

POLITECNICO DI TORINO

CORSO DI LAUREA MAGISTRALE IN
ARCHITETTURA PER IL PROGETTO SOSTENIBILE



TESI DI LAUREA MAGISTRALE

BIM for project management in federated models: The Trompone case study

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Luglio 2018

*To my Family
especially to
Nonno Felice.*

*"The success is achieved by ordinary people with extraordinary
determination." Z.Z*

ACKNOWLEDGEMENTS

Firstly i want to thank all the people were collaborating with me in the BIMforHealth group, because a part of this work is the results of a larger collaboration.

Then my gratitude goes to Anna Osello and Matteo Del Giudice for teaching me and to always providing many advices fundamental for this thesis development.

In last i want to thank prof. Fabio Manzone for giving me a precious consulting for what concern the building site organization and the working time schedule redaction.

ABSTRACT:

In a constantly changing field like construction industry, BIM represent the last revolution, which is deeply changing the whole process, from the design phase to the facility manage during all the life cycle.

In this scenario was developed this thesis, operating in a sensible facility such as healthcare complex like Trompone, where BIM was applied, firstly to have a restitution of the facility through shaping the state of affairs, creating a complex sharing strategy constituted basically by federated files and point clouds surveys, aimed to organize many actors working at the same project, providing a common data environment following the British standard.

In this context was developed the Winter Garden Project, placed in a facility courtyard, creating a 4D and 5D model, that represent the BIM strength, implementing the alphanumeric information degree applicable to the model, and using it to have a direct correspondence with the construction time schedule and a cost report, through the redaction of a Gantt chart, implemented by the addition of human and material resources. The results expected by the data implementation of the project, are to have a better management especially during the building site phase, for what concern costs and timing, detecting the project also during the construction phase, that allows a complete knowledge and the possibility to modify some aspects during construction, which aim is the improvement of the construction process.

CONTENTS:

Abstract

1. Introduction

1.1 BIM introduction	13
1.1.1 BIM history and definitions	15
1.1.2 BIM dimensions	19
1.1.3 BIM history and developments	21
1.1.4 BIM elements classification	23
1.1.5 Parameters	25
1.1.6 LOD	26
1.1.7 BIM strength and sharing	29
1.1.8 Italian & European BIM standards	32
1.1.9 CDE Common Data Environment	35
1.2 Study case	
1.2.1 The facility	43
1.2.2 State of Art, BIM for healthcare facilities	46
1.2.3 BIMforHealth a working group	50
1.3 Construction management	
1.3.1 BIM for 4D overview	55
1.3.2 WBS	57
UNI 8290	58
Masterformat	59
Omniclass	60
Uniclass	62
Unifomat	64
Comparison	65
1.3.3 BIM for 5D	68

2. Methodology

2.1 Sharing strategies into federate models	71
2.1.1 Data collection	74
2.1.2 CDE (Common Data Environment)	76
2.1.3 Shared coordinates	79
2.1.4 Sharing strategies	81
First scheme	82
Second scheme	84
Third scheme	86
Fourth scheme	90
Fifth scheme	92
Fifth scheme adopted	94
2.1.5 Point clouds use in federated files	98
2.1.6 Adopted coding	102

2.2 Shaping phase	109
2.2.1 Shaping state of affairs	111
2.2.2 Parametric families	115
2.2.3 Model division	116
2.2.4 Preliminary design considerations in Formit	119
2.2.5 Project model	
Structural model	121
Architectural model	126
MEP model	129
Topographic model	132
2.3 Construction management	135
2.3.1 WBS	136
2.3.2 Activity code	139
2.3.3 Key Note, code insertion in Revit	142
2.3.4 Revit phases	144
2.3.5 Time schedule, Gantt chart	145
2.3.6 Resources and 5D	153
2.3.7 Interoperability tests	158
2.3.6 4D simulation	161
3. Results & Future developments	169
3.1 Results	
3.1.1 Shaping results	171
3.1.2 Sharing strategies results	174
3.1.3 Project management Results	175
3.2 Future developments	181

Attachments

References

Bibliography

Acknowledgments

Acronyms:

AEC "Architecture engineering and Construction"

AIA "American Institute of Architects"

BEP "BIM Execution Plan"

BIM "Building Information Modeling, Model or Management"

BSI "British Standard Institute"

CAD "Computer Aided Design, Drawing, Drafting"

CDE "Common Data Environment"

CSC "Construction Specification Canada"

CSI "Construction Specification Institute"

FM "Facility Management"

GIS "Geographical Information System"

GUID "Global Unique Identifier"

HBIM "Historical BIM"

HVAC "Heating, Ventilation, Air Conditioning"

LEED "The Leadership in Energy and Environmental Design"

LIDAR "Light Detection and Ranging or Laser Imaging Detection and Ranging"

LOD "Level Of Detail or Level Of Development"

LOG "Level Of Geometry"

LOI "Level Of Informations"

MEP "Mechanical, Electric and Plumbing"

MTBL "Model To Be Linked"

NBIMS "National BIM Standard"

QTO "Quantity Take Off"

UNI "Ente Italiano di Normazione"

WBS "Work Breackdown Structure"

FORMATS:

.IFC "Information and Comunication Tecnology"

.MPP Microsoft Project format

.RCP Whole point cloud format

.RCS Point cloud regions format

.RVT Revit format

.NWC "Temporary trade specific file, Navisworks format"

.TXT Text document format

.XLSX Microsoft Excel format



INTRODUCTION

- .1 BIM INTRODUCTION**
- .2 STUDY CASE
- .3 PROJECT MANAGEMENT

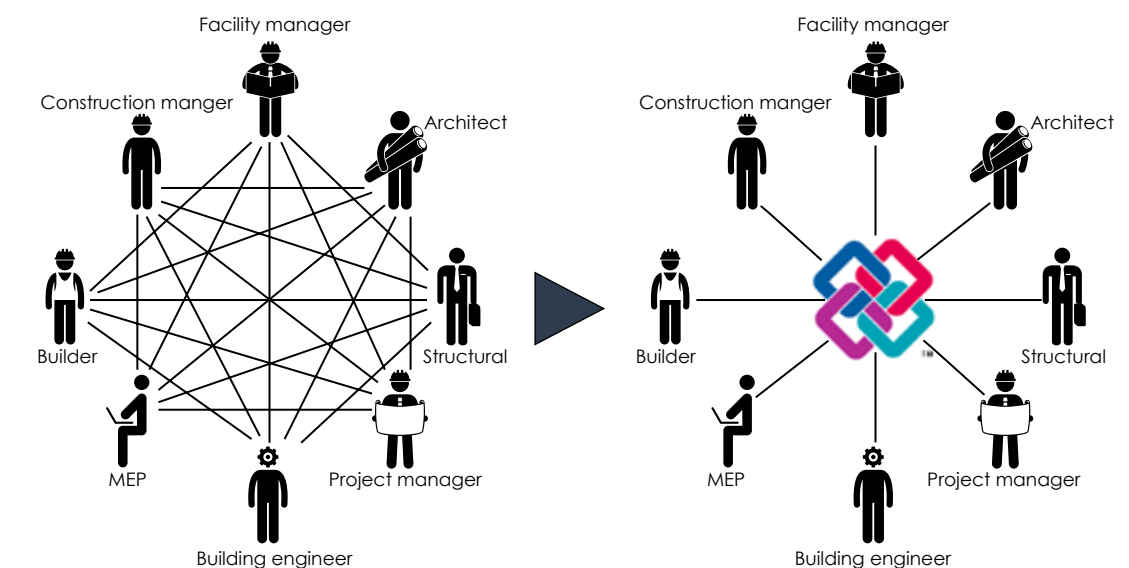
1.1.1 History and BIM definitions:

BIM intend as *Building Information Modeling*, is a method to **plan**, **design** and **manage** a facility, through a three dimensional model which also contain some other information further the dimensional ones, those kind of models can be used during all the **life-cycle** of the facility from the initial concept until the dismiss of the building. The range of use is large thanks to interoperability with other softwares that permit to share data between all stakeholders in the design and mange process which are operating in different fields.

The American National BIM Standard (NBIMS) Committee's introduces BIM as:

"Image for a moment all the individual actors in all the phases of a facility's life-cycle.

Imagine that all of the actors, working in familiar ways within their own specialty areas, are able to gather information, explore options, assemble, test, and perfect the elements of their work within a computer-based model before committing their work to be shared with or passed on to others, to be built, or to be operated. Imagine further that when it becomes necessary to share or pass a bundle of information to another organization, which may or may not be using the same tools, or to move it on to another phase of work, it is possible to safely and almost instantaneously (through a computer-to-computer communication) share or move just the right bundle of information without loss or error and without giving up appropriate control. In the imaginary world the exchange is standardized across the entire industry such that each item is recognized and understood without the parties having to create their own set of standards for that project team



Sharing schemes comparison 2D drawings vs BIM models

or for their individual organizations. Finally imagine that for the life of the facility every important aspect regardless of how, when, or by whom it was created or revised, could be readily, captured, stored, researched, and recalled as needed to support rel property acquisition and management, occupancy, operations, remodeling, new construction, and analytics. [1]" The acronym BIM can be indented in different ways , there are some definition to portray it, in the written references we can find some different description for it:

- BIM as Building information Modeling:

"With BIM technology, an accurate virtual model of a building is constructed digitally: When completed, the computer generate a model contains precise geometry relevant data needed to support the construction, fabrication and procurement activities needed to realize the building. [2]"

"Building Information Modeling [...] is a method that is based on a building model containing any information about the construction. In addition to the contents of the 3D object based models, this is information such as specifications, building elements specifications, economy and programmes. [3]"

[...] "a model need only two essential characteristics to be described as a BIM model: the first is that it must be a three dimensional representation of a building (or other facility) based on objects, the second it must include some information in the model or the properties about the object beyond the graphical representation. [4]"

- BIM as Building information Model:

"Is a digital representation of physical and functional characteristics of a facility. [...] a basic premise of BIM is the collaboration by different stakeholders at different phases of a facility life-cycle. [...] the BIM is a shared digital representation founded on open standard for interoperability. [5]"

"BIM is a data rich, object oriented, intelligent and parametric digital representation of the facility [...] [6]"

"A Building Information Model is 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. [7]"

- BIM as Beyond the Model:

"BIM is not a software application. BIM is an information based system that builds long-term value and advances innovation. It improves how projects get designed and built. It builds economic value in many areas.

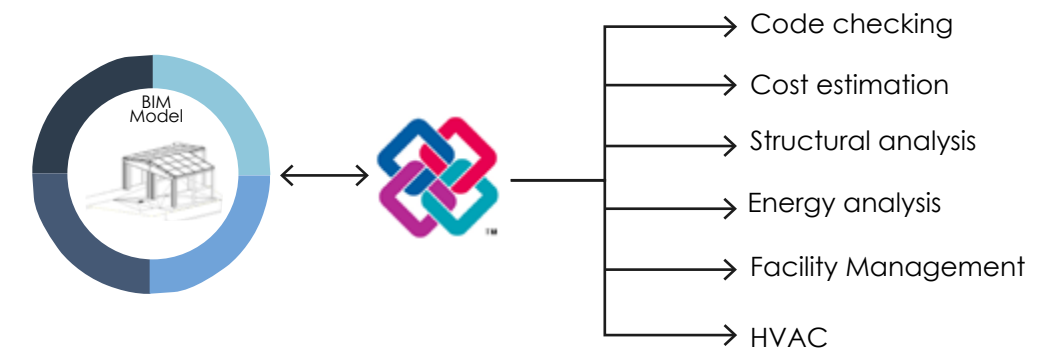
It improves the environment and people's lives. BIM is an evolutionary change in how people relate to the built environment. The speed of this change creates many opportunities for ambiguity. [...] we define BIM as Beyond the Information Model to align with the universal nature of the concept[8]"

As already said one of the most important aspects of BIM is the **interoperability**, between softwares that are used from the different actors, because engineering as architecture are a multi disciplines fields where is essential exchange of information in a construction process that include so many phases from the design concept passing through the facility management until the building dismiss.

That allows all the stakeholders to operate in a multi-disciplines common environment while using the same model that brings many advantages in comparison to, a normal CAD process where all informations exchange between the actors is made without having a common environment and where the more used format as .dwg .dxf .pdf are not ables to transmit enough information which understanding depends always by the interpretation by the actors involved.

To allow a better exchange of information between BIM actors there are a couple of files formats that's are .IFC or .XML where the BIM model is the base of the entire process and the central item, where all the others fields involved in the process are gravitating around and take informations from.

The **.IFC (Industry Foundation Classes) format** is an object-data based file format with a data model that was developed by buildingSMART, IFC defines an EXPRESS based entity-relationship model consisting of several hundred entities organized into an object-based inheritance hierarchy.



BIM and IFC files possible applications

At the most basic level, IFC divides all the entities presents in a project in rooted and non-rooted entities. Rooted entities are identified through a GUID (Global Unique Identifier) that is an 128-bit number used to identify information in a computer system, and that provides attributes for name, description and revision control.

Non-Rooted entities don't have a proper identity exists only if related to a Rooted entity.

IfcRoot is subdivided into three abstract concepts: object definitions, relationships, and property sets:

- IfcObjectDefinition captures tangible object occurrences and types
- IfcRelationship captures relationships among objects
- IfcPropertyDefinition captures dynamically extensible properties about objects.

The **.XML format** is a simplified spatial building model and also an alternative of .IFC files. Thus is a way to share data from an BIM model to other software that allows a multi-disciplines analysis of the facility, such as structural, thermic, lighting ecc.

1.1.1 BIM Dimensions:

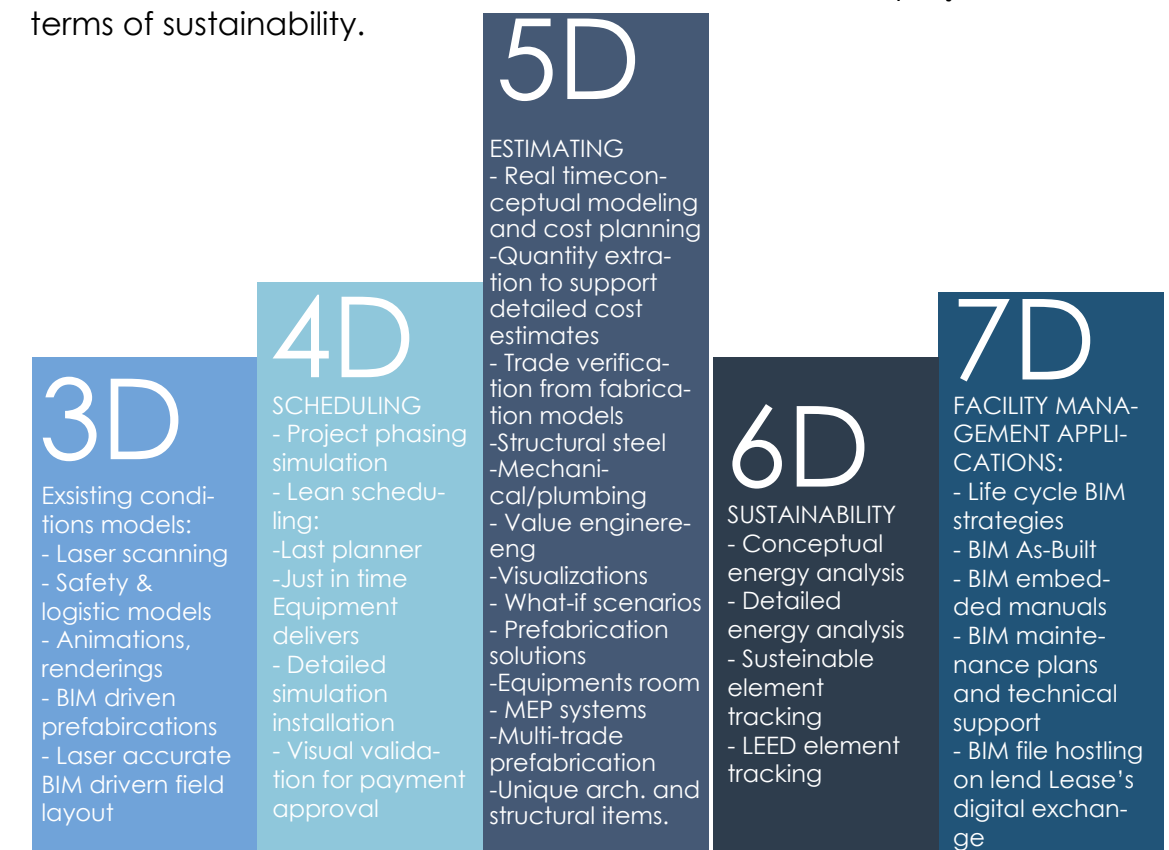
The BIM project goes beyond the normal 3 dimensional drawing typical of CAD approach, a BIM model suitably used can reach many level of informations such as:

2D / 3D: Typical drawing dimensions, it can produce 2D/3D drawings, the strength in those dimensions is that the software produce automatically those drawings, directly changing in any view when the operator made some modification at the model.

- 4D: The fourth dimension represent time, that's fundamental in manager activity to make a time - plan, to manage all the phases, the build site organization an all activities inside the process, as accessibility and avoid overlaps of different activities that could slow down the entire process.

- 5D: The cost represent the fifth dimension, it permit to monitor all the resources needed, to make more precisely plans then in the traditional way also thanks to a exactly count of materials and the interaction with the fourth dimension to cross timing and costs data.

- 6D: Sustainability: This approach allows to cross all the data presents in the model, and with interoperability tools to make energy simulation aimed to create different scenarios, to reach the best project choice in terms of sustainability.



BIM dimensions

- **7D: Facility Management:** Last dimension, applicable to the whole life-cycle of the facility, to make maintenance programs, and to organize all the activities related with the facility usage.

As described by Eselman the BIM dimensions are increasingly, and theoretically infinite: "4D is a planning process to link the construction activities represented in time schedules with 3D models to develop a real-time graphical simulation of construction progress against time. Adding the 4th dimension 'Time' offers an opportunity to evaluate the build ability and work-flow planning of a project. Project participant can effectively visualize, analyze, and communicate problems regarding sequential, spatial and temporal aspects of construction progress.

As a consequence, much more robust schedules, and site layout and logistic plans can be generated to improve productivity. Integrating the 5th dimension 'cost' to the BIM model generates the 5D model, which enables the instant generation of cost budgets and genetic financial representations of the model against time. This reduces the time taken for quantity take-off and estimation from weeks to minutes, improves the accuracy of estimates, minimizes the incidents for disputes from ambiguities in CAD data, and allows cost consultants to spend more time on value improvement. 6D allows extending the BIM for facilities management. The core BIM model is a rich description of the building elements and engineering services that provides an integrated description for a building. This feature together with its geometry, relationships and property capabilities underpins its use as a facilities management database. Incorporating sustainability components to the BIM model generates 7D models, which enable designers to meet carbon targets for specific elements of the project and validate the design decisions accordingly or test and compare different options. The 8th dimension incorporates safety aspects in both design and construction. In summary, BIM allows designers to more easily predict the performance of projects before they are built, respond to design changes faster, optimize designs with analyses, simulations and visualization, and deliver higher quality construction documentations. [9]"

1.1.2 History and BIM development:

The representation in architectural - engineering has changed along last 50 years, passing from a hand-drawing character to the introduction of CAD system in late seventies which changed a lot the way to produce drawings, thanks to those kind of software that allows to produce 2D and 3D drawings, CAD means basically two definitions:

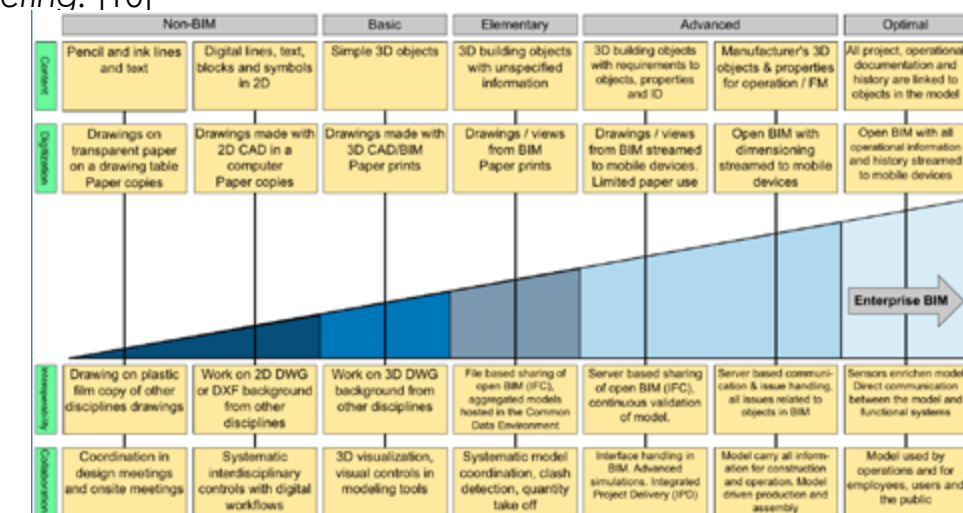
Computer aided Drafting it define the computer technology field which aim is to provide models typically in 2D of the technical drawing which describe the object which isn't the object.

Computer aided Design is the field in computer technology which purpose is to use software for the 2D or 3D representation to model the item which is the object of the job.

The use of CAD systems between '70 and '80 rise heavily when the designer realized the potential of this tool in terms to have more precisely drawings, avoiding errors and reducing timing, the other potentiality is to share in a digital way the files, but anyway the output is always a 2D drawing mostly printed in a paper sheet, where any actor involved works by himself in a individual way.

BIM was introduced in 1975 by Charles M. Chuck Eastman who defined BIM as following:

"Interactively defining elements deriving sections, plans, isometrics or perspectives from the same description of elements. Any change of arrangements would have to be made only once for all future drawings to be uploaded. All drawings derived from the same arrangement of elements would automatically be consistent any type of quantitative analysis could be coupled directly to the description, cost estimating or material quantities could be easily generated, providing a single integrated database for visual and quantitative analysis, automated building code checking in city hall or the architect's office. Contractors of large projects may find this representation advantageous for scheduling and material ordering. [10]"



BIM maturity scale [11]

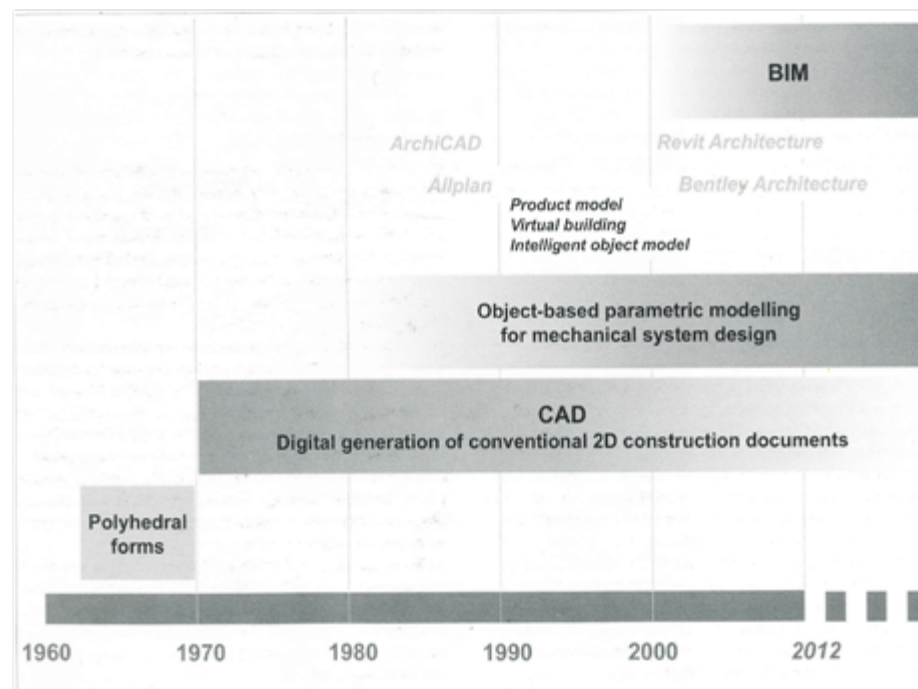
A BIM software was developed and commercialized firstly by Graphisoft an Hungarian softwarehouse in 1986 with the first software called Archicad, a long before those kind of programs were defined as BIM by Jerry Laiserin in 2002.

As showed in the previous picture, CAD systems stands at the level 0 which means the representation is made by simply and basics tool, that allows a 2D drawing it isn't a big change from the hand-drawing methodology, as knew the main weaknesses is the lack of coordination between the single drawings that increase costs by 25%.

Level 1 basically represent the step from 2D to 3D modeling leading to the first BIM application, still not coordinated.

In the second level there's the big change passing from a 3D representation to a BIM model which allows to bring many other informations such as costs, quantities, codes, or any other parameter composed by an alphanumeric sequence, using this kind of softwares, the use of this methodology with sharing strategies as the British standard BS 1192 : 2007, the same we used in this thesis permit to have a better coordination between the different designer and the different files, that should reduce waste by 50%.

Fourth level is what is still developing by who works in this sector, that's represent the interoperability in a opens source manner, leading to a complete share using an on-line platform available and queryable from anyone. It aim is to connect all the stakeholders creating a new kind of file independent from any software, and readable from anyone, that should allow a complete integrated process in a collaborative environment.



Drawings technical evolution [12]

1.1.3 Elements, Families, Types and Instances:

The BIM environment in Revit, that's the software it was used during the whole thesis, has a hierarchical structure to classify all the elements presents into the models, this hierarchical scale is done to have the possibility to work at many levels, that allows a deeper degree of detail, and a better manage of informations presents into the model.

The purpose of this classification of all elements present inside the BIM environment are many, and depends on what's your model oriented to. Any object present into a Revit file is categorized into this hierarchical classification that is represented in order by: Elements, Families, Types and Instances, this division is fundamental because any object has his own parameters connected at any of those levels.

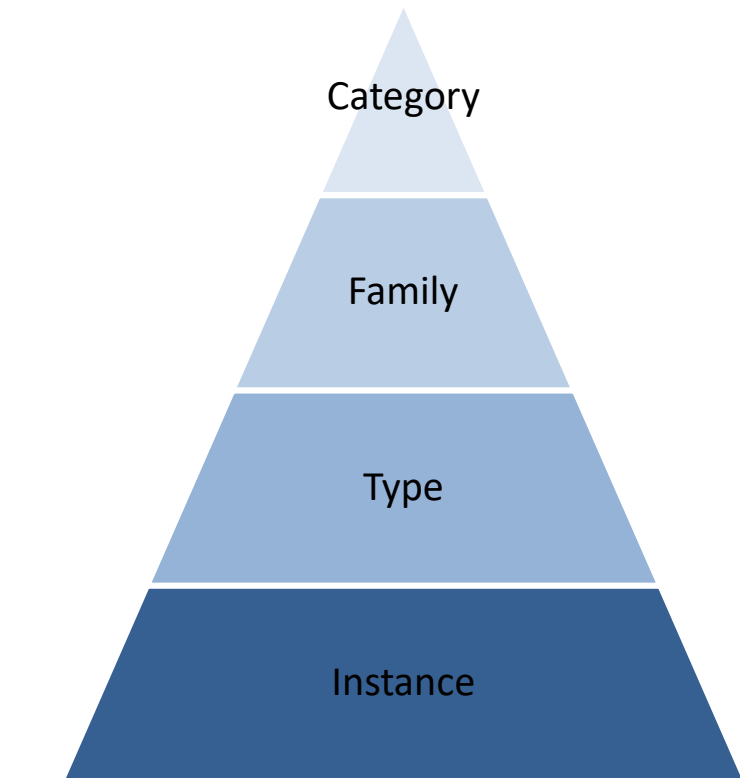
- **Categories or Elements:** any object inside a project is split into a categories, this is the first and biggest categorization, and includes all the object inside their own category, for example all the doors added in a project will be under the same category independently from the dimensions, materials or any other character, a door will always be categorized into door Elements categorization.

- **Families:** the division in families is the second approximation made to distinguish the elements, a family is a group of elements having a similar geometry, but what make two elements belonging to the same family are basically the properties of those elements, inside the same family some elements can have different values for some proprieties, but the set and the meaning of those properties is basically the same. There is three types of families.

- **System families:** are completely defined by Revit developers, are the families already presents into the software, it's not possible to delete those families but you can modify or create new families using those as a base for the new ones, simply doubling the original one.

- **Loadable families:** this kind of families usually are kind of components of the construction such as windows, doors, furnitures that in the construction process are usually installed in the building as a finished item. They can also be system elements compositing installations as HVAC, plumbing or electric. Those kind of family are possible to be created or modified directly in Revit families editor, unlike system families those are created by users and saved as .RSA file and loaded into a project.

- In Place Families: are normally create directly inside the BIM model with the same tools of loadable families, those families are widely used when you need a unique element into your project, and you don't expect to copy or reuse it, it isn't possible to create more types from a In Place Family as happens with the previous two.
- **Type:** is the sub-category of families, types are defined by parameters, there can be more types for the same family, it depends of the values of those parameters, families with same values of same parameters will be categorized in the same type.
- **Instance:** is the last degree of detail in an element, it basically depend from the place where the item is loaded, for example instance parameter for a window will be the position of the window relate to the wall that hosts the item.



BIM items classifications [13]

1.1.4 Parameters:

- There's basically three kind of parameters normally used in a Revit project, they are divided in shared parameter and project parameter both can be related to a type or instance:
- **Shared parameters:** Are parameter completely independent from any project or family, they are created and listed into an independent text file, that allows to share it, can also be used by different actors in different project, it's very useful in case of projects composed by many files, where anyone need to have the same parameters, that allows to avoid making every time the same procedure creating parameters from the beginning. Using this kind of parameter in multiple files project permit the software to recognize the same parameter it would be used for many purposes.
 - **Project parameters:** are defined inside the specific project, that doesn't permit the sharing between models, normally those kind of parameters are used in single project files, or anyway when the user knows certainly that he won't use this parameter related to this project anymore.
 - **Global parameters:** are very similar to project parameters but those can't be applied to an element inside the project but are used to define project characters such as define a value for a quote or a bond, connect a parameter to an instance property with the aim to define the value. To make a practical example it could be used in case we want to put beams under a floor, normally every time we want to put a beam we should insert an offset value for any beam, with global parameters it's possible to create a relation quote that will do it automatically.

```
# This is a Revit shared parameter file.
# Do not edit manually.
*META  VERSION  MINVERSION
META    2        1
*GROUP  ID      NAME
GROUP   1      Comune
*PARAM  GUID    NAME    DATATYPE    DATACATEGORY  GROUP  VISIBLE DESCRIPTION  USERMODIFI
PARAM   8951d411-58c3-4674-86c0-1b493fb4752b  Affidabilità  TEXT      1      1
PARAM   f2536e13-ded9-4112-9360-157e1bcc3e00  Nome edificio TEXT      1      1
PARAM   b0050b1e-abdb-4d40-81f4-a67904c17ca0  Tempo bullonatura h/t  NUMBER  1      1
PARAM   777afc26-1f8c-49a2-aaad-9c9aa2724385  Costo lavorazione €/Kg  NUMBER  1      1
PARAM   9bd43636-74e5-4433-9aee-3fa7ce2a0af3  Persiane        TEXT      1      1
PARAM   fb52cf47-d003-463f-a9c7-3f621fb2c59c  Area finestra   AREA      1      1
PARAM   d8f42948-f233-4a6f-a1f0-c8cf8fc856cc  Percentuale manodopera  NUMBER  1      1
PARAM   c1b2055b-752f-42c0-922a-74d0a5e79128  ID code TEXT    1      1      1
PARAM   f9ab5263-fe46-494f-ab28-bc86e351b629  Lavorazione     TEXT      1      1
PARAM   2607e76d-065d-4a0f-afd3-3fab400b42a9  Ore lavorative giornaliere  INTEGER  1
PARAM   3b24187f-ad9f-4366-8564-9070b39230ce  Posizionamento TEXT      1      1
PARAM   b4821184-3474-4b0b-be53-d6c393c4fc6c  Anno di costruzione  INTEGER  1      1
PARAM   db0fcf96-0044-41e6-bf7f-1b4c0811e9b0  Densità MASS_DENSITY  1      1
PARAM   3baf249e-4507-4e15-aecd-48d3fb2fd7e9  Numero componenti squadra tipo  NUMBER  1
PARAM   da8dfdb1-3144-48aa-a757-d193f8c8775f  Decorazione     TEXT      1      1
PARAM   7346afd1-83cc-452f-bf6c-c720d650065b  Costo           TEXT      1      1
PARAM   6e8e82d9-7e22-4e25-aec1-83e3140e4769  Tempo selezione e trasporto a piè d'opera (h/
```

An .txt file containing some shared parameter used in the project

1.1.5 LOD:

It becomes necessary to have a regulation about the level of detail and level of development of all those object modeled in the project, of course is not always required the highest level of detail for every object in any situation, to better understand what a LOD is and when to apply one or another LOD there are some regulation, the first is AIA E202 - 2008, by the *American Institution of Architects* (AIA), then has followed many others international regulation, and every country has is own regulation as Italy with UNI 11337-1:2017, or United Kingdom with UK PAS 1192-2:2013 which describe also the concept of BIM execution Plan (BEP) that's a previous plan that define all the goals to reach during the process and also the LOD to be used for every part of the model.

Thus LOD has two definitions:

- **Level of Detail (LOD):** is basically how much the object is detailed, depends on the 3D modeling and how much is accurate and close to the reality.

- **Level of Development (LOD):** is the degree of the informations associated to the object in the model, the degree to which project team members may rely on the information when using the model.

LOD are divided in five categories in growing order for detail and information presents into it , is important to say that is not only unnecessary to model every object with the highest level but it can be also unproductive, because of the several time spent to reach an high LOD and the effect that has in terms of time and costs, LOD are divided in a growing scale:

- **LOD 100:** The Model Element may be graphically represented in the Model with a symbol or other generic representation, but does not satisfy the requirements for LOD 200. Information related to the Model Element (i.e. cost per square foot, tonnage of HVAC, etc.) can be derived from other Model Elements.

- **LOD 200:** The Model Element is graphically represented within the Model as a generic system, object, or assembly with approximate quantities, size, shape, location, and orientation. Non graphic information may also be attached to the Model Element.

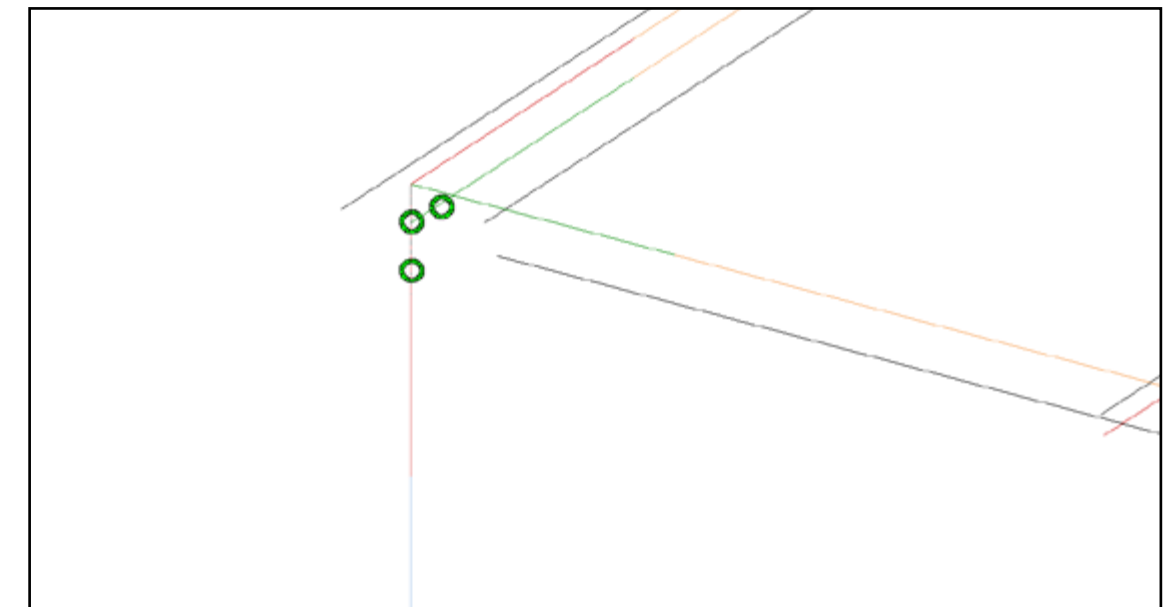
- **LOD 300:** The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of quantity, size, shape, location, and orientation. Non graphic information may also be attached to the Model Element.

- **LOD 350:** The Model Element is graphically represented within the Model as a specific system, object, or assembly in terms of quantity, size, shape, orientation, and interfaces with other building systems. Non graphic information may also be attached to the Model Element.

- **LOD 400:** The Model Element is graphically represented within the Model as a specific system, object or assembly in terms of size, shape, location, quantity, and orientation with detailing, fabrication, assembly, and installation information. Non graphic information may also be attached to the Model Element.

- **LOD 500:** The Model Element is a field verified representation in terms of size, shape, location, quantity, and orientation. Non graphic information may also be attached to the Model Elements.

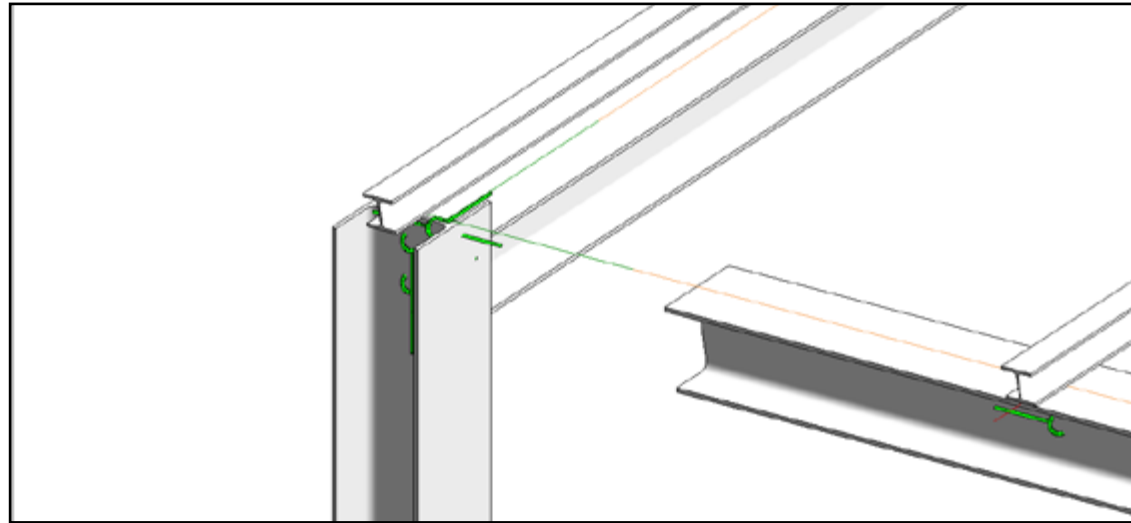
To better understand what a LOD is some examples are showed below an example took directly from the structure project made in this thesis, the graphic output is done using the detail view tool in the bar in Autodesk Revit which allow the user to decide between three levels of detail such as low, medium and high, that corresponds approximately to LOD 100, 300, 400.



An LOD 100 structural connection representation.

LOD 100:

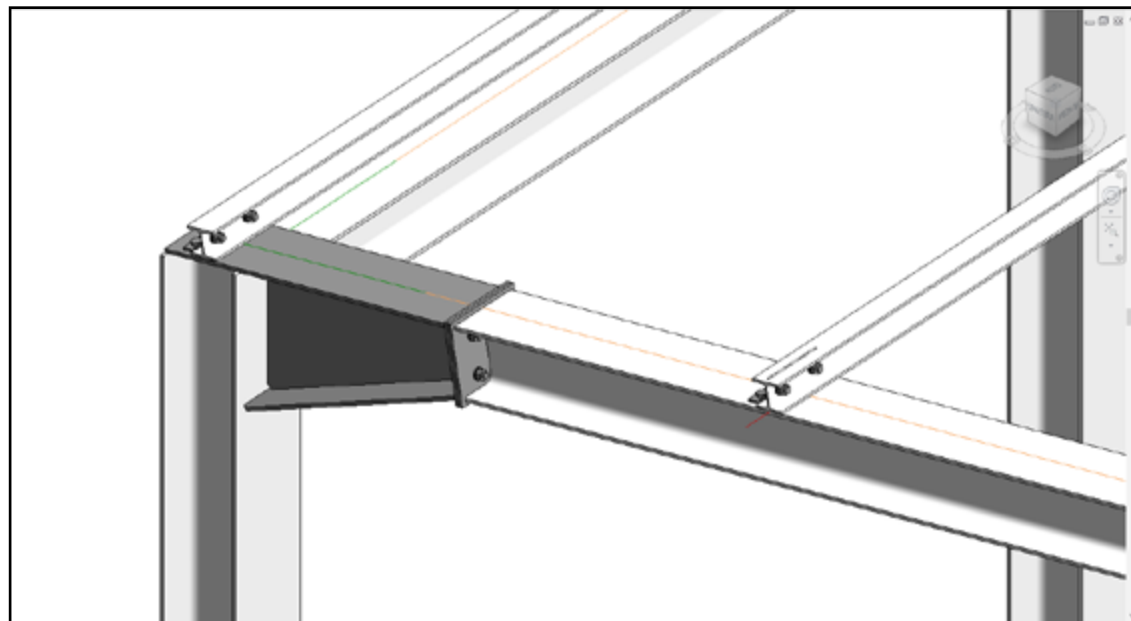
The representation is strictly schematic all the elements are represented just with simple lines, and the connections by symbols, the entire drawing has to be interpreted by the operator because in this case the image doesn't show enough information, only clicking on every elements the software show all the informations needed to recognize and to classify it.



An LOD 300 structural connection representation.

LOD 300:

The main elements are detailed represented, it's possible to recognize certainly the beams and the pillar shown with their own morphology, it still miss the connections between those main elements that are still represented by graphics symbols, that gives us the information about the presence of those connection but doesn't specify what kind of connection are and how are modeled.



An LOD 400 structural connection representation.

LOD 400:

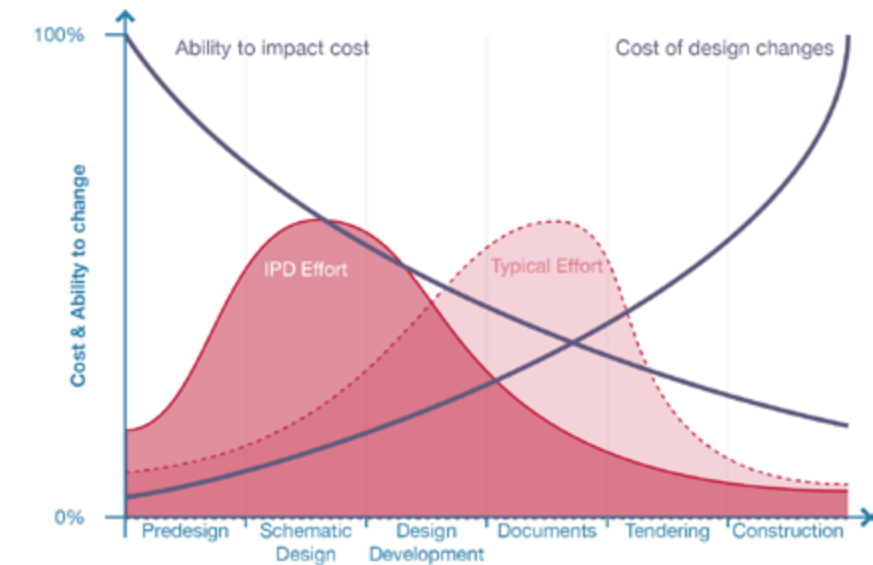
In this case the picture show a complete connection between a pillar and beams, the representation is highly detailed, and the connections that were just symbols in the lowest LOD now are showed with an high level of detail, it is also possible to recognize the bolts and other detailed elements.

1.1.6 BIM advantages and sharing strategies:

BIM methodology represent the second revolution in architecture and engineering project softwares, developed from mid nineties, and become widely used ten year later, the principal difference from a CAD software and BIM is that in the second methodology at the pure geometric three dimensional information typical from CAD as lines, arcs, symbols ecc, is applied also others kind of informations. Thus every single element in the project has not just a dimensional graphic information to be interpreted but is filled with many other informations such as cost, material, dimensions, position, ecc, that allows the designer and all the actors involved in the facility life-cycle, to manage those information and use it to improve in terms of costs, time and managing.

Furthermore the design process was developed creating a new way to make those elements more "smart" applying all those information required, so for example a door in a CAD environment in a plant view before was just a couple of lines interpreted by operator who gives it a door meaning, now in a BIM environment a door is unequivocally a door. Further a main feature in BIM is that the shaping is strictly **parametric** that permit a quick and precise control of the dimensions of any item, and gives a kind of cleverness to the objects.

To better understand the real advantages of BIM methodology, is useful to introduce the **MacLeamy's graph**, that was developed by this architect and showed in 2005 during *The American Institute of Architects*, he has elaborated in a chart the advantages brought by BIM methodology during a facility life-cycle. The chart shows how the use of BIM require a massive effort during the preliminary phase, that bring benefits during the following phases such as documentation and construction, while the traditional method's curve need a bigger effort in those steps while in preliminary design phases the effort needed is less.



MacLeamy Graph [14]

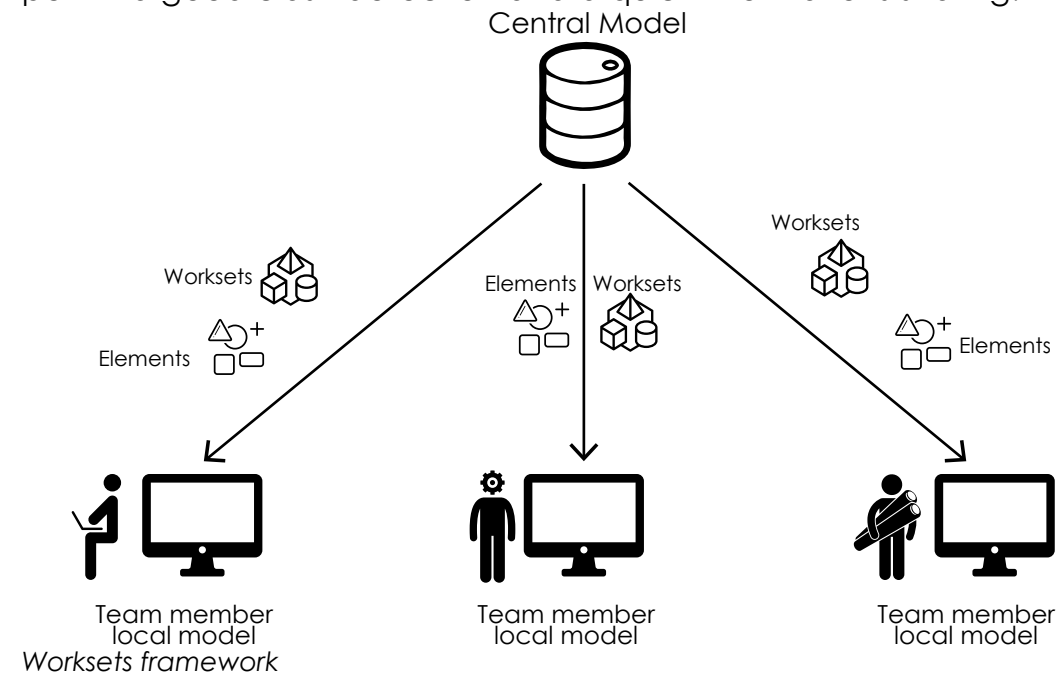
It's also possible to understand how design changes influence in terms of costs during all phases applied at the different process, and what's the impact cost and functional capabilities.

Reading this graph it's easy understand how there's a saving in terms of costs and time and an increase of project quality, using BIM.

Of course as I've already described the real strength of BIM is interoperability, that allows the exportation of all the informations required in some field inside the design, construction or managing process of the facility, having a single model which is a base for all the actors operating in all fields.

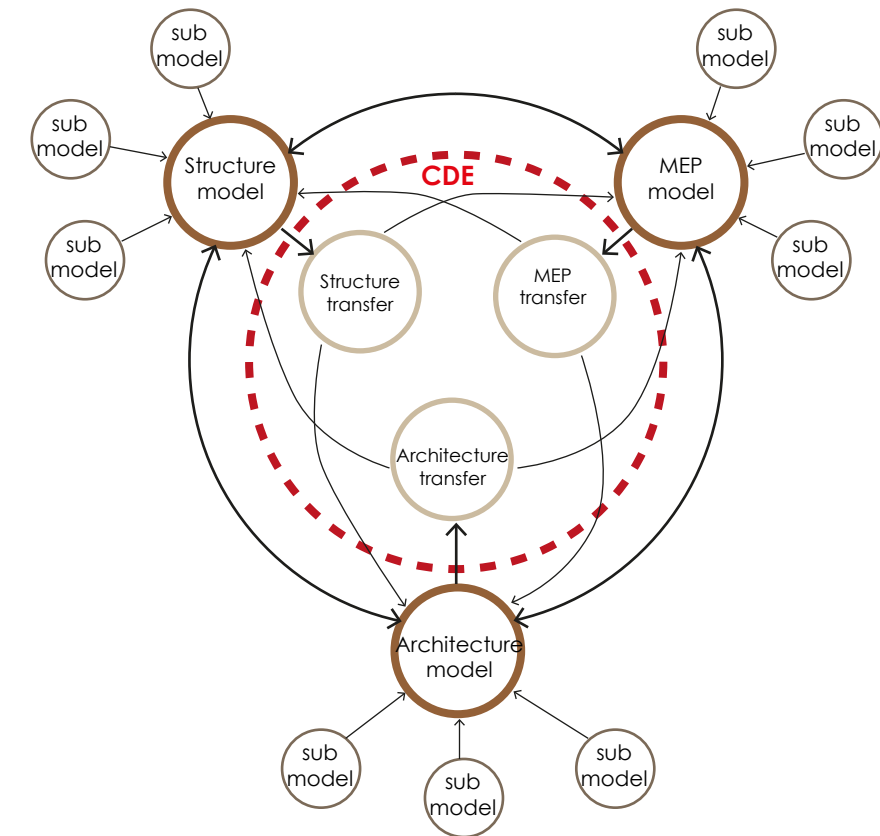
To permit this informations exchange and to manage the model in the different disciplines such as architectural, structural, mechanical ecc, there are different kinds of sharing possibles within the CDE, those possibilities are basically three:

- **Worksets:** This sharing strategy is based on a central file which coordinate all the others, that means the central model made by the actor who's responsibly of the process, is the one which coordinate all the others local model this method allows all the members working together at the same time on the same project in real time and also checking step by step if there are any interferences. Usually every local model represent a field inside the process like mechanical, structural, furnitures ecc. This method permit a good clash detection and a quick informations sharing.



