defects in the paint	5%		Paint the door
21-41 71 12 21	DO1.07	☑	☐	02/18/2022	Defects in the paint	5%		Paint the door
21-41 71 12 21	DOM.01	☐	☐	02/18/2022	-	0%		
21-41 71 12 21	DOM.02	☐	☐	02/18/2022	-	0%		

Figure A-13. *Condition Assessment schedule – Mezzanine and First Floor doors*

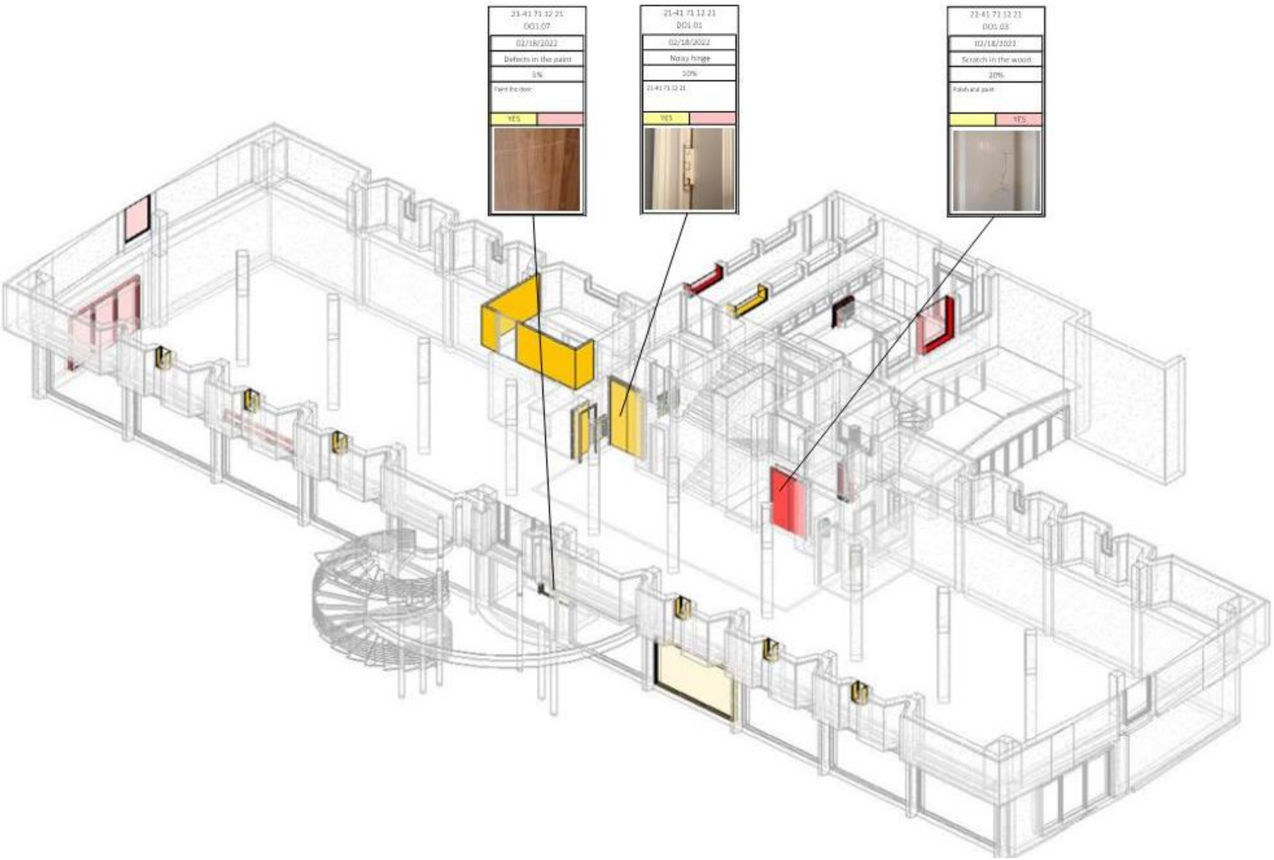
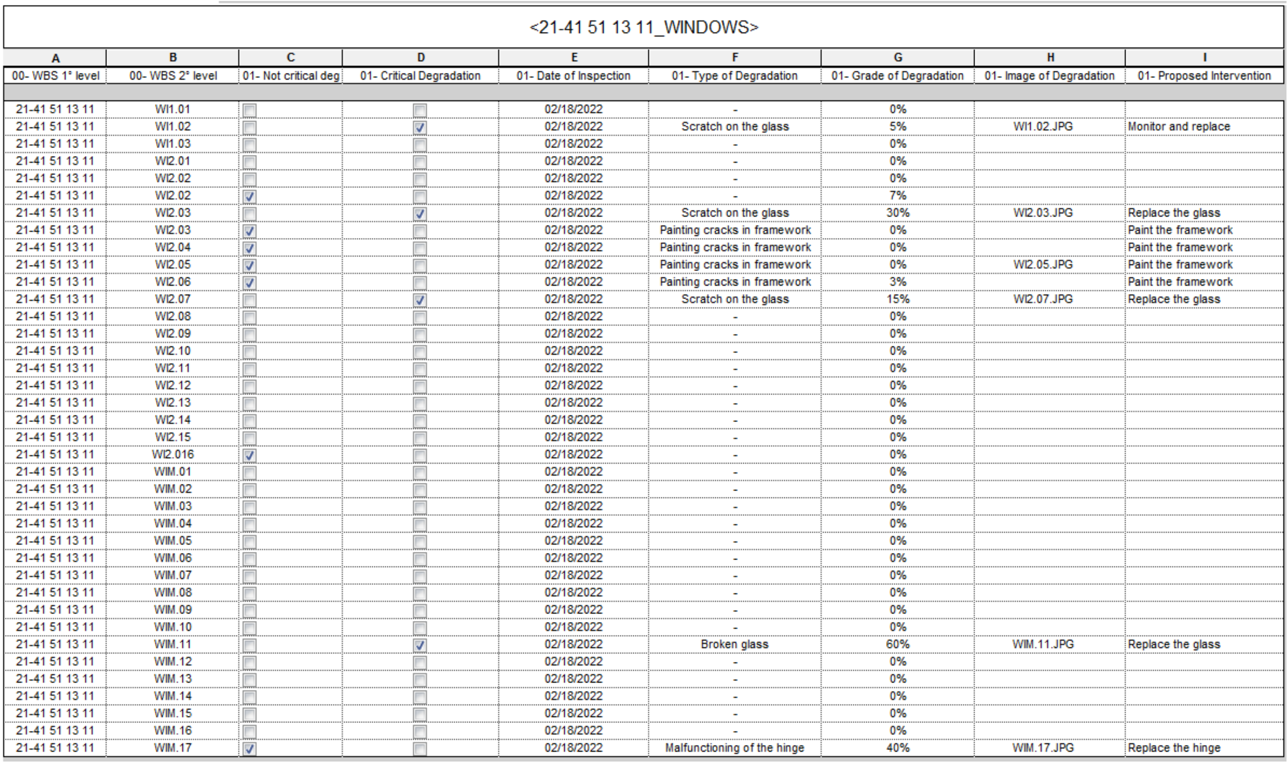


