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# DIM DATA SHARING FOR THE BUILDING PROCESS

Case study of Whitworth Park Aberdeen House

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“Se camminassimo solo
nelle giornate di sole,
non raggiungeremmo mai
la nostra destinazione”

(Paulo Coelho)

A *Voi,*
che ci siete soprattutto
nei giorni di pioggia.

# ACKNOWLEDGMENT

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# Introduction

In today's scenario, it has become increasingly common to hear about BIM but often confuses itself with its interpretation, sometimes it is traded for a software of product; instead, as the National Institutes of Construction define, "the digital representation of the physical and functional characteristics of an object". It is a "Construction Information Container" where you can enter graph data and some technical information about the expected life cycle. The purpose of this report is to show and highlight the advantages and potentials of this methodology in building and maintaining built environments, extending the theme of interoperability between two of the most used design software such as ArchiCAD and Revit. It is the theme of interoperability, horizontal and vertical, one of the study objects of the DIMMER project (District Information Modeling and Management for Energy Reduction), which has studied and validated a method to apply to the constructions involved in that system.

The method is developed in stages. First, you model the 3D of the building by entering all the information about the choice of materials, the type of structure and the energy characteristics, if the construction year is always the same or if there are added parts at a later time. From the model thus obtained, we also carry out energy studies, in terms of efficiency and $CO_2$ consumption.

As mentioned earlier, you create a container of data that can be consulted by other operators, so that communication is based on interoperability, in fact, in these phases, use of different format files (IFC, gbXML, dxf).

Associated with the BIM method there is the GIS method, linked to spatial geographic information: that is another way of collecting, storing and processing data to be geographically represented.

To provide a clear and complete reading key, the topic was dealt with in several phases.

The first step is a theoretical description of what is BIM, the path to its formulation and definition and how it has become a fundamental part of the constructive process in the construction industry; and how the entire DIMMER project was gravitating around it.

The second phase is a focused on interoperability: a thorough study on how to facilitate the exchange of information between engineers and architects, avoiding the imposition of certain software but trying to create a collaborative network through a common and interchangeable language.

Finally, the third phase, the Manchester case study on the development of an energy model first creating an architectural model and then perform energy analysis. In order to evaluate the reliability of the obtained model, it is possible verify the energy consumption and its performances.

# Chapter I

# BIM

[1] National Institute of Building Sciences (NIBS) introduces the meaning of BIM

## I.1 Why everyone talk about BIM?

BIM technology is increasingly used and recognized by engineers, architects and suppliers for reduce construction costs, increase quality and implement projects that could be impossible without digital support. It's a lot more than one technology, it is a methodology and provides those universal tools that are suitable to facilitating the job of the professional, ensuring more reliability and precision in the calculation and evaluation of the structural part of work, in the choice materials and their quantity, energy optimization and cost estimates of the intervention.

What the BIM introduces is a fundamental change, where the projects are not under the supervision of a single responsible figure. You can work individually, as the model is a central resource of information that allows to intensify communication and interdependence; that is, models BIM are collaborative platforms. So, collaborative processes promote communication, creating shared decisions and interdependence which allows the distinctions between parts.

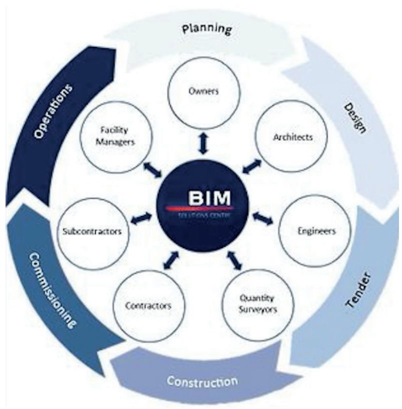



**Fig. 1**
BIM modeling services. (www.bimsolutionscentre.com)

> “ Imagine for a moment all of the individual actors in all of the phases of a facility’s lifecycle. Imagine that all of the actors, working in familiar ways within their own specialty areas, are able to gather information, explore option assemble, test and perfect the elements of their work within a computerbased model before committing their work to be shared with or passed on the others, to be built, or to be operated. [...] In this 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 the project team of 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 the needed to support real property acquisition and management, occupancy, operations, remodeling, new construction and analytics ” **[1]**

In general, it includes a series of technologies that are turning the way of designing and building: it is possible to use a rich database to virtually characterize all aspects, relevant to a structure or system. But, what distinguishes the classic CAD design from BIM? BIM is not a representation, but it is a simulation of the structure.