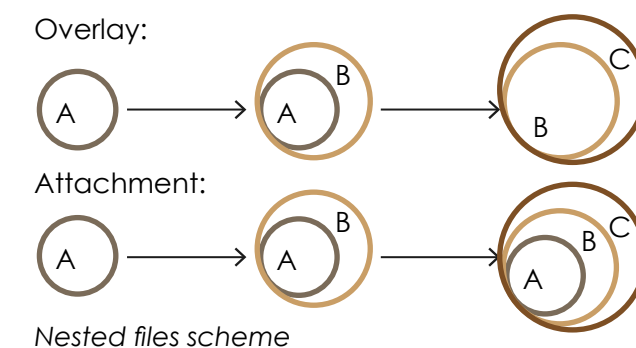
- **Links for Copy / Monitor:** This methodology works copying a selected item from another file into the current one, if this copied item change in the original file an alert message appear when you open the file and reload the linked one.

- **Linked Model:** This is the method used in this thesis work, creating a federated model composed by smaller models, having everyone the same shared coordination system. This kind of sharing allows different connections between the models, the management of those connections and the strategy, represent a large part of this thesis, it will be explained in details in the following chapter. The sharing phase happen in the Common data Environment (CDE), the linking operation can be done in two ways:



- **Overlay:** does not load nested models into the host model, so they do not display in the project.

- **Attachment:** loads nested linked models in the host model and displays them in the project.



1.1.7 Italian and european BIM standards:

In Italy was recently introduced for the first time a law that regulates the BIM use into public building works, the minister decree made by the public infrastructure ministry was published on 1st December 2017, as MIT n. 560 of 1/12/2017, also know as "BIM decree".

The decree is developed in nine articles, basically addressed to public administrations and generally to public works, estimated over hundred million budget, it doesn't concern private fields.

First article talks about the purpose of the whole decree that is to introduce BIM methodology, it also define modality and timing to be respected by public administrations and economic contractors, the mandatory use of methods and electronics item to be used during the whole building process, from the design stage to the administration of the building during it life-cycle.

Second article explains many definitions presents into the decree, are introduced definitions of: common data environment, public contracts, complex works, data manage plan ecc.

Third article says what is mandatory for the companies operating in this field as an training plan for the employers to get used and prepared to use electronics devices and items to make BIM projects, a maintenance and acquiring plane for what matters those items, an organization act that explain the process of acquiring, maintenance and managing, data and clash managers.

Fourth article define the concept of interoperability in two points, the first one assure the mandatory use of an open format it must be used during the whole process and it should allows the possibility to have a completely readable files by all the stakeholders.

Second point says all those files have to be shared into the previous mentioned Common data environment.

Fifth article says the public part in the building process after this decree can require the use of the tools and methods previously described.

Sixth article define the timing to be respected by the public administration and economic contractors in public construction to adopt BIM methodology, first expiring date for works over 100 mil. € is 1st January 2019, following it will be mandatory until 1 mnl. from 1st January 2025.

Seventh article says that it will be mandatory the use of LOD concept, and to define previously the aim to be achieve in terms of designing, data collecting, managing and archiving.

Article number eight define a public commissioner that have to detect and check, problems and difficulties found during the process, with the purpose to modify and improve the decree.

Last part define the applicability of this decree, to the works will begin after this publication, that will be active 15 days after the publication date.

A main international BIM standard is surely ISO/TC59/SC13, that represent a worldwide international standardization in BIM field.

This international standard is aimed to make some guidelines to be followed by designers and contractors to be part in a BIM process.

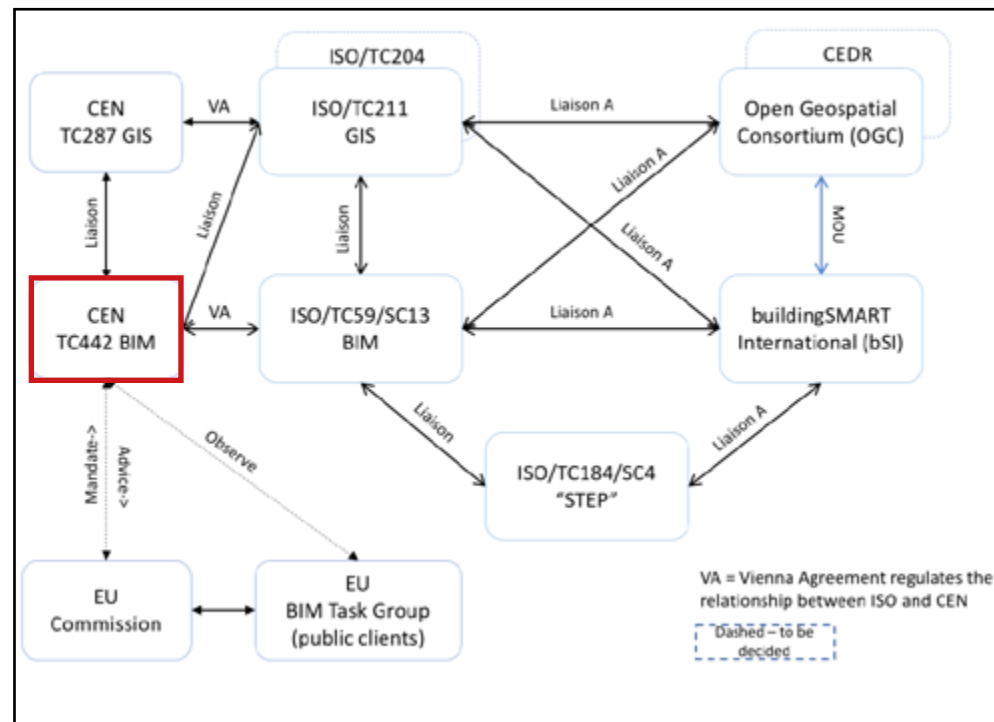
It was developed by ISO that's the International Standards Organization, then represent a worldwide guide, that in turns involves many other standards such as:

- ISO 12006-2:2015 Building construction, organization and information about construction works. Framework for classification of information.
- ISO 12006-3:2007 Building construction, organization and information about construction works. Framework for object - oriented information.
- ISO 22263 : 2008 Organization and information about construction works. Framework for management of project informations.
- ISO/TS 12911 : 2012 Framework for Building Information Modeling (BIM) guidance.
- ISO 29481-1:2010 Building information modeling - information delivery manual - Part 1: methodology and format.
- ISO 29481-2:2012 Building information modeling - information delivery manual - Part 2: International framework.
- ISO 16354 : 2013 Guidelines for knowledge libraries and object libraries.
- ISO 16757-1 : 2015 Data structure for electronic product catalogues for building services. Part 1: Concepts, architecture and model.[15]

This important international standard is strictly connected with the new european standard CEN TC442 introduced in the next page.

Recently was introduced also a European standard for BIM use into design and construction process, called CEN/TC 442, it aim is to define a common strategies to be used from all the parts involved, trying to use a codified and shared method for all European countries, this standard was set up to take charge of the standardization of all the information of building environment connected to BIM technology.

This last standard was thought to be a reference between the several standards already presents into the European standards scenery, composed by multiple fragmented regulations for any country.



International Standards scheme [16]

As described in the chart above, CEN/TC 442 is connected with many other standards, basically it shows two main fields that are GIS (geographic information system) and BIM and how the different standards are connected each others to create a common and inter-operable exchange of information which is the main purpose of the entire treatment.

It became necessary to have a standardization between all the European actors, to work on a common technical language, harmonization of product properties and classification tables.

The standard was released last year exactly in November 2017, it explains how heavy is the building economic sector in European economy and how this field can be improved. BIM should be used to save a part of those efforts in terms of money and time, it becomes with a market survey finding weaknesses in the building process, the results expected by the use of CEN/TC 442, are: Increase competitiveness of European contractor, facilitate data exchange, increasing sustainability.

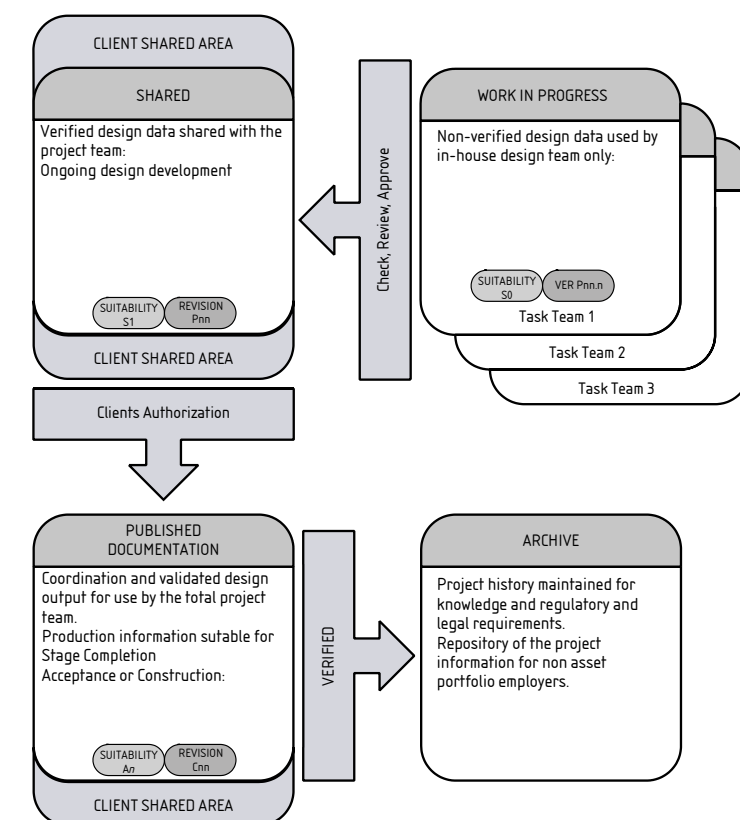
1.1.8 Common data environment:

One of the main challenge faced with during this thesis work was to create a Common Data Environment following what is contained in the **normative BS 1192 : 2007** redacted by the **British Standard Institution (BSI)** that is the British national body responsible to prepare British standards and others standard-related publications, information and services.

This normative explain and codify a way to share a BIM project with all the stakeholders, with the purpose to improve the entire work flow in an facility life-cycle, defining a precise way to be followed by the actors involved in the process, as is defined in the **normative BS 1192 : 2007**:

"This standard establishes the methodology for managing the production, distribution and quality of construction information,..., It is applicable to all parties involved in the preparation and use of information throughout the design, construction, operation and deconstruction throughout the project life-cycle and the supply chain. [17]"

As is suggested in the standard we've create an CDE using a online platform for sharing data such as DropBox, that allowed us to create a on-line folder shared with all the members of the thesis group.



BS 1192:2007 standard, workflow representation. [18]

The CDE was divided as is prescribed in the standard, generating four sub-folders that are:

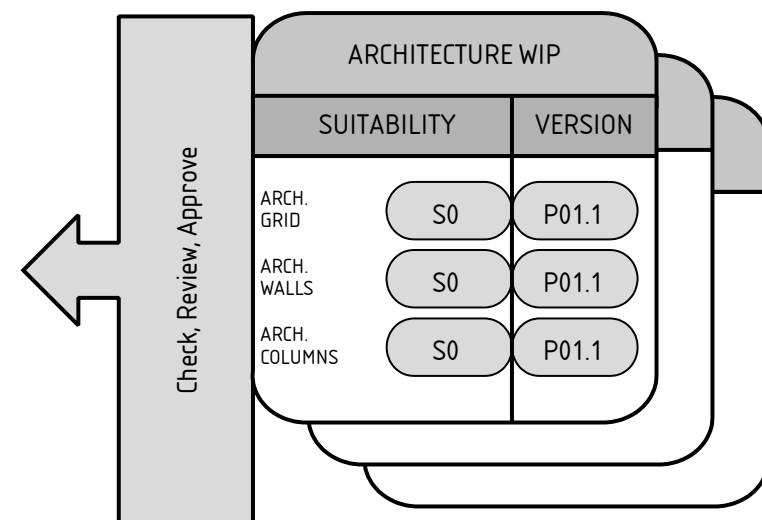
1- Work in Progress (WIP):

It's the first folder, where the members of the project team upload their work while are still working on it, before the approve by the coordinator, who has the responsibility to check the level reached by any actor and the goodness of the work done. As is explained in the regulation:

"The WIP area of the CDE is where members of the project team carry out their own work using their organization's software systems.

Whether the common repository or an organization's in-house repository is used, the models and documents should employ a similar management process as that used for the total project.

The organization is responsible for the quality of the WIP information and should ensure that appropriate checking and review processes are in place. [19]"



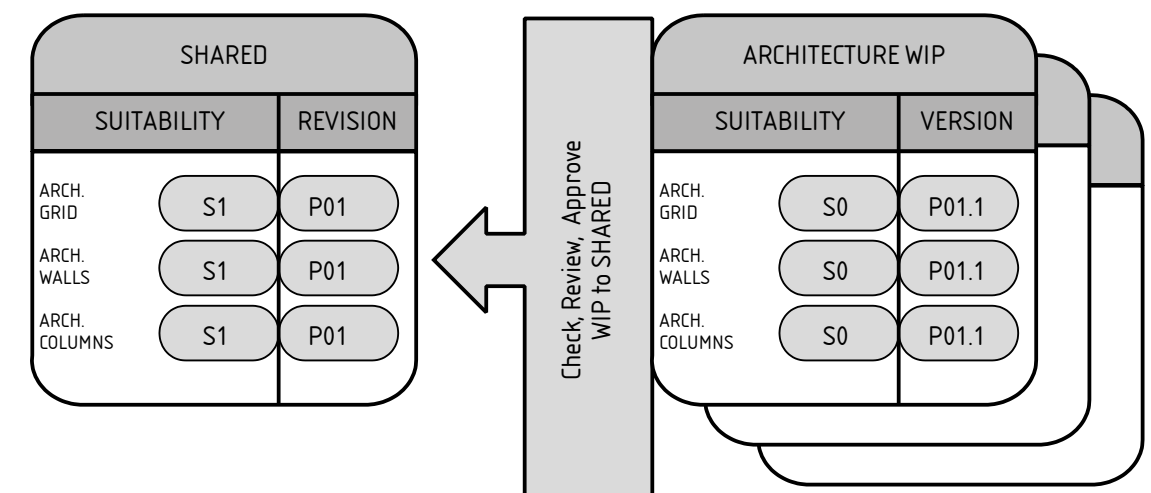
BS 1192:2007 standard, WIP folder. [20]

2 - Shared:

Shared folder represent the second step in the sharing process, the files are moving into this folder only under a previous approval by the coordinator, which verify that the work is completed and it was made following all the guide-lines previously agreed. Thus before moving in this folder the file should be checked, reviewed and approved by the coordinator according with the requirements established at the beginning of the process. It's mandatory that all the files in shared area must be unique, if for example a file present in this folder is downloaded and used as background information by others it should never be re-uploaded to save the information's uniqueness. As is described in the regulations:

"When the data is SHARED with the other members of the project team, the data is checked and issued to the CDE and the revision code is updated to indicate a major revision.

When a model has reached a status that is "fit for co-ordination" it should be made available in Shared area of the CDE. [21]"



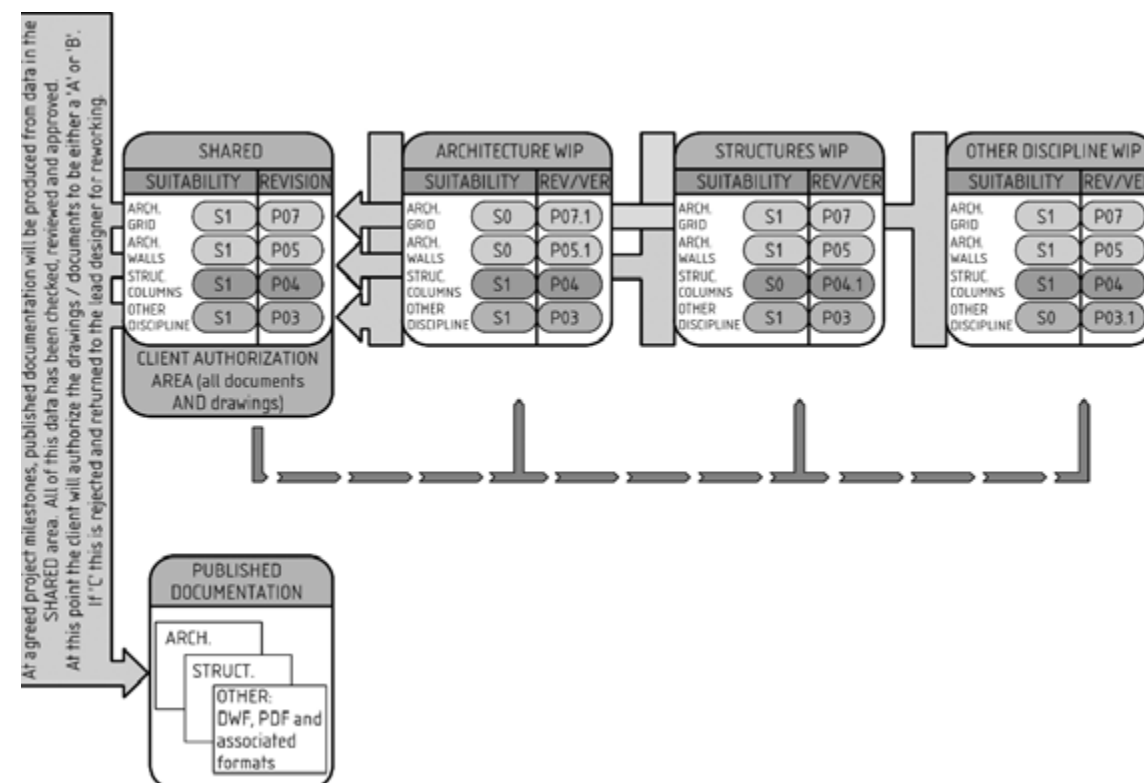
BS 1192:2007 standard, from WIP to Shared. [22]

3 - Published:

All the files are moving in this folder basically after the client's approval, is the second approve step to be done, after the first made by the project coordinator or the BIM manager, that allows to move from WIP to Shared, at this point the authorization have to come from the client that check the project and decide if approve it or not. If the client decide to don't approve the files to be changed have to come back at the Work in Progress (WIP) folder.

As is explained in the BS 1192 : 2007:

"Before information in the SHARED area of the CDE is made available to the wider project team, for example for tender or construction, it should be formally checked, approved and authorized. Suitable checking and approvals processes should be defined and applied. Once the document has been approved and authorized, the revision changes from "Preliminary" to "Contractual" [23]".

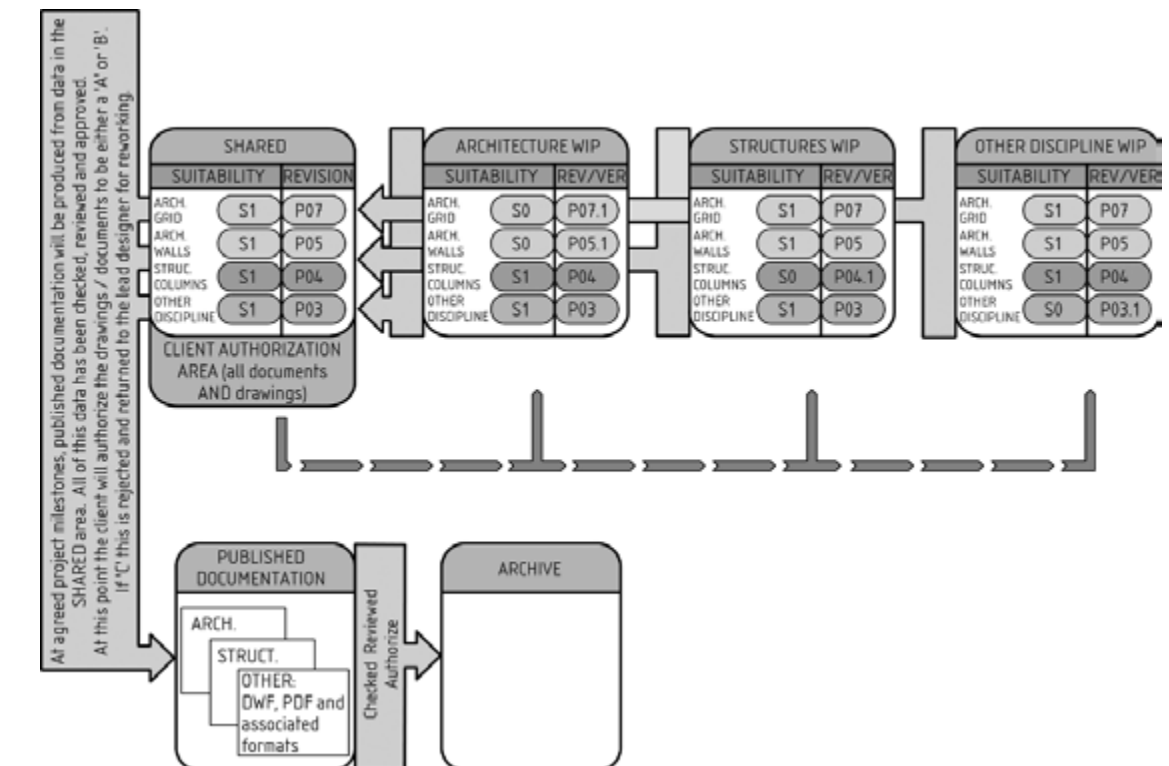


BS 1192:2007 standard, published folder. [24]

4 - Archive:

This is the last step, of the sharing process, it came at the end, this folder is the final destination of all the project files, to preserve the availability of all informations to permit those following activities during all the life-cycle of the facility:

- History of the transfer of project informations
- Asset register
- Models
- Documents
- Legal purposes
- Operation e maintenance informations
- Change audits



BS 1192:2007 standard, complete workflow representation, archive folder. [25]



INTRODUCTION

- .1 BIM INTRODUCTION
- .2 STUDY CASE**
- .3 PROJECT MANAGEMENT

1.2.1 The facility:

- Location:

The facility where we are operating is the Sanctuary of “Beata Vergine del Trompone”, that is located in Piedmont more precisely in Vercelli province, 40 Km away from Turin, in a tiny town named Moncrivello, located in a flatland which is crossed by Dora Baltea river, this part of Piedmont is characterized by several cultivation of rice, and is situated close to one of the most important highway and railway national connection between Turin and Milan that are just a few km far.

- The story:

The sanctuary is located exactly in the place where the legend say that has been a apparition of the Madonna on 2nd April 1559, who made a miracle to cure a woman (named Domenica Millianotto) that was hunchbacked, stutterer and was suffering of epileptics attacks.

The miracle it happened when that woman has seen the Madonna apparition on top on a catted log usually called in the local dialect “trumpa” changed in “trompone” for the big dimensions of that bole. After those events this place become famous as a holy place, and many people started to come here to be treated or to see the apparition.

- First building “La Rotonda”:

The first part of the whole complex was built in late 1563 and was terminated in 1568, “La Rotonda” is 22 meters tall, with a 10 meters diameter covered by a wonderful dome surmounted and covered by a 20 sides lantern. Nowadays is the central part of the church, but at the beginning was the only building present in this place, with a own facade, that represent the first sanctuary.



Trompone facility aerial photo. [26]

- The Sanctuary construction:

It was during 1594 when was decided to build the sanctuary as we know it today, the project was entrusted to the engineer Melchiorre Piantino, one year later in 1595 were built the structure foundations, that developed in a three naves church, the naves are divided by eight stone columns, and the original Rotonda was incorporated in the main church body, becoming the point of cross, in the Christian cross shaped plant. The new facade is 20 meters tall, and 15 meters wide, anticipated by front porch covering the entrance. The sanctuary has been consecrated on 13th October 1781 by bishop Gaetano Costa d'Arignano, and dedicated to "Beata Vergine degli Angeli".

- The convent:

On 21 September 1627, the complex was left under Franciscan's management, they started to welcome many pilgrims, and due to this new function it became needed a new facility where to welcome all those people. With this purpose in mind they started to build the convent, that construction lasted for more than 20 years, completely financed by faithful donations. The convent located beside of the sanctuary, it has a square shaped plant, with a big courtyard in the middle, surrounded by two floors building where are located the accommodations for the pilgrims and for more than 20 friars.



Monumental facade photo. [27]

- The Seminary:

The last part of the whole complex was built in late XIX century, more precisely the construction has been started on 10th September 1881, after being expropriated and left under a Napoleon's Empire decision in 1802, then reused by the Cistercians for forty years, afterwards the early born Italian State made a law which removed all the religious congregations in 1855 expropriated the facility one more time, until the final re-buy made by the church in 1880.

The entire facility was left under bishop's Fissore's control who established here the new seminary school, creating a new three floors building in the north side of the complex, the new facility consisted in two wings with monumental facades, which gives stateliness to the entire complex, the new construction was ended after 13 years also because of the bishop Fissore's death occurred in 1889, that has slowed down the building construction.

- The new function, an Healthcare facility:

The seminary was closed in 1970, and has become the last function that is still going on, the original idea came from Mons. Luigi Novarese who wanted to bring here an healthcare function, coming back to the original attitude of this place since the miracle which started all the story, that's to cure and take care of those people whose need. Thus Mons. Luigi Novarese who has founded "I Silenziosi operai della Croce" which is a company established here in 1970 whose purpose is to carry on the healthcare facility and take care of the sick people.

Nowadays the facility hosts different kinds of sick people, mainly people affected by serious motor handicap, while the second floor guests a residence for elderly, and in the convent are still living some priests.

The last addition to the complex was made in 2006 and consisted in a new healthcare facility built in front of the church, that is specialized in the recovery of people affected by motor handicap. In the XIX century wing at the ground floor are also guests some courses by the Università Cattolica del Sacro Cuore.



Medical activities inside the facility. [28]

1.2.2 State of art: BIM for healthcare facilities

BIM approach is widely used in healthcare facilities, due to the complexity of those building, and for the need they have to be always under control and to be detected with accuracy, because of the special environment required. Especially in a structure like Trompone where the patients are affected from serious illnesses, and they need to stay always in a controlled environment.

The use of BIM for this kind of facilities can be pretty useful, thanks to the control of informations, it could be made a better plan for the facility management, or manage some other aspects of the building, such as energy consumption, activities organization, actually to detect any aspect of the building during the life-cycle. Of course this approach is also important during the design stages, as already described it brings many advantages such as : saving times thanks to a detailed 3 dimensional project of any elements meant to avoid clash between construction items. Thanks to the seven dimensions of BIM methodology described in the previous chapter, meant to detect construction organization in construction phase focused on saving time through planning every activity in building site, predicting costs and managing sustainability in terms of energy balance. To better understand the potentiality of BIM approach in project and manage of healthcare facilities I've studied some cases, two developed in Italy in Ferrara University and in Rome University "La Sapienza", one between University of Western Australia and Chongqing University in China, and others in Sweden where was build the biggest hospital completely designed in BIM, and another case in USA.

- First case treat about the modeling in BIM environment of the **Azienda Ospedaliero-Universitaria Careggi of Florence**, this project is included in a larger called **STREAMER** that is an industry-driven collaborative research project on Energy efficient Buildings, which aim is to reduce energy use in healthcare districts in EU by 50% in next 10 years, through involving all the stakeholders in the process using BIM-GIS technology. The facility in this case has been built at the beginning of 20th century and was subject of many intervention during the past century. The project consist in three principal purposes: Renovation of the buildings, reorganization of the transportation network inside and outside the hospital area and to reduce the number of the buildings merging university research and hospital activities [29].

The objectives achieved in this research work are:

- Understanding the energy consumption in one of the building complex.
- Modeling the oldest building in BIM environment to evaluate the way to intervene
- The development of a district plan finalized to planning and managing energy production.

This research showed that is possible to save a considerable amount of money over a million per year in energy saving, considering the size of the facility, and the number of actors populating this place daily such as patients, doctors, nurses, employers, visitors ecc.

All those simulation have been possible thanks to the BIM methodology creating different scenarios useful to evaluate the best strategy to reach the sustainability goal.

- Second case of BIM methodology applied to an healthcare facility is developed by Department of civil engineering of University "La Sapienza" in Rome, this research article is focused on a low impact healthcare facility project. According with the American standard the building operations are classified in base of the kind of work and the production of powder, interruption of services, level of noise ecc; all those things can disturb firstly the patients then all the actors in the hospital day-life. Then another classification by wards based on the level of vulnerability of the patients, the matrix between those classification permit to identify any situation possible inside a construction site in an healthcare facility [30].

The second step was to identify all the activities and behaviors of all the actors in the healthcare facility and in the construction site to compare with the aim to avoid any interference between the activities. This research purpose is to define a common strategy between the actors of an construction site in an healthcare facility, through providing an integrated model for simulation to reduce the possibility of clash between the activities and supporting all the professional actors of both environment in a constantly rising cases of renovation or new construction in existing healthcare facilities.

- A huge aspect about the usage of BIM related to healthcare facilities is the Facility Management, to elaborate this field I've examined two research articles made by Webb school of Construction, Arizona State University in USA, and a partnership research between Curtin University of Western Australia and Chongqing University of China, that have the purpose to understand which are the informations required to make a correct Facility Management for healthcare facility, beginning from a correct exchange of information between all the actors involved, and to streamlining the information flow. It appears clear that most common fail in the process happen during information exchange between the phases of the project, basically it happens for the complexity and for the several number of information needed to make a FM in a complex facility like an hospital. The Facility manager task is to organize all those informations, to find a correct way to share all the data between the actors and to make a inter-operable BIM model oriented to a FM. The data required are divided in three categories: Attributes data, Portfolio and documents [31].

The FM is mostly used for the maintenance of the facility, to detect and program the ordinary maintenance to avoid critical situation occurred by an absent plan of upkeep, to organize all the activities in a complex public building such as cleaning service, maintenance service ecc. Another strength of this approach is the monitoring of energy use, that become widely used especially in public facilities such as healthcare buildings where the energy consumption is one of the biggest point in the economic balance. A practical example is included in the second article where the research group made a BIM model based on existing drawing of the Shanghai Disaster Tolerance Center oriented to make a FM plan, where for example a reciprocating compressor sited in the basement floor has to be changed. The FM plan developed shows what is the best path to reach the item, that allows the operator to take the quickest and the most save way in order to reduce times and risks in an normal maintenance intervention, that is just a example of the potential of the data included in a BIM model could be used in a maintenance activity [32].

- The last article I'd like to include in my research work treat about a the biggest healthcare facility BIM model ever built. It's the New Karolinska Hospital in Stockholm, Sweden. This huge project obtained under a 3 billions \$ investment has over 320.000 square meters, with 12000 rooms, 35 operating theaters. A main task was to build a huge structure like this beside the existing hospital and university-research center creating a high level of noise and making big quantity of dust that could affect the patients and those who works in the existing facility. The main task required by the Swedish government was to create a BIM model that could be used during all the life-cycle of the building for different tasks. At the end the model contains over a million items everyone with key attributes and precise location. Of course the model developed wasn't useful just in the design phase but was thought to be used during all the life of the building, for example the project includes 29 automated guides vehicles to connect the different parts of the facility to deliver medical supplies, clean sheets ecc. The staff will be informed of the deliver via their mobile devices and BIM is used as address book to accomplish this new futuristic function. Also the transports used to materials delivery where scheduled using BIM with the aim to reduce transport traffic around the building site, using hybrid and lower-emission trucks according with Skanska Green Site protocol. As said before to avoid disrupting normal activities in the existing Karolinska hospital and to make all the process faster were used several pre-fabricated parts, just considering for example the 740 bathroom pods completely prefabricated, transported in sealed containers to the local storage and brought on site "just in time" to be placed, also this aspect was completely manage using BIM. Obviously BIM method required more investments and an additional time in design phase that will be repaid if

we consider all the life-cycle of the facility, including the management and the effect on the environment considering that is also a gold LEED rated building, that allows to save more than 65% of energy using technological supplies and renewable energy coming from geothermal system, from first projections the new hospital will demand around 110 Kwh/sqm requiring 40% less then others comparable facilities. This represent surely one of the best results using BIM in a healthcare facility, it's not only the biggest project ever done in this field, but it's also shows how to manage a high level complexity facility from the pre-design phase during all the life-cycle until the facility manage plan. BIM approach results really useful only if is planned and applied at any phase from the beginning with a shared method involving all the actors [33].

I've selected those five articles between several I've read, because they are treating different focus about the BIM use in healthcare facilities worldwide, they are witnesses about how useful can be BIM approach in high complex buildings such as hospitals, but also shows how sensible are those kind of buildings, due to the critical condition of the patients which are often suffering heavy illnesses, and for the need of all the actors involved in a building process in a healthcare district to continue work ensuring patients and workers health.



New Karolinska Hospital in Stockholm [34]

1.2.3 BIM for Health a working group:

BIM for Health is a thesis working group born in September 2017, inside "Drawing TO the Future" office in DISEG (Department of Structural, Geotechnical and Building Engineering) of Politecnico di Torino, with the aim to make a master thesis on BIM, related with an healthcare facility like Trompone.

The first step was to make a photographic and metrical survey of the facility that was previous divided in five parts which are the RSA (the monumental '800 part) and the park behind, the sanctuary with the convent, the winter garden, the green house and the east wing used as a storage. Any component of the group modeled a part with the purpose to make a coordinated federated model, to have a base model to work on it, in our singular project or focus to be developed and which are the real goal of this thesis work.

The process didn't follow a theoretically perfect path, because of some trouble occurred during the job, for example everyone had to begin modeling before receiving the photogrammetric survey, due the need to start working considering that we received the complete survey only three months after the beginning date when someone in the group had already finish his thesis.

That brought many errors in the final model, I'll discuss in the next fully dedicated chapter that will treat about the usage of point clouds in federate BIM model.

Anyway the group originally composed by five people everyone with different focus to be developed such as the project of the winter garden inside the courtyard with the related focus on construction management, or the new Alzheimer wing project made with the augmented reality focus, or the LEED certification for the sanctuary part to be achieved always adopting BIM methodology, those are just some examples of what this group has done and is still doing with other student which have joined the original group after the first phase.

This introduce the first real step in this thesis, the modeling phase of an historical building also called HBIM, it's widely know that BIM softwares are not developed to model historical buildings characterized by unusual elements in contemporary architecture such as arcs, vaults, columns and decoration parts, and it's easy to understand how many of those items were present in an historical facility like Trompone Sanctuary which is six centuries old complex.

For that reason many items were shaped in an simplified way, according with the goal established at the beginning, because as is explained in the previous chapter one of the most important things in BIM pre-design phase is to decide which is the LOD (Level Of Detail and Level Of Development) to use in according with the goal to be achieved, modeling every item

with the highest level of detail it's often a waste of time an resources, and it results useless most of times.

Thus the first common aim was to create a federate model using linked models as explained in a shared coordination system in the way that when we've joined all the models in the federate everyone went in the right position with a right orientation, all this sharing phase was created on an on-line platform such as Dropbox following what's written in the British standard 1192:2007. Also following all the prescription by the British Standard there were some errors done due our absent experience in this field, (for most of us was the first approach to BIM), errors we tried to resolve when our experience was rising and we've gained more consciousness.



INTRODUCTION

- .1 BIM INTRODUCTION
- .2 STUDY CASE
- .3 PROJECT MANAGEMENT**

1.3.1 BIM for 4D an overview:

The fourth dimension of BIM project represent the time, and applied to a construction process more precisely represent the time needed to make all the tasks required to bring at the end a construction.

Anyway project management has larger use then construction industries and can be applied to any kind of product, many people has tried to give a definition to project management, maybe the first was Oisen in '50: *"Project Management is the application of a collection of tools and techniques (such as the CPM and matrix organization) to direct the use of diverse resources toward the accomplishment of a unique, complex, one-time task within time, cost and quality constraints. Each task requires a particular mix of theses tools and techniques structured to fit the task environment and life cycle(from conception to completion) of the task.* [35]"

Another definition is provided by the UK Association of Project Manager (APM): *"The planning, organization, monitoring and control of all aspects of a project and the motivation of all involved to achieve the project objectives safely and within agreed time, cost and performance criteria. The project manager is the single point of responsibility for achieving this"* [36].

In construction industry that represent a really powerful tool for designer and generally for any stakeholder involved in the process, this aspect that nowadays represent a weaknesses because most of times is redacted in a inaccurate way due to a data leak between the model commonly made by 2D drawings and the time-line of the tasks.

The time-line in Italy is still not mandatory for any new construction, that is required only for public works of a high degree of complexity it is regulated by decree Art 40 DPR_207/2010, perhaps because the importance of this tool is still not deeply understood.

This powerful tool goes beyond the typical quantity and cost report, because only managing time aspect is possible to have a complete control and a whole overview of the entire process, of course 4th and 5th dimensions are strictly connected, because costs depends by the time, and the timing depends by many elements depending by the costs estimated such as: number of employees, tools and construction techniques used, ecc.

Due to the peculiar characteristic of a building site, that is steadily changing, it becoming necessary to have a dynamic representation that allow the designer to better understand which could be the critical issues and prevent it.

BIM is commonly used aimed to design, but due to the increasingly demand by owners and contractors, of a following phase are becoming required models though in terms of manage the process during the construction and for the maintenance in form of facility management.

In this scenario the 4D is the first step to improve the BIM model, trough adding the fourth dimension, thus the timing applied to a construction process, it allows to manage not only the pure time dimension, but softwares like Autodesk Navisworks permits to navigate the complex model to have a clash detection, aimed to find possibly interferences between items, to organize and manage the operations in the construction site.

Basically the fourth dimension can be resumed in the following four points:

- Identification and resolution of interferences between all the stakeholders involved in the process, the use of 4D applied a building project can involve different figures with different tasks, one of the main aim is to connect all of them and to find a common language to make an integrated project, where is considered the designing phase passing trough a time-line redaction.
- Planning and designing a 4D model, that allows to make simulations aimed to avoid spacial and temporal interferences, in terms of organization of the tasks aimed to avoid overlapping, and designing the building site take conscious of the spacial limits in which operate into, to assure the feasibility, also having the possibility to have a dynamic checking of the process progress, controlling the deadlines respects.
- The possibility to use the building information model to make also a 5D project, using the quantity estimation make in BIM environment, implemented by the time dimension, then the work estimation to have a complete overview of costs due to the integrated project.

All of those previous points were faced in this thesis, obviously many tasks requires a specify knowledge, and many efforts, commonly are made by working group that includes different professional actors, where in a real situation the main challenge is to create a common strategies to be followed by all the components of the working group, aimed to follow an integrated process where the model can have an highest level of complexity, completely managed to exploit the real strength of BIM.

With those premise, the project treat in this thesis is a little structure composed mainly by prefabricated items, which represent a low level of complexity because was completely managed by a student without any experience in this field.

1.3.2 WBS (Work Breakdown Structure):

The WBS is a list of every task expected in a project, is a powerful tool for the project manager aimed to identify all the activities presents, and it's helpful to understand all the sub-tasks, and to represent them in a hierarchical way, easily readable.

The WBS creates a relationship between the final product, in this case a winter garden project, with all the tasks to be made to accomplish the final artefact.

One of the fundamental principles that regulates the WBS is 100% rule, it says that the 100% of the activities and the works must be included in the WBS, internal or external at the final product, any activities should be mentioned. The rule must be applied to all the degree of the hierarchical representation, the secondary tasks should be represent the 100% of the main task that includes them.

An important focus should be made on the level of detail of the WBS, to understand which is the highest point of detail of the tasks sub-division, because if the items are too small and to many it's gonna be difficult to track them especially if are planned in a far future, an effectual method may be using the progressive elaboration, that consist in developing the most detailed parts of the WBS just before the work beginning.

The WBS for building industry is regulated in many countries, any of them propose a different hierarchical classification of many categories, that could be not only constructive elements, but also activities, management process, spaces, ecc. all can be useful to recognize and classify an entity in a construction process, from the preliminary phase until the dismiss.

In the following pages some of those standard that regulates the building construction industry are analyzed to understand the differences between the classification more used worldwide, that includes Unifomat, Uniclass, Masterclass, Masterformat and the italian standard UNI 8290. Some of them were created or uploaded recently to be adaptable with new design standard and basically to be better used by BIM softwares, others like italian UNI 8290 is from eighties and it's obviously not thought to be used by new design softwares, and it also result obsolete to represent the actual construction industry.

UNI 8290:

The UNI 8290 is an Italian standard made by UNI the italian standard organization, it was released for the first time in 1983, the aim is to divide all the construction element in a hierarchical classification divided in three level respectively: Class of technology units, technology units and class of technical elements. The standard was thought to be extensible trough adding new levels until the fifth, anyway in the original version are present only the first three already mentioned.

The decomposition of the building complex in smallest part is hierarchical beginning from a biggest grouping called Class of technology units in turn decomposed in smallest parts.

Trough this classification is possible to identify the technical elements and to understand from which field it's coming from, that appear useful to create a table of codes aimed to make analytic estimations, and to create a hierarchical decomposition of the entire complex also called WBS, where is possible to list all the tasks required to accomplish a building project, those kind of informations begins to be very useful with the BIM use, that is a easiest way to obtain a 4D and 5D project, applying those codes to items contained in BIM environment that could store many information in any elements in form of parameters, and use them to make project management, cost analysis.

CLASSIFICAZIONE E TERMINOLOGIA (NORMA UNI 8290 - 1981)		
Classi di unità tecnologiche	Unità tecnologiche	Classi di elementi tecnici
1. Struttura portante	1.1 Struttura di fondazione	1.1.1 Strutture di fondazione dirette
		1.1.2 Strutture di fondazione dirette
	1.2 Struttura di elevazione	1.2.1 Strutture di elevazione verticali
		1.2.2 Strutture di elevazione orizzontali e inclinate
		1.2.3 Strutture di elevazione spaziali
	1.3 Struttura di contenimento	1.3.1 Strutture di contenimento verticali
		1.3.2 Strutture di contenimento orizzontali
	2. Chiusura	2.1.1 Pareti perimetrali verticali
		2.1.2 Infissi esterni verticali
	2.2 Chiusura orizzontale inferiore	2.2.1 Solai a terra
		2.2.2 Infissi orizzontali
	2.3 Chiusura orizzontale su spazi esterni	2.3.1 Solai su spazi aperti
		2.4.1 Coperture
	2.4 Chiusura superiore	2.4.2 Infissi esterni orizzontali

UNI 8290 excerpt [37]

Masterformat:

Masterformat is a standard for information classification related to building industry, developed in USA an Canada respectively by CSI (Construction Specification Institute) and CSC (Construction Specification Canada) with the aim to classify informations related to facilities constructions and maintenance.

It was released for the first time in 1995 when it contained 16 tables, the standard was uploaded in 2004 expanding from 16 to 50 divisions, then each division is split in many sections.

02 24 00	Environmental Assessment
02 24 13	Natural Environment Assessment
02 24 13.13	Air Assessment
02 24 13.43	Water Assessment
02 24 13.73	Land Assessment
02 24 23	Chemical Sampling and Analysis of Soils
02 24 43	Transboundary and Global Environmental Aspects Assessment
02 25 00	Existing Material Assessment
02 25 16	Existing Concrete Assessment
02 25 16.13	Concrete Assessment Drilling
02 25 19	Existing Masonry Assessment
02 25 19.13	Masonry Assessment Drilling
02 25 23	Existing Metals Assessment
02 25 23.13	Welding Investigations
02 25 26	Existing Wood, Plastics, and Composites Assessment
02 25 29	Existing Thermal and Moisture Protection Assessment
02 25 29.13	Waterproofing Investigations
02 25 29.23	Roofing Investigations
02 26 00	Hazardous Material Assessment
02 26 23	Asbestos Assessment
02 26 26	Lead Assessment
02 26 29	Polychlorinated Biphenyl Assessment
02 26 33	Biological Assessment
02 26 33.13	Mold Assessment
02 26 36	Hazardous Waste Drum Assessment

Masterformat excerpt [38]

It's possible to see the four levels classification in Masterformat very close to the previous already explained, it's always composed by a couple of numbers series that define in a hierarchical way the item or the activity present in a building process.

The difference between Masterformat and the others is that Masterformat i compressed in a unique table, instead Omniclass and Uniclass are split in multiple tables, that represent the first division in those standards.

Ominclass:

Omniclass is very useful tool to store informations about buildings and projects, it was born in North America where is widely used, it can be adopted during the whole building life-cycle, from the designing phase to the dismiss.

Omincalss was thought to include all the construction levels of detail, and for any destination, industrial, residential or commercial. It is composed by 15 tables, each one treating different kind of informations and anyone could be used separated to the others depending on which kind of information is required, the 15 tables are:

- 11 Construction function
- 12 Forms
- 13 Spaces by function
- 14 Spaces by form
- 21 Elements
- 22 Works results
- 23 Products
- 31 Phases
- 32 Services
- 33 Disciplines
- 34 Roles
- 35 Tools
- 36 Informations
- 41 Materials
- 49 Properties

The classification of any set of tables can be used individually to identify a element, or many of those codes can be joined to identify a more complex item. As explained directly in the standard:

“The scope of OmniClass is designed to encompass objects at every scale through the entire built environment, from completed structures, vast projects, and multi-structure complexes to individual products and component materials. It is designed to address all forms of construction, vertical and horizontal, industrial, commercial and residential. In a break from many of the systems that have preceded it, Omniclass also addresses actions, people, tools and informations that are used or take part in the design, construction, maintenance and occupancy of these facilities [39]”.

OmniClass Number	Level 1 Title	Level 2 Title	Level 3 Title	Level 4 Title	Definition
13-25 19 00		Secondary Circulation Spaces			A portion of a floor required for access to some subdivision of the floor, that does not serve all occupants on a floor, and is not defined as primary circulation Space.
13-25 19 11			Door Set-Back		A recess in a vertical wall plane that contains an access and egress to a tenant area, or amenity area, or building service area.
13-25 21 00		Restricted Spaces			Space that is normally available for use but is set aside by regulatory authority, such as clear space requirements for electrical closets.
13-25 23 00		Refuge Spaces			An enclosed space that is protected from the effects of fire permitting a delay in required egress travel time.
13-31 00 00		Education and Training Spaces			Space used for education.
13-31 11 00		Breakout Space			A space associated with a classroom or training room that is designated for discussions, side meetings, and breaks.
13-31 13 00		Lecture and Classroom Spaces			Spaces used for classes, lectures, symposiums, and speeches.
13-31 13 11			Lecture Classroom		A room in which teaching or learning activities can take place.
13-31 13 13			Classrooms (age 9 plus)		A room in which teaching or learning activities can take place for older children, ages 9 and over.
13-31 13 15			Classrooms (ages 5–8)		A room in which teaching or learning activities can take place for younger children, ages 8 and younger.
13-31 13 17			Lecture Hall (Fixed Seats)		A large room used for instruction, typically at a college or university, with a capacity in the hundreds.
13-31 13 19			Assembly Hall		A hall where many students and teachers can congregate.
13-31 13 21			Seminar Room		A space for conducting a course offered for a small group of advanced students.
13-31 15 00		Class Laboratories			A space used primarily for formally or regularly scheduled instruction that require special purpose equipment or a specific space configuration for student participation, experimentation, observation, or practice in an academic discipline.
13-31 15 11			Open Class Laboratory		An educational space that provides controlled conditions in which scientific research, experiments, and measurement may be performed for teaching purposes.
13-31 15 11 11				Physics Teaching Laboratory	An educational laboratory space for teaching physics through hands on experimentation and demonstration.
13-31 15 11 13				Astronomy Teaching Laboratory	An educational laboratory space for teaching astronomy through hands on experimentation and demonstration. May require a planetarium and rooftop observation platforms.
13-31 15 13			Research/non-class Class Laboratory		A space used for laboratory experimentation, research, or training in research methods; professional research and

Omniclass excerpt [40]

Here is showed a piece of table number 13 (spaces by functions), it's possible to see how is similar to the Uniclass, the code is composed by couples of numbers, beside the item name and a short description, in this case is specified the space name and a description of the activities expected inside .

Uniclass 2015:

Uniclass is an English format, published for the first time in 1997, it covers a large range of any kind of classification in construction industry, it was strongly modified in 2015 and called Uniclass 2 or Uniclass 2015. It was modified basically to make it more usable from new architectural and engineering methodology and technologies such as BIM, the new structure also allows to modify the tables and improve them, adding new voices in accord with future new adds due to technology improvements [41], it provides:

- Unified classification system
- Hierarchical chart suite
- Decimal classification system
- ISO 12006-2 Compatible system

The tables are organized to define any item in a detailed hierarchical way, they are divided in eleven tables:

- Activities
- Complexes
- Elements
- Entities (by shape)
- Entities (by function)
- Project phases
- Construction products
- Spaces
- Systems
- Work results
- CAD

All those tables identifies items, spaces or activities assigning a code to any of them, the code is constituted by couples of decimal numbers, the first couple define the general group which own the item, until reaching the sub-group where are specified the attributes of the selected element.

- SS_30 Roof, floor and paving systems
- SS_30_10 Pitched, arched and domed roof structure systems
- SS_30_10_30 Framed roof structure systems
- SS_30_10_30_25 Heavy steel roof framing systems

This above is an example of a roof classification, beginning from a general building horizontal system as a roof or a floor, reaching the highest level of

621	SS_30_10_30	30	10	30		Framed roof structure systems
622	SS_30_10_30_20	30	10	30	20	Glazed unit roof framing systems
623	SS_30_10_30_25	30	10	30	25	Heavy steel roof framing systems
624	SS_30_10_30_30	30	10	30	30	Heavy steel roof space frame systems
625	SS_30_10_30_35	30	10	30	35	Heavy steel roof space truss systems
626	SS_30_10_30_45	30	10	30	45	Light steel roof framing systems
627	SS_30_10_30_60	30	10	30	60	Precast concrete roof structure systems
628	SS_30_10_30_70	30	10	30	70	Reinforced concrete roof framing systems
629	SS_30_10_30_85	30	10	30	85	Timber roof framing systems
630	SS_30_10_50	30	10	50		Monolithic roof structure systems
631	SS_30_10_50_70	30	10	50	70	Sprayed concrete roof systems
632	SS_30_10_60	30	10	60		Panel roof structure systems
633	SS_30_10_90	30	10	90		Unit roof structure systems
634	SS_30_10_90_50	30	10	90	50	Masonry roof systems
635	SS_30_12	30	12			Flat roof, floor and deck structure systems
636	SS_30_12_05	30	12	05		Beam and block floor systems
637	SS_30_12_15	30	12	15		Concrete plank floor systems
638	SS_30_12_20	30	12	20		Deck systems
639	SS_30_12_30	30	12	30		Flat roof and floor cassette structural insulated panel (SIP) systems
640	SS_30_12_32	30	12	32		Framed decking systems
641	SS_30_12_33	30	12	33		Framed floor systems
642	SS_30_12_34	30	12	34		Framed mezzanine systems
643	SS_30_12_35	30	12	35		Glass unit masonry floor systems
644	SS_30_12_45	30	12	45		Lift-up concrete plank floor systems

Uniclass 2015 excerpt [42]

detail, defining what kind technology system and which material is used in the selected item. Here is showed a excerpt of Unicalass from System table, where is showed the entire code in the first column composed by all the couples of number presents in the following columns representing respectively Group, Subgroup, section and sub-section, last column is filled wit a short description.