Figure A-14. *Condition Assessment 3D - Mezzanine and First Floor doors*



<21-41 51 13 11_WINDOWS>

A	B	C	D	E	F	G	H	I
00- WBS 1° level	00- WBS 2° level	01- Not critical deg	01- Critical Degradation	01- Date of Inspection	01- Type of Degradation	01- Grade of Degradation	01- Image of Degradation	01- Proposed Intervention
21-41 51 13 11	WI1.01	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI1.02	☐	☑	02/18/2022	Scratch on the glass	5%	WI1.02.JPG	Monitor and replace
21-41 51 13 11	WI1.03	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.01	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.02	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.02	☑	☐	02/18/2022	-	7%		
21-41 51 13 11	WI2.03	☐	☑	02/18/2022	Scratch on the glass	30%	WI2.03.JPG	Replace the glass
21-41 51 13 11	WI2.03	☑	☐	02/18/2022	Painting cracks in framework	0%		Paint the framework
21-41 51 13 11	WI2.04	☑	☐	02/18/2022	Painting cracks in framework	0%		Paint the framework
21-41 51 13 11	WI2.05	☑	☐	02/18/2022	Painting cracks in framework	0%	WI2.05.JPG	Paint the framework
21-41 51 13 11	WI2.06	☑	☐	02/18/2022	Painting cracks in framework	3%		Paint the framework
21-41 51 13 11	WI2.07	☐	☑	02/18/2022	Scratch on the glass	15%	WI2.07.JPG	Replace the glass
21-41 51 13 11	WI2.08	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.09	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.10	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.11	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.12	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.13	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.14	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.15	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WI2.016	☑	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.01	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.02	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.03	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.04	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.05	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.06	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.07	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.08	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.09	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.10	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.11	☐	☑	02/18/2022	Broken glass	60%	WIM.11.JPG	Replace the glass
21-41 51 13 11	WIM.12	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.13	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.14	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.15	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.16	☐	☐	02/18/2022	-	0%		
21-41 51 13 11	WIM.17	☑	☐	02/18/2022	Malfunctioning of the hinge	40%	WIM.17.JPG	Replace the hinge