Uniformat II:

Uniformat II is a standard method to organize and classify informations related to a building process, it was born in 1997 jointly with ASMT, CSI and CSC [43], the criteria of Uniformat are:

- Classifications hierarchical structure
- Content choose by sector operators in base of high incidence of costs

Uniformat is a classification based on three levels: the first one join the main object categories families such as foundations, partitions, enclosures ecc. The second level represent a decomposition of the first one in sub-groups, the third specify the objects presents in the previous one, in the last version was introduced a fourth level to have a deepest level of detail.

ASTM Uniformat II Classification for Building Elements (E1557-97)

Level 1 Major Group Elements	Level 2 Group Elements	Level 3 Individual Elements
A SUBSTRUCTURE	A10 Foundations	A1010 Standard Foundations A1020 Special Foundations A1030 Slab on Grade
	A20 Basement Construction	A2010 Basement Excavation A2020 Basement Walls
B SHELL	B10 Superstructure	B1010 Floor Construction B1020 Roof Construction
	B20 Exterior Enclosure	B2010 Exterior Walls B2020 Exterior Windows B2030 Exterior Doors
	B30 Roofing	B3010 Roof Coverings B3020 Roof Openings
C INTERIORS	C10 Interior Construction	C1010 Partitions C1020 Interior Doors C1030 Fittings
	C20 Stairs	C2010 Stair Construction C2020 Stair Finishes
	C30 Interior Finishes	C3010 Wall Finishes C3020 Floor Finishes C3030 Ceiling Finishes
D SERVICES	D10 Conveying	D1010 Elevators & Lifts D1020 Escalators & Moving Walks D1090 Other Conveying Systems
	D20 Plumbing	D2010 Plumbing Fixtures D2020 Domestic Water Distribution D2030 Sanitary Waste D2040 Rain Water Drainage D2090 Other Plumbing Systems
	D30 HVAC	D3010 Energy Supply D3020 Heat Generating Systems D3030 Cooling Generating Systems D3040 Distribution Systems D3050 Terminal & Package Units D3060 Controls & Instrumentation D3070 Systems Testing & Balancing D3090 Other HVAC Systems & Equipment

Uniformat II excerpt [44]

Comparison:

After analyze those five standards, made basically to have an overview of the systems of classification in building industry, that is the base to understand and start a classification work to be done in according with the main aim of this thesis.

It become necessary to make some comparison between the standards, including in a table the attributes presents in any standard, it's emerged that the most complete standard is Omniclass that includes all the categories, not only in one table but it is possible to have a multiple comparison between tables to obtain a more complex code that can represent a item in all it characteristics.

Then Uniformat II like MasterFormat and UNI 8290 have just the category identification, with their three degree of specification, beginning from the more general landing to a more specified item but still standing in a general category definition.

Masterformat instead goes until define the typology of the item, to be more clear is useful make an example: in UniFormat II an exterior wall is defined at the maximum level of detail as an "exterior wall" being part of "exterior enclosure" and before in "shell" category as shown:

B SHELL	B10 Superstructure	B1010 Floor Construction B1020 Roof Construction
	B20 Exterior Enclosure	B2010 Exterior Walls B2020 Exterior Windows B2030 Exterior Doors
	B30 Roofing	B3010 Roof Coverings B3020 Roof Openings

Uniformat II excerpt [45]

Instead in Omniclass ther's more detailed definition, having many possibilities to define a exterior wall, in base of the typology of the construction, this difference represent an highest level of definition in terms of detailing.

280	Ss_25_13_05	25	13	05	Adobe block wall systems
281	Ss_25_13_24	25	13	24	Dry stone wall systems
282	Ss_25_13_30	25	13	30	Gabion wall systems
283	Ss_25_13_33	25	13	33	Glass wall systems
284	Ss_25_13_33_33	25	13	33 33	Glass block wall systems
285	Ss_25_13_33_64	25	13	33 64	Prefabricated glass block wall systems
286	Ss_25_13_35	25	13	35	Gypsum block wall systems
287	Ss_25_13_45	25	13	45	Lead brick wall systems
288	Ss_25_13_50	25	13	50	Masonry wall systems

Uniclass 2015 excerpt [46]

The same comparison can be made with others standards such as UNI 8290 or Masterformat where the degree of detailing is the same of Masterformat and it define just the typology of the selected item.

21-02 20	Exterior Vertical Enclosures
21-02 20 10	Exterior Walls
21-02 20 10 10	Exterior Wall Veneer
21-02 20 10 20	Exterior Wall Construction
21-02 20 10 30	Exterior Wall Interior Skin
21-02 20 10 40	Fabricated Exterior Wall Assemblies
21-02 20 10 50	Parapets
21-02 20 10 60	Equipment Screens
21-02 20 10 80	Exterior Wall Supplementary Components
21-02 20 10 90	Exterior Wall Opening Supplementary Components

Omniclass excerpt [47]

23-13 21 00		Blocks and Bricks			
23-13 21 11			Concrete Masonry Units		
23-13 21 11 11				Concrete Blocks	
23-13 21 11 13				Exposed Aggregate Concrete Masonry Units	
23-13 21 11 15				Fluted Concrete Masonry Units	
23-13 21 11 17				Interlocking Concrete Masonry Units	
23-13 21 11 19				Molded Face Concrete Masonry Units	
23-13 21 11 21				Prefaced Concrete Masonry Units	
23-13 21 11 23				Preinsulated Concrete Masonry Units	
23-13 21 11 25				Sound Absorbing Concrete Masonry Units	
23-13 21 11 27				Split Face Concrete Masonry Units	
23-13 21 13			Calcium Silicate Masonry Units		
23-13 21 15			Glass Masonry Units		
23-13 21 17			Adobe Masonry Units		
23-13 21 19			Clay Masonry Units		
23-13 21 19 11				Common Bricks	
23-13 21 19 13				Face Bricks	
23-13 21 19 15				Fire Bricks	

Omniclass excerpt [48]

41-30 10 25 13		Ceramic
41-30 10 25 13 11		Brick
41-30 10 25 13 13		Earthenware
41-30 10 25 13 15		Terracotta
41-30 10 25 13 17		Fired Shale
41-30 10 25 13 19		Porcelain
41-30 10 25 13 21		Vitreous China

Omniclass excerpt [49]

49-71 19 00		Single Dimensions		Properties that quantify a specific distance or angle.
49-71 19 11			Standard or Custom Size	Designator given to an item based on its overall dimensions compared to predefined measurements or in stock items.
49-71 19 13			Length	The shortest distance between the ends on a specified point of measure of the material. Usually differentiated from width by being the longer of the two.
49-71 19 15			Width	The shortest distance between the ends on a specified point of measure of the material. Usually differentiated from length by being the shorter of the two.
49-71 19 17			Distance	Refers to the measurement of the space between two points or planes.
49-71 19 19			Span	The maximum horizontal distance for supporting constructions for total load.

Omniclass excerpt [50]

In those four tables representing OmniCalass 21-23-41-49 is understandable how combining different codes coming from different tables is possible reaching an high level of detail in an item classification using this standard, instead of the others that doesn't reach even the material specification. As in the previous tabs representing Unifomat and Masterformat in those above the external wall could be define in all it aspects.

Based on those consideration and researches it was possible resuming all the standards studied in a short and easily understandable chart that represent the standards and in which field they are defining items.

ATTRIBUTES	UNI 8290	MASTERCLASS	UNIFORMAT II	UNICLASS II	OMNICLASS
CATEGORY	✓	✓	✓	✓	✓
TYPOLOGY	✗	✗	✗	✓	✓
MATERIAL	✗	✗	✗	✗	✓
DIMENTIONS	✗	✗	✗	✗	✓
PERFORMANCES	✗	✗	✗	✗	✓
PROPERTIES	✗	✗	✗	✗	✓

Comparison scheme.

It's also important to say that this representation was made for what concern the item classification intended as building component, some of those standards includes many other categories that can define other aspects and not everyone was considered to make this chart.

Classification systems	OmniClass	MasterFormat	UniFormat	Uniclass
Country of origin	North America	North America	North America	UK
Produced by	CSI and CSC	CSI and CSC	CSI and CSC	CPic and NBS
Language	English	English	English	English
Purpose and properties	Organization, sorting and retrieval of product information for all objects in the built environment in the project life cycle.	A master list for organizing construction work results, requirements, products and activities. Mostly used in bidding and specifications.	For arranging construction information, organized around the physical parts of a facility known as functional elements mainly used for cost estimates.	For all aspects of the design and construction process. For organizing library materials and structuring product literature and project information
Framework	ISO 12006-2, ISO 12006-3, MasterFormat, UniFormat, EPIC	Industry practice and gradual development	ISO 12006-2 , Professional judgment	ISO 12006-2 , SfB, CAWS, EPIC, CESMM
Grouping principle	faceted	hierarchical	hierarchical	faceted
Organization and taxonomies	15 inter-related tables categorized by number and name. A combination of Table 21, Table 22 & Table 23 allows for classifying a product precisely.	One table with a series of six numbers and name: Level one with 50 divisions (2004 version) each is made up of level two, level three, and sometimes level four numbers and titles for more detailed areas of work results.	One table with alphanumeric designations and titles in five levels: level one is in nine categories separated by their special function. Level 2 separates them into constituent parts, level 3, 4 and 5 further subdivide them.	The division among facets is based on the alphabet in 11 tables and within each facet by decimal scale up to 6 digits. Table G, J, K and L can be used for classifying product models.

A Comparison of Construction Classification Systems Used for Classifying Building Product Models. [51]

1.3.4 BIM for 5D project:

The fifth dimension is related to costs, as explained in introduction chapter, is strictly connected to the fourth detention, due to this relationship it came also automatically estimate costs after making the 4D study.

Nowadays the costs control are mandatory for any kind of project, in this period where one of the biggest challenge in construction industry is to avoid waste of money, and to obtain a highest level of sustainability in terms of economic sustainability, those kind of tools permits to have a 360 degrees control of the project, including the change that could happen during the process, making a dynamic model able to be changed and to adapt itself, giving instantly new costs reports. The BIM costs manager importance is increasing and becoming everyday more important as P. Smith said: "[...] the value of the cost manager in being able to simulate and explore various design and construction scenarios for the client in real time through having their cost data and quantities integrally linked in the live BIM model. This certainly raises the value of the cost management service but is dependent on the cost manager having BIM capability/expertise, sharing their cost data in the model and having the experience, expertise and intuition to analyze and critique the information that is being generated by the model [52]".

Through the BIM use is possible to have an high detailed Quantity Take-Off (QTO), giving to any item a cost in term of parameter applied to the elements in the model, integrating those information with the WBS and the timeline that defines timing and resources required to accomplish any task is possible to manage those aspects, understanding the best option to improve costs and building site organization.

Instead of the traditional way, BIM approach aimed to define quantity allows to have a direct connection between the items present in the model and the count reports automatically made inside the software, this strength typical of BIM allows to avoid data leak, that is the most common failure in the traditional CAD process.

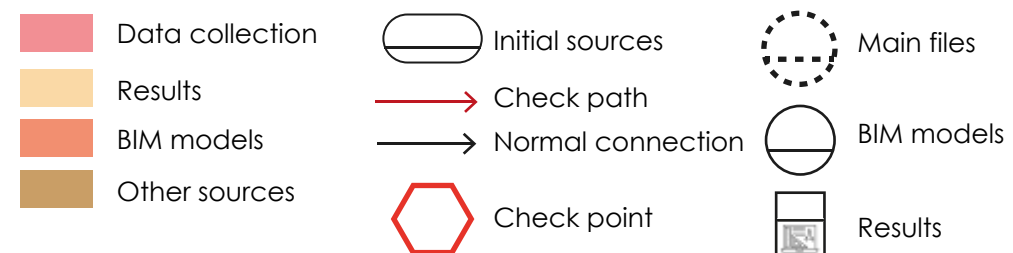
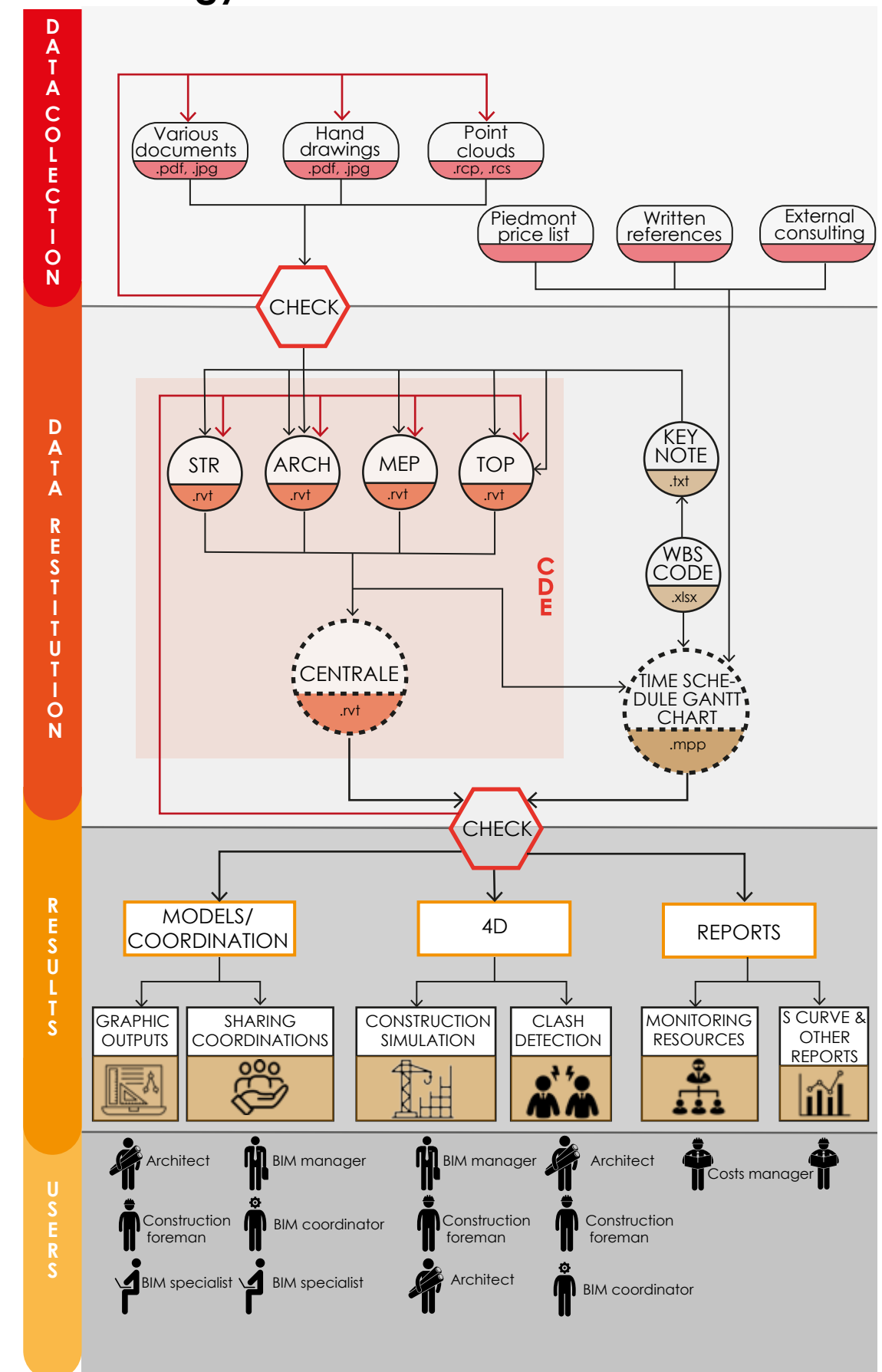
Passing through those two additional dimensions was the main goal of this thesis, aimed to reach a high detailed tasks time-line connected to a QTO to establish the amount needed to accomplish the whole winter garden project.

In the following chapter, completely dedicated to the methodology it will be explained all the process took to reach a 5D project in BIM environment, and finally the results obtained to understand how the BIM use integrated with other software can be useful and helpful to accomplish the goal to avoid wasting in terms of money and time, further others secondary tools like clash detection and building site organization.



METHODOLOGY

- .1 SHARING STRATEGIES**
- .2 SHAPING PHASE
- .3 CONSTRUCTION MANAGEMENT

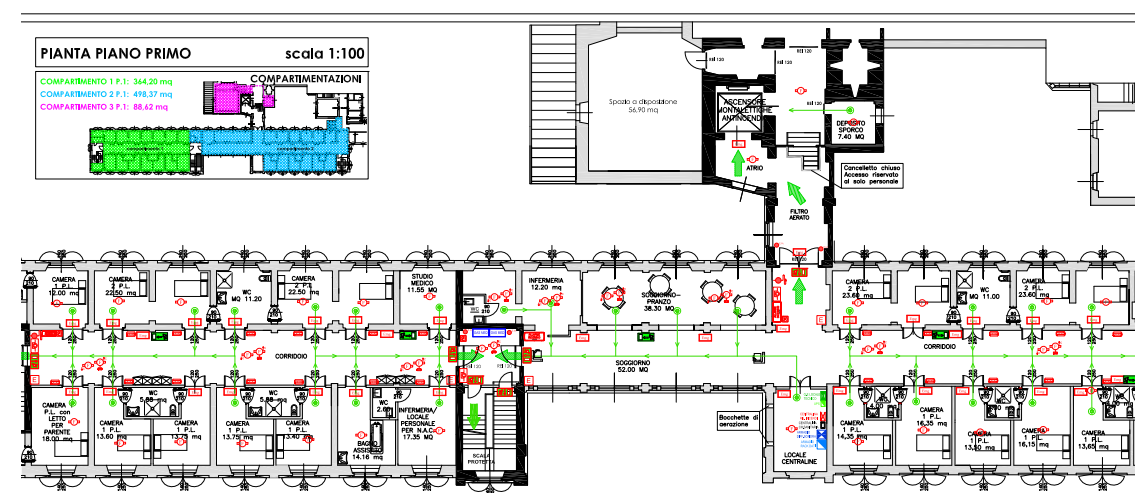
Legend:**Metodology scheme:**

2.1.1 Data Collection:

The first practical step was a research phase, aimed to find the most quantity of information about the facility, basically due to the need to have a base to start modeling on. Due to the leak of information at the beginning of the thesis, the firsts shaping steps were made on photographic surveys made by ourselves, basically for what concern the monumental facade, that was obviously not enough.

Then the first complex model made through the mass use, has been made based on a photographic map took from Google maps, it was used also if it appear clearly not reliable just to have a approximate model to start work on.

Firsts real spacial in forms of drawings were provided by Ing. Luigi Barbero who made a refurbishment project for the facility.



First floor plant [53]

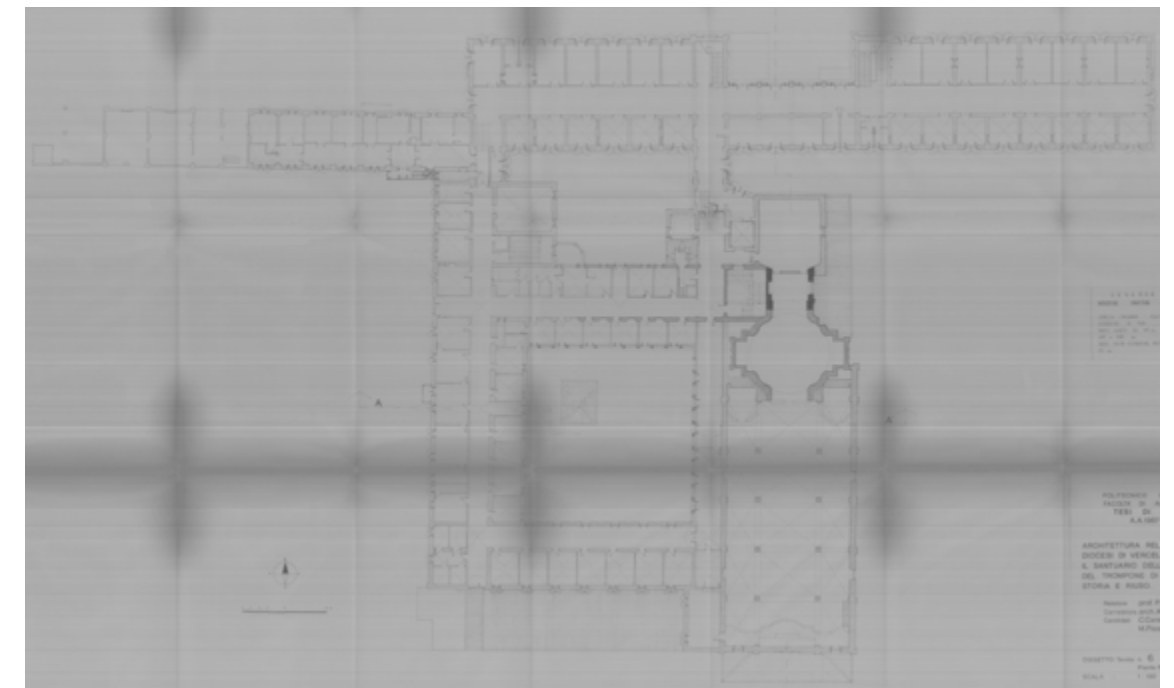


North monumental facade [54]

Those two drawings are some of that provided by the engineer, after some survey made by ourselves we've established that aren't reliables, then we left them, because we've found a more precisely drawings made by the current Moncrivello's mayor, arch. Pissinis



Church south facade [55]



Ground floor plant [56]

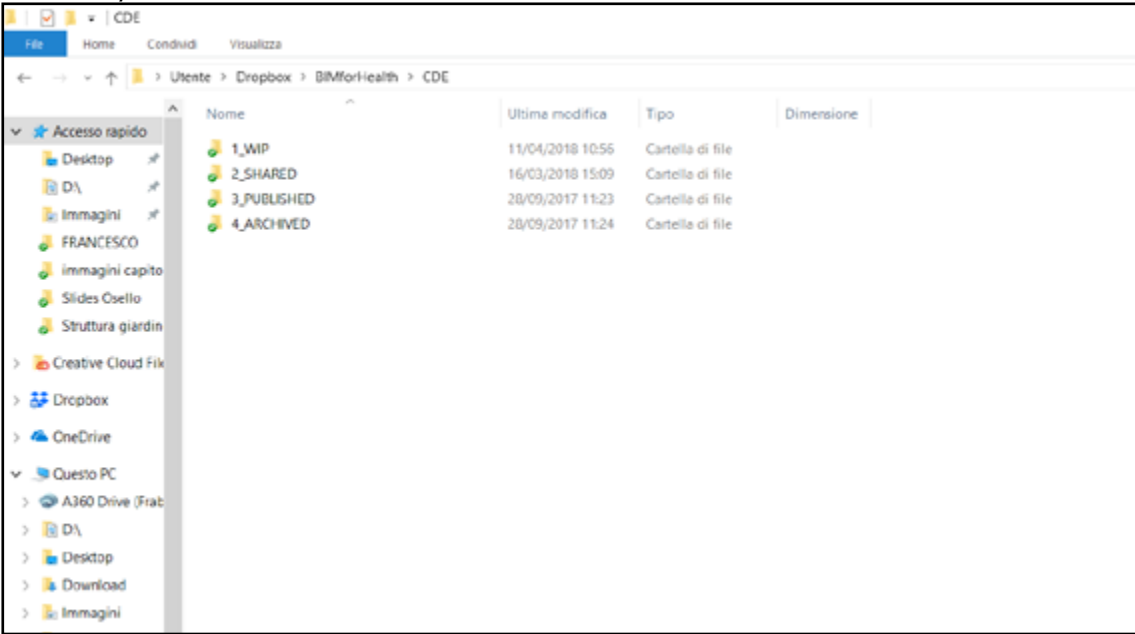
Those hand-drawings are incredibly detail-rich, and made in an incredible accurate way, we used them as a first really reliables sources. As said those come from the Moncrivello's mayor thesis in architecture made in the late eighties, this thesis has as main goal to represent the whole complex with an accurate and high detail level. After some surveys made by ourselves by common instrument like a laser yardstick we found these drawings much more reliables then the previous ones, though the firsts are more recent and made by more precise electronic devices and CAD software. Then the data collection has another step, with the point-cloud survey provided by prof. Piras that was the last source the most reliable and the one we used until the end, anyway a dedicated following chapter will explain the use of these source.

2.1.2 Common Data Environment (CDE):

The British standard adopted to make a sharing environment for all the students working on this facility was already explained in standards terms in the Introduction chapter, following those guide-lines we've created our own Common data environment, using an on-line platform such as DropBox, that is a file hosting service, that offers cloud storage, file synchronization, and personal cloud.

This sharing platform has been chosen because of it's availability also in a free mode, it doesn't requires particulars procedure to be followed and the sharing environment can be joined constantly by new members, this strength in terms of dynamism, and the familiarity we already had with this platform are the reasons why we've choose it.

Anyway it has also some weaknesses, such as the service completely depends from the internet connection quality, that means that sometimes it could be difficult to have a quick synchronization, or it can also be impossible in case of internet connection absence, or also there could be problems in case of contemporary use of the same file (one will be in conflict), or there can be some data leak.

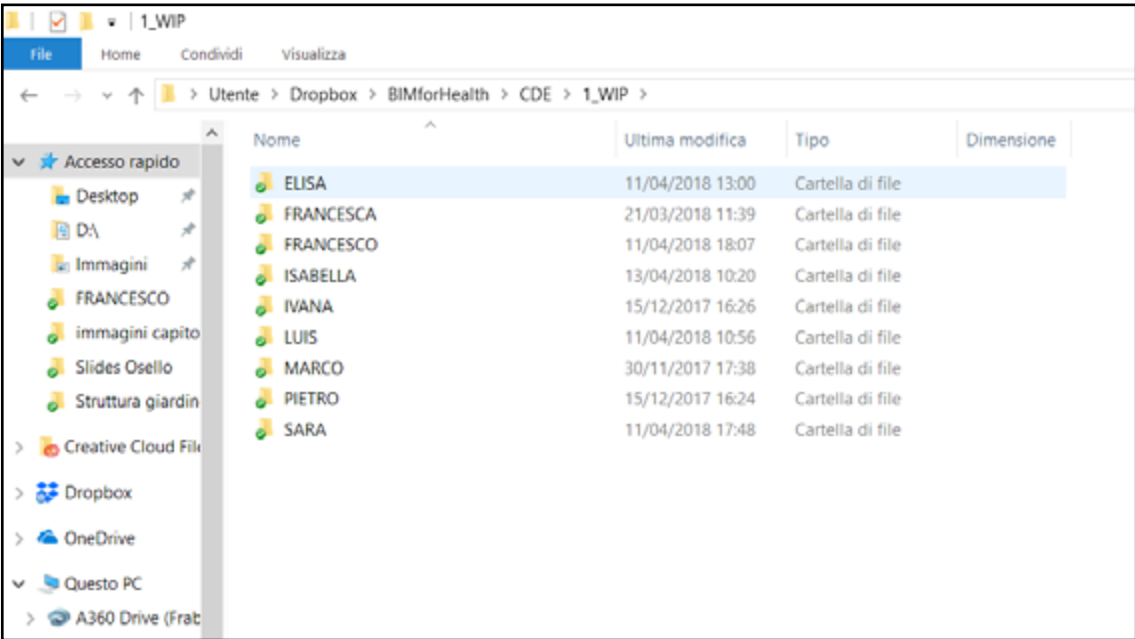


Common Data Environment Overview.

The picture above show the first folder containing the whole CDE for this project, that has four sub-folders as normed in the British standard 1192 : 2007, Work in Progress (WIP), Shared, Published and Archived, the content and the sharing rules of those folders is already explained in chapter 1. Out of the CDE folder was created another one independent from the common data environment, but always shared within all the participant called "Document", where everyone stores his documents related to the thesis works, such as standards, sources to make them available to the

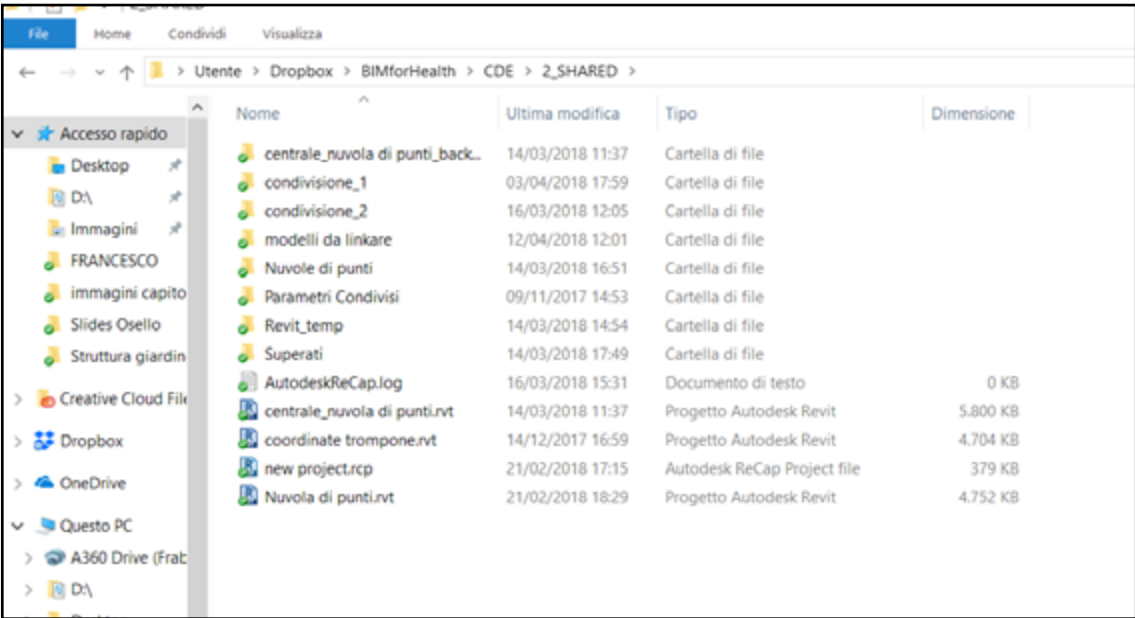
others group members.

Here is shown the Work in progress sub-folder, that contains in turn other sub-folders for each member, here as explained in the British standard are stored all the files composing the whole project in a temporary phase, before being approved.



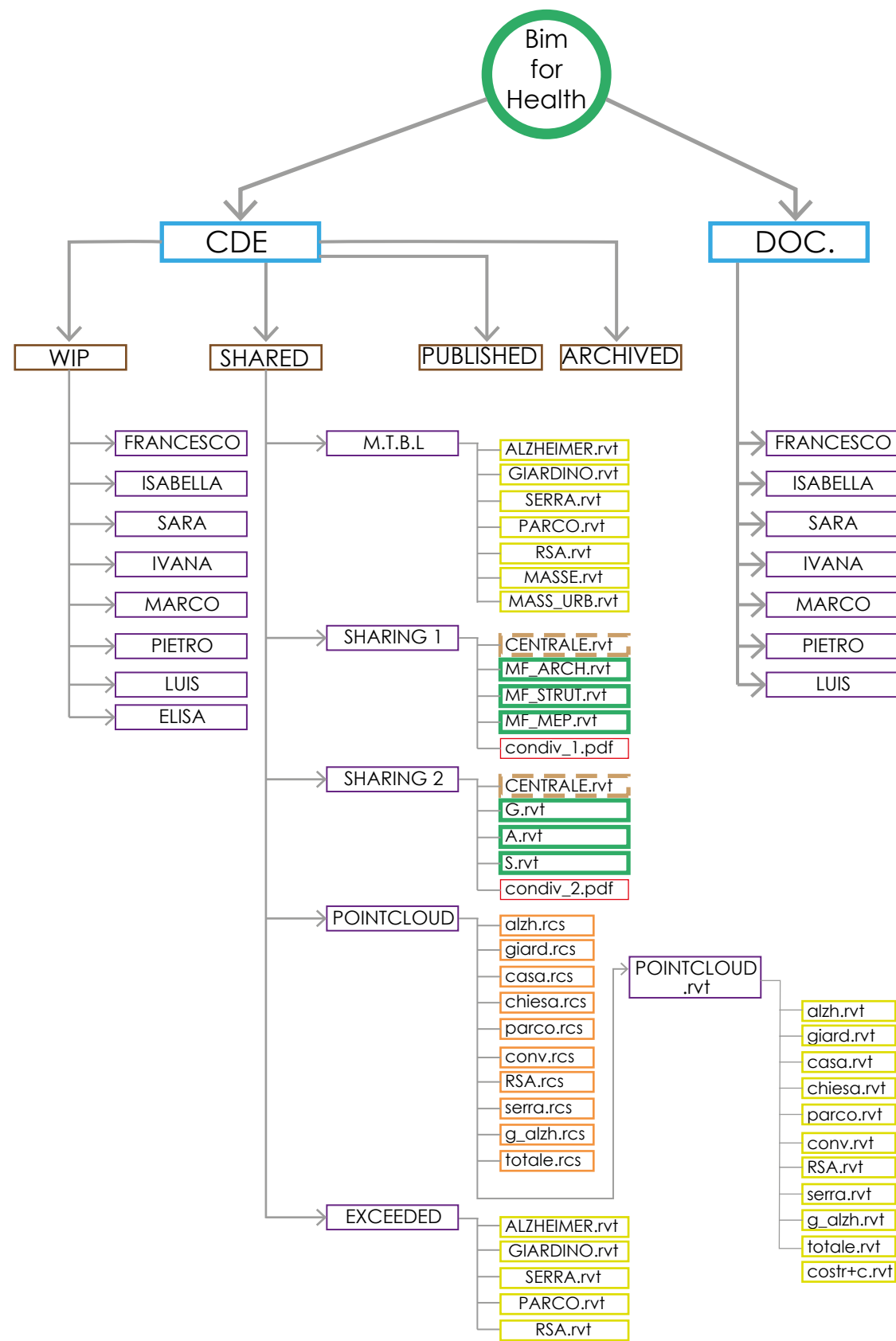
WIP folder contents.

Then the shared folder, that contains many items such as the model files approved then shared, split in two sharing sub-folders that contains two different strategies to share federate models into a BIM environment, then all the ReCap files that represent the point-clouds survey split in regions and attached into the model files, passed files, shared parameters ecc.



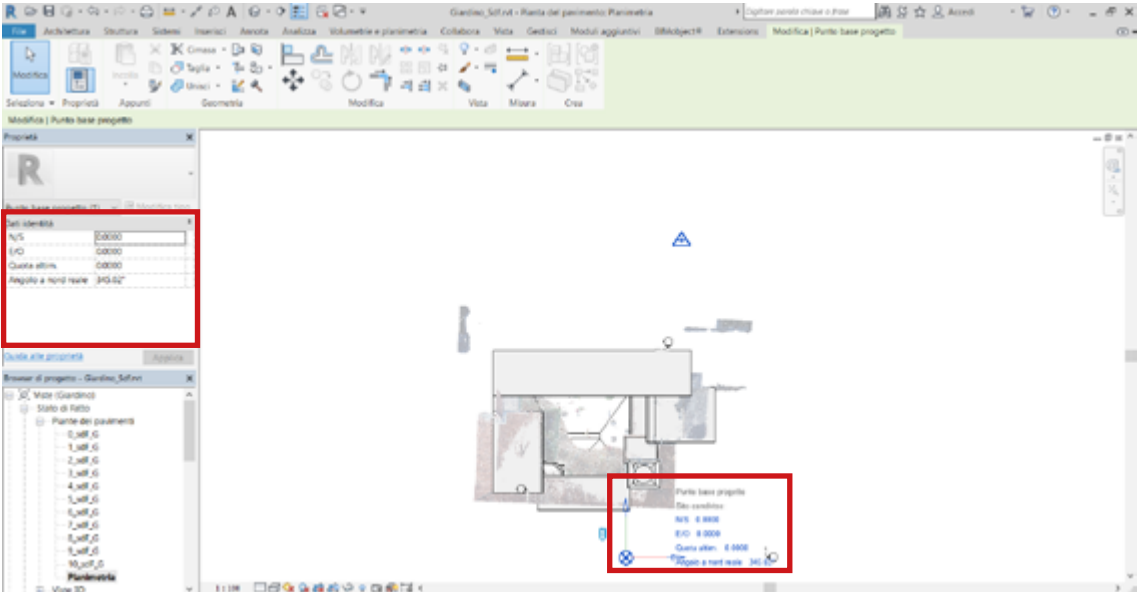
Shared folder contents.

Common Data Environment Scheme:



2.1.3 Shared Coordinates:

To make a federated model, where are attached multiple single models as I'll explain in the following pages, become necessary have a shared coordinate system adopted by all the singles files, this coordinate file was made in Revit taking two points obtained by a topographic survey. Those two points previously obtained were insert in Revit, where in default template are present, the first one is the project base point that is the origin of the project.



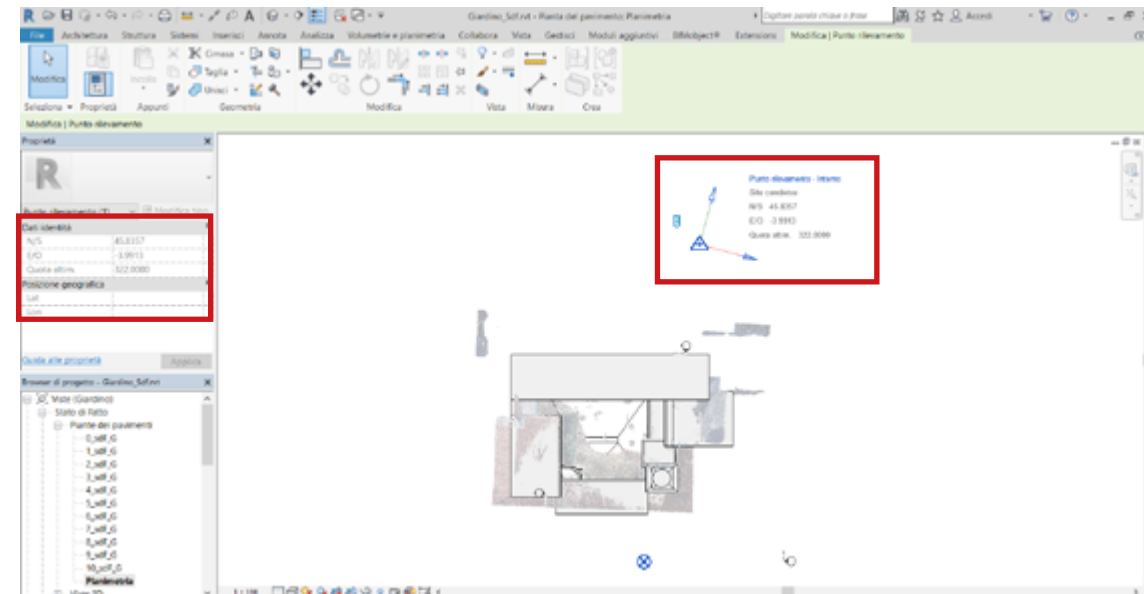
Plant view, with survey base point highlighted.

This point was left with coordinates N/S= 0.0000, E/W=0.0000, the only value has been changed is the angle between the real north and the project north, real north represent the real orientation of the project, the angle between the real north and the project north considered as a straight line like a common representation of north, that is used to have an orthogonal representation of the project, aimed to permit an orthogonal shaping that could be difficult otherwise with the real orientation, the value insert was 345.02° degrees clockwise.

Legend:

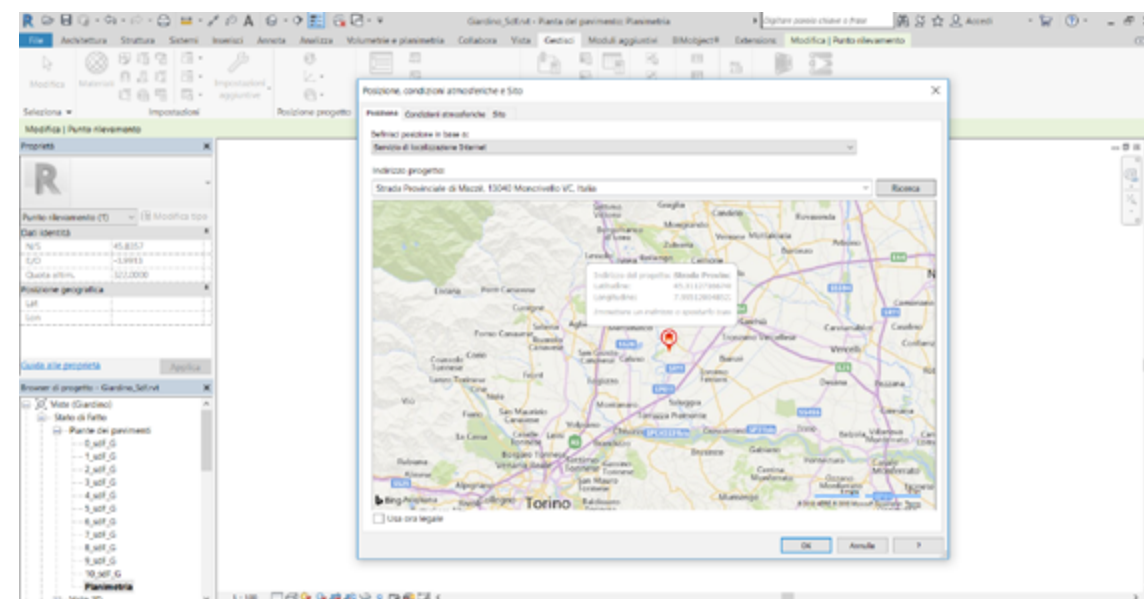
- Main folder
- Main folder (CDE)
- CDE division folder
- Personal folder (3rd degree)
- Central file
- Single .rvt files
- Coordination guidelines
- WIP .rvt files

The second point insert into the project is the one that was measured through a topographic survey, it define an exactly point on the earth surface in terms of latitude and longitude, the value insert through a GPS survey are N/S= 45.8357 and E/W=-3.9913, of course to materialize a point on the earth surface was necessary insert also the altitude on the sea level that is = 322.000.



Plant view, with survey point highlighted.

Revit also allow to insert the real position in a map, as shown the model was localized in the real place where it be, this tool can be useful mostly to make energetic simulations, because et any position are connected climatic average data such as wet bulb and dry bulb temperature took from the closest weather station.



Project georeferencing in Revit.

2.1.4 Sharing strategies:

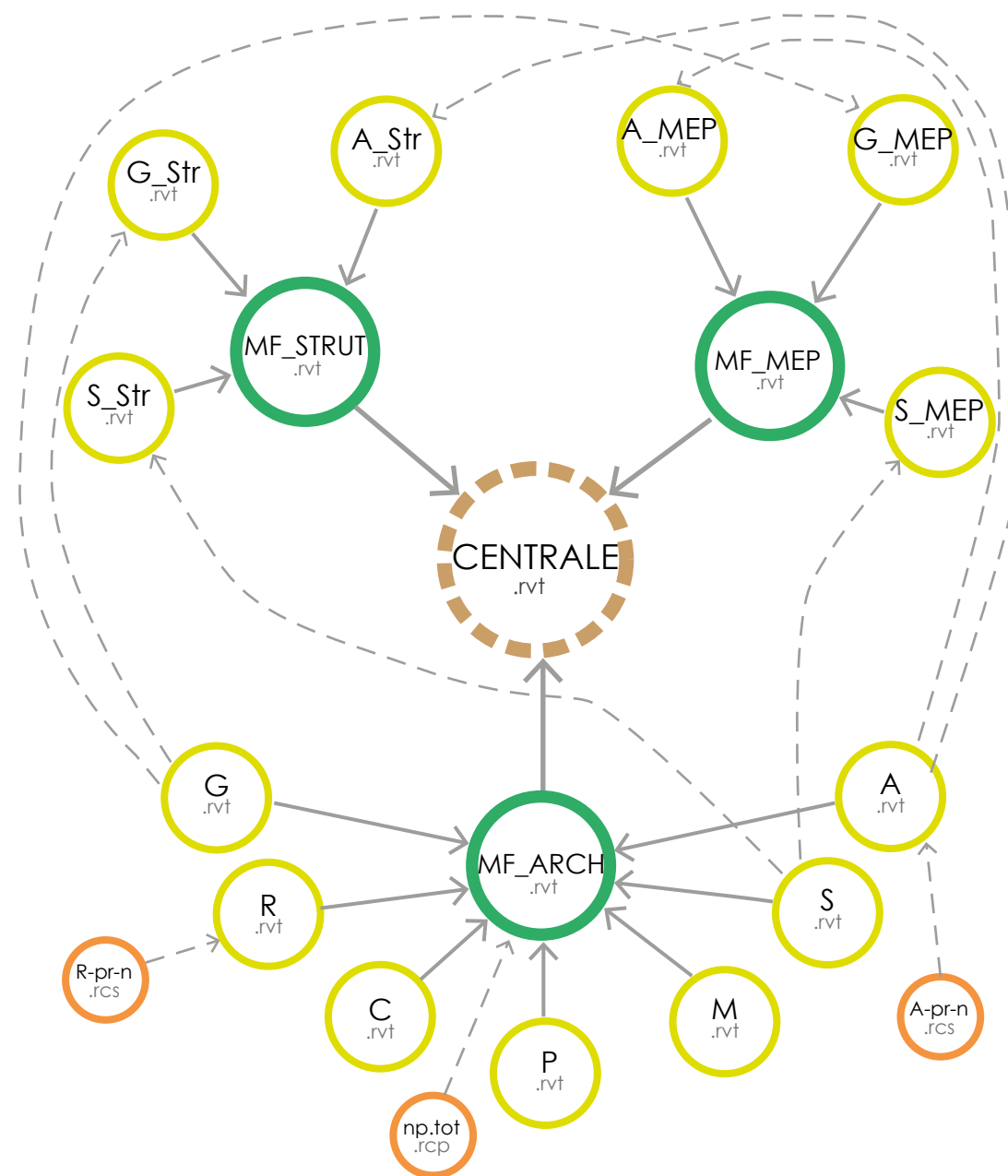
As already introduced the main point of the first part was to understand and find a way to create a federated model using linked file inside Revit, that is one sharing methodology, the one we've chosen because the more congenial in a situation where each group member was modeling a different part of the complex, divided not by disciplines as architectural, structural and MEP, but facility parts.

This distinction has changed after this first part which aim was to shape the existing facility, in the second part where everyone has focused on his own project the sharing strategy has been changed, because also the aim was changed, beginning from an "as is" model, added with ours projects everyone made by the three disciplines joined model.

A long time was spent after we received the point cloud survey, the manage of point clouds in federate BIM model was a significant part of this thesis, we made many attempts to find the best way to use those files linked to ours models.

The following schemes shows a temporal work-flow we've used to make our federate model of whole complex, we've made many attempts before finding the best way, of course this field is still under research then there isn't a codified way to figure out any situation, thus this is why we've used five sharing strategies, modifying according to our knowledge degree and the material we got, for example is easy to see a big change after we received the whole point cloud survey.

2.1.4.1 Sharing strategy 1:



The first sharing phase was thought with the basic scheme we will bring until the end, the scheme is split in three main areas that are architectural, structural and MEP (mechanical, electric and plumbing), represented by as many central files that includes all the single models for any field.

As explained all the architectural files were split by the team members to shape the existing complex, this operation was done without any survey except for two point clouds made for the Alzheimer wing and the RSA wing by the students assigned to those parts, linked by Overlay, a kind of connection that means the lost of those information in the federate model.

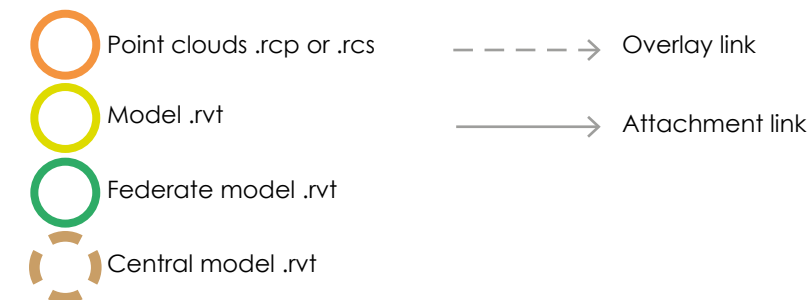
My part of the winter garden was shaped firstly following a hand survey made by myself and only later when we got the whole point cloud I've adjusted it. Others parts such as the church and the convent were shaped based on two documents basically such as the Moncrivello's Mayor thesis where he has redesigned the whole facility, and other drawings made by an engineer who has made a project in the complex.

Thus the central architectural model is made by all the single models compositing the whole facility with attachment links, that allows to have all the single models nested in the architectural federate file.

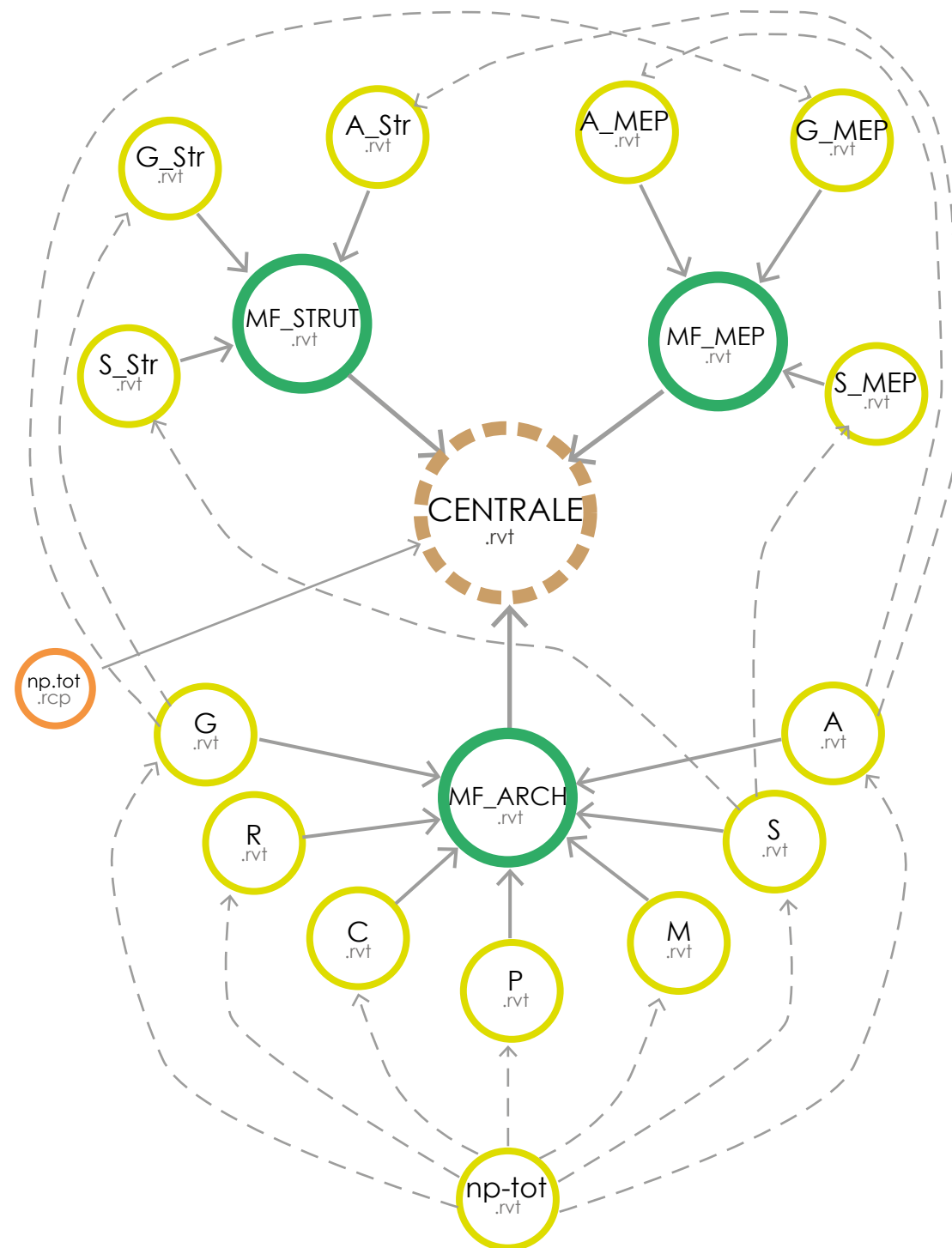
The same procedure was used for the structural and MEP files, but those fields are presents only in our single projects and not in the existing facility model, due to evident limits we weren't able to shape any aspect of a such a complex facility.

Then all the federate files representing three fields as described are joined in the central file always by attachment links bringing back all the single models that allows the user to switch on or off the visualizing and other options for any single file compositing the central one.

Legend:



2.1.4.2 Sharing strategy 2:



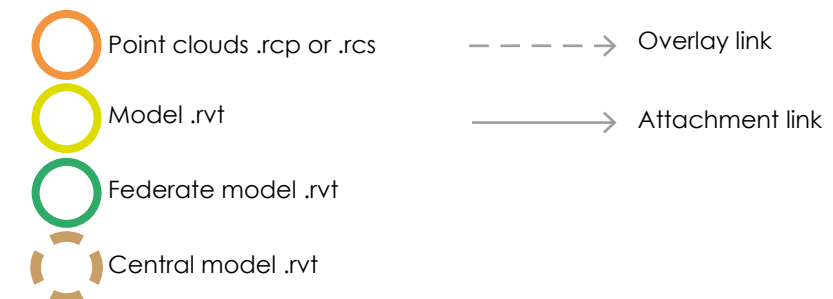
In this second scheme is represented for the first time the whole point-cloud survey, the general scheme is pretty similar to the first one, except for the treatment of the survey files, and some files added.

In this case the whole point-cloud was previously saved into a Revit (.rvt) file which is linked into any architectural model by Overlay link that is not an efficient procedure due to the repetition of the same file as much as single models are, and the lost of the data uniqueness that is considered wrong in a federated file process like this.

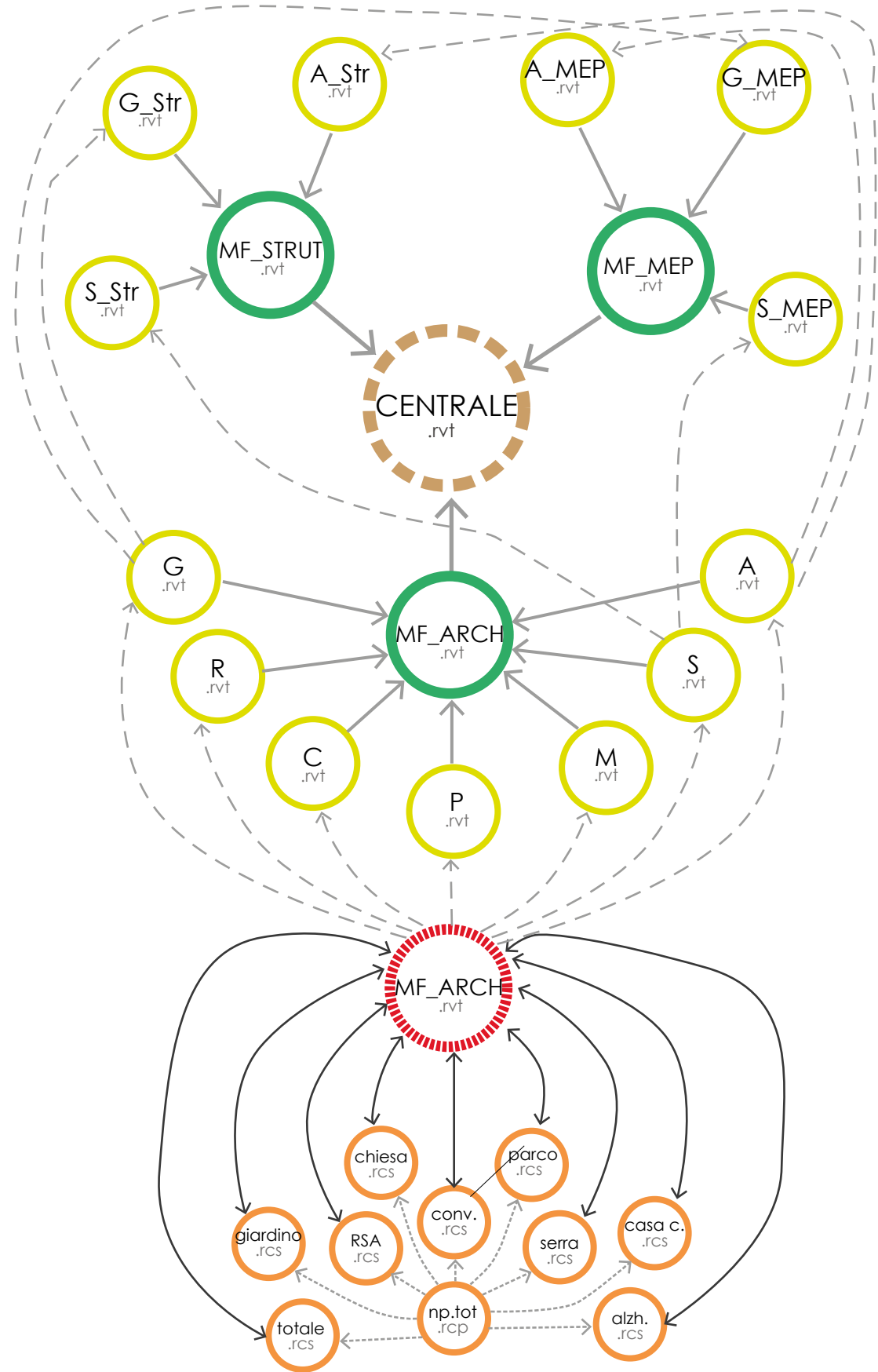
For what concern the survey it is lost in the central architectural file due to the use of overlay links, the whole point-cloud is also charged into the central file directly as a .rcp file that is the extension for a point-cloud file, passed previously in Autodesk ReCap software, this procedure will be explained in a following dedicated chapter.

It's also possible see the addition of some other files filling some blank as some MEP files.

Legend:



2.1.4.3 Sharing strategy 3:

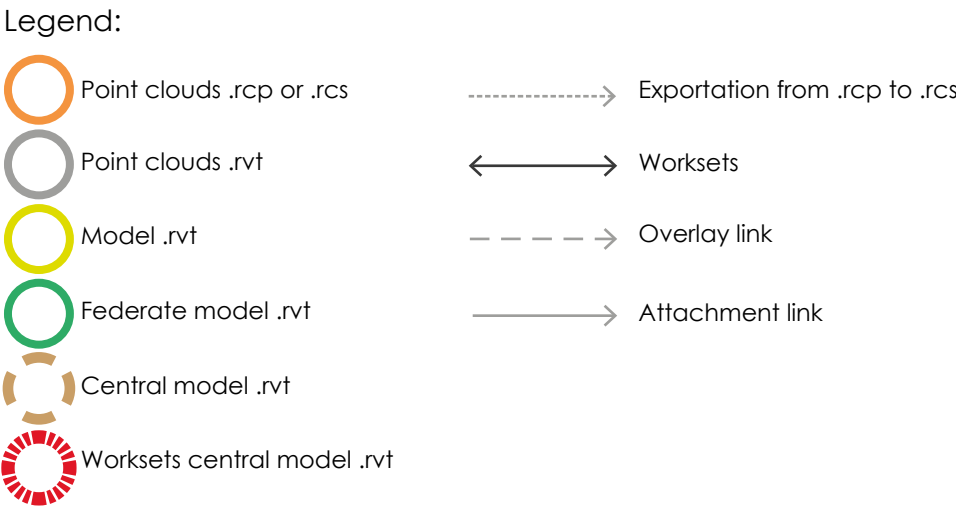


In this third scheme the management of point-clouds become more complex, with the aim to have a more rational share of those file this attempt preserve the same layout of the previous what is changing is the manage of survey files indeed.

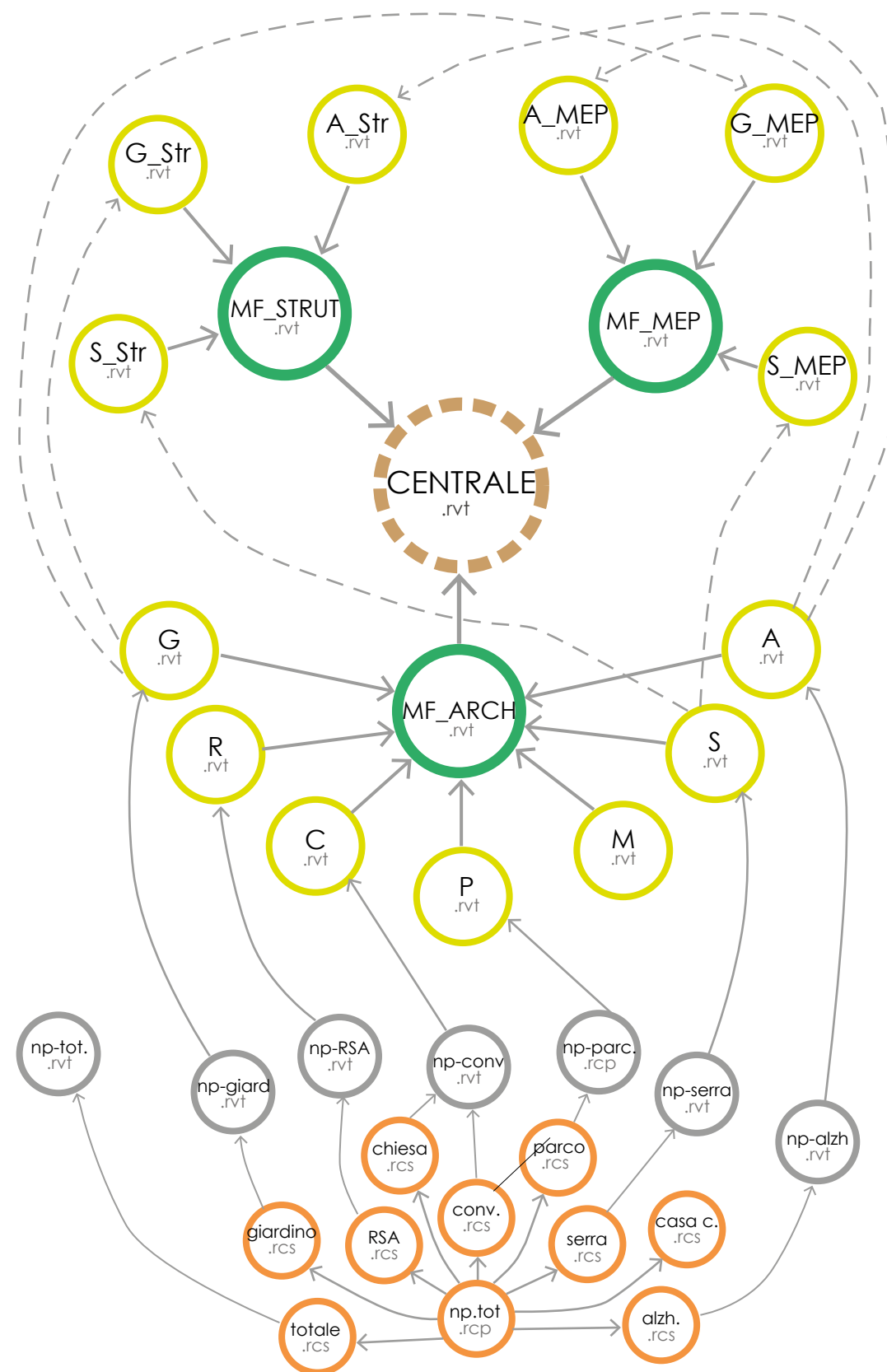
To overtake the repetition of information due to the wrong sharing of pint-cloud in the previous scheme, where the whole point-cloud where linked every time to any architectural file and was always visible entirely, we tried to mix the sharing strategy introducing a Worksets file composed by different local files represented by all the regions made in Autodesk ReCap, where any region represent basically a building part divided in team members as said.

Creating a worksets model the whole point-cloud was divided in many .rcs files that is a sub region of .rcp, that represent the whole survey. All those worksets represented by local files are included in the central model that is every time linked into all architectural file, in this way is possible to switch off all those regions that are not useful in any single part and maintain visible only the part we are interested in.

Anyway also this sharing scheme wasn't considered satisfactory because we've found many troubles during the process such as sharing weaknesses due mixing sharing methodology as linked and worksets files, strength and weaknesses about sharing strategies of point clouds will be discuss in a following dedicated pages.



2.1.4.4 Sharing strategy 4:



Fourth and last scheme is the one finally used, it was reached through many attempts and many consideration made during several time because any attempt required a long time to be thought and actualized.

In this case the whole point-cloud called (np-tot .rcp) was split in many regions that are loaded into Revit files, with the aim to obtain Revit files, that makes easier to manage the link procedure and the visibility settings once is linked.

Then every .rvt file containing the point-cloud portion is linked by overlay into any architectural Revit models, where the shaping phase can start, modeling on a detailed survey that allowed to understand the real shape of the facility and to correct all the errors made previously due to an incorrect survey, here it was noticed that all the sources used until this point weren't correct at the level of detail required.

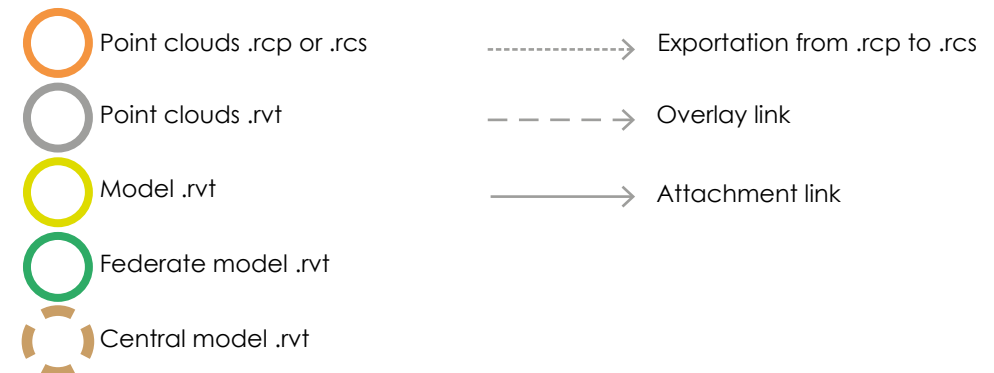
The models were linked by overlay with the aim to loose these files in the federated because are useful until the shaping phase.

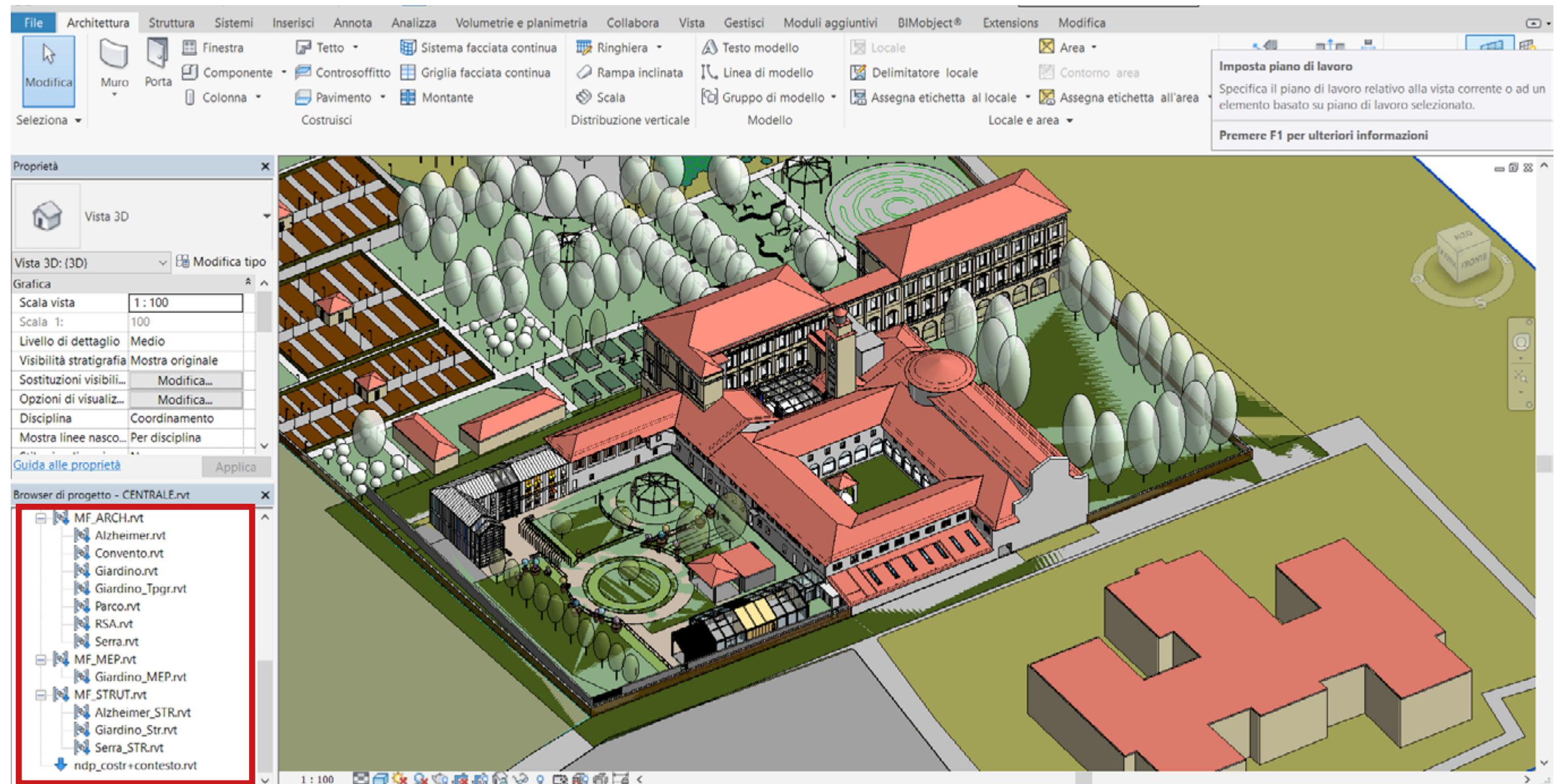
Then the general scheme remains basically the same from the beginning creating three federated files, one for any main field all again linked into the central file that will contain all information about what is modeled.

This sharing strategy is also thought to be augmented by others actors, will work on the same facility, the structure we've used is created to be a base for the future to reach a highest level of detail an to be filled with the leak parts in structural and MEP fields.

It also should be improved the model "as is" of the complex because some parts were shaped before having the whole point-cloud by people whom already left the working group when we've received the survey.

Legend:



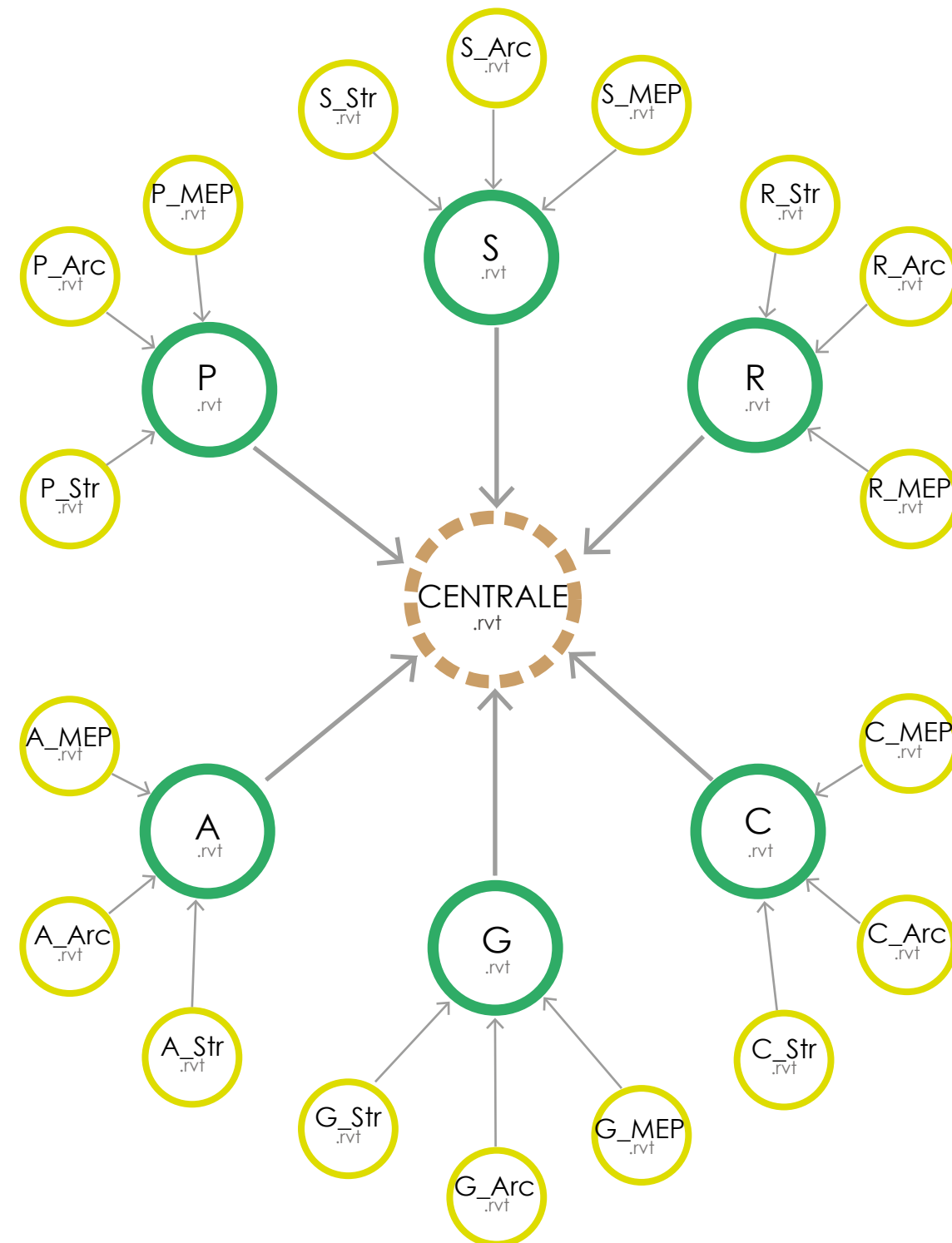


Central federated model representing first sharing strategy adopted, with project browser highlighted.

This picture shows the whole Revit model in a project phase, it's possible to see some new intervention like the greenhouse, the Alzheimer wing and more hidden the winter garden inside the courtyard. Surrounded by the red square there's the project browser that shows the hierarchical organization of the whole facility in BIM environment, this solution represent the fourth sharing strategy with three federate files one for any main field (arch, strut, MEP) composing the central model, any federate bring back

some nested models, for example the architectural one is composed by seven files, structural by three and MEP only by one, at the lists bottom is possible to see represented with a different symbol the whole point-cloud survey linked directly in the central file as showed in the scheme.

2.1.4.5 Sharing strategy 5:



The fifth strategy represent the last step of sharing phase in this work, someone has as focus of his thesis a project to insert into the existing complex, such as the winter garden inside the courtyard, the new building for people affected by Alzheimer illnesses, a new greenhouse ecc.

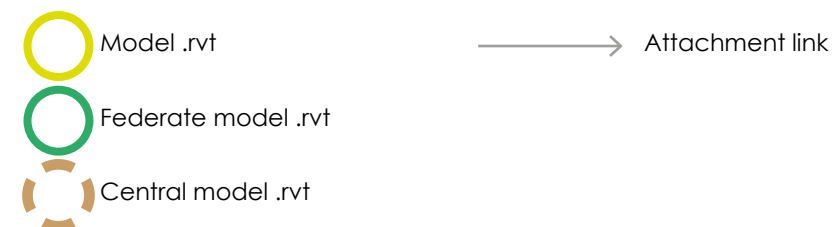
This scheme was thought to manage those projects, anyone is divided in three main files architectural, structural, MEP as usual, all linked into a new federated file, by attachment link to don't loose the file in the second link degree, then all those federates are joined into a central one that contain all the projects.

This second scheme completely different from the firsts four is though specify to represent the project phase of the process, and like the others is designed to be extended in a future phase, it could look like there's not the existing complex into this sharing work-frame, but is like in the others the architectural file is made considering basically two phases (present and project phase), is not the same for structural and MEP, because as already said we didn't shaped those aspects of the existing complex.

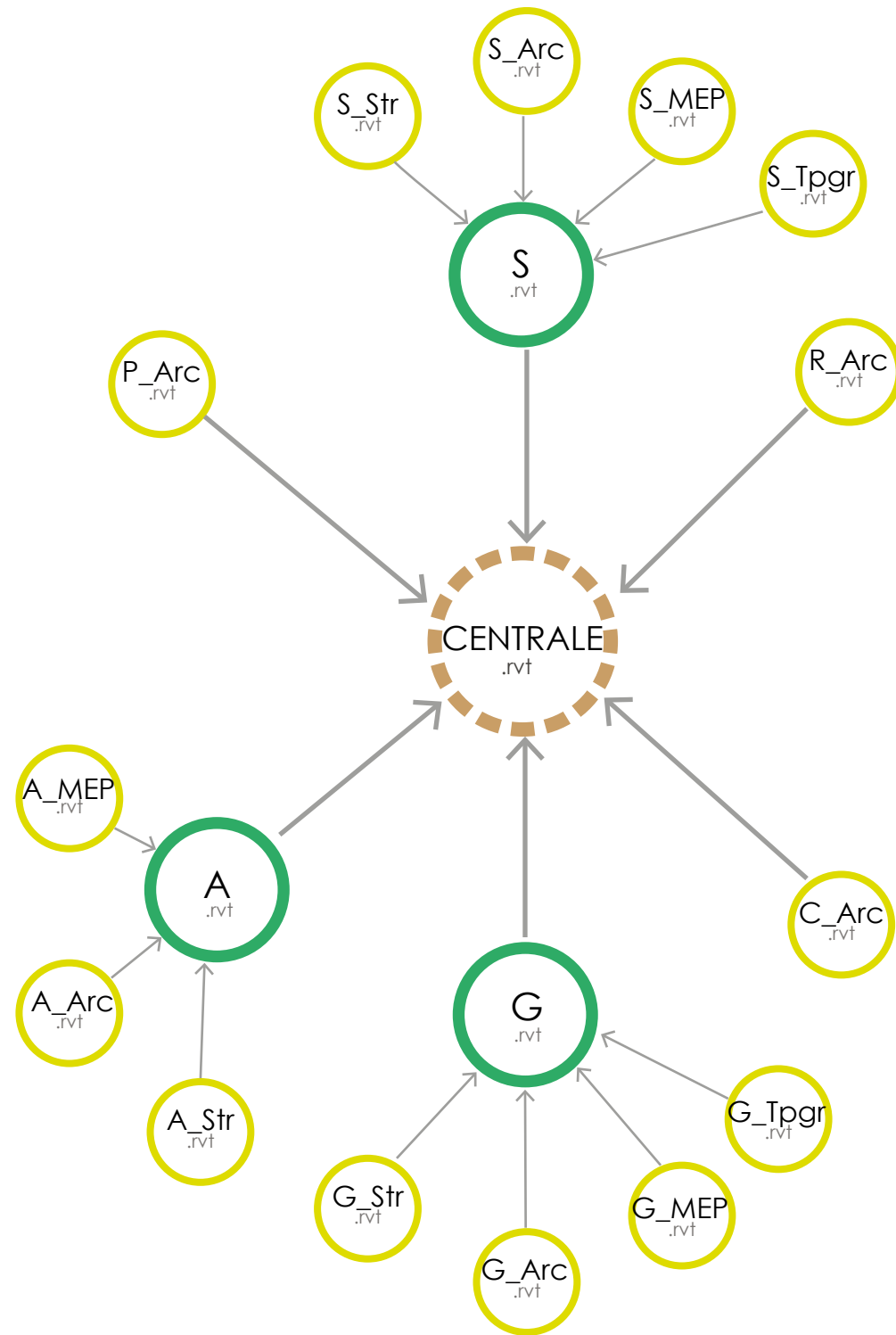
In this work-frame the basic organization of all files has radically changed, basically due the need to have a federate file which is inclusive of all project files, so the intermediate federated file is not anymore made by field but by project, in the previous strategy the federated intermediate file was made in base of the field (architectural, structural or MEP) where we were operating and it was containing all those file belonging to his category, in this scheme the federated file is containing those files typically forms a project in BIM environment.

There were created those two sharing strategies to have a better organization into the common data environment, and aimed to have a project detection especially during the transition from the WIP to SHARED folder. All the strategies can be improved and added with future works, we've chosen to work with both to leave any possibilities open, that wasn't possible otherwise.

Legend:



2.1.4.6 Sharing strategy 5 adopted:



Following the previous ideal scheme, this one represent the one finally adopted, the difference consist basically in the leak of structural and MEP files for what concern the RSA wing, the park and the convent that were shaped just thinking about the architectural field.

Then G that represent the Winter Garden and S that's the greenhouse are implemented trough the addition of an topographical file, that results useful in construction management scenario aimed to calculate the quantity of ground to be moved in excavation activities, particularly to estimate a timing to accomplish the task and have a price based on the ground volume dug and moved out of the building site.

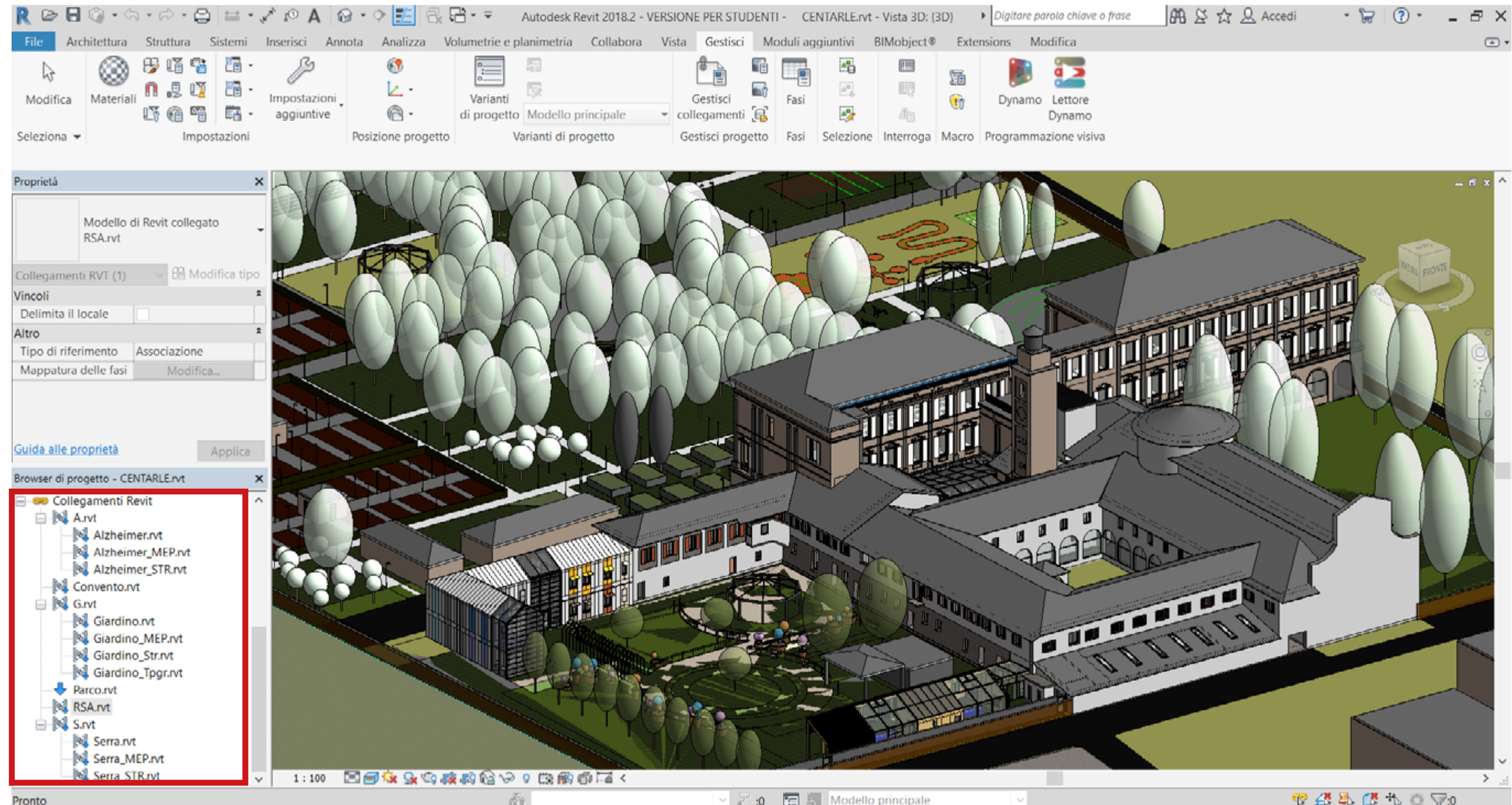
Legend:

Model .rvt

Federate model .rvt

Central model .rvt

Attachment link



Central federated model representing second sharing strategy adopted, with project browser highlighted.

In the picture above that represent the second sharing strategy adopted in Revit, the project browser shows the division made by projects, and not anymore by field, where the federated files A, G and S represents nested files containing respectively single project files like architectural, structural, MEP and topographic, and some single architectural files completing the whole facility such as the RSA wing, convent and church.

2.1.5 Pointcloud use into federated model:

The treatment of point-clouds inside our federated models deserve a focus, firstly because it took a long time and many efforts were spent to figure out how to better use those survey provided by prof. Piras office.

Firstly is necessary to say that there was a fault in the process because the survey was received a long after our thesis work beginning date, and some people have already finished their thesis, then most of complex parts were shaped before having the survey, so it represent a important fault into the process, it should be improved and corrected by future thesis students will work on it.

The survey has made by professor Piras and his collaborators in November 2017, it is a result from the joining of two kind of surveys, first the one located inside the courtyard where I'm operating, this survey was made with laser scanner (LIDAR) technology that allowed us to have a high detailed model of this part of the complex, the rest of the facility was took-over by photogrammetrical methodology using a camera integrated drone, then those two surveys were joined making a good quality point-cloud of the whole facility for what matters the external shape of the complex, obviously it wasn't took the survey of the inside environment, it would required too much time and a huge file size it could be hard to use, and it would be definitely useless to the designing purposes.



Point-cloud survey plant view.



Point-cloud survey plant 3D view.

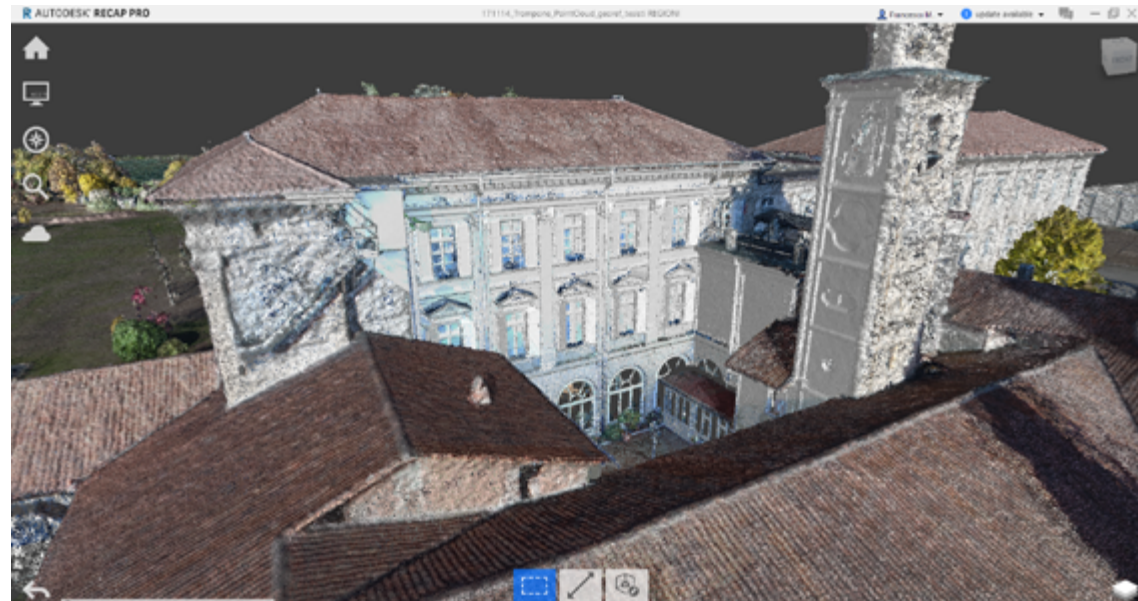
The whole point-cloud was previously imported into Autodesk ReCap, that is a software which purpose is to manage those kind of surveys.

A fundamental tool used in ReCap was the division in regions of the complex, that allowed a model splitting into different regions represented by our previous division. So the point-cloud was divided in eleven regions representing: the church, convent, courtyard, RSA wing, park, ecc. these regions were handled as explained before into the sharing strategies.

When the point-cloud was imported into the file it needs a re-orientation of the real north, Revit permit to have two different visualization of the north into a project: Real north and Project north, the real north represent the real orientation of the project refer to the project north that has a classic orientation in our case the facility has a difference between real and project north of $14^{\circ} 48' 58''$. The point-cloud was created and loaded into the project already having this orientation but is refer to the project north instead of real north so to be correspondent we had to apply a negative angle value of $-14^{\circ} 48' 58''$ to make it match with the model.



Point-cloud orientation.



Central courtyard point-cloud survey made by LIDAR technology.

Referring to the manage of those surveys into the sharing strategies of the federated model treated in the previous chapter, were made some considerations, basically because it was a big part of our treatment, there were found different strength and weaknesses for any of those strategies, until leading to the final scheme we finally used.

- **First scheme:** It's the oldest strategy, thought in an informations leak situation where we were operating just with two point-clouds refer to the RSA north facade and the Alzheimer wing, made by ourselves that represent the .rcs files present in the first scheme linked to files A and R, those surveys are completely inaccurate without any topographic reference between each others.

- **Second scheme:** This is the first attempt we made with the entire survey provided, it basically consists in a creation of an .rvt file containing the whole survey to be linked anytime by overlay at each architectural file compositing the federate model.

Strength:

- Uniqueness of .rcp file containing all the survey information.
- It's easy to manage visualizing settings into the linked file.
- Easiness and velocity of manage link as a sharing method.

Weaknesses:

- Redundancy of informations due to the repetition of the whole file inside any architectural model.
- Survey loosing into the central file, it could be relinked.
- Files too heavy containing the whole point-cloud.

- **Third scheme:** first attempt to rationalize and organize the point-cloud through the division by region in Autodesk ReCap, then the file is decomposed in different smallest files .rcs, to avoid the repeated share of the whole survey. To make it possible we've created as many worksets as many regions are present into the survey, creating then a central file composed by eleven worksets, mixing two completely different ways to share model into Revit, linked files and worksets file.

Strength:

- Uniqueness of .rcp file containing the point cloud.
- Easiness to manage visual settings of different worksets into linked file.

Weaknesses:

- Difficulty of managing rights in the central file containing all the worksets representing the survey regions, it can be modified only by the owner of those rights then from who has created it.
- Opening and visualization of central file slow and complicated that need every time the workset and worksets properties release.
- Impossibility to manage visualize settings into the second link.

- **Fourth scheme:** Use of the point-cloud divided in .rcs regions by Autodesk ReCap, everyone loaded into the same file .rvt copied as many time as many are the regions, and in any file are deleted 9 regions, to obtain 10 .rvt file containing each one just the fair region.

Than any .rvt file containing a region is linked into the correspondent .rvt architectural file by overlay in this way the survey will be lost in the second link degree, to don't show it in the central file, where will be linked directly the whole .rcp point-cloud where is possible to have an easier manage of the regions directly in the central file.

Strength:

- Easiness to manage visualization properties into the linked file.
- Easiness and rapidity of manage link as a share method.
- Subdivision by regions avoid the information redundancy as in the second scheme.

Weaknesses:

A too long and complex procedure making ten different files each containing a different part of the whole point cloud.

2.1.6 Adopted Coding:

It is mandatory to follow a process based on the Standard **BS 12192 : 2007** as it was done to have a clear classification for any file involved in the sharing scheme previously explained, have a identified and clear classification is not just mandatory by the British standard but also suggested, without a codification used and respected by all the stakeholders involved particularly in a federated file process it could be impossible to have a successful coordination, and it can bring several problems and waste of time and money.

The following codings have been created:

One for the linked files name depending on the folder where the file is stored (WIP or SHARED).

Second classification's aim is to rationalize and create a order into shared folder that contains shared Revit files, point-clouds survey files, shared parameters text files, and passed old files that are also stored in a dedicated folder inside the common data environment.

Third classification is made to codify all levels present in all projects, that classification isn't mandatory but decided by ourselves to have a more tidy view into the model.

WIP_architectural		
Study case	Codify	Example
Alzheimer wing	A_aaaa_mm_gg	A_2017_12_15.rvt
Winter Garden	G_aaaa_mm_gg	
RSA	R_aaaa_mm_gg	
Park	P_aaaa_mm_gg	
Convent	C_aaaa_mm_gg	
Greenhouse	S_aaaa_mm_gg	
Mass	M_aaaa_mm_gg	
WIP_structural		
Study case	Codify	Example
Alzheimer wing	A_STR_aaaa_mm_gg	A_STR_2017_12_15.rvt
Winter Garden	G_STR_aaaa_mm_gg	
RSA	R_STR_aaaa_mm_gg	
Greenhouse	S_STR_aaaa_mm_gg	
WIP_MEP		
Study case	Codify	Example
Alzheimer wing	A_MEP_aaaa_mm_gg	A_MEP_2017_12_15.rvt
Winter Garden	G_MEP_aaaa_mm_gg	
RSA	R_MEP_aaaa_mm_gg	
Greenhouse	S_MEP_aaaa_mm_gg	

SHARED_architectural		
Study case	Codify	Example
Alzheimer wing	Alzheimer	Alzheimer.rvt
Winter Garden	Giardino	
RSA	RSA	
Park	Parco	
Convent	Convento	
Greenhouse	Serra	
Mass	Masse	
Coordination file	MF_disciplina	MF_ARCH

SHARED_structural		
Study case	Codify	Example
Alzheimer wing	Alzheimer_STR	Alzheimer_STR.rvt
Winter Garden	Giardino_STR	
RSA	RSA_STR	
Greenhouse	Serra_STR	
Coordination file	MF_disciplina	MF_STR

SHARED_MEP		
Study case	Codify	Example
Alzheimer wing	Alzheimer_MEP	Alzheimer_MEP.rvt
Winter Garden	Giardino_MEP	
RSA	RSA_MEP	
Greenhouse	Serra_MEP	
Coordination file	MF_disciplina	MF_MEP

In WIP folder that represent a temporary phase of those files they are named with the letter that distinguish any project in base at where the project is located as widely explained, the name is completed by the date of last upload.

In Shared folder the naming has been changed, cause the files are not supposed to change frequently, then the file is named with his proper name plus the add of a suffix (MEP or STR), only the coordination file is named with the date that shows the last update.

Folder name	SHARING_1
<u>Contain</u>	<u>File name</u>
.rvt file of the federate architectural model	MF_ARCH.rvt
.rvt file of the federate structural model	MF_STR.rvt
.rvt file of the federate MEP model	MF_MEP.rvt
Central .rvt file divided by disciplines	CENTRALE.rvt
Sharing strategies .pdf scheme adopted by federate models and the central model	Condivisione_1.pdf

Folder name	SHARING_2
<u>Contain</u>	<u>File name</u>
.rvt file of the federate model not divided by disciplines instead by areas	CENTRALE.rvt S.rvt G.rvt A.rvt
.pdf scheme of the connection strategy adopted in the federate model	Condivisione_2.pdf

Nome cartella	MODELS TO BE LINKED
<u>Contain</u>	<u>File name</u>
The .rvt architectural files of any model region, are the files to be linked in the federate models in both condivision strategies	Alzheimer.rvt Giardio.rvt RSA.rvt Masse.rvt Serra.rvt Convento.rvt Parco.rvt URB_Masse Topografia
The .rvt structural files	Alzheimer_STR.rvt
The .rvt MEP files	Alzheimer_MEP.rvt
Federate model of the ambit, used in sharing strategy 2	A.rvt
NB	Questi file negli schemi di condivisione vengono indicati con la sola lettera iniziale maiuscola

Folder name	POINT CLOUDS
<u>Contain</u>	<u>File name</u>
Folder and files of the pointcloud survey	171114_Trompone_PointCloud_georef_tesisti REGIONI.rcp
Any ambit has its own pointcloud region .rcs	Alzheimer.rcs Giardio.rcs RSA.rcs Masse.rcs Serra.rcs Convento.rcs Parco.rcs ecc....

RVT nuvola di punti folder, contains the .rvt files where were imported the .rcs files to be connected by Overlay, as shown in sharing strategy 1	ndp_alzheimer.rvt ndp_giardio.rvt ndp_rsa.rvt ndp_masse.rvt ndp_serra.rvt ndp_convento.rvt ndp_parco.rvt ecc..
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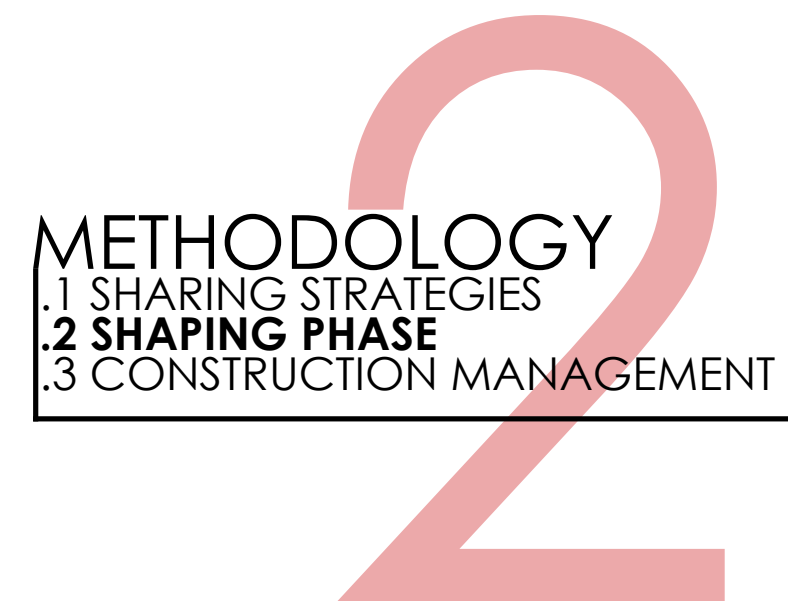
Folder name	SHARED PARAMETERS
Contain	File name
Shared parameters folder that contains the parameter .txt file .	Comune.txt

Folder name	EXCEEDED
Contain	File name
Exceeded folder that contains the exceeded files previously loaded in Models to be linked folder.	Normally are .rvt files

Those tables shows the order into SHARE folder inside the common data environment, the two sharing strategies adopted previously explained have each one a folder dedicated containing the federated file and the .pdf where is explained the rules to be followed in the sharing process. Other folders contain all those files to be linked as named before in WIP folder, one is dedicated to the point-clouds survey files split in .rcs that is the extension for those kind of file previously elaborated in Autodesk ReCap, and .rvt that represent point-clouds loaded into a Revit file. Then there are two other folders one for text files containing shared parameters and the last one for exceeded files.

Floor	LEVEL NAME
Alzheimer wing example	
Ground floor: Fact status Project status	0_SdF_A 0_SdP_A
First floor: Fact status Project status	1_SdF_A 1_SdP_A
Second floor: Fact status Project status	2_SdF_A 2_SdP_A
Winter Garden example	
Piano terra: Fact status Project status	0_SdF_G 0_SdP_G
Piano primo: Fact status Project status	1_SdF_G 1_SdP_G
Piano secondo: Fact status Project status	2_SdF_G 2_SdP_G

Levels into different projects were codified basically to have a order into the different views in federate models, any single project has a codification for both phase (existing and project), the name is composed firstly by the floor number, second the code that identify the phase, third the letter which define the project according to the general codification.