Figure A-15. *Condition Assessment schedule - First Floor windows*

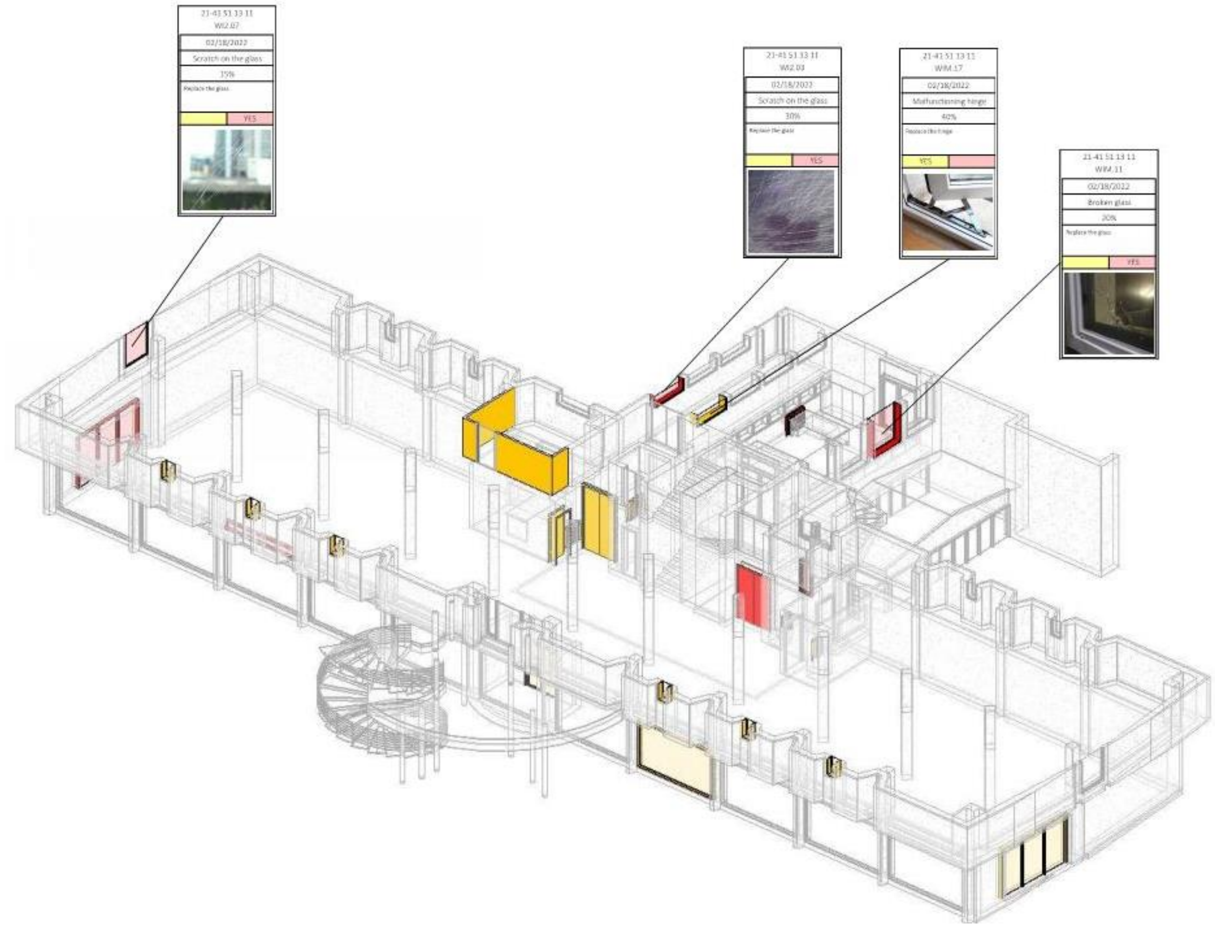


Figure A-16. *Condition Assessment 3D - First Floor windows*

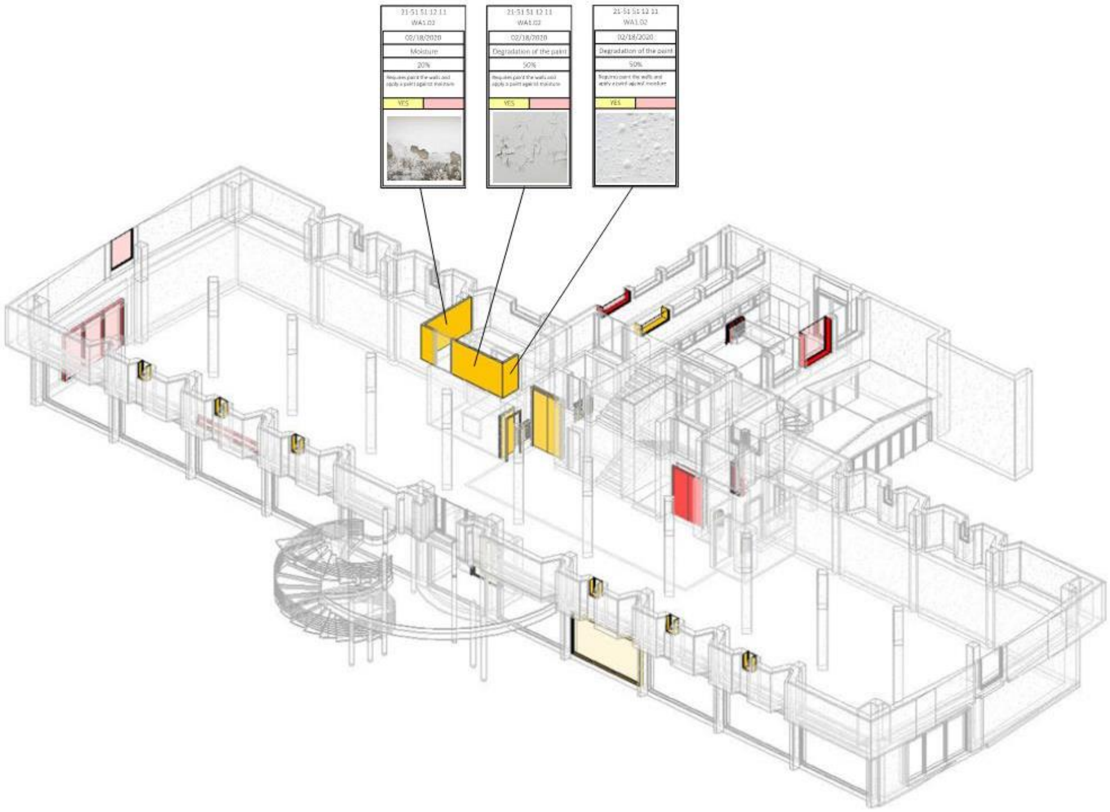


Figure A-17. *Condition Assessment 3D - First Floor walls*

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