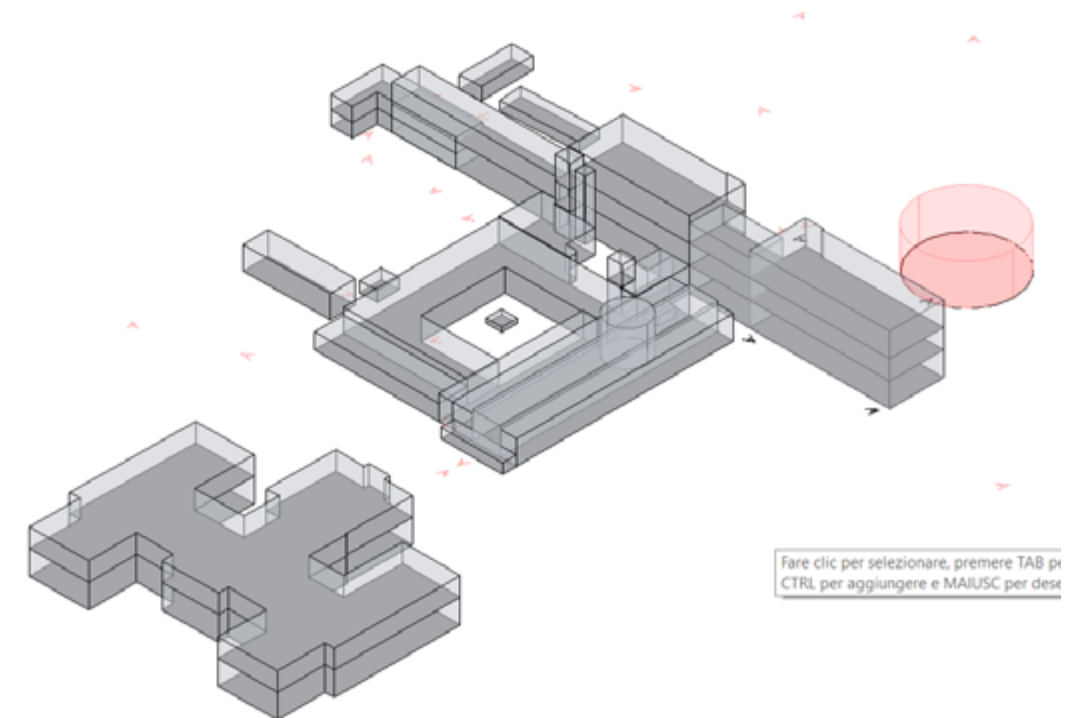


2.2.1 Shaping state of affairs:

The first shaping phase done was about shaping in BIM environment the existing part of the courtyard enclosed between the RSA wing and the convent, that is a complicated space not designed, but a result of construction of other buildings from different ages (RSA is XIX century, while sanctuary construction begun in XVI century), whose surrounds the courtyard and whose shape this non-organic space.

So the first model obtained of this space comes from a manual survey made by an electronic meter, that will result wrong when will be compared with the survey obtained by laser-scanner.

The first phase was to create a **mass file** containing all the buildings represented as a mass beginning from a plan, this kind of representation isn't precise but was necessary to have a base where relate all the others model to share a common coordinate system.



Imagine of mass file from Autodesk Revit.

The mass file is really useful, not only as a base to all the others files, but also for town planning counts and to have a general representation that allow to make preliminary considerations, it can also be used to shape the context in an urban situation for example to evaluate the shade made by the other buildings around our object.

Beginning from the mass model, I've started modeling the courtyard that will guest the winter garden project, I've used a high LOD to shape this part, because of the nature of the buildings that surrounds this space that required a high accuracy, it was necessary in according to the project standard to detailing the model also creating some families by myself to reach the goal to represent in the best and more accurate way the built environment.

Remembering that this first phase is shaped only according with a manual survey and with some other sources such as a thesis of the current mayor of Moncrivello Mr. Pissinis who is an architect who made is thesis on this complex making a survey and redrawing the entire facility.



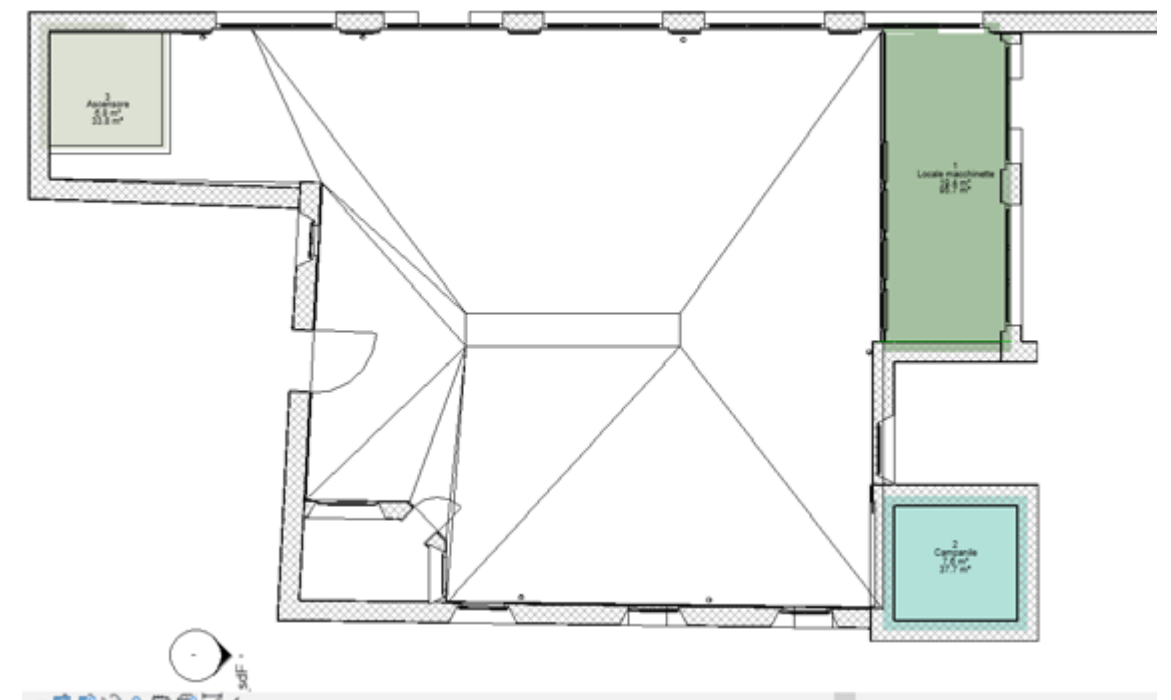
Courtyard state of affairs BIM model in Revit.

The model shaped "as is", for what matter the shape, has several hypothesis for what matter the materials due the impossibility to certainly know the structure of the items, like walls, roofs columns, decorations ecc. Anyway we assume right that every structure as walls or vaults are composed by bricks recovered by plaster, roofs are covered by bricks tile as well.

To be more precise I've shaped some families basically windows families, because i wanted to reach an higher level of detail and the pre - uploaded families in Revit weren't enough to satisfy this LOD.

The plant represented below is a fair representation obtained after the usage of a point cloud survey, but is useful to understand how the space is shaped by askew walls in the oldest part, that was represented wrong after first survey. Here is possible to see that all the walls are considered of the same type, modeled in Revit as a 50 cm thin walls with 46 cm of full brick closed by 2 cm per side of plaster.

It's also possible to see how the windows are shaped creating completely parametric families which required several time. Another particularity is the floor that presents slopes towards the center where there is a manhole which pick meteoric water.



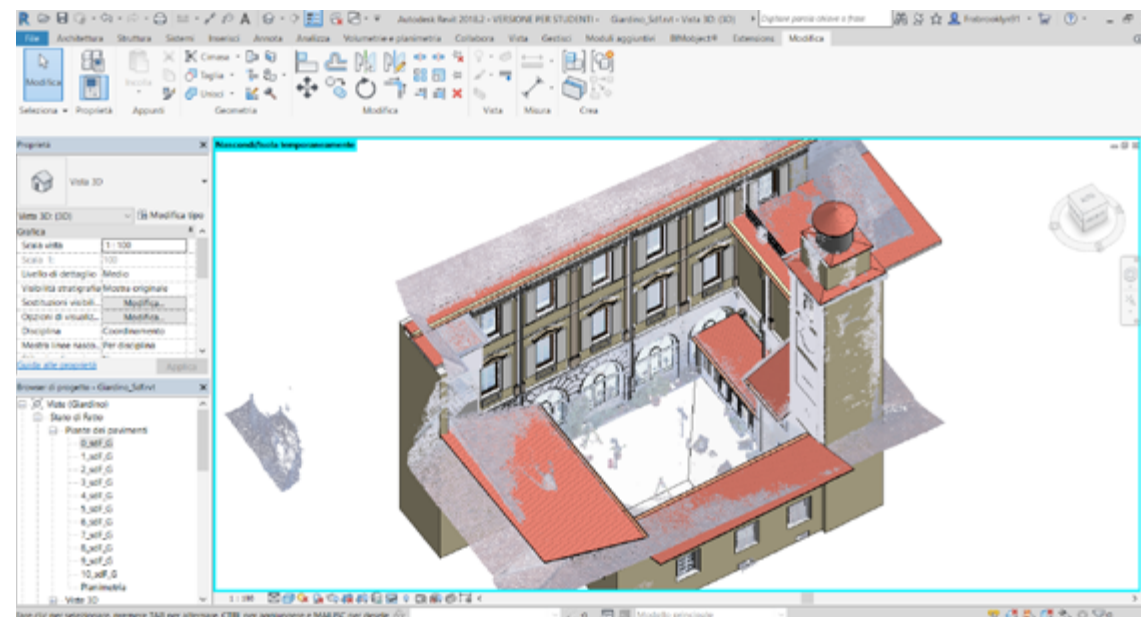
Courtyard plant.

There are three spaces signed as locals, the one in the north-west corner is an elevator, the other with almost the same shape in the opposite corner is a bell tower, and the biggest above is probably an abusive space create by prefabricated items to guest a small relax area with a coffee machine and some chairs. The access at the courtyard are basically four one on each side, and the several windows are spread, in different levels this weird position is due at the different ages of those buildings, and it was a loud limit for the winter garden project.

As already mentioned, the courtyard is enclosed between two buildings that were already shaped by others group members, so my model could be a duplicate for those elements already present in the model, it becomes clear that the attachment of those two other models (RSA and the convent) were wrong, due to the absence of the point-cloud survey during the shaping phase.

Thus after the survey was received, the modeling phase has been started, with an high level of accuracy, trying to improve what already was existing increasing the level of detail reaching what was considered satisfactory for a small portion like this one.

Once the courtyard was shaped as described before, to avoid the repetition of all those items already shaped in the two models compositing the courtyard, i had to split my model in two parts to be pasted into those model instead of the existing wrong parts.

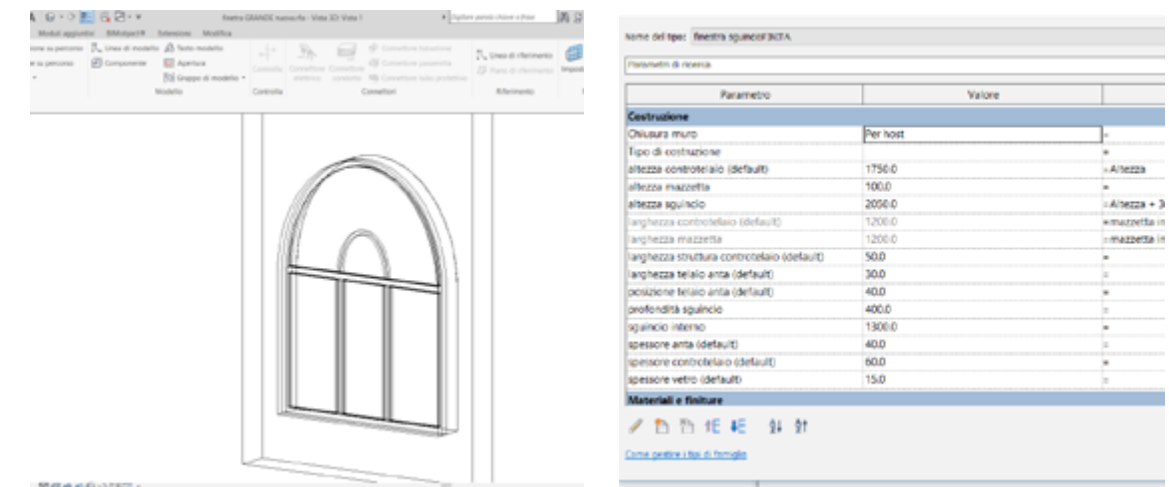


Courtyard model with point-cloud survey.

This operation to split my model into the others compositing the courtyard wasn't easy, for many interferences with the existing models, it was about deleting many items to replacing them with those shaped by me.

I made basically two attempts, using two different tools presents in Revit, the first attempt was through the use of Copy/Monitor tool, the second one was using the more easy command to Copy/Paste, in the following pages I'll describe those two approach.

2.2.2 Parametric families:



Window parametric family 3D picture.

Parameters panel.

The most expensive activity in terms of efforts and time spent was the creation of parametric families at high level of complexity such as the windows that surrounds the courtyard.

It was necessary to shape the windows due to the absence of those kind of historical windows in the pre - loaded families in Revit.

Those kind of families are defined as an high level of complexity [26], due to the multiple families nested in the final one, for example for what concern the family shown in the pictures above is the result of many nested families. The first step was shaping the structure that guests the windows, thus the wall hole, then the space that guests the windowsill.

Afterwards was shaped the sill, then the windows proper structure beginning from the window sub-frame, passing through the frame containing the real window, composed by the frame and the glassed part.

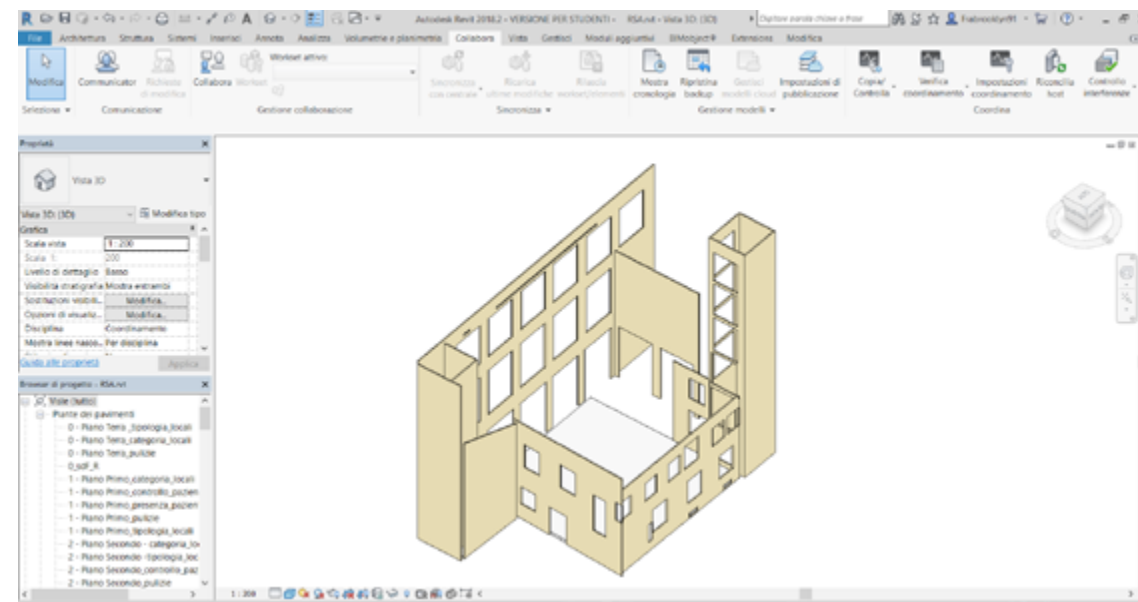
All those sub families are nested and one in the others, that allows a complete control of the whole family, permit to change dimensional parameters moving all the elements compositing the family coordinately. All the families created can be managed in the parameter settings, basically were created two kind of parameters: dimensional and material parameters, respectively divided in type and instance parameters, aimed to have a complete control of all the aspects catheterizing those windows.

2.2.3 Model division:

Copy/Monitor is a Revit tool that permit to share items between models, it's already shortly described in the introduction chapter when there were explained the sharing methods.

It is a tool that allow to copy selected items from a model to be pasted in another, the peculiarity of this tool is that the item pasted can be monitored in the new model, in that way when the item change in the original file an alert appear to notice about that change.

If you're operating in a federate file with the same coordinate system in both files, copied items will automatically goes in the fair place, this would be a perfect tool to make this task to split my model in two parts owned by two different files, but Copy/Monitor tool has a loud weaknesses that is able to operate just with some kind of items and families, such as levels, columns, walls, floors, so it results impossible to copy many items compositing my model, for example all the windows were represented by simples rectangular holes into the walls, due to this weaknesses this tool was definitively discarded.

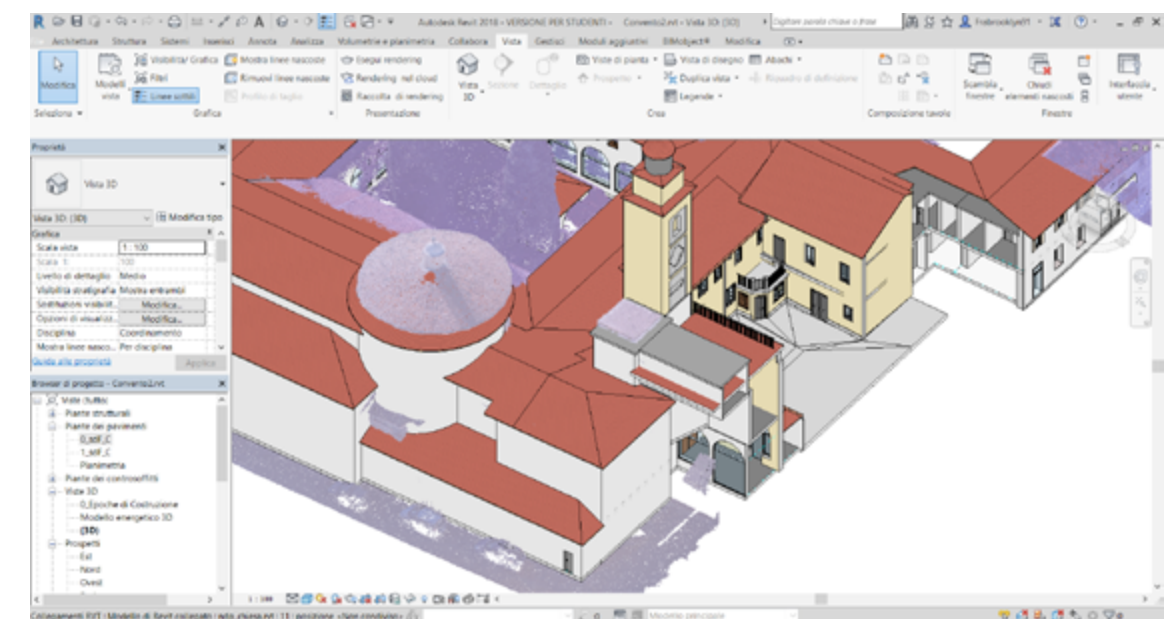


Items copied by the copy/monitor tool.

Above is shown the result of Copy/Monitor use, as said it's able to copy just a few category items, that result clearly insufficient.

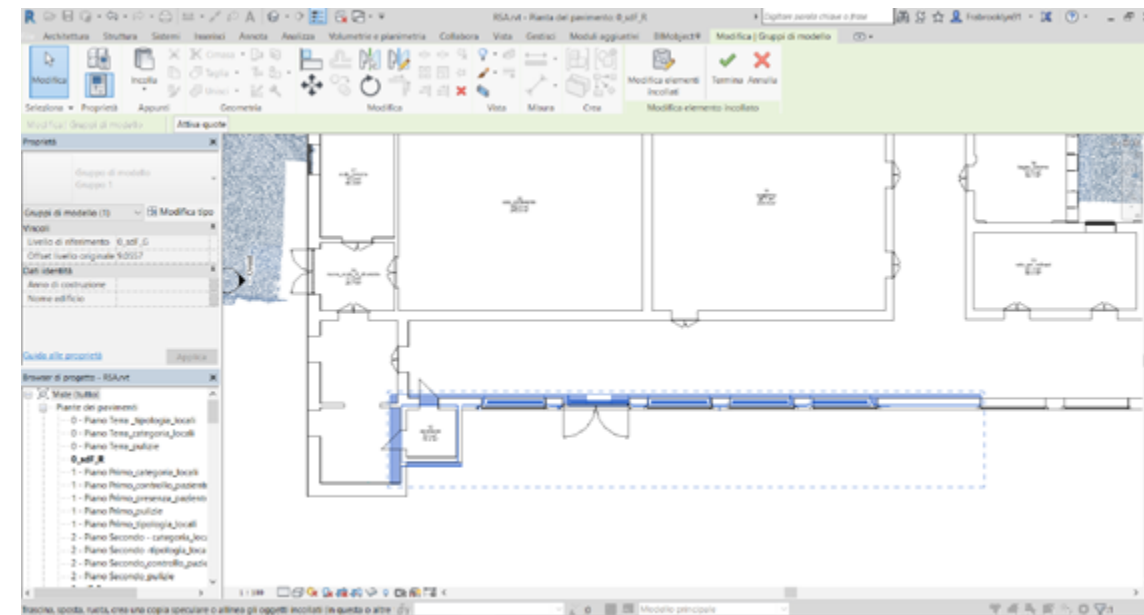
Copy/Paste is a simple tool that allows to copy selected items and paste them in another file, it can be used with any kind of element, unlike the Copy/Monitor.

It was the second attempt because is not really satisfactory, basically because it doesn't allows a control made between the origin file and destination file, it's just a simple copy/paste made in any software, unfortunately this is the only way to achieve what was my goal to split the model in two others copying every item with all their properties and parameters. It was a slow and mechanical process to copy and paste any item, this process brings many possibilities to make something wrong, like forgetting some elements or pasting it in the wrong place.



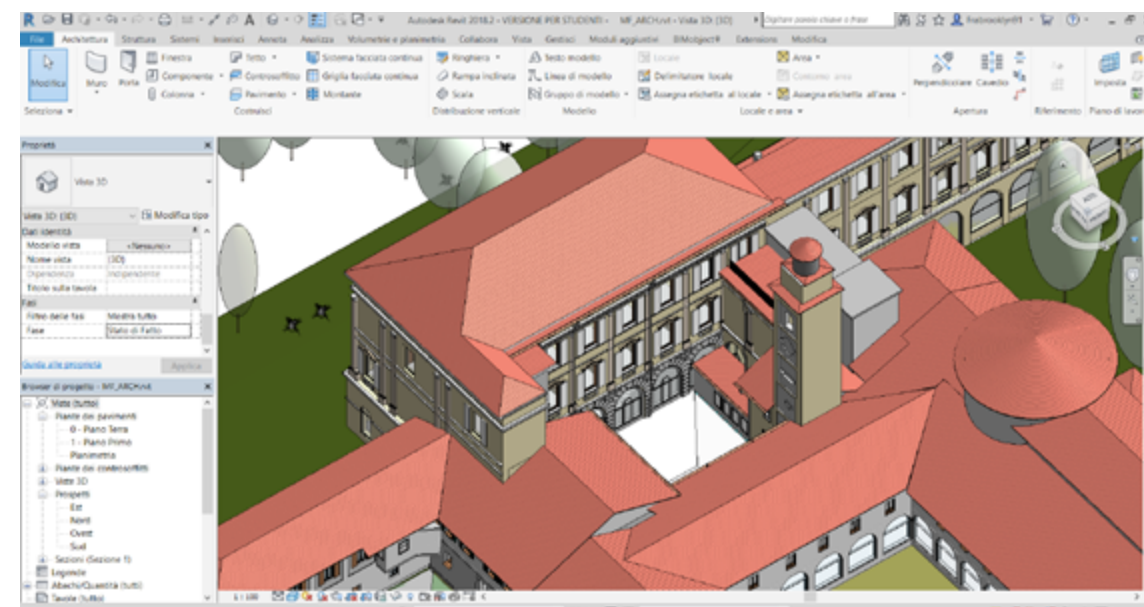
Courtyard model split in the Convent and RSA files.

A complicated phase was to make organic the different parts (the existing one and the attached one), because only the courtyard was shaped in the right shape based on the point-cloud survey, so the task was to adapting the existing model to the new one that is composed by awry walls as in the reality, it required several times to make everything coincident between three models.



Copy/paste tool in RSA wing.

It's also inaccurate the way to paste selected items into the final file, anyway there's a guide (dashed line) that shows where is the right place to attach the selection, but this operation has to be made by the operator, with the risk to make some errors, unlike the previous attempt with Copy/Monitor tool where the selection was automatically pasted in the fair place.



The whole model after the split process.

The result is an detailed model, this became the central part of the project, the only one carefully shaped based on a laser scanner survey, that represent the original point which the whole model is based on, and the starting point to be used in a future improving of this facility model.

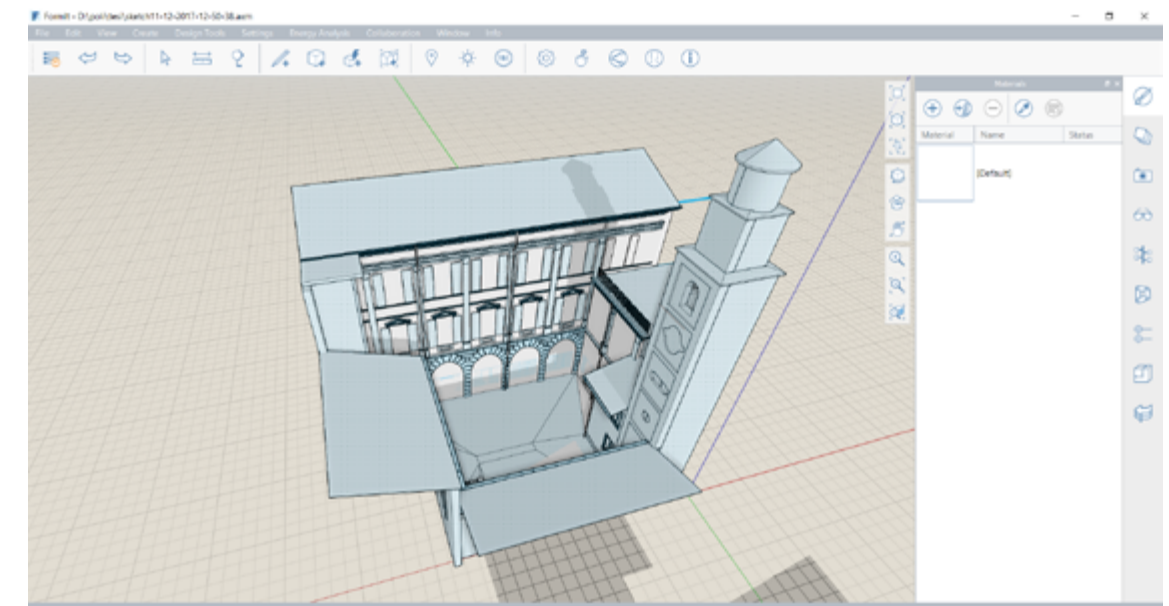
2.2.4 Preliminary project considerations in Formit:

After those preliminary steps, aimed to prepare the context where the project will be insert, is started the real project phase, which aim is to design a winter garden to fill the void in the courtyard, this project results wanted by all the people that daily lives this complex, affected by illnesses, their families, and all those people who works here like doctors, nurses and who manage the facility, and it's aimed to live this space during the whole year, now is used just in the warmest seasons.

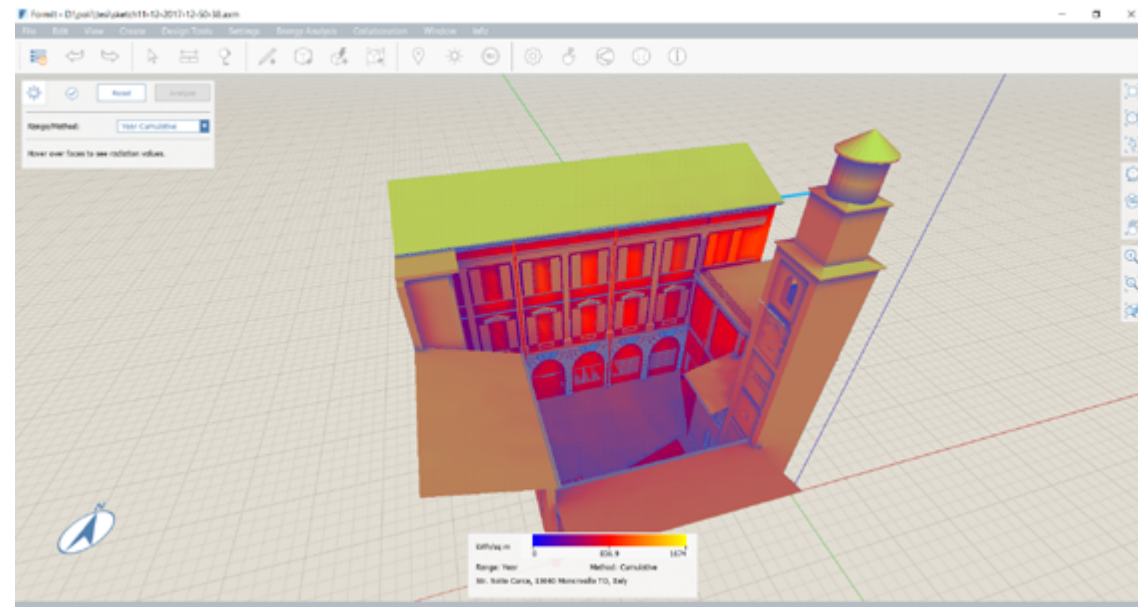
The first real designing step was made to understand how the buildings that surrounds the courtyard affect this place basically with their shade, and how to optimize the solar radiation.

To make those kind of considerations was used a preliminary project software like Autodesk Forimt, that is expressly created to make preliminary designing steps considering the environment characteristics, especially to make preliminary studies on shadows, orientation, sun analysis.

A problem was immediately found in the exportation of the existing model from Revit to Forimt, because the second can read just some kind of elements, like mass, walls (with some exceptions), floors and few others. Thus the model was loaded into Formit, to be completed and integrated in the missing parts, by a shaping directly in Formit environment, that allows a basic shaping very close to some other software like Sketchup where is possible to design basic solids.



Courtyard model in Autodesk Formit.

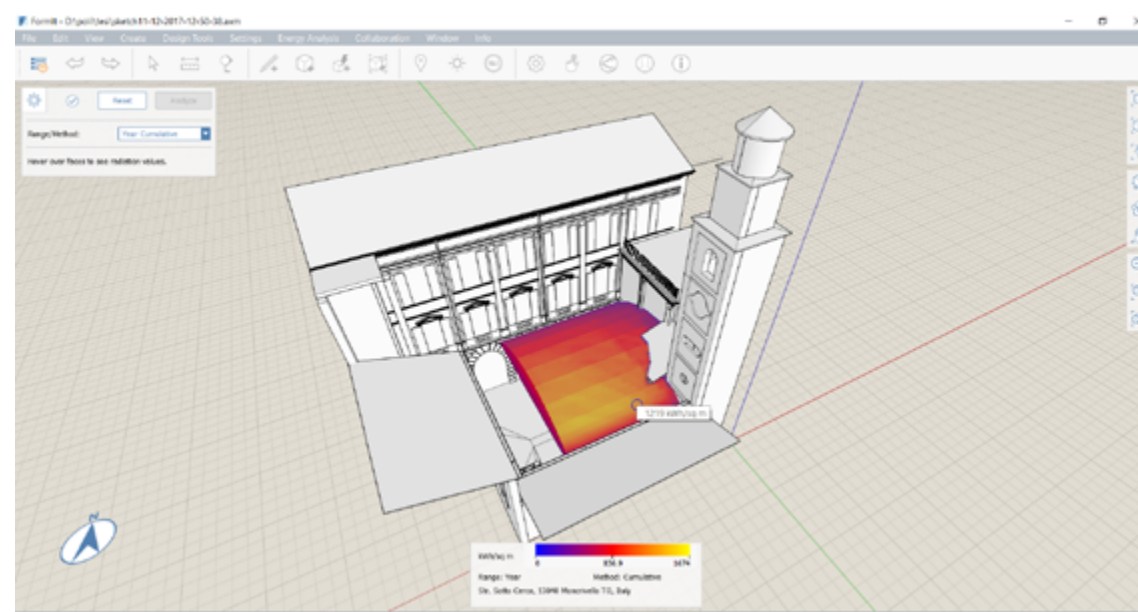


Solar analysis made on courtyard surfaces.

As said it's possible to create some kind of analysis, like solar analysis shown in the picture above, it was very useful in a project like this where the solar radiation is a main aspect in the design process.

Anyway it wasn't possible to extrapolate a precise output or a average value for solar radiation, but the only output was a colored model based on the legend that show a value in Kwh/sqm, it can be just read as a reference to better understand the solar incidence.

This kind of analysis was made on the existing facades that surrounds the courtyard, and also on some project proposals for the winter garden.



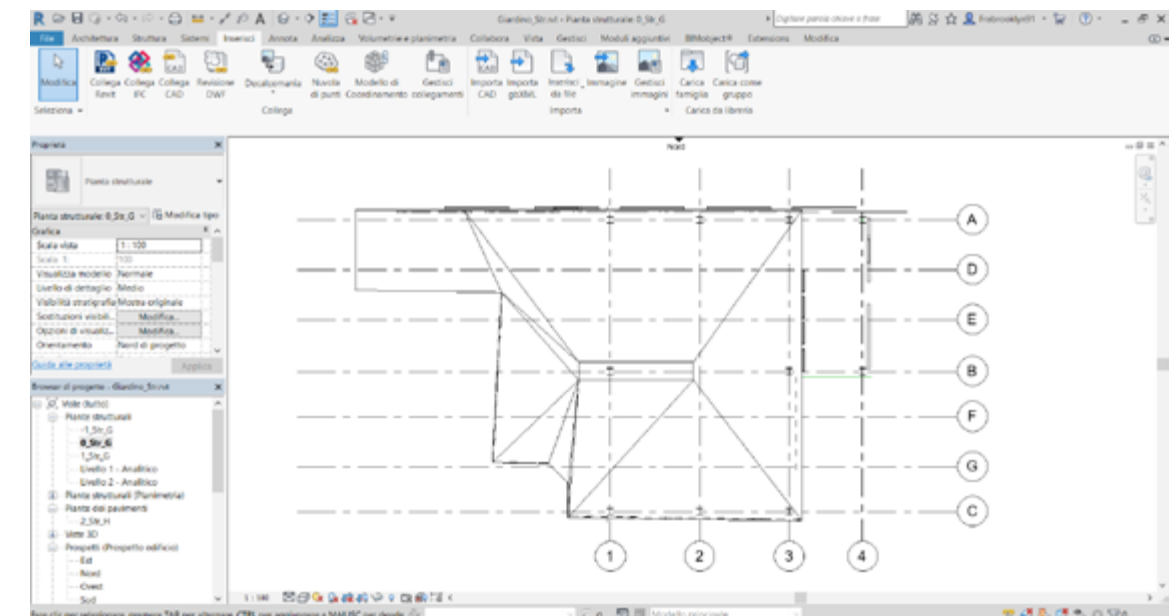
Solar analysis made on project proposal surfaces.

2.2.5 Project Model:

As explained in the fifth sharing scheme the project was divided basically in four file each one corresponding to a fields as architectural, structural, MEP and topographic, was necessary splitting the project to use different templates according with the field where we were designing.

Structure:

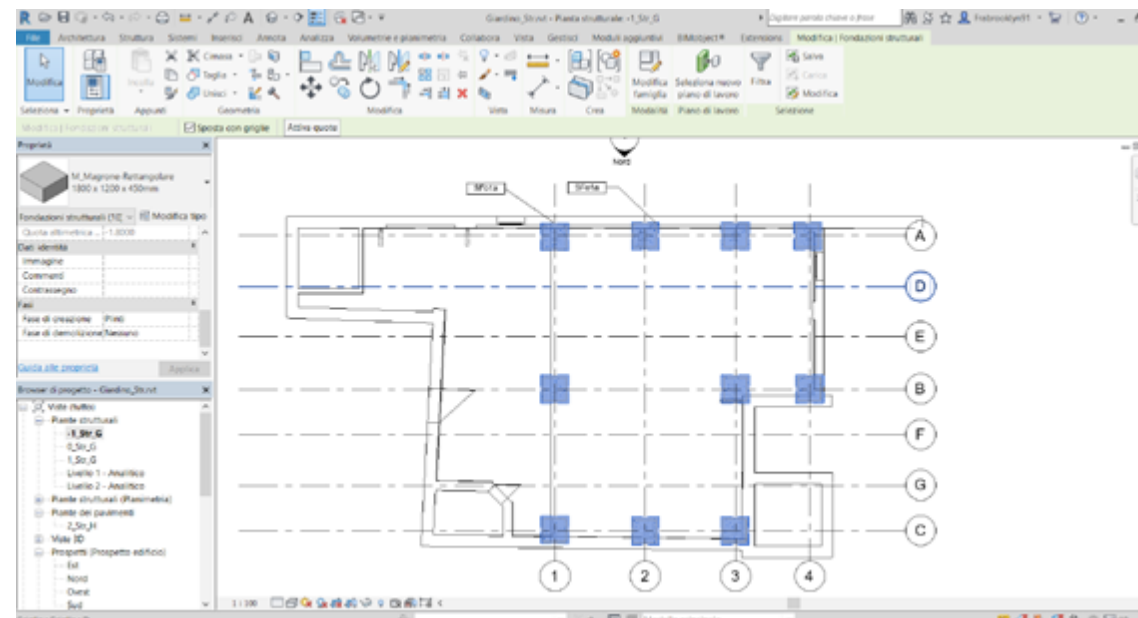
The first part designed was the structure, following a logical design path, so the structure was tough as a steel frame based on concrete foundation, firstly was created a structural grid aimed to have a precise placement of all items in the project, as I will explain in following chapter it will be a part of the identification code useful to make a building site organization.



Structural grid.

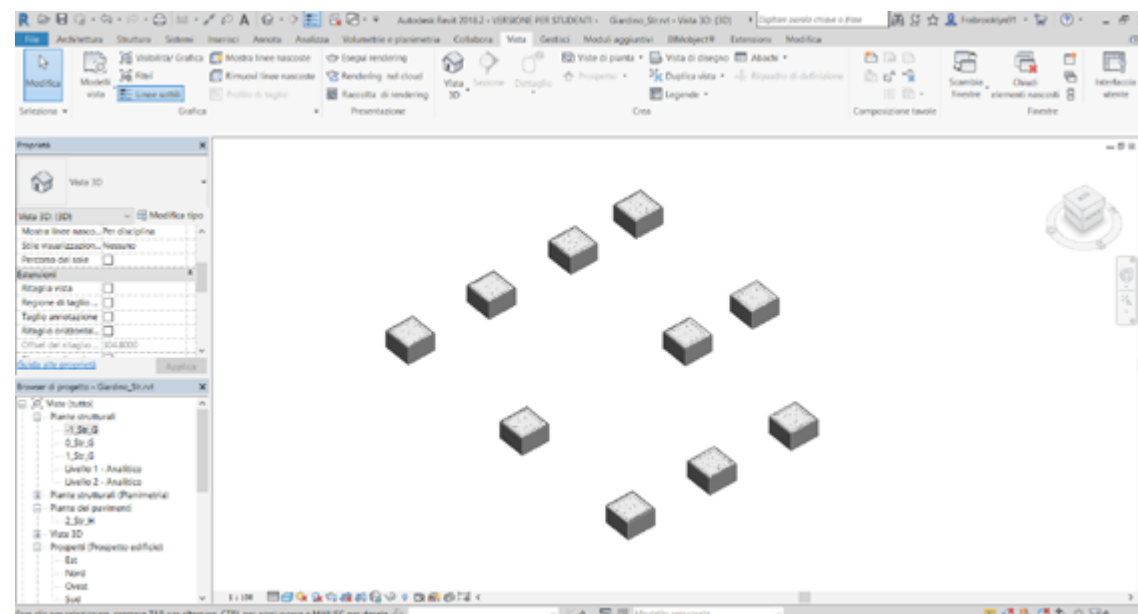
As is possible to see the structure was tough to respect the morphology of the existing complex, then is aimed to don't cover the several windows presents in the courtyard, that was a mandatory point to be respected, thus the grid was made with constant distance between the lines due to the distance between the windows in the north facade. The main structure is represented by lines from 1 to 4, and horizontal A, B, C, all the others horizontal lines are representing secondary beams.

First part of the structure shaped are the foundations, that are represented by concrete plinth positioned one meter deep to the ground level, it was decide to use this kind of foundation for the small entity of the project that doesn't required a more complex foundation system.



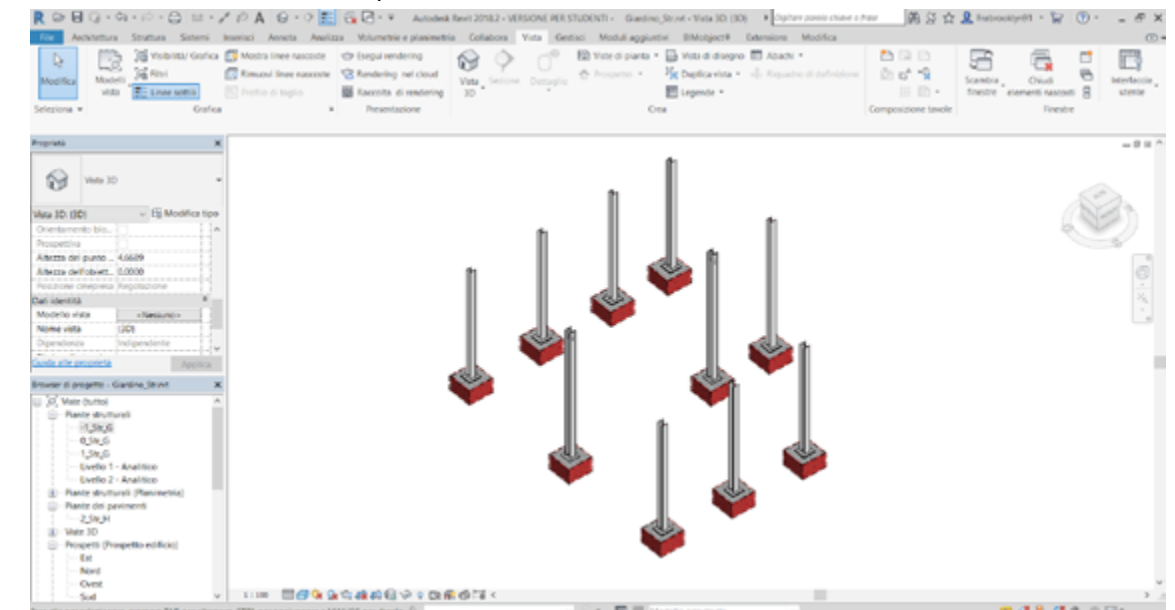
Plinth foundations.

Then for project managing necessity were shaped also the framework inside the concrete plinth, and also the quarterdeck aimed to show all the phases of the construction, so it was required the designing of all the components presents in the process.



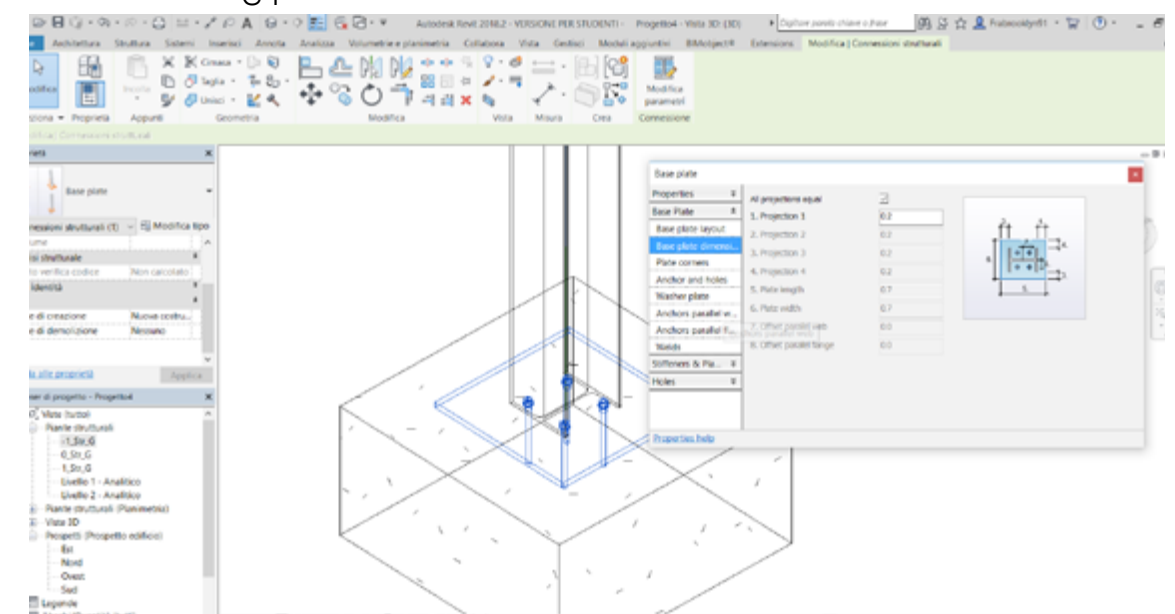
Plinth surrounded by formworks.

The second step was to positioning the steel columns, were used a HE300A column, one for each plinth, that are bolted to the foundation.



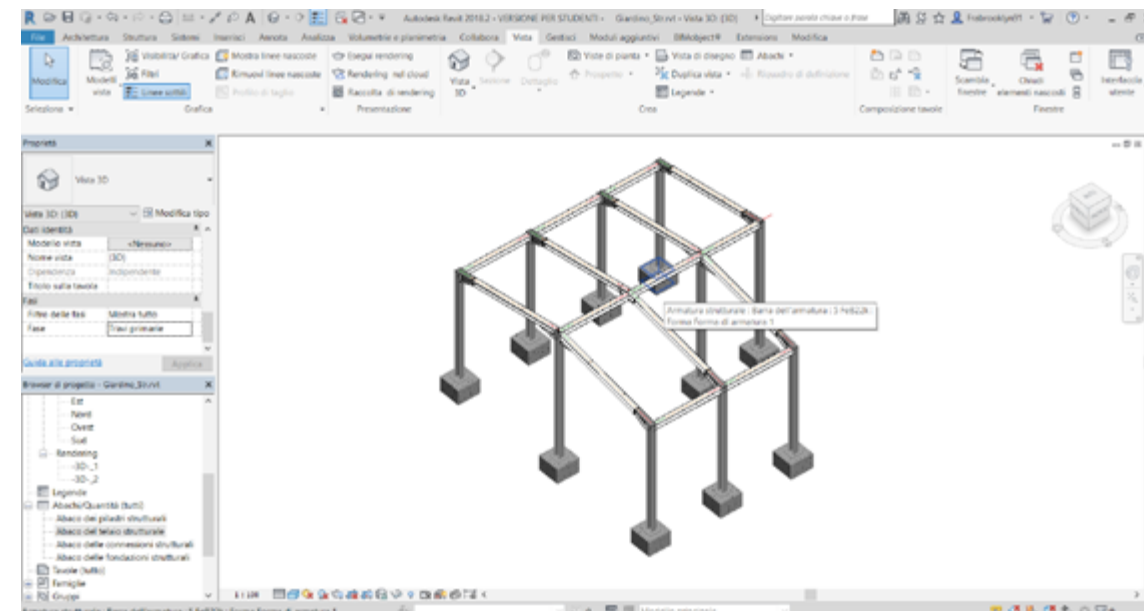
Columns assembled on concrete foundations.

Steel connections are made with a Revit extension called Advance Steel Connection for Revit, this is a very useful tool, also easy to manage it can create in a semi-automatic way steel connections between structural items, modifiable through a parameter manage tool that allow the user to manage, and change some determinate parameters, a weaknesses in this extension is the impossibility to add new parameters, and it's also difficult to manage the existing parameters into the abacuses. The connection between the columns ant the plinth is a Base plate bolted with four screw, all those parameter could be editable from the parameter panel showed in the following picture.



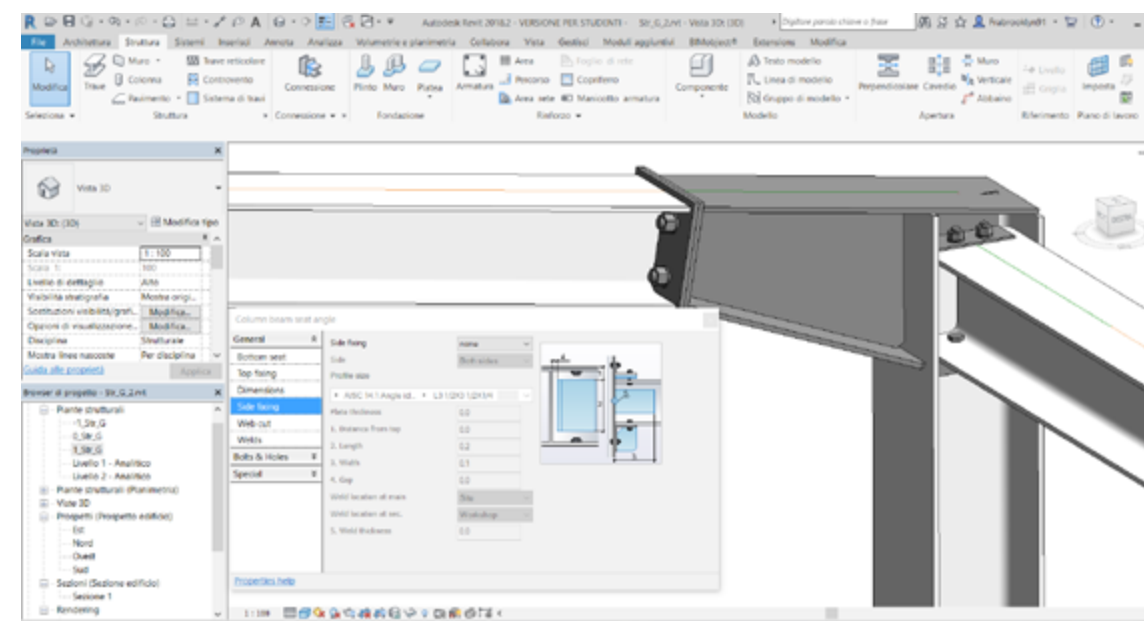
Steel connection between column and foundation detail made in Advance Steel.

Always following a logical path were created the beams, that are basically of two typology an HE260A for what matters the main warping and a HE100A for the secondary warping.
All those beams totally 23 were shaped with several steel connections.



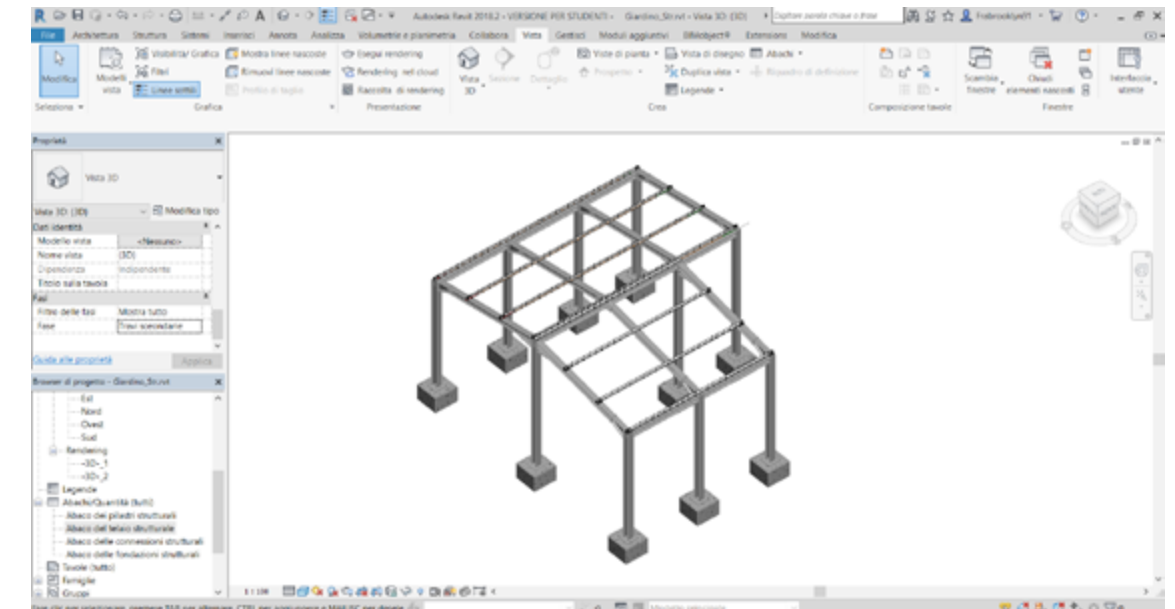
Main beams assembled.

In the picture below is showed a complex node between a pillar an orthogonal beam and an sloped beam that required a multiple steal connection where many parameters were managed.



Steel connection between column and beam detail made in Advance Steel.

The last step for what matter the structure was to create the secondary beams system composed by HE100A steel beams, leaning on the main ones.



The complete winter garden structure.

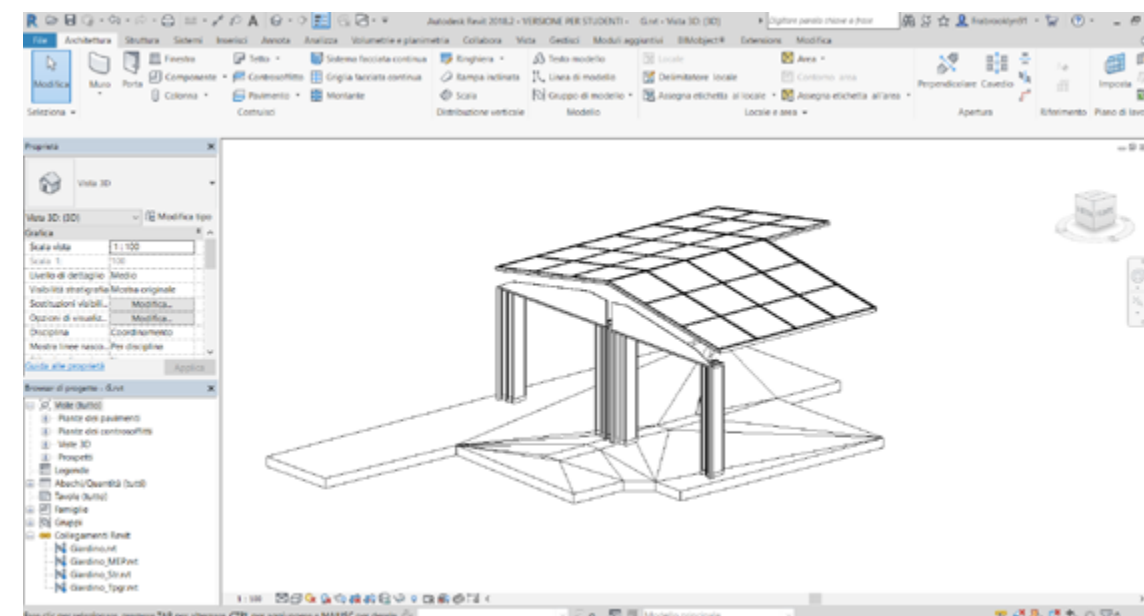
In the picture above is possible to see the whole structure, that represent a simple structure based on a simplified orthogonal grid.

Architectural:

The architectural model is pretty basic, consisting basically in glass parts making all the enclosure of the winter garden, due to the property of this kind of project to be as transparent as possible aimed to heat the environment during winter time exploiting the solar radiation.

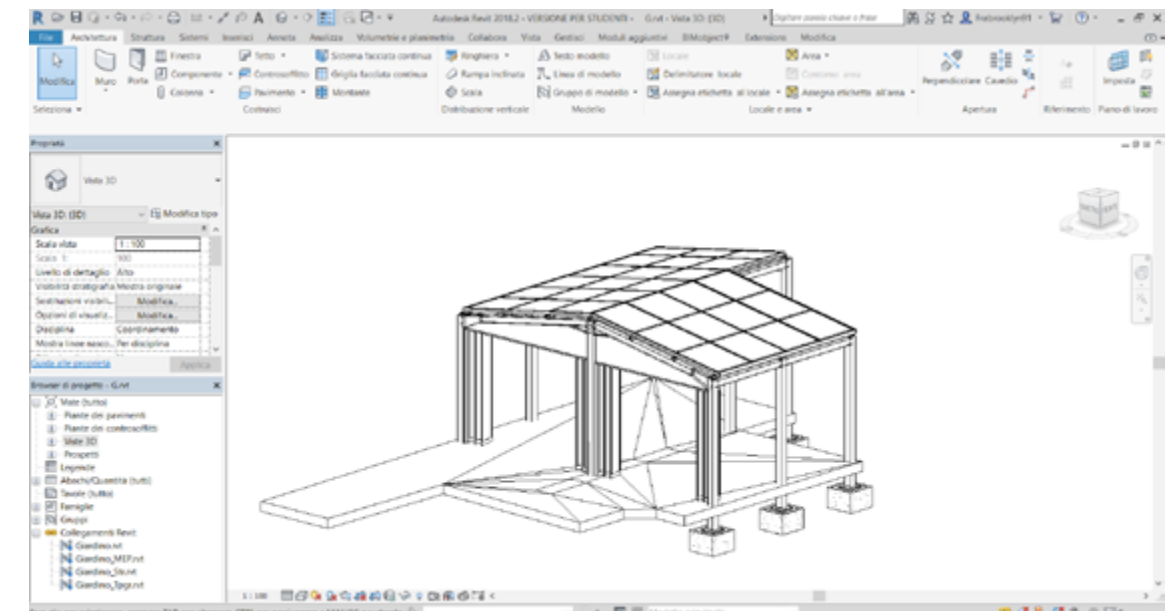
The fixtures compositing the cover are thought to be open as the frame used to close the winter garden in the courtyard at the ground level, in that way the project can be open for more then 80% of his external surfaces, to guarantee a complete environmental condition control, especially during the warmest seasons where the space inside the enclosure could be too hot to be lived comfortably.

Except the enclosures the architectural model includes also new floor creation due to the demolition of the old one to permit the dig for the foundations, and the creation of a new slope to pick meteoric water in a new plumbing system.



Architectural items present in the model.

In the picture above it is possible to see the few components compositing the architectural model, those are as previously said the glass cover composed by motorized frame composed by three square shaped windows that could move leaving 2/3 open, two big french windows completely openable, and some more glass surfaces not openable to close the environment.



Architectural and structural models joined.

In a chronological way the first work to be done is the new floor that is divided in two parts, the deepest is made by a concrete basement, then to be completed there's another layer, more properly a finish layer made by ceramic tiles posed above a low thin lean concrete layer, aimed to make a low slope (under 1%) to pick meteoric water.

Modifica assieme

Profilo: Pavimento
Tipo: Laterale Cementizio - 30 cm
Spessore totale: 0.1000 (Default)
Resistenza (R_c): 0.0000 (m²/N)
Massa termica: 0.00 kJ/K

Funzione	Materiale	Spessore	Ripiegature	Materiale strutturale	Variabile
1 Contorno del nudo Strati sopra ripiegatura		0.0000			
2 Finestra 1 (4)	Finestra, Quadro	0.0400			
3 Struttura (1)	Sabbia e Calcestruzzo	0.1000			
4 Contorno del nudo Strati sotto ripiegatura		0.0000			

Inserto Elimina Sì No

Finish floor stratigraphy parameters.

Modifica assieme

Profilo: Pavimento
Tipo: Laterale Cementizio
Spessore totale: 0.1000 (Default)
Resistenza (R_c): 0.0000 (m²/N)
Massa termica: 0.00 kJ/K

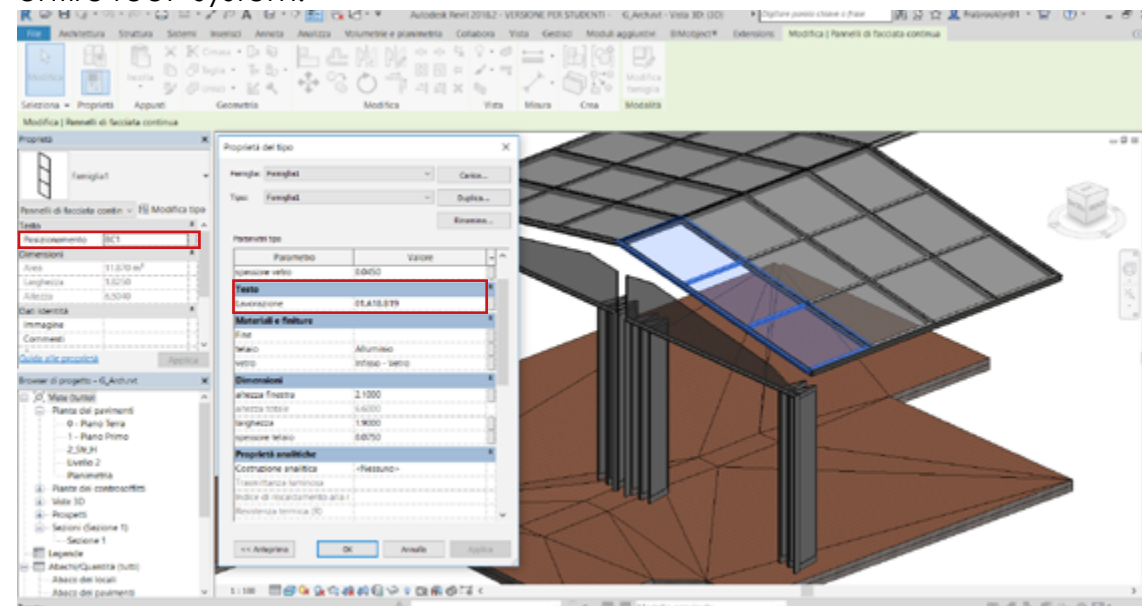
Funzione	Materiale	Spessore	Ripiegature
1 Contorno del nudo Strati sopra ripiegatura		0.0000	
2 Finestra 1 (4)	Calcestruzzo - Gettato in	0.1500	
3 Contorno del nudo Strati sotto ripiegatura		0.0000	

Inserto Elimina Sì No

Concrete floor stratigraphy parameters.

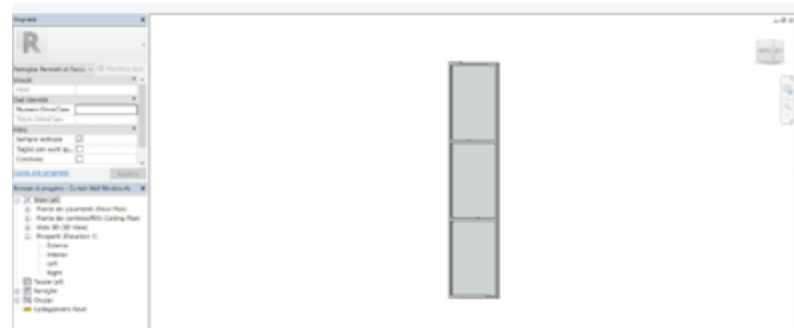
In the pictures above is shown the material parameter settings, where is possible to recognize the type of material the width and the position related to the element layers, also some physics parameter that allows to check in real time the changing between layers and physics setting.

It is very important to explain that many efforts were spent to shape the model elements in a way to be used to reach the final aim of this thesis that is to make a focus on 4D project, to do that for example the cover roof was shaped firstly as a curtain glass roof, then to make any of the windows compositing the system distinguishable and to allow the applicable of different parameters aimed to make the project managing it became necessary to model a new family that represent a motorized window, and to apply it to the curtain glass roof system, in that way the cover is not composed anymore by panels impossible to be distinguished one to another and where was possible to apply parameters only at the entire roof system.



Activity code parameters underscored applied to a project item.

The speech became clear if we see the picture above were are underscored an example of two parameter applied to one of the window compositing the cover system, where I've used a position parameter aimed to know exactly where the item is related to the structural grid, and a manufacture parameter connected to manufacture list made by Piedmont Region to allow a direct identification about what kind of works this element needs and what are the costs connected to this element and the relatives works connected.



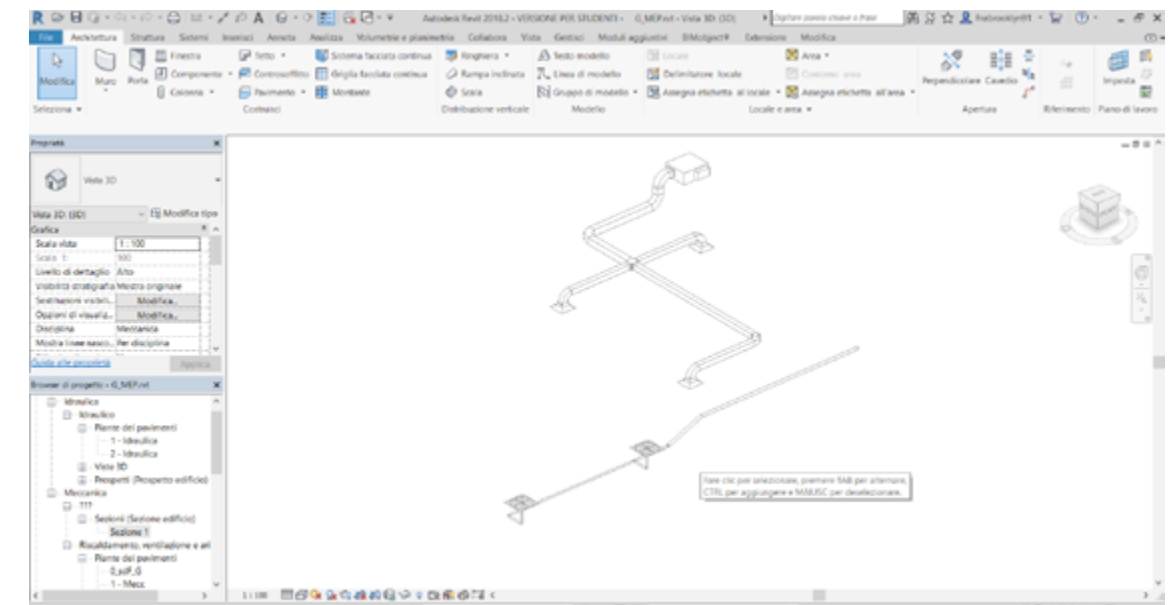
A roof window parametric family.

MEP:

Technological system has been required, and also if is a secondary part in the project it was necessary to shape them, even without certain size because of absence of physics calculation due to the leak of time, and because it wasn't the focus of this work, that represent a weaknesses to be improved, maybe by following students will work on this facility.

The system project basically includes two kinds of installations, the most important, in terms of costs, resources required and shaping phase efforts is for sure the HVAC (Heating, ventilation and air conditioning), made to accomplish the loud necessity to have in any climatic situation a controlled environment and to guarantee always a good air quality, due to the specific condition of the patients presents in the facility that needs always specifics climatic conditions.

As said the system project is made by an HVAC system and a plumbing system basically to pick meteoric waters, because the project is in a open courtyard where disposal of meteoric waters is mandatory.

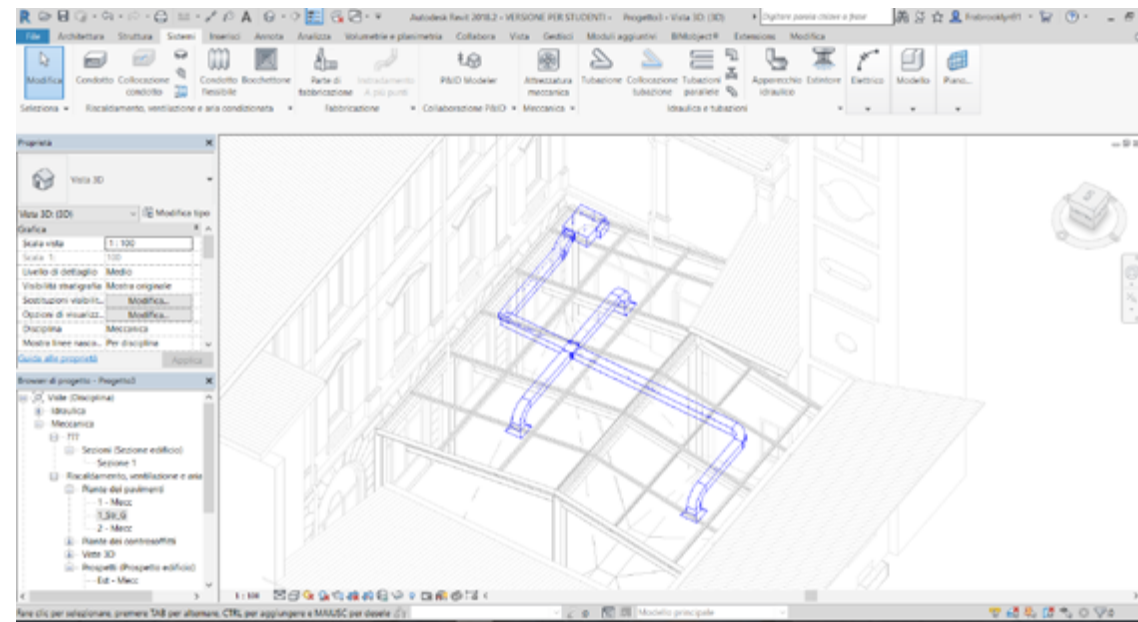


An HVAC and plumbing systems 3D representation.

In the picture are showed both system used with all the items compositing them, this part was shaped in a different file, beginning from a dedicated template that allow to design the installations very precisely.

The HVAC system is shaped to be attached at the beams and to stay suspended at more than 4 meters from the ground level to avoid interferences with the activities made in this space.

The designing phase of those kind of system is pretty easy in Revit, because is made automatically, the only step required is to positioning the pipes union and the conditioner, then the software create many option to connect the items previously positioned, and the designer just has to choose which option results more congenial to the project aims.



HVAC system insert in the whole model.

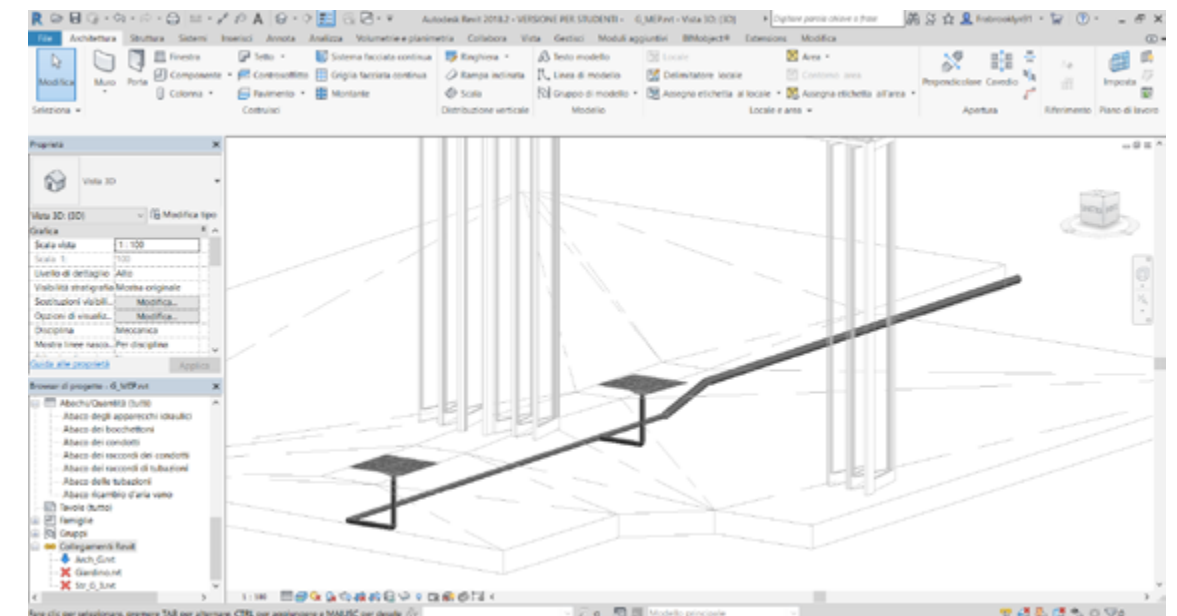
Thus the HVAC installation is made by three pipes union positioned in the best way to cover all the surface inside the winter garden aimed to have a good ventilation spreading.

The system is also composed by a first part of conduct which has a section square of 25x25 cm, then is split in three smaller conducts 20x20 cm section, all the conducts are completed by special parts that will be listed as all the other parts composing the project to make the project managing, filled by custom parameters as showed for the windows in the cover roof.

The second part of this model, in designing phase was about the plumbing system, as already said it's tiny part just aimed to pick the meteoric waters that is mandatory because the project is situated in an open courtyard.

This system is already existing, and it's only repeated because of the demolition of the existing floor to make foundations of the winter garden structure.

It also must be changed due to the change of the floor slope, because of the positioning of two new french windows to close the winter garden in a place where is present a manhole.



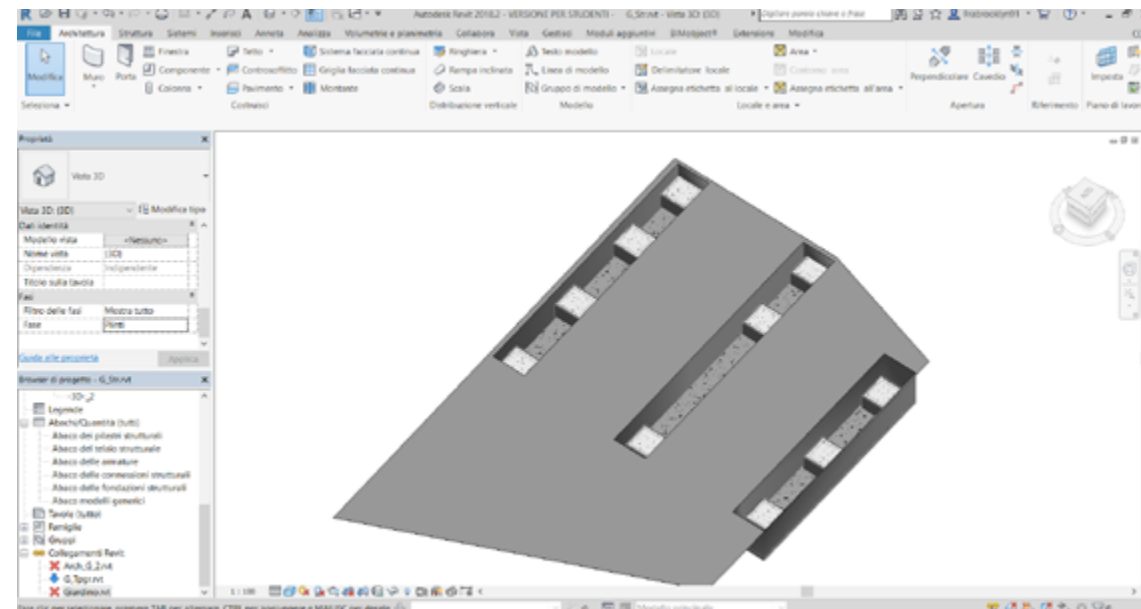
Plumbing system insert in the whole project.

Very simple as said the system is composed by two manholes connected each others by 65 mm diameter tube, that become a 100 mm diameter after the second manhole, to collect water coming from both.

I've shaped the tube until the existing facility, thinking a connection to existing plumbing system, that wasn't possible to know where exactly is.

Topographic model:

In project managing phase, that represent the next phase over the shaping one, when all the tasks were listed it became necessary to have a fourth model to be attached at the previous three, that is a topographic model which only purpose is to represent the excavation to be made to create the concrete foundations.

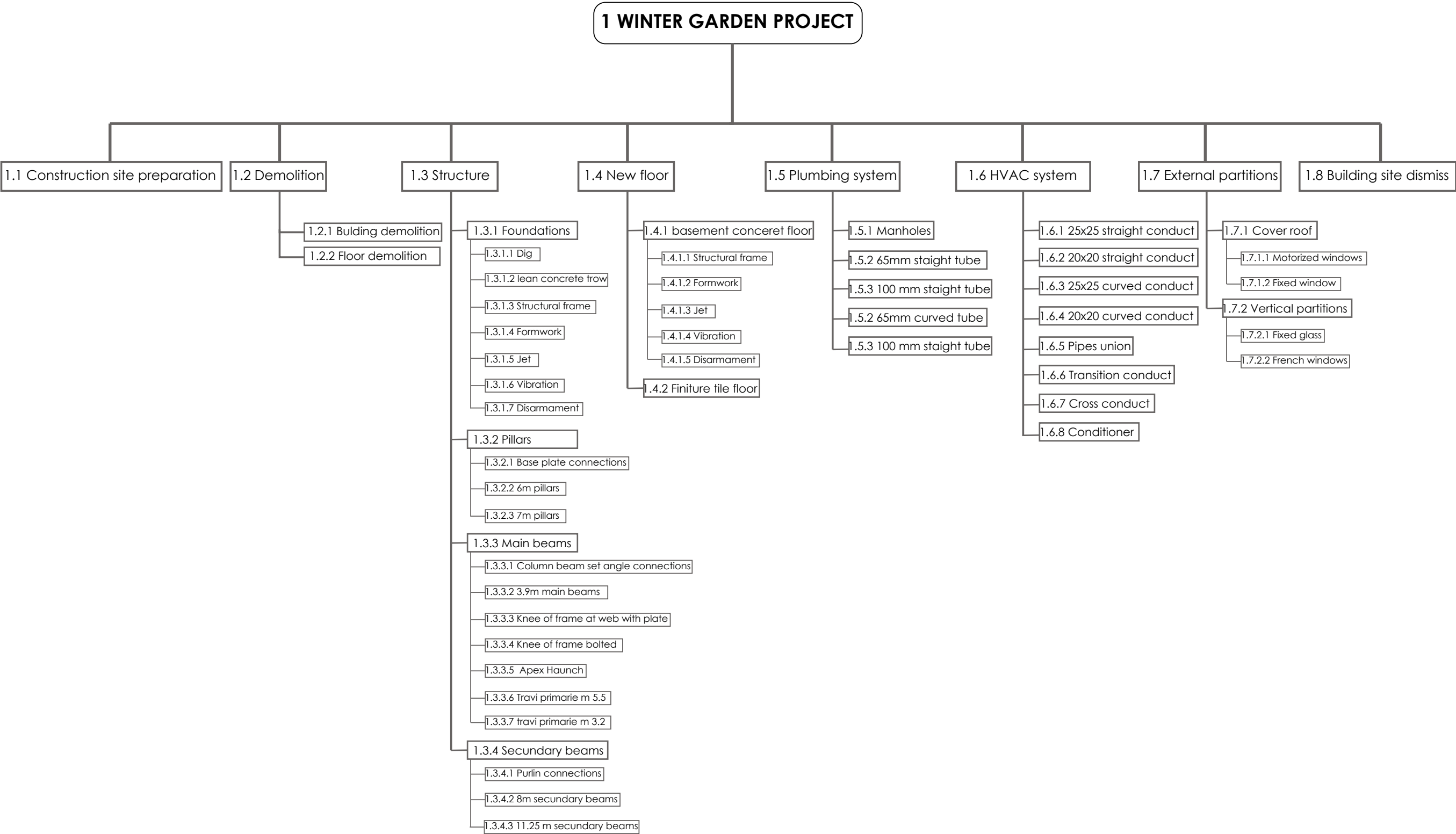


Topographic model with the excavations.

It became necessary because it was mandatory to estimate the quantity of hearth to be dug to make the foundations, that represent the first task after the demolition. Trough the use of Revit abacus is easily possible to estimate the volume of ground to be dug in a very fast way, that allows to establish a timing and to make a cost forecast. Those next steps will be explained in the following chapter entirely dedicated.



2.3.1 WBS:



The WBS creation was the first step to have a complete knowledge of any task required to accomplish the project. As shortly explained in the introduction chapter the Work Breakdown Structure is aimed to decompose in a hierarchical way all the activities connected to the project, in this case activities are strictly connected to materials required, based on the Piedmont price list.

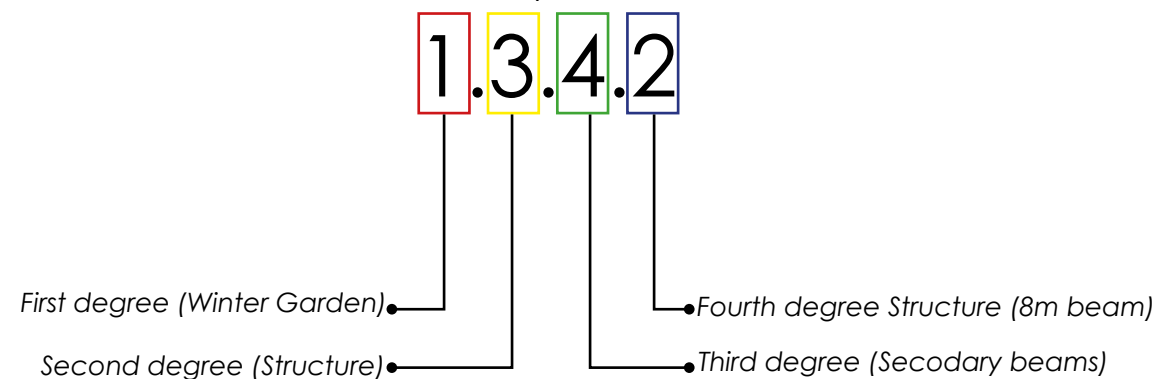
In first degree the tasks were split in eight bigger categories, in turn: Construction site preparation, Demolition, Structure, New floor, Plumbing system, HVAC system, External partitions and Building site dismiss, those categories were identified to have a generalized first classification, following were divided in other more specific tasks.

It's possible deduce from the WBS scheme that the structure is the main part of the whole project, the one that requires more tasks to be accomplished, and surely the category that need more time to be finished.

In structure case is possible to decompose the whole hierarchical scale, because the first degree as said is represented by "structure" in turn split in: Foundations, Pillars, Main beams and secondary beams, all of those again divided in smallest tasks representing the last degree of this hierarchical scale.

The WBS is represented by a numeric division separated by a point, every number represent a degree of the scale as shown below.

8m Secondary beam WBS code:



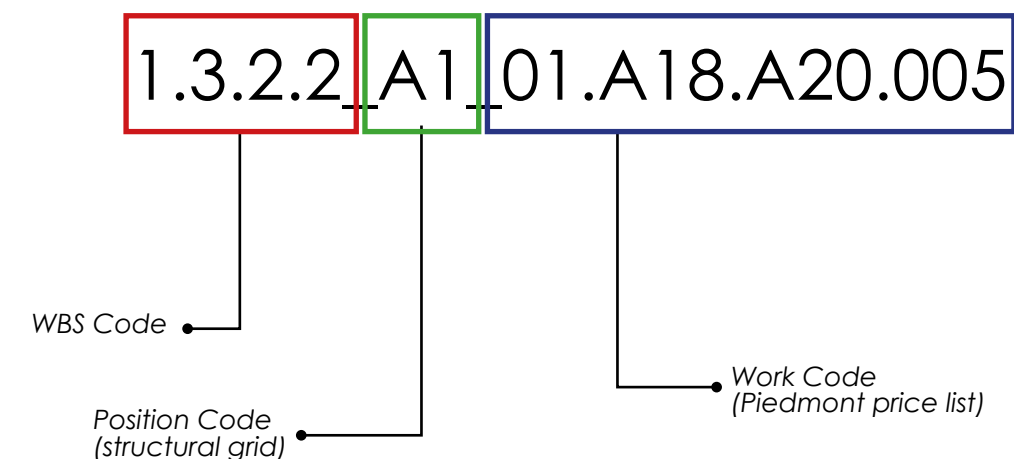
In this way the decomposition is clear and easy to be managed and to be improved adding more tasks when required, the WBS was tough in project management field, to have a previous decomposition aimed to have a clear overview of all tasks, then the whole code was implemented by the creation of another more complex code which include some other informations further the WBS.

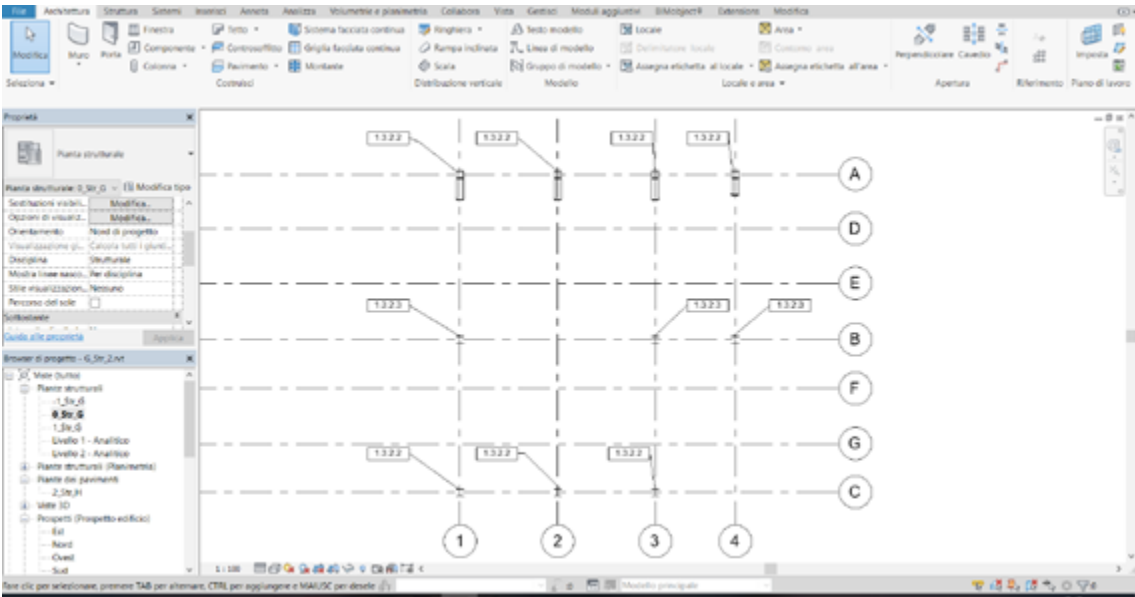
2.3.2 Activity Code:

Following the WBS structure, after many analysis on the existing codification standards presents in construction industry, it became necessary to create a customized code to be applied to any item present in the project, aimed to have a clear classification of any element and to have a bidirectional correspondence between the model in Autodesk Revit and the time schedule made in Microsoft Project.

The code created is split in three main parts, that will include a large range of information, all those were considered important in a project management scenario, anyway despite the high level of complexity of the code only the first part will be used in the construction simulation, leaving the others parts as a theoretical implementation for a more complex project.

The first code part was created following the WBS scheme, it was applied to any element exactly as developed in WBS and explained in the previous pages, aimed to have an univocal identification for all elements. The second part of the code represent the position of any item inside the model and it's based on the grid made in the structural model, this second part won't be used, because the specificity degree doesn't go beyond the Type in Revit, being the position an Instance attribute, that characterize every single element. Last part of the codification is the correspondent code in the Piedmont price list that represent the work required for any item to be done, and it brings other informations such as prices and labor percentage.





Keynote labels applied to some structural items.

The second part represent the grid above, anyway as said it wasn't applied at the items, because after some considerations due to the very small size of the project it results useless distinguish in the project management equal elements positioned in different places, due to the short work time applied to those items it would require a too much detailed time schedule leading an hourly schedule instead a more manageable daily schedule. It was insert because was thought in a early stage but definitely not applied once understood his uselessness, instead the position code could be a very useful and powerful tool in big size building sites, where the spacial organization in an high complex environment is suggested. The last part represent the work required applied to any item, it is useful to make the following step in a project management process, that's the 5D, represented by costs, and the Piedmont price list is the official source, it wasn't used especially to make a 4D simulation, but to apply prices to have a costs overview, that was required as one of the main goal of this thesis.

204	01.A17.N00.030	Piccole riparazioni di tende alla veneziana comprendente la rimozione della tenda, revisione dei meccanismi di manovra, la sostituzione delle funicelle, il ricollocamento della tenda: 27,50% al m del prezzo della tenda nuova	%	27,50	01.A18 OPERE DA FABBRO <i>Nota: 1) la saldatura, nelle opere in cui e' prevista, e' stata computata aumentando del 7% la quantita' riguardante la provvista del materiale metallico. 2) i serramenti metallici che vengono pagati a mq debbono essere dimensionati in modo da poter superare la prova di inflessione e quella sottocarico. 3) i collocamenti in opera comprendono la provvista e posa di ali e tasselli, e, dove occorrono, gli scalpellamenti, il piantamento delle bocchette sul pavimento, il trasporto del manufatto dal deposito al luogo di posa l'opera del muratore e l'assistenza del fabbro alla posa</i>
	01.A17.N00.035	Medie riparazioni di tende alla veneziana comprendenti la rimozione della tenda, la sostituzione di parte dei meccanismi di manovra, la sostituzione delle funicelle o dei nastri a scaletta, il ricollocamento in opera della tenda: 55% al m del prezzo del	%	55,00	
	01.A17.N00.040	Revisione di serramenti in legno consistente nel ritocco alle battute nella revisione della ferramenta senza applicazione dei rappezzi: 8% del prezzo del serramento nuovo	%	8,00	
	01.A17.N00.045	Piccole riparazioni di serramenti in legno consistenti nell'applica-			
	01.A18.A10	Carpenteria per grandi orditure o industrializzata, capriate, tralicci, pilastri e simili, compresa coloritura ad una ripresa di antiruggine, escluse le sole opere murarie			
	01.A18.A10.005	In ferro in profilati normali e lavorazione saldata	kg	1,96	0,74 37,96%
	01.A18.A10.010	In ferro in profilati normali e lavorazione chiodata o bullonata	kg	2,44	0,88 35,88%
	01.A18.A20	Posa in opera di carpenterie in ferro, per grandi orditure, tralicci, capriate, pilastri e simili			
	01.A18.A20.005	In profilati normali con lavorazione saldata, chiodata o bullonata	kg	2,77	2,44 88,21%

Piedmont price list excerpt [57]

A	B	C	D	E	F	G	H
Nota chiave	Posizionamento	Livello di base	Lavorazione	Codice identificativo	Costo €/Kg	Fase di creazione	Volume
1.3.2.2	A1	-1_Str_G	01.A18.A20.005	1.3.2.2_A1_01.A18.A20.005	2,44	Pilastri	0,07 m³
1.3.2.2	A2	-1_Str_G	01.A18.A20.005	1.3.2.2_A2_01.A18.A20.005	2,44	Pilastri	0,07 m³
1.3.2.2	A3	-1_Str_G	01.A18.A20.005	1.3.2.2_A3_01.A18.A20.005	2,44	Pilastri	0,07 m³
1.3.2.2	A4	-1_Str_G	01.A18.A20.005	1.3.2.2_A4_01.A18.A20.005	2,44	Pilastri	0,07 m³
1.3.2.3	B4	-1_Str_G	01.A18.A20.005	1.3.2.3_B4_01.A18.A20.005	2,44	Pilastri	0,08 m³
1.3.2.2	C3	-1_Str_G	01.A18.A20.005	1.3.2.2_C3_01.A18.A20.005	2,44	Pilastri	0,07 m³
1.3.2.2	C2	-1_Str_G	01.A18.A20.005	1.3.2.2_C2_01.A18.A20.005	2,44	Pilastri	0,07 m³
1.3.2.2	C1	-1_Str_G	01.A18.A20.005	1.3.2.2_C1_01.A18.A20.005	2,44	Pilastri	0,07 m³
1.3.2.3	B1	-1_Str_G	01.A18.A20.005	1.3.2.3_B1_01.A18.A20.005	2,44	Pilastri	0,08 m³
1.3.2.3	B3	-1_Str_G	01.A18.A20.005	1.3.2.3_B3_01.A18.A20.005	2,44	Pilastri	0,08 m³

Structural items abacus, with activity code parts.

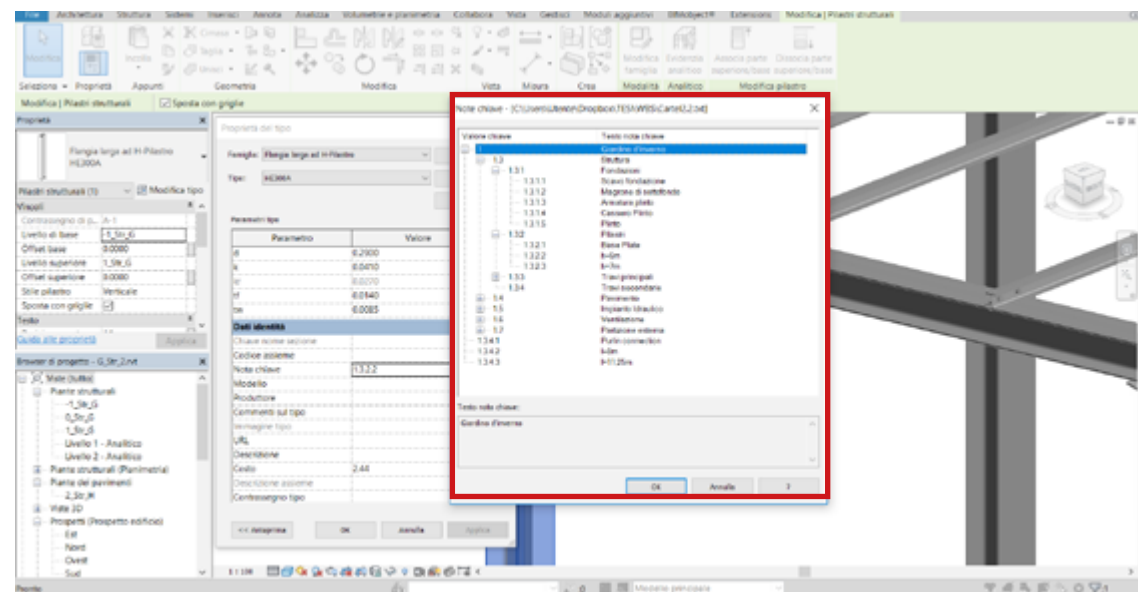
In the abacuses, there was created the whole code, through the combination of the three existing parameters previously explained, despite was used only the key note as a Type parameter to be insert into the time schedule in the Gantt chart, the predisposition to this more complex code was made in a previous stage when all those consideration about the uselessness in small project like this weren't done. Anyway the creation of a mixed code results of the join of Type and Instance parameters cannot be applied to the items through the abacuses, but should be created an operation passing through Dynamo, a visual programming tool, that permit to manipulate different parameters, combining them and finally applying to selected items.

2.3.3 Key note, code insertion in Revit :

The WBS parameter was applied to all elements present into the model through the Key Note parameter, that's an existing Type parameter already present in Revit, as explained in the introduction chapter Element parameters in Revit are split in Type and Instance parameters, in this case was used a Type parameter like the Key Note to insert the code into the model, because wasn't considered important to specify the position of any element, but the items identifications in a WBS structure is enough to accomplish the project management goal.

To import the WBS code into Revit and use it as a Key Note parameter was necessary make a tabs content all the WBS structure, once is imported into Revit it's easy to apply a Key Note to any element. To make the table readable by Revit was created in Excel content the whole WBS structure. As shown in the next page, the Excel sheet contain the WBS code, a short element description and a hierarchical structure that allows Revit to recognize the classification and make it quickly selectable.

The Key Note can be also applied to materials, anyway this possibility wasn't used in this case, due to the absence of complex elements composed by different materials such as a multi stratigraphy wall.



Keynote parameter assignment.

In the picture above is shown the Key note panel, opened from the Type property, where is possible to choose the key note from a hierarchical structured table imported in Revit as a .txt file, obtained from the following Excel table.

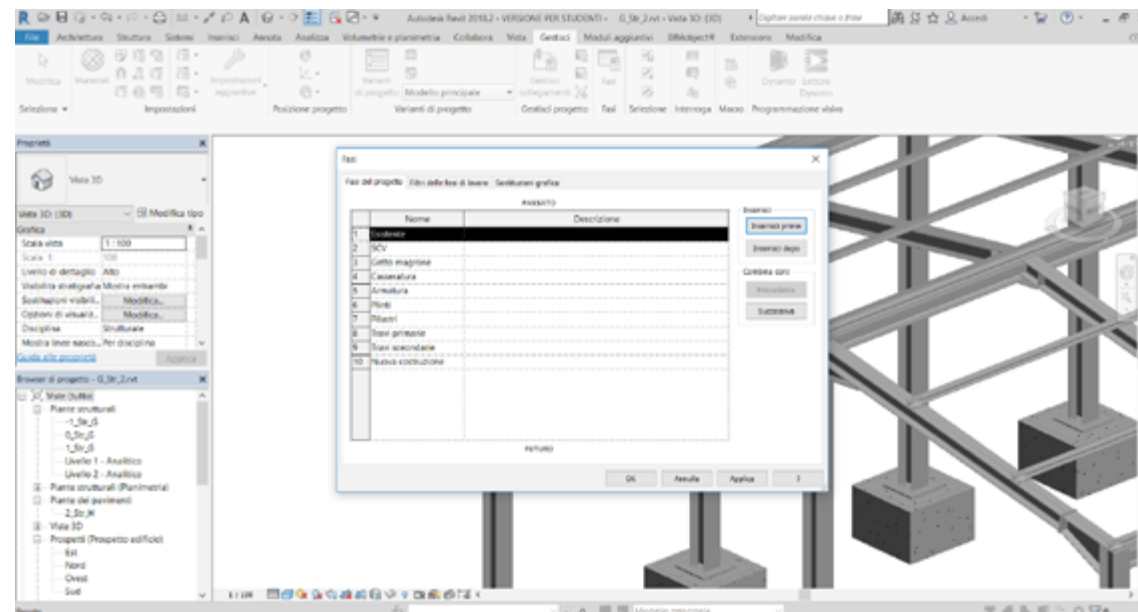
1	Giardino d'inverno			
1.3	Struttura	1		
1.3.1	Fondazioni	1.3	1	
1.3.1.1	Scavo fondazione	1.3.1	1.3	1
1.3.1.2	Magrone di sottofondo	1.3.1	1.3	1
1.3.1.3	Armatura plinto	1.3.1	1.3	1
1.3.1.4	Cassero Plinto	1.3.1	1.3	1
1.3.1.5	Plinto	1.3.1	1.3	1
1.3.2	Pilastri	1.3	1	
1.3.2.1	Base Plate	1.3.2	1.3	1
1.3.2.2	h=6m	1.3.2	1.3	1
1.3.2.3	h=7m	1.3.2	1.3	1
1.3.3	Travi principali	1.3	1	
1.3.3.1	Column beam seat angle	1.3.3	1.3	1
1.3.3.2	l=3,9m	1.3.3	1.3	1
1.3.3.3	Knee of frame at web with plate	1.3.3	1.3	1
1.3.3.4	Knee of frame bolted	1.3.3	1.3	1
1.3.3.5	Apex Haunch	1.3.3	1.3	1
1.3.3.6	l=5,5m	1.3.3	1.3	1
1.3.3.7	l=3,2m	1.3.3	1.3	1
1.3.4	Travi secondarie	1.3	1	
1.3.4.1	Purlin connection	1.3.4	1.3	1
1.3.4.2	l=8m	1.3.4	1.3	1
1.3.4.3	l=11,25m	1.3.4	1.3	1
1.4	Pavimento	1		
1.4.1	Sottofondo cls	1.4		
1.4.2	Finitura piastrelle su magrone	1.4		
1.5	Impianto Idraulico	1		
1.5.1	Scarico pavimento	1.5	1	
1.5.2	tubazione dritta d=65mm	1.5	1	
1.5.3	tubazione dritta d=100mm	1.5	1	
1.5.4	tubazione curva d=65mm	1.5	1	
1.5.5	tubazione curva d=100mm	1.5	1	
1.5.6	Tubazione transizione	1.5	1	
1.6	Ventilazione	1		
1.6.1	condotto dritto 0,25x0,25	1.6	1	
1.6.2	condotto dritto 0,2x0,2	1.6	1	
1.6.3	condotto curvo 0,25x0,25	1.6	1	
1.6.4	condotto curvo 0,20x0,20	1.6	1	
1.6.5	Diffusore mandata	1.6	1	
1.6.6	Condotto rettangolare transizione	1.6	1	
1.6.7	Condotto rettangolare croce	1.6	1	
1.6.8	UTA	1.6	1	
1.7	Partizione esterna	1		
1.7.1	Finestra copertura	1.7	1	

.txt file containing the WBS code, loaded in Revit.

2.3.4 Revit phases:

The first step done to manage the fourth dimension, was to create different phases in Revit, the project phases in Revit is a powerful tool, that allows to manage all the items present in a model related with the correspondent phase, this tool result very useful in the abacus manage making some phase filters to separate and apply any element to the correspondent phase, avoiding for example an information overlapping, mixing elements coming from different phases.

In this case were created several phases in all files composing the federate model, to allow a right visualization in a temporal scale, beginning from the demolition of the existing floor, passing through the excavation, until the real construction from the foundation till the finish. It's also possible to match all the phases coming from different files, creating a correspondence between them, aimed to don't loose the single file phases in linked model.



Phases creation in Revit.

The phases creation in Revit doesn't results useful to the final 4D simulation, because the timing was managed in a more complex and detailed way using tools like Gantt chart and a time schedule in MS Project, anyway it result a powerful method to split various items connected to their phase, aimed to have a ordered classification that can be very useful in big dimension project where the abacuses contains perhaps thousands items, and have a phase classification can make the model more manageable, and quantity counts related to any phase can be essential.

2.3.5 Time schedule Gantt chart:

The most important moment in a 4D project is the redaction of a time schedule that's a powerful tool widely used i many industry environments, not only in the construction industry but can be applied to any productively activities.

That consist to associate to any task previously individuated in the WBS a timing, in this case, where the goal was also to implement the project with a costs analysis then reach the fifth dimension applying the resources in terms of costs to any tasks.

The Gantt chart developed for the first time in 1917 by the American engineer Henry Laurence Gantt [58], it is an easy readable time schedule where to any task is applied a timing, so a initial and final date, a resource in terms of material, work or a cost resource, in that way is possible to manage in one integrated tool all what concern costs, time, human resource and monitoring in real time the accomplishing degree of the project, that permit to have a complete overview of the process and a detailed control of all the entities are influencing the construction.

To create a time schedule was used an apposite software that's Microsoft Project, which allows to import the previous WBS and to apply to any task a timing, showing directly a Gantt representation, that's a chart composed by timing on the horizontal axis, and the tasks on the vertical.

To have a more tidy organization the software make relationship between the tasks, and there can be four relations types:

End - Start: Is the more common relationship used, the following activity begins when the previous ends.

Start - Start: Two or more activities begins at the same time.

End - End: Two activities are connected by the final date, so they can start in different moments but have to finish on the same date.

Start - End: The selected activity has to end when the other starts.

As previously shortly introduced in MS Project is possible to load for any task the correspondent resources, that allow an highest control level, through the working team organization, avoiding tasks overlapping, guarantee a precise workers organization.

To have a complete time schedule, and a detailed organization, is also important to insert into MS Project other parameters aimed to specify some significant aspects in the building site organization:

- Homogeneous working groups:

First step is to divide all tasks in main group , to better understand which tasks should stay in the same group, aimed to organize in a temporal way all the process, the subdivision helps to monitor the activities and the workers.

- Intervention squad:

Understand the employees number required to accomplish the project is one of the first step, is important to estimate who is doing a determinate task and when. For example in a excavation task one will move the excavator, two will place the ground and possibly a fourth helping in case of need.

- Costs:

As said in the Gantt chart are insert also the costs in form of resources, costs can be about material and human, they were obtained from the Piedmont prices list.

- Working hours:

It's also mandatory to insert a working hours program, that simply define the daily working hours, it was insert a normal time schedule. The final report shows the total amount of working hours, aimed to provide the possibility to manage it adapting to the necessities and possible issues.

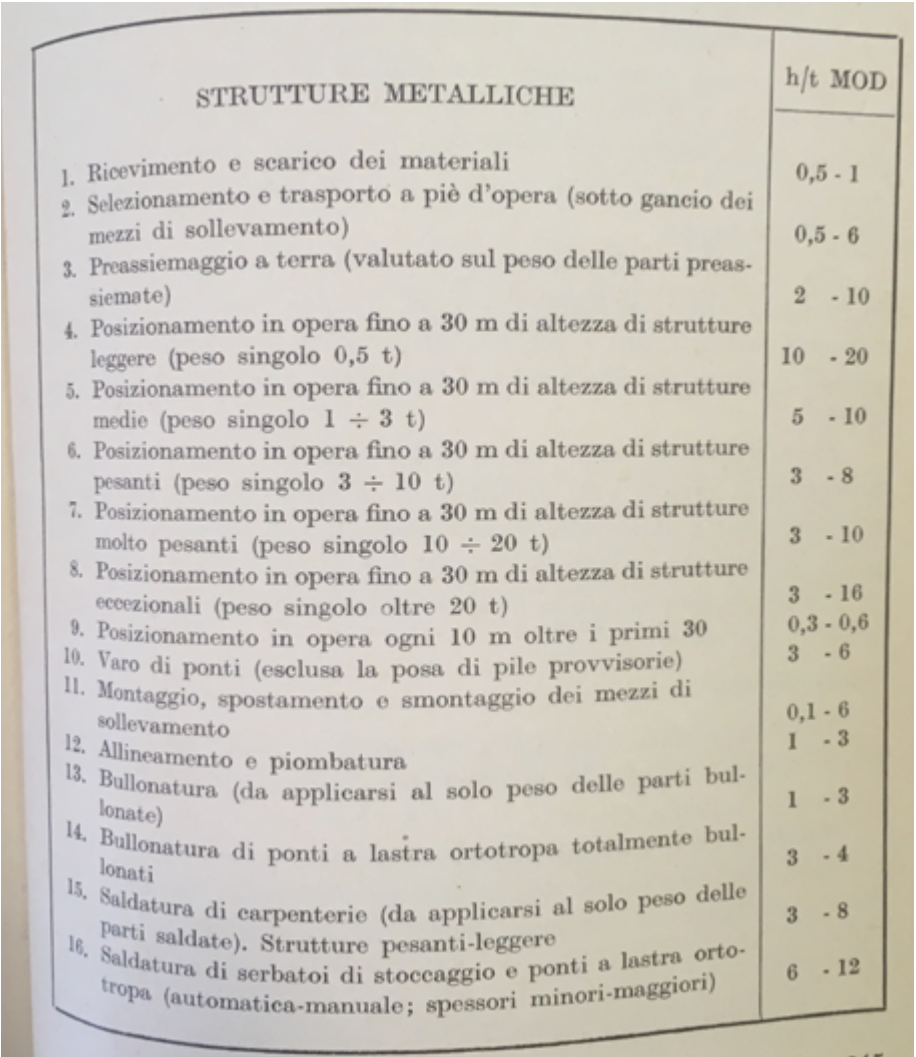
- Working days:

That define the working days in a normal week, it was insert a normal working week from Monday to Friday, from 8 to 12 then from 1 to 5 that result a normal 40 hours work week for all the employees.

- Works overlapping:

To avoid tasks overlapping, then a multiple employee assignment at the same time, MS Project shows an advisement, the overlapping can be planned in a fair way if is split into more employees, clearly it results wrong if one employee has more then one task assigned at the same time.

A focus should be made on the timing sources, because it results clear after many searches that there's a leak of information about timing in construction industry, indeed only for what concern the metal structure was found a certain source, also if it's 40 years old it was used. For all others activities was consulted professor Fabio Manzone who is an expert in construction tasks timing, he has provided all the missing timing, based on his personal experience.



STRUTTURE METALLICHE		h/t MOD
1. Ricevimento e scarico dei materiali		0,5 - 1
2. Selezionamento e trasporto a piè d'opera (sotto gancio dei mezzi di sollevamento)		0,5 - 6
3. Preassemblaggio a terra (valutato sul peso delle parti preassemblate)		2 - 10
4. Posizionamento in opera fino a 30 m di altezza di strutture leggere (peso singolo 0,5 t)		10 - 20
5. Posizionamento in opera fino a 30 m di altezza di strutture medie (peso singolo 1 ÷ 3 t)		5 - 10
6. Posizionamento in opera fino a 30 m di altezza di strutture pesanti (peso singolo 3 ÷ 10 t)		3 - 8
7. Posizionamento in opera fino a 30 m di altezza di strutture molto pesanti (peso singolo 10 ÷ 20 t)		3 - 10
8. Posizionamento in opera fino a 30 m di altezza di strutture eccezionali (peso singolo oltre 20 t)		3 - 16
9. Posizionamento in opera ogni 10 m oltre i primi 30		0,3 - 0,6
10. Varo di ponti (esclusa la posa di pile provvisorie)		3 - 6
11. Montaggio, spostamento e smontaggio dei mezzi di sollevamento		0,1 - 6
12. Allineamento e piombatura		1 - 3
13. Bullonatura (da applicarsi al solo peso delle parti bullonate)		1 - 3
14. Bullonatura di ponti a lastra ortotropa totalmente bullonati		3 - 4
15. Saldatura di carpenterie (da applicarsi al solo peso delle parti saldate). Strutture pesanti-leggere		3 - 8
16. Saldatura di serbatoi di stoccaggio e ponti a lastra ortotropa (automatica-manuale; spessori minori-maggiori)		6 - 12

Assembly timing table, for steel structure [59]

The table shows the timing for different tasks such as transport, dump and assembly giving a timing based on the elements weight, calculated in hour / ton, all those factors were calculated in Revit abacuses, through the new parameter creation, obtaining the mass from the multiplication of two existing parameters such as density and volume.

F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Costo €/Kg	Fase di creazione	Volume	Densità	Massa elemento	Tempo posizionamento peso singolo < 0.5 t h/t	Tempo posizionamento in opera (h)	Tempo bullonatura h/t	Tempo bullonatura effettivo (h)	Tempo ricevimento e scarico materiali	Tempo selezionamento e trasporto a piè d'opera (h/t)	Tempo ricevimento	Tempo trasporto a piè d'opera effettivo	Tempo totale assemblaggio	Costo materiale
2.44	Pilastri	0.07 m³	7500.00 kg/m³	503.19 kg	10	5.0	1	0.5	0.5	0.5	0.3	0.3	6.0	1227.8
2.44	Pilastri	0.07 m³	7500.00 kg/m³	503.19 kg	10	5.0	1	0.5	0.5	0.5	0.3	0.3	6.0	1227.8
2.44	Pilastri	0.07 m³	7500.00 kg/m³	503.19 kg	10	5.0	1	0.5	0.5	0.5	0.3	0.3	6.0	1227.8
2.44	Pilastri	0.07 m³	7500.00 kg/m³	503.19 kg	10	5.0	1	0.5	0.5	0.5	0.3	0.3	6.0	1227.8
2.44	Pilastri	0.08 m³	7750.00 kg/m³	616.13 kg	10	6.2	1	0.6	0.5	0.5	0.3	0.3	7.4	1563.4
2.44	Pilastri	0.07 m³	7500.00 kg/m³	503.19 kg	10	5.0	1	0.5	0.5	0.5	0.3	0.3	6.0	1227.8
2.44	Pilastri	0.07 m³	7500.00 kg/m³	503.19 kg	10	5.0	1	0.5	0.5	0.5	0.3	0.3	6.0	1227.8
2.44	Pilastri	0.07 m³	7500.00 kg/m³	503.19 kg	10	5.0	1	0.5	0.5	0.5	0.3	0.3	6.0	1227.8
2.44	Pilastri	0.08 m³	7750.00 kg/m³	614.41 kg	10	6.1	1	0.6	0.5	0.5	0.3	0.3	7.4	1499.2
2.44	Pilastri	0.08 m³	7750.00 kg/m³	614.41 kg	10	6.1	1	0.6	0.5	0.5	0.3	0.3	7.4	1499.2
													64.4	13696.2

Pillars abacus with assembly time calculation.

F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
Costo €/Kg	Fase di creazione	Volume	Densità	Massa elemento	Tempo h/t	Tempo posizionamento in opera (h)	Tempo bullonatura h/t	Tempo bullonatura effettivo (h)	Tempo ricevimento e scarico materiali (h/t)	Tempo ricevimento e scarico effettivo	Tempo selezionamento e trasporto a piè d'opera (h/t)	Tempo trasporto a piè d'opera effettivo	Tempo totale assemblaggio	Costo materiale
2.44	Travi primarie	0.03 m³	7500.00 kg/m³	253.18 kg	10	2.5	1	0.3	0.5	0.1	0.5	0.1	3.0	617.8
2.44	Travi primarie	0.03 m³	7500.00 kg/m³	253.18 kg	10	2.5	1	0.3	0.5	0.1	0.5	0.1	3.0	617.8
2.44	Travi primarie	0.03 m³	7500.00 kg/m³	253.18 kg	10	2.5	1	0.3	0.5	0.1	0.5	0.1	3.0	617.8
2.44	Travi primarie	0.03 m³	7500.00 kg/m³	253.18 kg	10	2.5	1	0.3	0.5	0.1	0.5	0.1	3.0	617.8
2.44	Travi primarie	0.03 m³	7500.00 kg/m³	252.51 kg	10	2.5	1	0.3	0.5	0.1	0.5	0.1	3.0	616.1
2.44	Travi primarie	0.03 m³	7500.00 kg/m³	252.51 kg	10	2.5	1	0.3	0.5	0.1	0.5	0.1	3.0	616.1
2.44	Travi primarie	0.04 m³	7500.00 kg/m³	317.88 kg	10	3.2	1	0.3	0.5	0.2	0.5	0.2	3.8	775.6
2.44	Travi primarie	0.05 m³	7500.00 kg/m³	360.03 kg	10	3.6	1	0.4	0.5	0.2	0.5	0.2	4.3	878.5
2.44	Travi primarie	0.04 m³	7500.00 kg/m³	327.56 kg	10	3.3	1	0.3	0.5	0.2	0.5	0.2	3.9	799.2
2.44	Travi primarie	0.05 m³	7500.00 kg/m³	364.45 kg	10	3.6	1	0.4	0.5	0.2	0.5	0.2	4.4	889.2
2.44	Travi primarie	0.05 m³	7500.00 kg/m³	343.11 kg	10	3.4	1	0.3	0.5	0.2	0.5	0.2	4.1	837.2
2.44	Travi primarie	0.05 m³	7500.00 kg/m³	359.90 kg	10	3.6	1	0.4	0.5	0.2	0.5	0.2	4.3	878.1
2.44	Travi primarie	0.04 m³	7500.00 kg/m³	327.56 kg	10	3.3	1	0.3	0.5	0.2	0.5	0.2	3.9	799.2
2.44	Travi primarie	0.03 m³	7500.00 kg/m³	207.59 kg	10	2.1	1	0.2	0.5	0.1	0.5	0.1	2.5	506.5
2.44	Travi primarie	0.03 m³	7500.00 kg/m³	196.50 kg	10	2.0	1	0.2	0.5	0.1	0.5	0.1	2.4	479.5
2.44	Travi secondarie	0.02 m³	7500.00 kg/m³	128.32 kg	10	1.3	1	0.1	0.5	0.1	0.5	0.1	1.5	313.1
2.44	Travi secondarie	0.02 m³	7500.00 kg/m³	128.32 kg	10	1.3	1	0.1	0.5	0.1	0.5	0.1	1.5	313.1
2.44	Travi secondarie	0.02 m³	7500.00 kg/m³	128.32 kg	10	1.3	1	0.1	0.5	0.1	0.5	0.1	1.5	313.1
2.44	Travi secondarie	0.02 m³	7500.00 kg/m³	120.89 kg	10	1.2	1	0.1	0.5	0.1	0.5	0.1	1.5	295.0
2.44	Travi secondarie	0.02 m³	7500.00 kg/m³	179.29 kg	10	1.8	1	0.2	0.5	0.1	0.5	0.1	2.2	437.5
2.44	Travi secondarie	0.02 m³	7500.00 kg/m³	179.29 kg	10	1.8	1	0.2	0.5	0.1	0.5	0.1	2.2	437.5
2.44	Travi secondarie	0.02 m³	7500.00 kg/m³	179.29 kg	10	1.8	1	0.2	0.5	0.1	0.5	0.1	2.2	437.5
2.44	Travi secondarie	0.02 m³	7500.00 kg/m³	179.29 kg	10	1.8	1	0.2	0.5	0.1	0.5	0.1	2.2	437.5
													66.5	13530.8

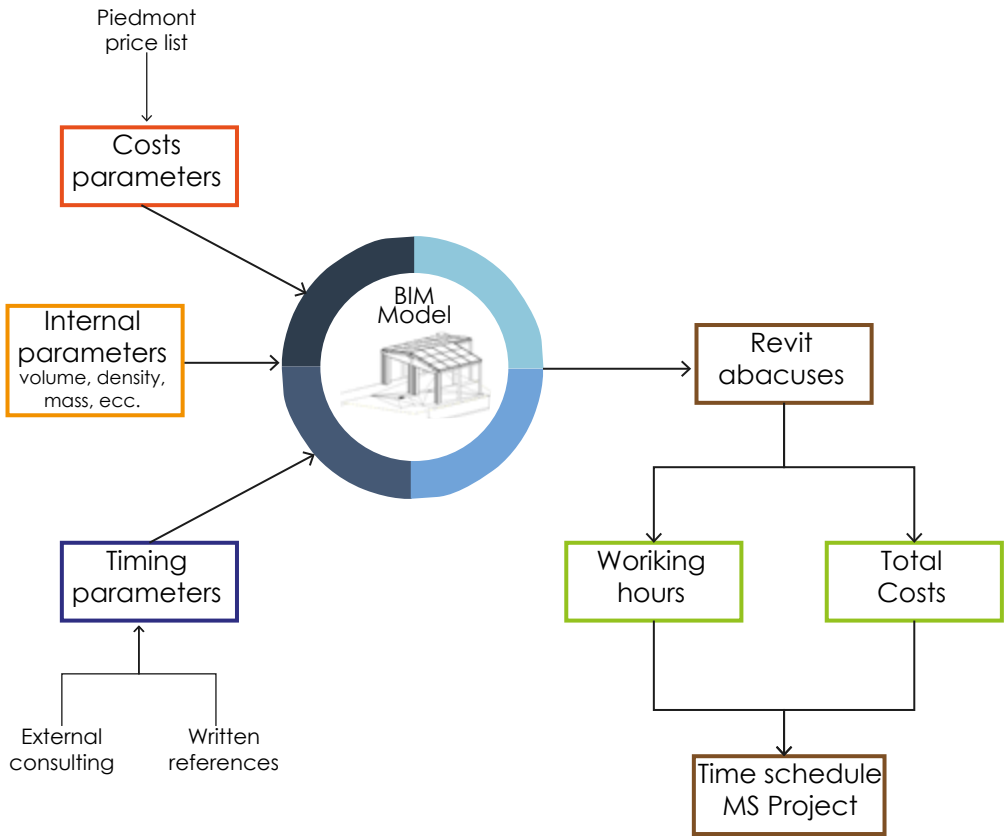
Beams abacus with assembly time calculation.

In those two abacuses is possible to see what said before, the two existing parameters like volume and density, multiplied give the mass of all elements, then all are multiplied for the correspondent value, representing the time needed to dump, move and assembly all those structural elements, reaching a final count of all the hours required to accomplish those tasks, that represent a main structural model.

The abacuses use is one of the strength of BIM, there's not possible to have information leak between the model and those kind of reports, because the abacuses are just a representation of the parameters present into any model elements, where is possible to combine them, to add and make operations between parameters.

Thus this is the way used to obtain a timing for what concern the structure, then was insert in MS Project to make the Gantt chart.

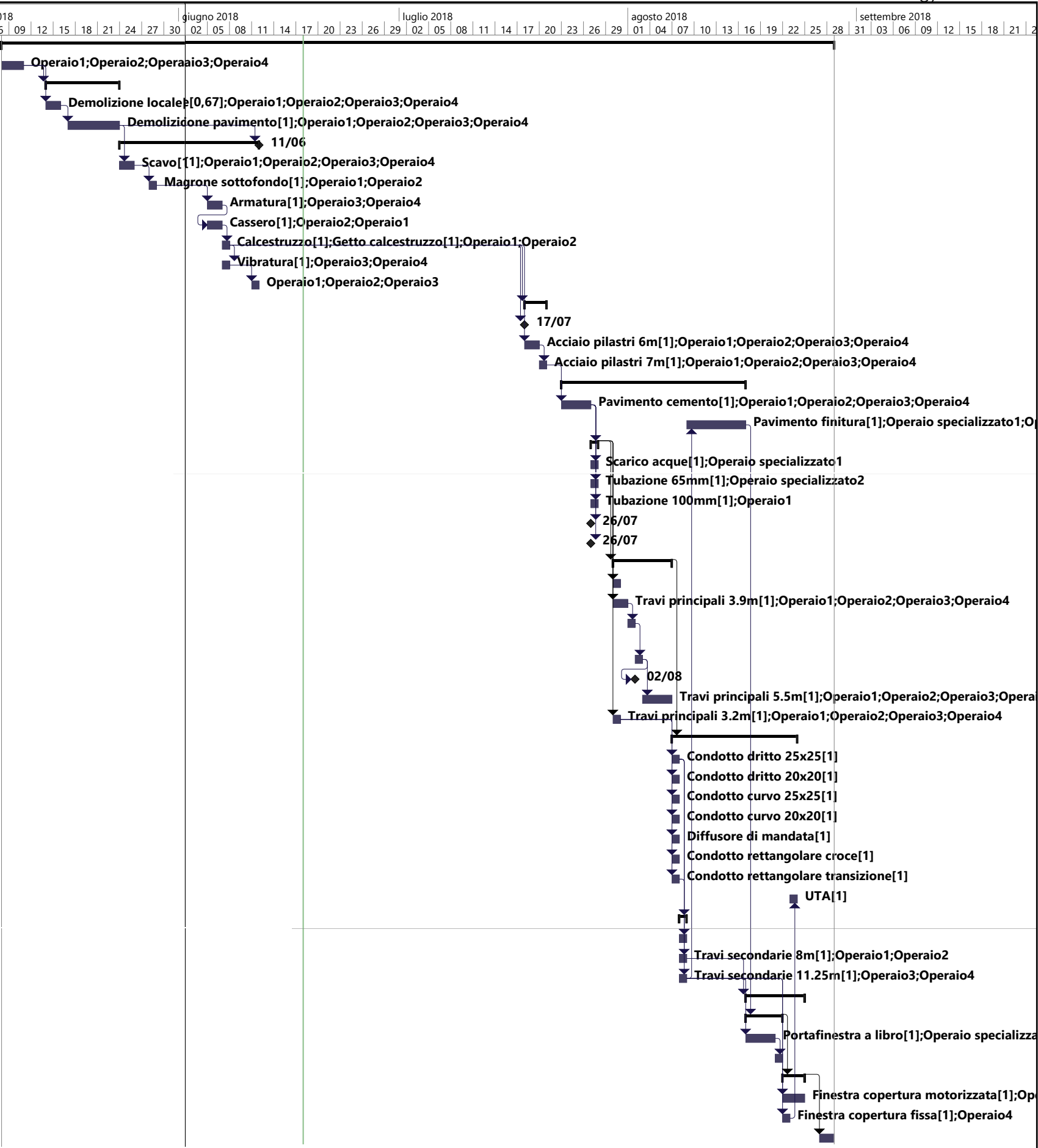
The source used shows a range for any value, I've always taken the lowest value, because of the obsolescence due to the 40 years old of the source, otherwise it could result a too high value for all voices.



2. Methodology

ID	Modalità attività	Nome attività	Durata	Inizio	Fine	Testo 3
1		1 Progetto Giardino d'Inverno	81 g	mar 08/05/1	mar 28/08/18	
2		1.1 Allestimento Cantiere	3 g	mar 08/05/1	gio 10/05/18	
3		1.2 Demolizione	8 g	lun 14/05/18	mer 23/05/18	
4		1.2.1 Demolizione fabbricato macchine	2 g	lun 14/05/18	mar 15/05/18	
5		1.2.2 Demolizione Pavimentazione	5 g	gio 17/05/18	mer 23/05/18	
6		1.3 Fondazioni	13 g	gio 24/05/18	lun 11/06/18	
7		1.3.1 Scavo	2 g	gio 24/05/18	ven 25/05/18	1.3.1.1
8		1.3.2 Getto magrone	1 g	lun 28/05/18	lun 28/05/18	1.3.1.2
9		1.3.3 Armatura	2 g	mar 05/06/1	mer 06/06/18	1.3.1.3
10		1.3.4 Casseratura	2 g	mar 05/06/1	mer 06/06/18	1.3.1.4
11		1.3.5 Getto	1 g	gio 07/06/18	gio 07/06/18	1.3.1.5
12		1.3.6 Vibratura	1 g	gio 07/06/18	gio 07/06/18	1.3.1.5
13		1.3.7 Disarmo	1 g	lun 11/06/18	lun 11/06/18	1.3.1.5
14		1.4 Pilastri	3 g	mar 17/07/1	ven 20/07/18	
15		1.4.1 Connessione Base Plate	0 g	mar 17/07/1	mar 17/07/18	1.3.2.1
16		1.4.2 Montaggio pilastri 6m	2 g	mer 18/07/1	gio 19/07/18	1.3.2.2
17		1.4.3 Montaggio pilastri 7m	1 g	ven 20/07/1	ven 20/07/18	1.3.2.3
18		1.5 Nuovo Pavimento	19 g	lun 23/07/18	gio 16/08/18	
19		1.5.1 Pavimento di battuto in cemento	4 g	lun 23/07/18	gio 26/07/18	1.4.1
20		1.5.2 Pavimento finitura	6 g	gio 09/08/18	gio 16/08/18	1.4.2
21		1.6 Impianto idraulico	1 g	gio 26/07/18	ven 27/07/18	
22		1.6.1 Scarico a pavimento	1 g	ven 27/07/1	ven 27/07/18	1.5.1
23		1.6.2 Tubazione dritta d 65mm	1 g	ven 27/07/1	ven 27/07/18	1.5.2
24		1.6.3 Tubazione dritta d 100 mm	1 g	ven 27/07/1	ven 27/07/18	1.5.3
25		1.6.4 Tubazione a gomito d 65mm	0 g	gio 26/07/18	gio 26/07/18	1.5.4
26		1.6.5 Tubazione a gomito d 100mm	0 g	gio 26/07/18	gio 26/07/18	1.5.5
27		1.7 Travi primarie	6 g	lun 30/07/18	lun 06/08/18	
28		1.7.1 Montaggio Column beam seat ar	1 g	lun 30/07/18	lun 30/07/18	1.3.3.1
29		1.7.2 Montaggio travi primarie 3.9m	2 g	lun 30/07/18	mar 31/07/18	1.3.3.2
30		1.7.3 Montaggio Knee of frame at web with plate	1 g	mer 01/08/18	mer 01/08/18	1.3.3.3
31		1.7.4 Montaggio Knee of frame bolted	1 g	gio 02/08/18	gio 02/08/18	1.3.3.4
32		1.7.5 Montaggio Apex Haunch	0 g	gio 02/08/18	gio 02/08/18	1.3.3.5
33		1.7.6 Montaggio travi primarie m 5.5	2 g	ven 03/08/1	lun 06/08/18	1.3.3.6
34		1.7.7 Montaggio travi primarie m 3.2	1 g	lun 30/07/18	lun 30/07/18	1.3.3.7
35		1.8 Impianto ventilazione	13 g	mar 07/08/1	gio 23/08/18	
36		1.8.1 Montaggio condotto dritto 0.25x1	1 g	mar 07/08/1	mar 07/08/18	1.6.1
37		1.8.2 Montaggio condotto dritto 0.20x1	1 g	mar 07/08/1	mar 07/08/18	1.6.2
38		1.8.3 Montaggio condotto curvo 0.25x1	1 g	mar 07/08/1	mar 07/08/18	1.6.3
39		1.8.4 Montaggio condotto curvo 0.20x1	1 g	mar 07/08/1	mar 07/08/18	1.6.4
40		1.8.5 Montaggio diffusore mandata	1 g	mar 07/08/1	mar 07/08/18	1.6.5
41		1.8.6 Condotto rettangolare croce	1 g	mar 07/08/1	mar 07/08/18	1.6.7
42		1.8.7 Condotto rettangolare transizion	1 g	mar 07/08/1	mar 07/08/18	1.6.6
43		1.8.8 Montaggio UTA	1 g	gio 23/08/18	gio 23/08/18	1.6.8
44		1.9 Travi secondarie	1 g	mer 08/08/1	mer 08/08/18	
45		1.9.1 Montaggio Purlin connection	1 g	mer 08/08/1	mer 08/08/18	1.3.4.1
46		1.9.2 Montaggio travi secondarie 8m	1 g	mer 08/08/1	mer 08/08/18	1.3.4.2
47		1.9.3 Montaggio travi secondarie 11.2	1 g	mer 08/08/1	mer 08/08/18	1.3.4.3
48		1.10 Partizioni esterne	6 g	ven 17/08/1	ven 24/08/18	
49		1.10.1 Montaggio partizioni verticali	3 g	ven 17/08/1	mar 21/08/18	
50		1.10.1.1 Porta finestra a libro	2 g	ven 17/08/1	lun 20/08/18	1.7.2.2
51		1.10.1.2 Vetrata fissa	1 g	mar 21/08/1	mar 21/08/18	1.7.2.1
52		1.10.2 Montaggio finestre copertura	3 g	mer 22/08/1	ven 24/08/18	
53		1.10.2.1 Finestre automatizzate	3 g	mer 22/08/1	ven 24/08/18	1.7.1.1
54		1.10.2.2 Finestra fissa	1 g	mer 22/08/1	mer 22/08/18	1.7.1.2
55		1.11 Dismissione cantiere	2 g	lun 27/08/18	mar 28/08/18	

2. Methodology



In the Gantt chart made to have a detailed time schedule is possible to understand how complex can be a construction management process, if for such as a small dimension project, constituted by a basic level of complexity, were managed many tasks combined with resources and costs.

All the tasks represents a Type in the Revit model, associated by the WBS code insert in Revit as Key Note passing trough the process previously described, and in MS Project as a value present in the last column of the previous picture, inserting the WBS code manually, that means some errors can be done during this data filling phase.

The first column in the Gantt chart represent a task numbering, basically in temporal order, as though in the work program.

In the following column are written the tasks names, in terms of a short description, just to easily identify the tasks, beside was created automatically a WBS code by MS Project, that doesn't match with the one create by myself that is compositing the activity code used in the construction management process.

Every task then has a initial and final date, established by the construction manager, in this case obtained by the previous calculus for what concern the steel structure or the values provided by the advice by professor Fabio Manzone.

Then the last column contain the WBS code applied also to the Revit model useful to have a direct connection between the element and the correspondent task in the simulation software, as Navisworks that will be treat in the following pages.

The chart composed by horizontal lines representing the tasks, easily readable where the length represent the craft duration, and with a proper symbology are also represented the relationship between the activities, further at every lines are associated the resources needed to accomplish the selected activity.

MS Project can also make some reports about costs, employees and work organizations, that's a very powerful tool to manage all the aspects in a construction management process in construction industry.





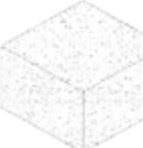

2.3.6 Resources and 5D:








In the Gantt chart is possible to see all the material resources used in the project, obtained through the Piedmont price list, applied to the respectively values calculated in the Revit abacuses.



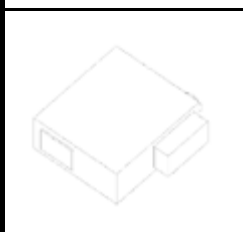
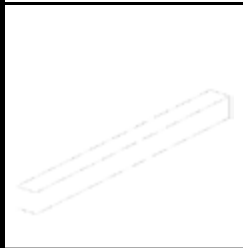

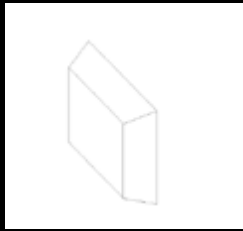
Thus the time schedule in MS project integrated with the BIM model reach the fifth dimension, that's a goal of this thesis, have a 5 dimensions complete managing of a simply project passing trough the BIM use.

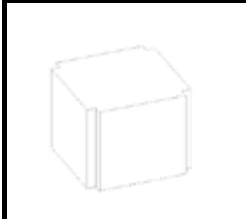
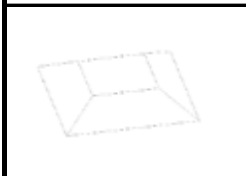
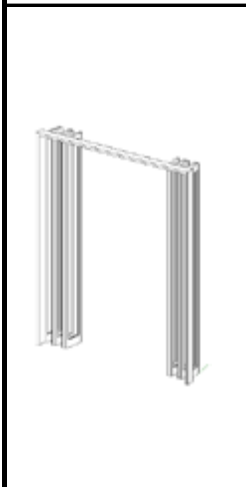
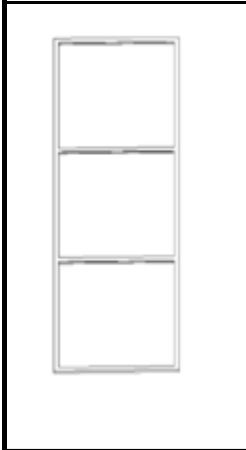
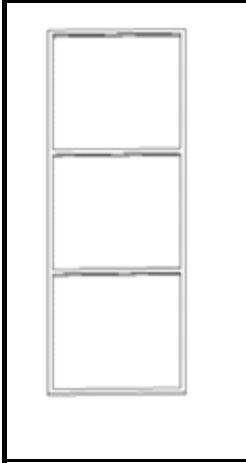
As said the costs are obtained using the following price list that includes also the labor percentage, thus it was obtained a complete price including materials and labor, so the process was calculated through the abacuses in BIM environment, achieving an estimation of the quantity for any element, then any quantity was multiplied for the corresponding cost identified in the price list, the finally applied to the Gantt chart where timing and costs are included and subsequently applied to the model.

In the following pages are shown the complete tables containing all the elements present in the project, with the respective costs, quantities and a short labor description took from the Piedmont price list.

Picture	Name	Work	Quantity	Price	Cost
	EXCAVATION	Scavo in trincea a pareti verticali di materie di qualunque natura purché rimovibili senza l'uso di mazze e scalpelli, compresa ogni armatura occorrente per assicurare la stabilità delle pareti, con sbadacchiature leggere, compresa l'estrazione con qualsiasi mezzo delle materie scavate ed il loro deposito a lato dello scavo. Con mezzo meccanico ed eventuale intervento manuale ove necessario, fino alla profondità di m 3 e per un volume di almeno m³ 1.	122 m3	17,4	1.948,80 €
	LEAN CONCRETE	Sottofondo per pavimenti di spessore fino a cm 15 Formato con calcestruzzo cementizio avente resistenza caratteristica di kg/cm² di 150, per ogni cm di spessore e per superfici di almeno m² 0,20	56 m2	3,53	197,68 €
	QUARTERDECK	Casserature per strutture in cemento armato, semplice o precompresso, a sezione ridotta quali solette, traversi etc., compreso il puntellamento ed il disarmo misurando esclusivamente lo sviluppo delle parti a contatto dei getti In legname di qualunque forma	38,40 m2	43,37	1.665,41 €
	ARMATURE	Barre per cemento armato lavorate e disposte in opera secondo gli schemi di esecuzione in acciaio ad aderenza migliorata B450A o B450C per gli usi consentiti dalle norme vigenti	1,5 Kg	234,45	351,67 €
	CONCRETE PLINTH	Calcestruzzo a prestazione garantita, in accordo alla UNI EN 206-1, per strutture di fondazione (plinti, cordoli, pali, travi rovesce, paratie, platee) e muri interrati a contatto con terreni non aggressivi, classe di esposizione ambientale xc2 (UNI 11104), classe di consistenza al getto S4, Dmax aggregati 32 mm, Cl 0.4; fornitura a piè d'opera, escluso ogni altro onere: per plinti con altezza <1.5m, platee di fondazione e muri di spessore < 80 cm.	98,34 m3	23,04	2.265,75 €
	CASTING	Getto in opera di calcestruzzo cementizio eseguito con l'ausilio della gru compreso il nolo della stessa. In strutture di fondazione.	37,95 m3	23,04	874,37 €

	VIBRATION	Vibratura mediante vibratore ad immersione, compreso il compensoper la maggiore quantità di materiale impiegato, noleggio vibratore e consumo energia elettrica o combustibile.	8,55 m3	23,04	196,99 €
	PILLARS	Carpenteria per grandi orditure o industrializzata, capriate, tralicci, pilastri e simili, compresa coloritura ad una ripresa di antiruggine, escluse le sole opere murarie In ferro in profilatino normali e lavorazione chiodata o bullonata.	2,44 Kg	5367,28	13.098,60 €
	BEAMS HE260	Carpenteria per grandi orditure o industrializzata, capriate, tralicci, pilastri e simili, compresa coloritura ad una ripresa di antiruggine, escluse le sole opere murarie In ferro in profilatino normali e lavorazione chiodata o bullonata.	2,44 Kg	4314,91	10.528,38 €
	BEAMS HE100	Carpenteria per grandi orditure o industrializzata, capriate, tralicci, pilastri e simili, compresa coloritura ad una ripresa di antiruggine, escluse le sole opere murarie In ferro in profilatino normali e lavorazione chiodata o bullonata.	2,44 Kg	1230,44	3.002,27 €
	CONCRETE BASEMENT FLOOR	Pavimento di battuto in cemento, liscio e bocciardato, spessore cm 10, con calcestruzzo a dosaggio 200 kg, compreso spolvero di cemento in ragione di kg 5 per m². Servizio materiali eseguito con l'ausilio di mezzi di sollevamento (Per ogni cm in più di spessore aumento del 12%)	41,38 m2	210,67	8.717,52 €
	FINISH TILES FLOOR	Posa in opera di pavimento in piastrelle di monocottura e similari, eseguita con idoneo adesivo cementizio conforme alla norma UNI EN 12004, compresa la sigillatura dei giunti con idoneo stucco cementizio, escluso il sottofondo	39,24 m3	210,67	8.266,69 €
	MANHOLE	Fornitura di caditoie o chiusini con telaio in PVC antiurto, con portata minima garantita di q10-11 di carico concentrato, adatti per marciapiedi, cortili, impianti sportivi, aree verdi. Per pozzetti in cemento dimensioni cm40X40	38,78 cad	2	77,56 €

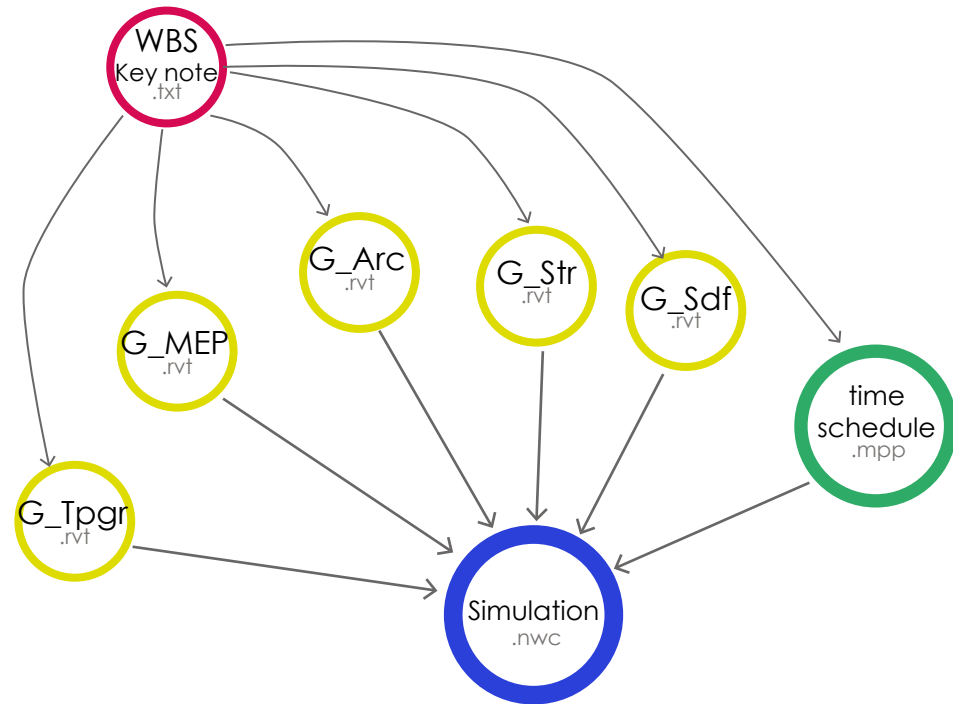
	TUBES 65mm	Posa in opera di tubazioni, raccordi e pezzi speciali, per condotte di fognatura, tubi pluviali, etc, per condotte tanto verticali quanto orizzontali, compresa la saldatura elettrica dei giunti, staffe in ferro per ogni giunto se verticali e staffe speciali per ogni giunto se orizzontali fissate ai solai, esclusi gli eventuali scavi e reinterri. in polietilene duro tipo Geberit - pe	10,01 m	9,24	92,44 €
	TUBES 100 mm	Posa in opera di tubazioni, raccordi e pezzi speciali, per condotte di fognatura, tubi pluviali, etc, per condotte tanto verticali quanto orizzontali, compresa la saldatura elettrica dei giunti, staffe in ferro per ogni giunto se verticali e staffe speciali per ogni giunto se orizzontali fissate ai solai, esclusi gli eventuali scavi e reinterri. in polietilene duro tipo Geberit - pe	13,33 m	9,22	122,84 €
	UTA	Provvista e posa in opera di armadi condizionatori raffreddati ad aria: Per potenzialita' fino a 9000 fr/h	4999,1 cad	1	4.999,10 €
	AIR CONDUCT	Provvista e posa in opera di canalizzazione in lamiera di acciaio inox, di qualsiasi sezione, tipo graffato o chiodato o saldato, di qualsiasi dimensione, forma o spessore, comprese eventuali flange per giunzioni, staffe o tiranti di sostegno, opere murarie, ecc.	16,15 Kg	82,33	1.329,57 €
	AIR CONDUCT CURVED	Provvista e posa in opera di canalizzazione in lamiera di acciaio inox, di qualsiasi sezione, tipo graffato o chiodato o saldato, di qualsiasi dimensione, forma o spessore, comprese eventuali flange per giunzioni, staffe o tiranti di sostegno, opere murarie, ecc.	16,15 Kg	19,43	313,79 €
	AIR CONDUCT JUNCTION	Provvista e posa in opera di canalizzazione in lamiera di acciaio inox, di qualsiasi sezione, tipo graffato o chiodato o saldato, di qualsiasi dimensione, forma o spessore, comprese eventuali flange per giunzioni, staffe o tiranti di sostegno, opere	16,15 Kg	4,67	75,42 €

	AIR CONDUCT SPECIAL SHAPES	Provvista e posa in opera di canalizzazione in lamiera di acciaio inox, di qualsiasi sezione, tipo graffato o chiodato o saldato, di qualsiasi dimensione, forma o spessore, comprese eventuali flange per giunzioni, staffe o tiranti di sostegno, opere	25,77 Kg	2,29	59,01 €
	AIR CONDUCT PIPE UNION	Provvista e posa in opera di anemostato per distribuzione aria in fusione di alluminio anodizzato per diametro 150	49,95 cad	3	149,85 €
	FRENCH WINDOW	Fornitura e Posa in opera di Serramenti metallici esterni, completi di telaio in profilati a taglio termico e vetro montato tipo camera bassoemissivo, per finestre, e portefinestre con marcatura CE (UNI EN 14351-1), di qualunque forma, tipo, dimensione e numero di battenti profili fermavetro, gocciolatoio, serratura, ferramenta e maniglia. Con trasmittanza termica complessiva Uw=<2,0 e =>1,6 W/m²K (UNI EN ISO 10077-1) esclusa la fornitura al piano. In alluminio, ad ante, aventi superficie superiore a m² 3,5	386,97 m2	54,35	21.031,82 €
	MOTORIZED ROOF WINDOW	Fornitura e Posa in opera di Serramenti metallici esterni, completi di telaio in profilati a taglio termico e vetro montato tipo camera bassoemissivo, per finestre, e portefinestre con marcatura CE (UNI EN 14351-1), di qualunque forma, tipo, dimensione e numero di battenti profili fermavetro, gocciolatoio, serratura, ferramenta e maniglia. Con trasmittanza termica complessiva Uw=<2,0 e =>1,6 W/m²K (UNI EN ISO 10077-1) esclusa la fornitura al piano. In alluminio, ad ante, aventi superficie superiore a m² 3,5	386,97 m2	109,14	42.233,91 €
	FIX ROOF WINDOW	Fornitura e Posa in opera di Serramenti metallici esterni, completi di telaio in profilati a taglio termico e vetro montato tipo camera bassoemissivo, per finestre, e portefinestre con marcatura CE (UNI EN 14351-1), di qualunque forma, tipo, dimensione e numero di battenti profili fermavetro, gocciolatoio, serratura, ferramenta e maniglia. Con trasmittanza termica complessiva Uw=<2,0 e =>1,6 W/m²K (UNI EN ISO 10077-1) esclusa la fornitura al piano. In alluminio, ad ante, aventi superficie superiore a m² 3,5	263,45 m2	8,62	2.270,94 €

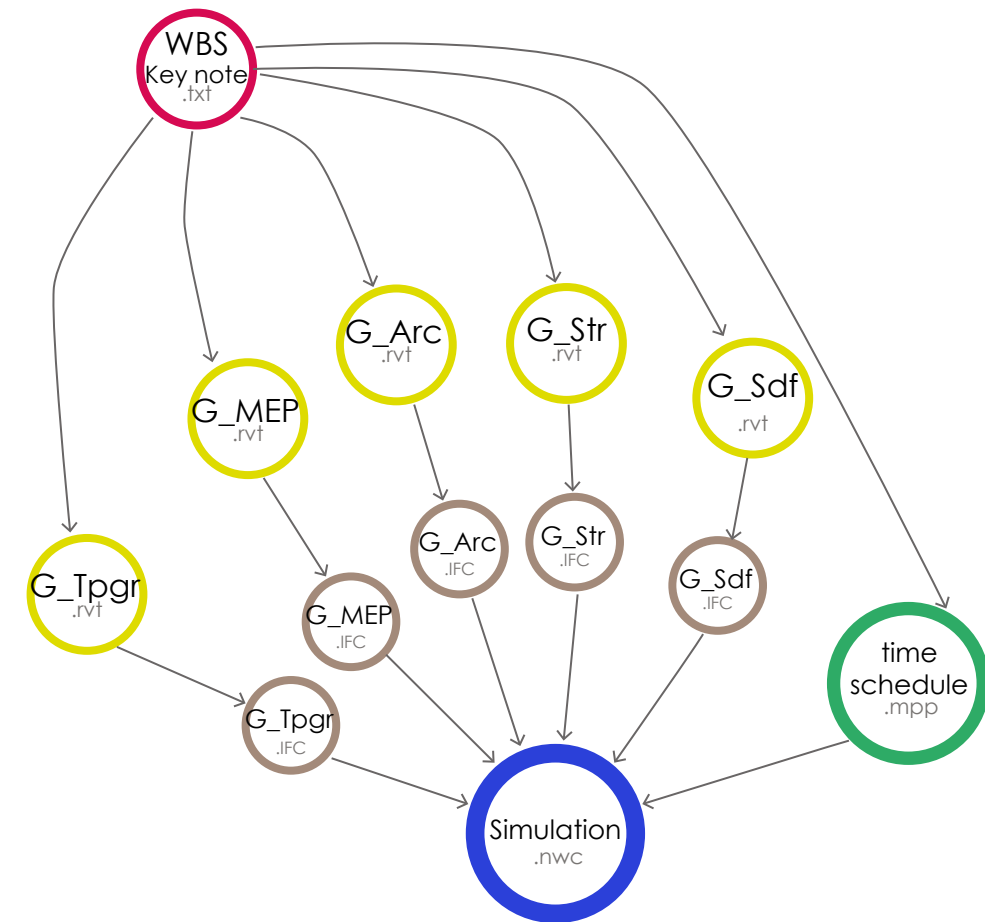
2.3.6 Interoperability tests:

About the import files in Navisworks were made some interoperability tests, aimed to understand the difference between three kind of files: .rvt, .nwc, .ifc, and of course the best way to obtain a fair import into the simulation software.

- .rvt the normal Revit file extension was the first attempt, following the previous scheme, the five .rvt files were imported into Autodesk Navisworks, where there were some leak, basically about the structural connections previously shaped in Advance Steel, that was the only weakness, because otherwise is the faster way to export and all other elements were imported in Naviswork fairly.

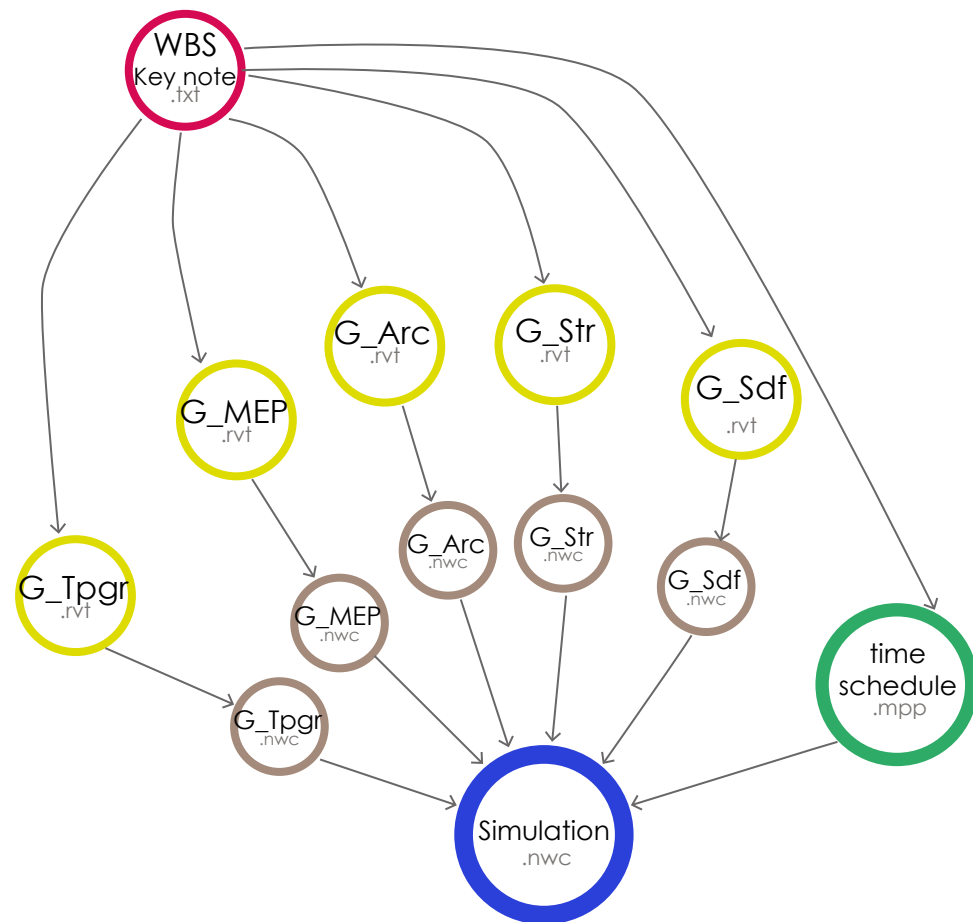


- .IFC files, are the common standard kind of files for interoperability, works well between Revit and Navisworks, there's some imprecisions in some elements shape, once are open in Navisworks, imprecisions that could be easily fixed changing some value in .IFC exportation panel, the following scheme represent the one more step compared to the previous, that consist in the exportation from .rvt to .IFC.



- .nwc, (temporary trade specific file), is the Navisworks format that can be exported directly from Revit, using a tool specially present in Revit, after the previous tests with .IFC and .rvt files this is the one which gives best results, exporting the whole model without leak or geometric errors, settings were managed to have a correct exportation especially for what concern structural connections, due to a improvable interoperability between Revit and Advance Steel.

The scheme structure is the same to the previous, there's always one more step converting .rvt files in .nwc, before connection wit the .mpp time schedule in Autodesk Navisworks.



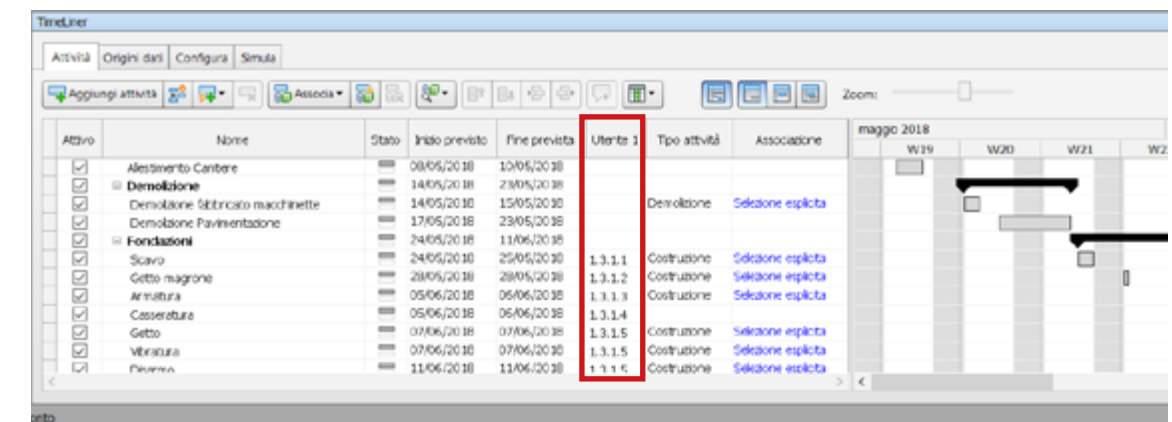
2.3.7 4D simulation:

Once obtained the BIM model in Revit and the time schedule in MS Project, the last step to be done is make a construction simulation, connecting the two previous documents then the five Revit models containing the whole project split in the various disciplines and the time schedule.

To accomplish this goal it was used Autodesk Navisworks, this very useful software permit to make many activities, firstly is an accurate navigator that allows to navigate the project to make a clash detection between all the elements present in the project aimed to find possibly interferences, thanks to a high developed navigation tools, and to make a review reporting the eventual interferences with drawing tools to all the actors involved in the design process.

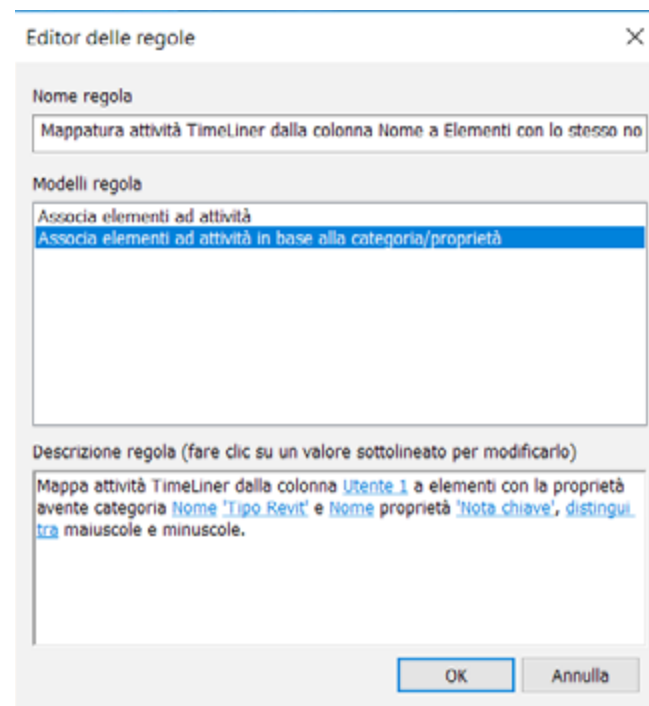
Then the possibility to create a correspondence between the time schedule and the BIM model, through an automatize identification between specified parameters, in this case the WBS code in MS Project and the same code present as an Type parameter in all Revit elements permit to create a matching rules that associate automatically any elements with the corresponding task, then to a timing.

Thus in Navisworks is possible to create a simulation that shows the construction process following the timing decided in the time schedule, this tool allow the construction manager to suddenly understand if there's some fails in the process.



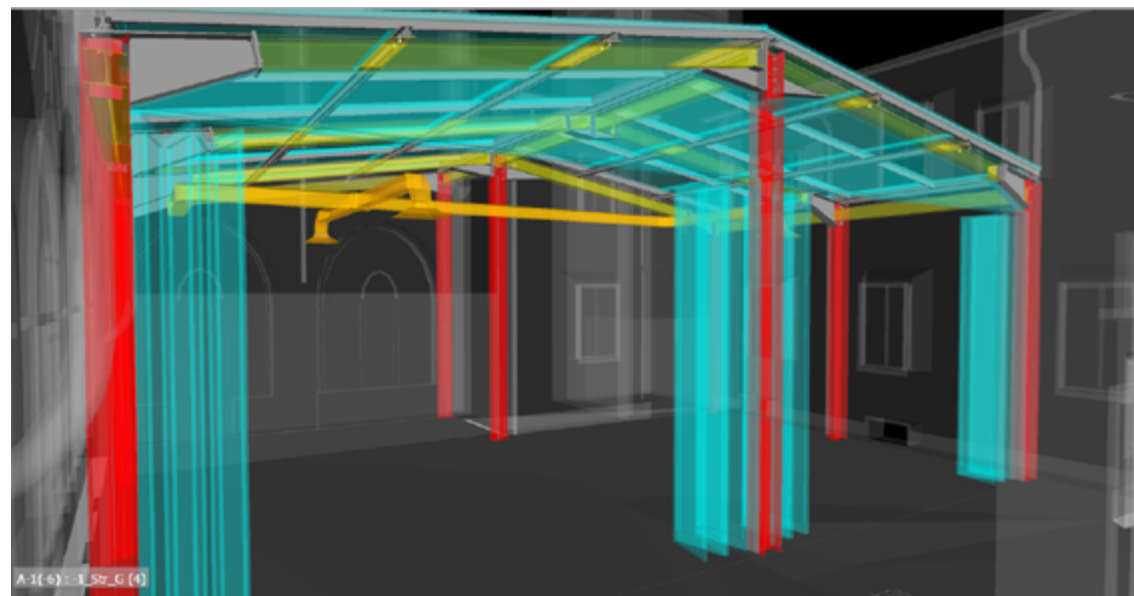
Gantt chart loaded in Navisworks, with WBS code highlighted.

In the picture above is shown the Time schedule imported into Navisworks, thanks to the WBS code under the "Utente 3" column, and the matching rules shown in the picture below, is possible to create the connection between the documents, that's the real strength, and permit to save time due to a extremely complex association process, that should be done manually otherwise.



Association rules in Autodesk Navisworks.

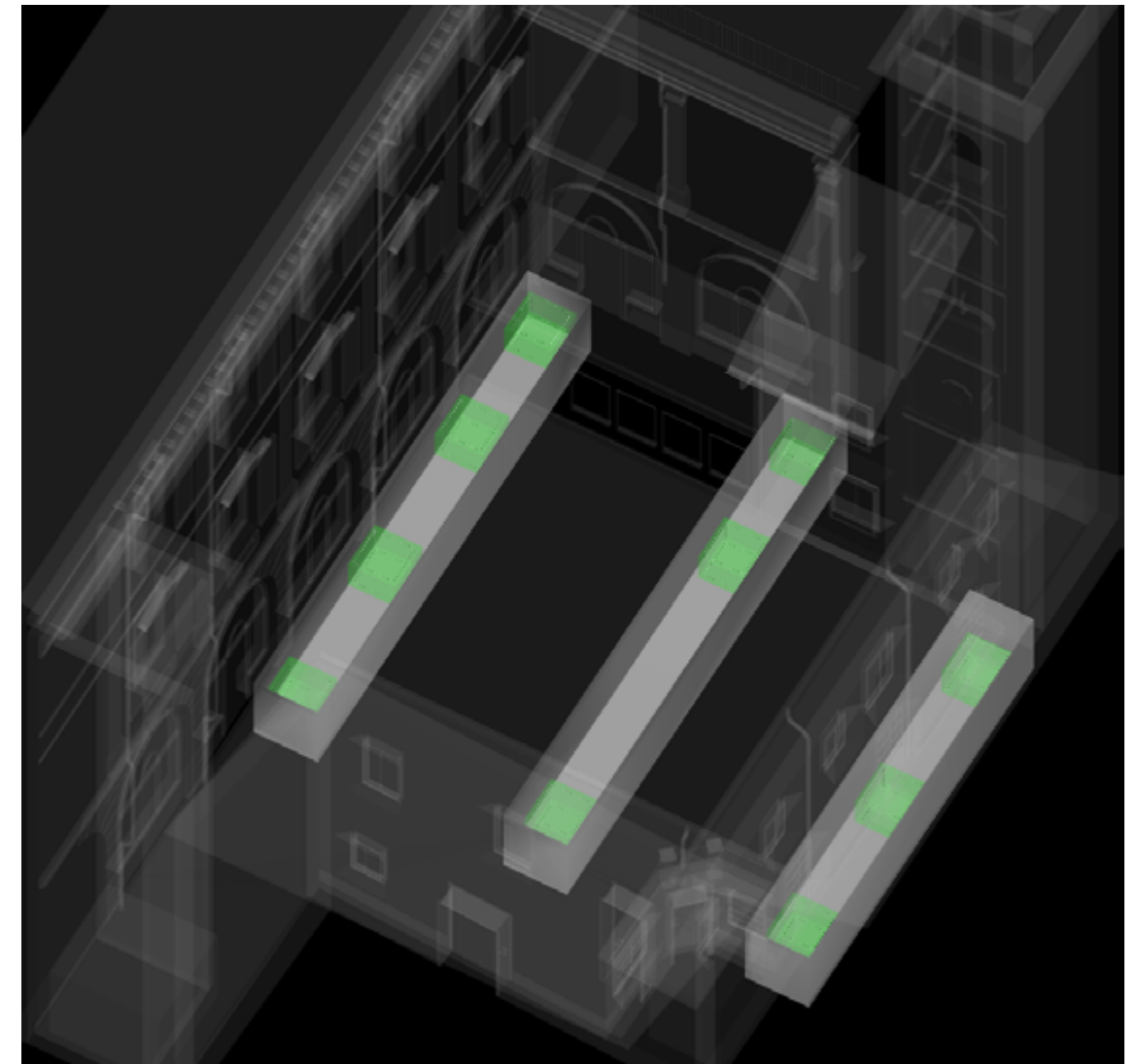
The matching rule done put in contact the various documents loaded in Navisworks, creating an automatic association.



Project view in Autodesk Navisworks.

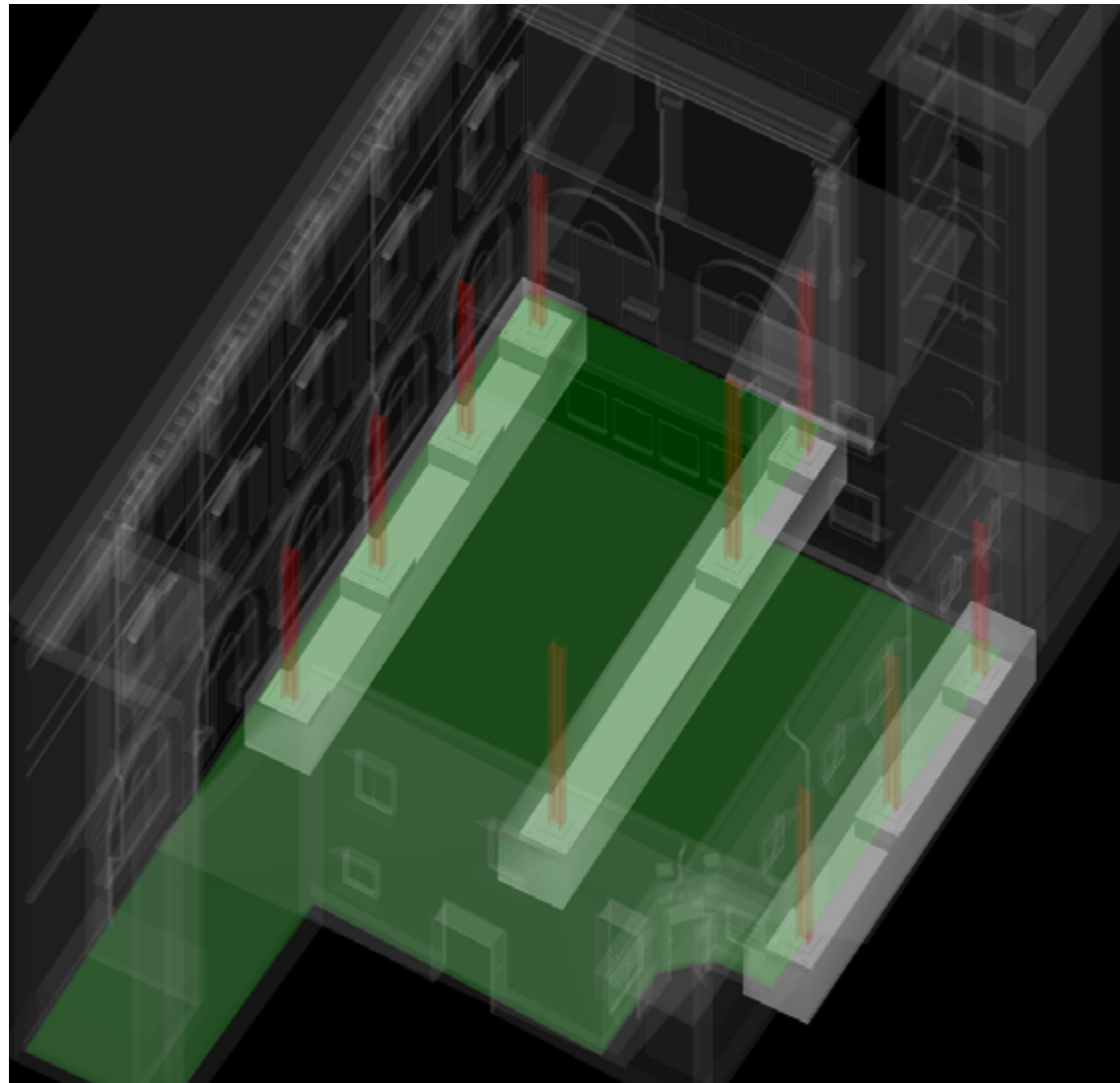
Once the simulation has been done, the model was navigated to find possible interferences, then to any categories was applied a color to distinguish the elements contained into the model.

- Foundations: Here there's a representation in Navisworks of the construction simulation, in this picture is shown the foundations creation into the excavation, marked in green that means a new construction.



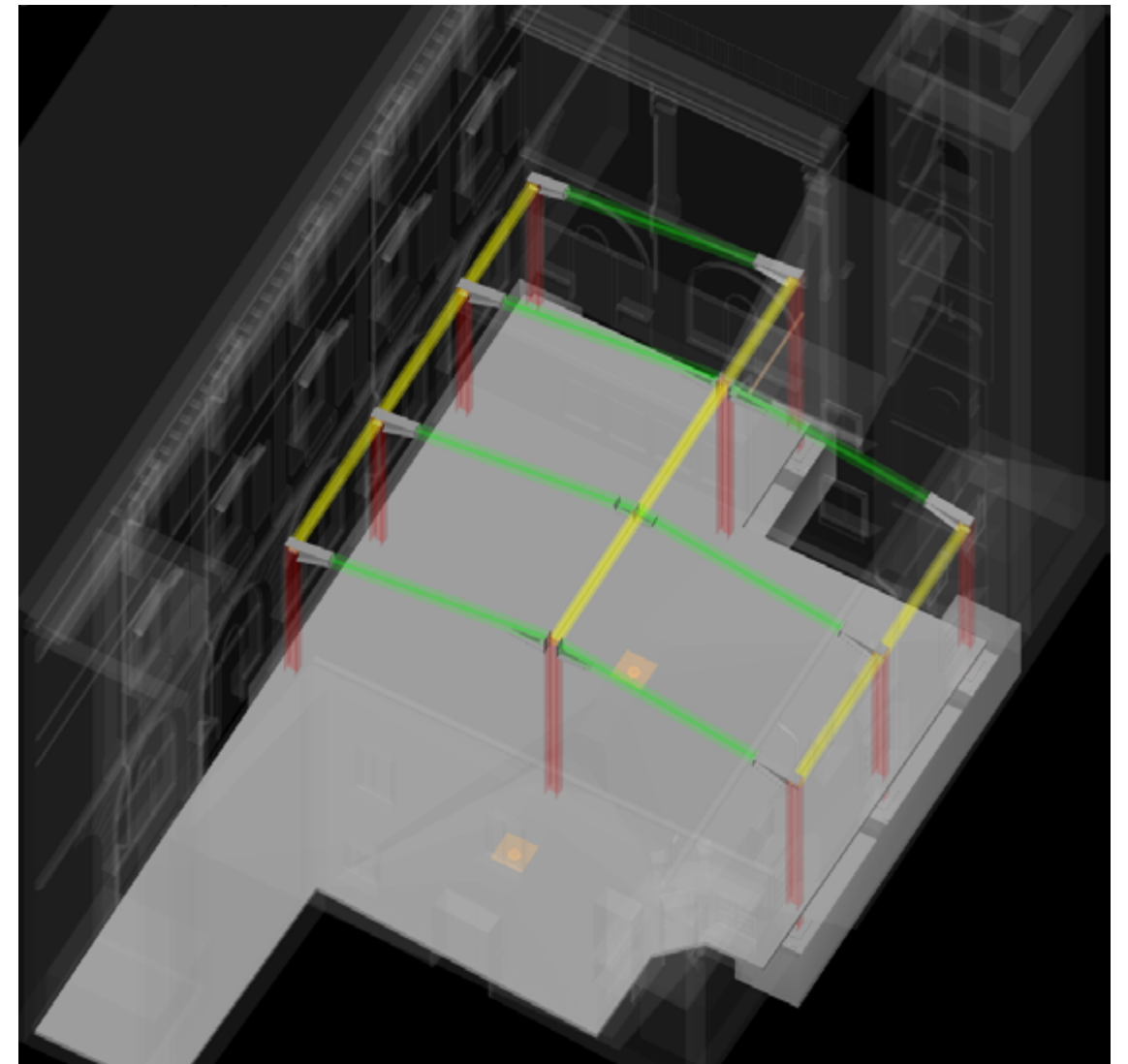
Navisworks simulation, excavation phase.

- Columns: this following step shows the pillars assembly, suddenly followed by the new basement concrete floor.



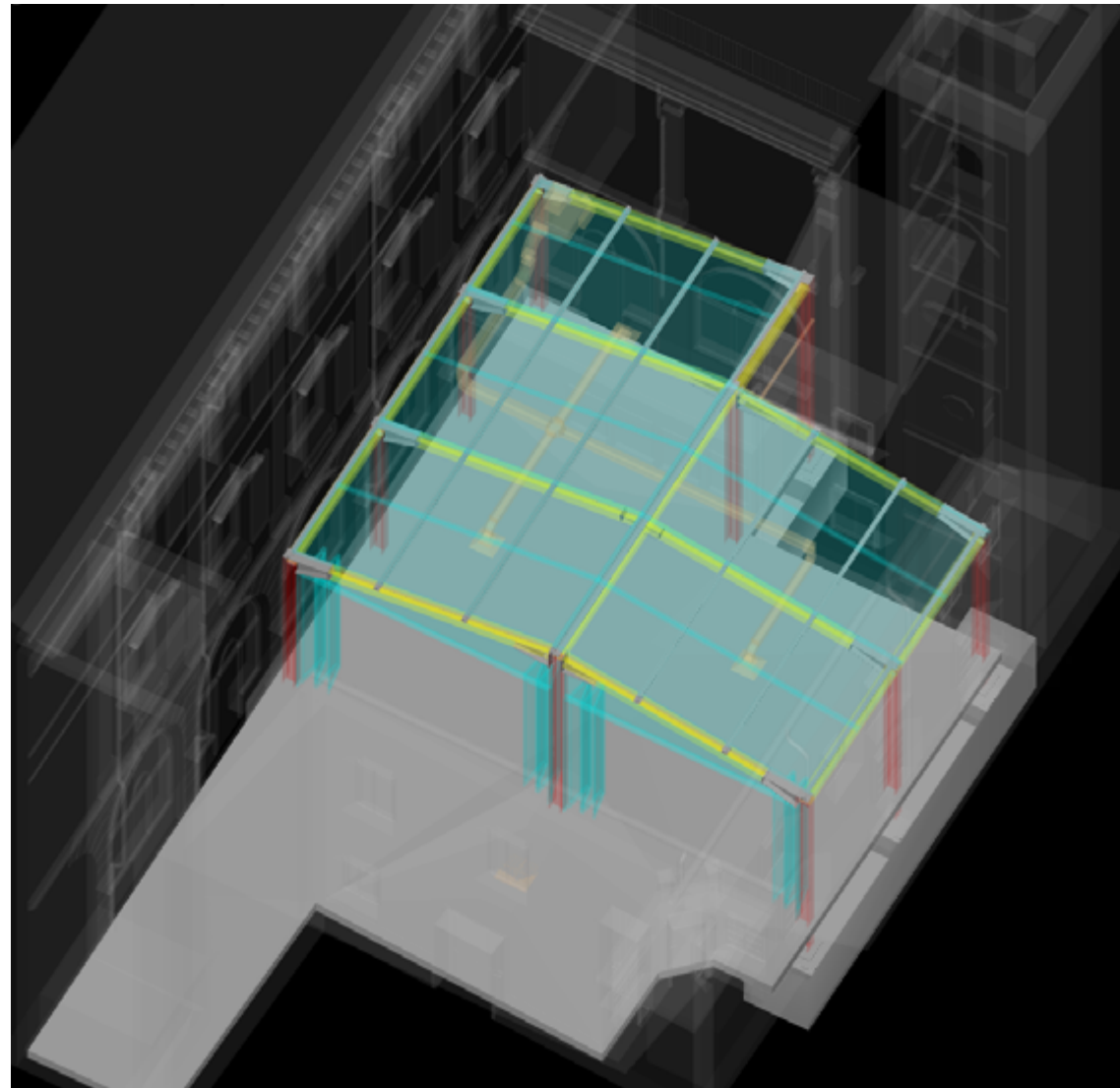
Navisworks simulation, pillars assembly phase.

- Beams: the main beams assembly, represented in yellow, it happen after the steel connection mounting.



Navisworks simulation, main beams assembly phase.

- The whole project representation in the simulation, it's possible to see the different items composing the project, the glassed parts are colored by a light blue, columns by red, beams in yellow and HVAC system in orange.



Navisworks simulation, the complete project.



3.1.1 BIM Modeling results:

The first result reached in this work, is the capability to shape a project in BIM environment, using different templates such as Architectural, Structural and MEP, everyone with its properties.

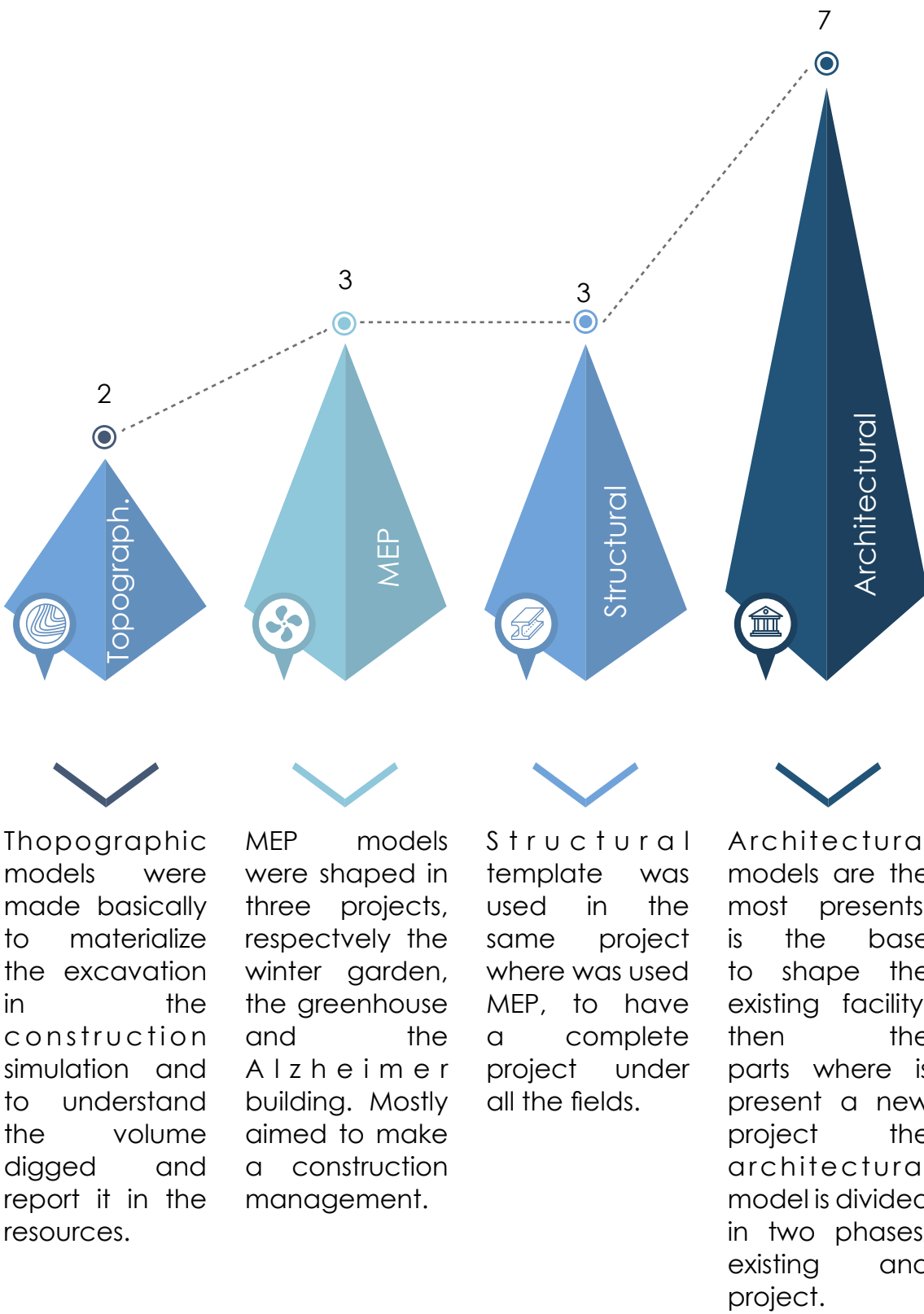
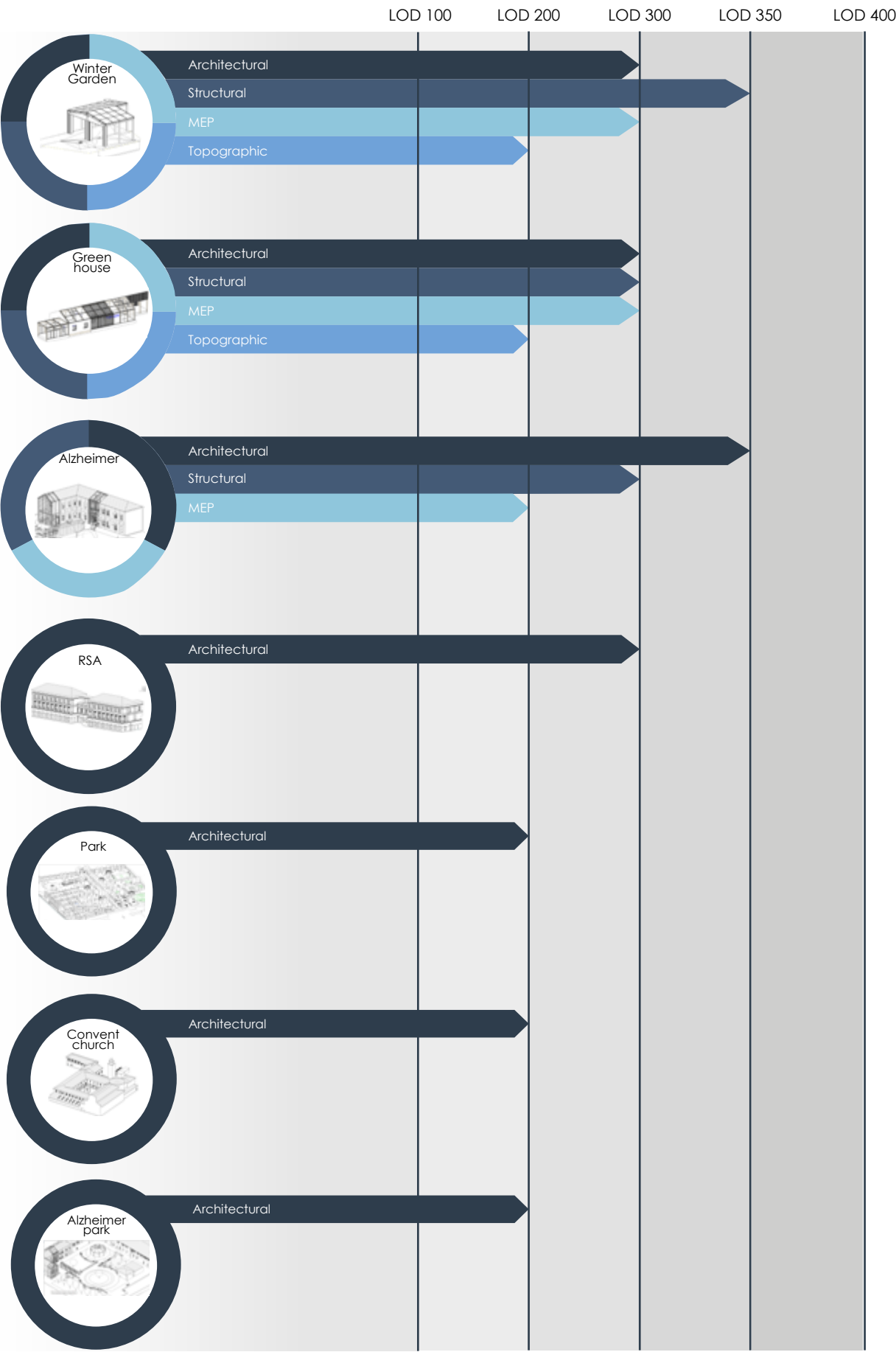
The deep knowledge reached in the parameters use, aimed to accomplish the main tasks of this thesis through the parameter creation, manipulation and application to the items present in the project, is surely the most valuable result reached in shaping phase, meant as the ability to shaping the items present into the model with the clear purpose to reach a goal, that in this case was the construction management then the fourth and fifth dimension.

Then the shaping meant as the restitution of the existing complex was improved by the point clouds use, and by the creation of new parametric families at high level of complexity, that helped to understand what a parametric item really is and its potentiality.

A preliminary consideration was done on the LOD to be use in the project, this aspect of the BIM shaping is still not completely codified, the LOD choice was done in according with the project aims, but is still not possible to associate a LOD to an defined goal such as 4D or 5D or even virtual reality ecc. Anyway the LOD used to shape different parts of the model was heterogeneous, leading to an highest LOD for what concern the structural connections, due to the precision of the Advance Steel tool.

The LOD definition is a very important step in the decision process in the preliminary phase because it's what will establish the efforts to spent in the shaping phase, and the modeling results to be reached aimed to obtain a determinate output from the BIM model. Thus is not possible to understand what LOD was really used, because of the absence of a certain LOD average calculation between different items shaped with different LOD.

The restitution of the Trompone complex reached an not completely satisfactory degree, because of some process fails, due to the late use of a reliable survey, thus the federated model still has many errors, and leak, to be adjusted and improved in the future, anyway this work make a important solid base to work on, creating the first BIM model for this facility and a sharing strategy that can surely be improved in the future. With our work we've established the guidelines to be followed to work in BIM environment on this complex, that's surely one of the goal of this whole work. The facility shaping has reach the following degree as showed in this scheme.



3.1.2 Sharing strategies results:

Surely most time in this work was spent finding the best strategy to share the BIM models in a common data environment created following the British standard, connected with the point-clouds use that has modified many times our strategies leading to the final two strategies adopted.

The use of links results a quick and useful method to share big data quantities coming from a multitude of files, otherwise impossible to contain in one single model, the two strategies finally adopted responds to the necessity to operate into a common data environment.

Of course the strategies were developed between many options, and it's clear that we didn't tried all the sharing possibilities because are theoretically infinite. Thus using different kind of links and in some attempts also mixing both basic sharing method, link and worksets, aimed to manage the visualization of point clouds survey files nested in multiple link degree.

Anyway there were found some weaknesses in the process, such as the impossibility to share the same path of nested files in different federate files, or the leak when some files present in the federate is moved, all the connection should be relinked.

The strength is that those kind of connections made all the models easily manageable, where a federate file never pass 5 mb, also if there's connected many heavy files.

The objective reached was to create a sharing strategies that works, satisfying the sharing and visual necessities, it was also thought to be implemented by theoretically infinite other models, aimed to have a growing degree of detail, improving the existing model, that can also be implemented by new projects on the facility. As previously said it was created a base to work on in the future, for what concern the shaped model and also for the sharing strategies into federated models that compose the whole BIM model of the Trompone facility.

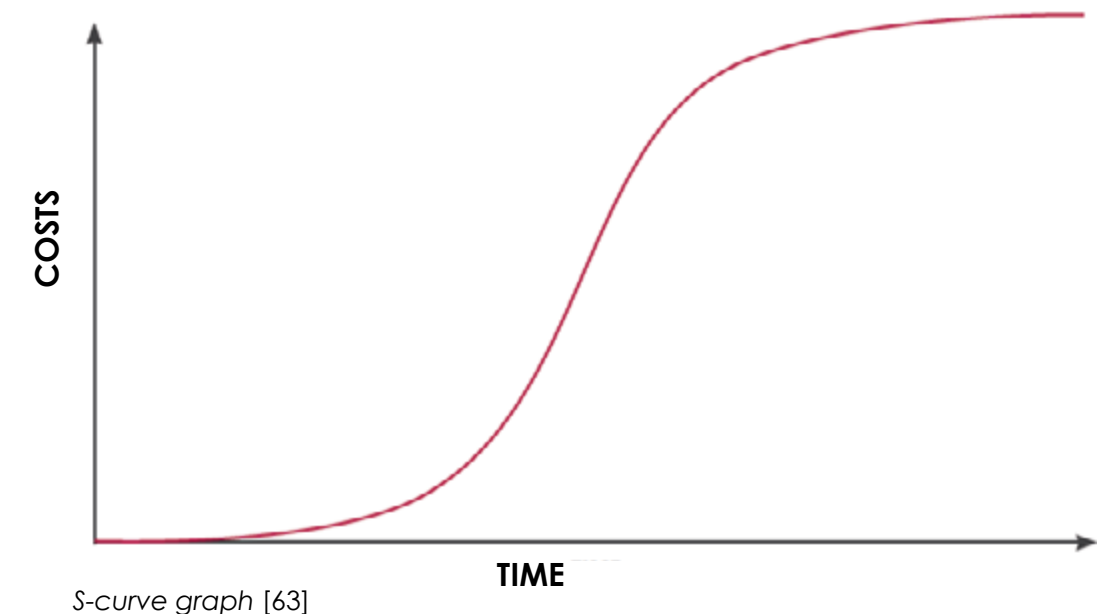
The two strategies finally adopted were widely explained and discussed in the methodology chapter, and it's finally possible to say that this kind of sharing method results useful in a dynamic environment, specially in our case where the working group was composed by several people constantly changing. The two sharing strategies adopted are thought to be used in different moments of the process and by different actors, while the first strategy is though to be used by the BIM specialists during the shape phase. Instead the second strategy adopted was created to detect the models by the BIM coordinator during in a clash detection phase, especially during the transition from WIP to Shared folder in the common data environment.

3.1.3 Project management results:

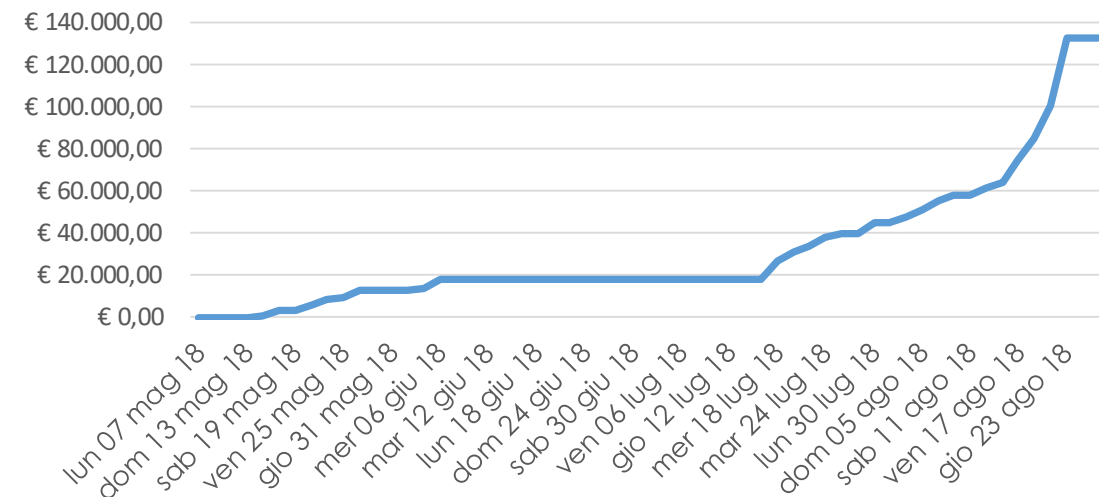
The project management is aimed to control any aspect of the construction phase, basically passing through the time and costs control. In this paper was developed this aspect, that represent a higher control level of the construction process, which request is constantly growing up especially in big structures, containing a huge number of resources to be managed.

In this scenario the Gantt chart connected to the BIM model was already widely explained, in all it strength, but it was possible to extrapolate from MS Project some reports that better shows the relation between timing and resources applied to this project, which study can be very useful to understand how a construction process works, and how the related resources can be managed.

- S Curve, this is a project management fundamental chart, representing the relation between costs and time, then the two main elements I wanted to control in my project, normally the curve has to have a S shape, where in the first part the curve has a low slope, growing in the central part due to the main effort in terms of resources spent related to time, leading to a low slope again in the final part normally representing the construction site dismiss where the efforts majority were already spent. The derivative of the curve in any point represent the effort coefficient spent in that determinate moment of the construction process[60].



S CURVE TIME/COSTS

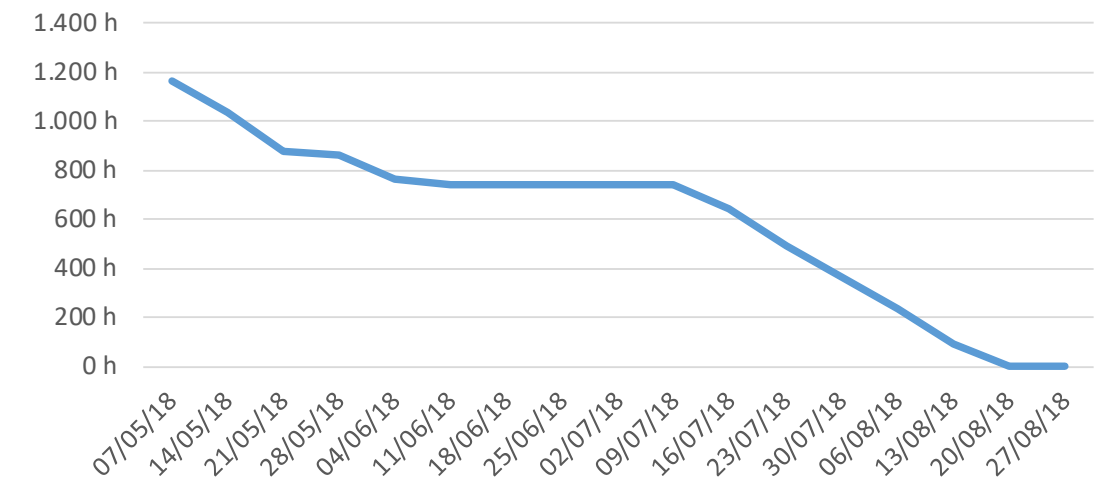


Winter garden S-curve project.

The chart above represents the S curve extrapolated from the time schedule made in MS Project, it's possible to find suddenly some differences between the one showed in the previous page, firstly because the ideal S curve previously showed represent a medium-long time work, instead my project lasts 81 days, this aspect make my curve flatter, secondly the central part has zero slope due to the 28 days needed to seasoning of the concrete in the foundations, that usually happen also in normal temporal length project, but the concrete seasons time is spread along a longer time and it doesn't make the curve so flat, anyway the chart preserve the S shape.

Those charts represent one powerful tool used by the project manager aimed to understand the relationship between the resources that he has to administrate and to manage in the best way to accomplish the project goals, and also represent the results of the application of traditional methodologies such as time scheduling and quantity surveying to new technology like BIM that are revolutionizing the construction industry.

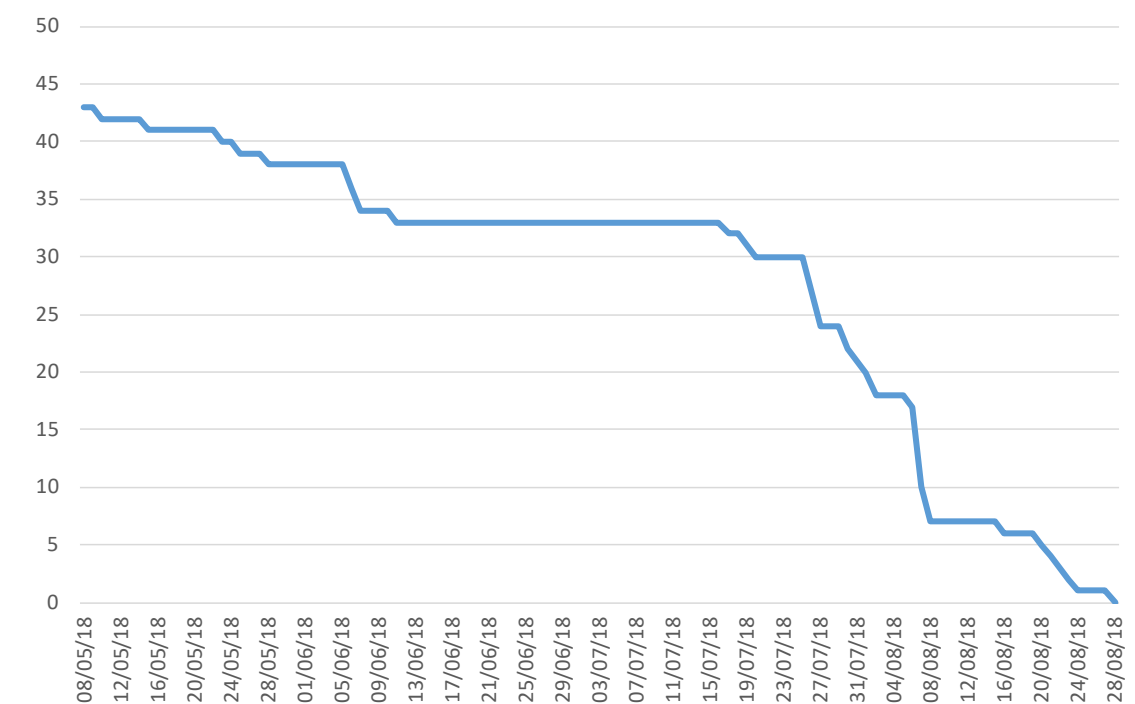
CUMULATIVE WORK REMAINING



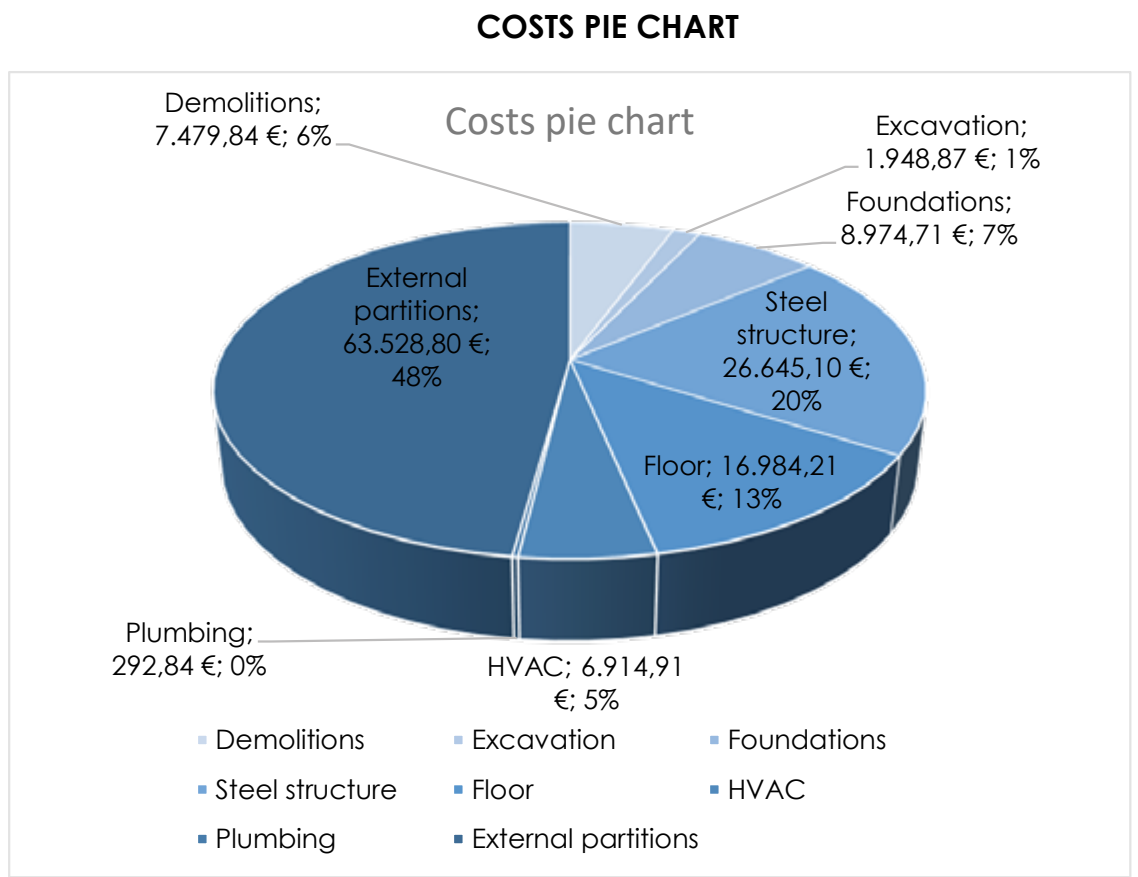
Cumulative work remaining chart.

The chart above shows the a kind of S curve reverse, represented on the vertical axis the remaining working hours, while on the horizontal is always shown the construction process timing, it is possible to find a correspondence between this chart and the previous one where is always represented a no flatten central part always due to the concrete seasoning in the foundations. The same chart content is showed below, but working hours are replaced by activities created in the Gantt chart, in relationship with time in the horizontal axis as before.

ACTIVITIES REMAINING



Activities remaining chart.



In the chart above is showed a pie chart representing the project costs, it's possible to see how the external partitions are covering almost the 50% of the whole project costs amount. The second biggest voice is represented by the structure that cover the 20%.

Also this chart obtained as an 5D project output is a result of the combination of BIM model and Gantt chart in MS Project, and represent a reliable report aimed to understand and manage the project costs.



3.2 Future developments:

The construction industry is deeply changing in the last years, and BIM methodology is a fundamental part of this process, leading to a more automatized industry, managed by BIM softwares.

This thesis represents an attempt to deepen these aspects, trying to use BIM to reach others' goal further than the normal BIM modeling.

Surely the shaping phase can be implemented by other informations where was found a leak, improving the LOD, that wasn't developed enough for what concerns the existing facility due to the leak of many information such as: materials, systems, physics attributes etc, basically for all the information except the dimensional ones.

The sharing strategies can be improved, due to the many troubles occurred already explained it wasn't possible to establish common families, materials and parameters to be used during the shaping phase, that should be done to have an organic model composed by the same items agreed by all the actors in the preliminary phases. As well the LOD used in the model aren't organics, and weren't decided previously, in accordance with the model goals, but developed step by step with the project growing, that leads to a not organized LOD value, and the impossibility to establish an exactly LOD with whom the project was developed. This point occupies a central spot in the speech about construction industry and BIM, the necessity to understand which LOD is required to any task and find a way to calculate an average LOD value in models composed by different detail degrees.

The project management that represents a large part of this thesis becomes a fundamental tool in construction industry, but also in other industry fields. In this thesis was treated beginning from the project tasks decomposition made in the WBS code, that was made by myself after analyzing the most common standards codification currently used, where was found a multitude of classifications, and a future improvement is to create a common code to be used worldwide putting in contact all the various classifications.

Anyway the activity code created for this project is composed by three parts, where only the first one was really applied to the BIM model to create a temporal simulation, due to the small entity of the project as widely explained in the methodology chapter.

Surely a future development is to apply also the other parts of the activity code to all elements in the project assuring firstly a more detailed plan considering any single element with its positioning attribute, that wasn't useful in such a small project, but becomes necessary in larger size buildings, then the last code part applied to have a direct connection with the cost source, and finalized to obtain a cost survey.

ATTACHMENTS

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Grazie alla professoressa Anna Osello e all' ing. Matteo Del Giudice, al laboratorio DrawingTOtheFuture del DISEG e a tutte le persone che ci lavorano e lo vivono, per avermi aiutato in questo lungo percorso di tesi, sopportato e sopportato e per creare un ambiente virtuoso dove l'apprendimento e la ricerca sono uno stimolo ancor prima di essere un obbiettivo.

Grazie alla mia famiglia per il costante sostegno, per aver sempre creduto in me, e non avermi mai fatto mancare niente.

Grazie a Meuri e Matte senza i quali non riuscirei neanche a immaginare questo lungo viaggio.

Grazie a La Coruña, l'ETSAC, agli amici, il surf, le feste, la spiaggia e per aver segnato un capitolo indelebile della mia vita.

Grazie a New York, a chi mi ha accolto a braccia aperte, e ha avuto la pazienza di insegnarmi, e di trasmettermi un'attitudine.

Grazie a tutti gli amici di Ande semplicemente per essere quello che sono, una seconda famiglia.

Grazie a chi, con il suo cammino, è stato fonte di ispirazione continua.

Grazie a Via Baltimora.

Grazie a Cri, Muz e Matti.

Grazie al Gruppo I.

Grazie ai viaggi in treno, le sveglie alle 6 del mattino e a tutte le giornate passate al Poli.

Grazie a tutte le persone che ho incontrato durante il mio percorso, che inconsapevolmente mi hanno lasciato qualcosa, e che mi hanno reso la persona che sono oggi, e saranno parte della persona che diventerò domani.

Grazie.