At the base of each project there is a number of goals and criteria to reach from which you make a list of development hypotheses. BIM is considered as a process of developing, analyzing data of virtual model generated for softwaretoolsindifferentaspects. The theoretical developments of the BIM suggest that not only is it useful for geometric modeling of performance of a building, but it can also help in project management construction and cost control and lifecycle.

If the pattern is widely respected during construction, will become one useful tool for the designer to manage and operate the structure of the work. In each case, the information contained in the model can be used for the modeling management, additions and maintenance. As explained in the beginning, when it comes to designing a complex work, there will not be a single design, but every technical figure will have its own prototype; so, in theory, these models will have to be in symbiotic, communicating with each other transparently. This is what this system aspires.

In the current practice, it happens when passing through a software to the other, from platform to platform, there is a loss of data: translators may not transfer all information, and created inconsistencies and errors, which can be reduced by bugs. For this reason the design must be as clear as possible. The essential element to achieving an optimized model consists the ability of each person to communicate freely, where decisions are taken by those who are at the most appropriate level of competence and must know how to take advantage of the team’s knowledge. It must be demanded opening and transparency from the team.

In conclusion, BIM is committed to the constant improvement of quality and efficiency in the constructive environment, however, the current business and models contractual does not encourage its use, in fact they permanently inhibit it collaboration within it.

The goal is therefore to do this system a design standard, creating contractual relationships centered on making decisions that best think of the project and start again equally the responsibilities of all participants.

## I.1.a History of BIM


The concept of Building Information Model was born around the 70's through semantic data models in mechanical engineering. In the beginning, these models were designed as logic boards for machines for the production of engineering parts and, subsequently, were adapted for the building industry as well. BIM has acquired several names, such as: product model, virtual building or intelligent object model, but has only been in use for the last twenty years.

The term BIM began to spread when the idea of Virtual Building Solution was introduced with Graphisoft's Archicad software. This software has enabled technical figures to create a three-dimensional virtual representation of their project instead of traditional two-dimensional drawing. This was a fundamental breakthrough, as it provided a large amount of data inside the building model, including information such as geometry, building spatial data, properties and the amount of items used in the project.

The first person to divulge this term was Jerry Laiserin, an analyst focused on future technology in the building industry. He alongside designers and builders in the choice of technology systems. He was written numerous articles and participated in several seminars and workshops, contributing to defining key concepts of digital practice in the twenty-first century.

## I.1.b Switch from CAD to BIM

The term CAD stands for Computer-aided Design, which refers to the information technology sector that is used to utilize software technologies and in particular computer graphics to support the design of both virtual and real artifacts.
It is therefore a very generic term that usually refers to software-oriented software systems (civil, industrial, electronic); they are usually represented in vector form (dxf, wmf, eps).

In the early 1980s, the explosion of the CAD computer phenomenon radically transformed the way in which thousands of designers worked, but over the years they realized that instrument of representation was nothing more than a digital pencil, which the evolution of technology, we have moved to 3D modeling.

Around the 90s, very powerful and versatile 3D software was released, which marked the inexorable transition from two-dimensional design to dimensional. In the beginning, their purpose was to create a tool of support the visualization of what you were planning, creating a realistic view or a render that can concretize and help you give an idea of what the project would be when it was realized.

BIM, on the other hand, represents a working methodology, an important opportunity that could completely revolutionize design, so that all design figures can work in a coordinated and efficient way, thanks to the interoperability of this approach, optimizing the time and cost. BIM is used to digitally design and create a building.

**BIM is not a technology but a process.**

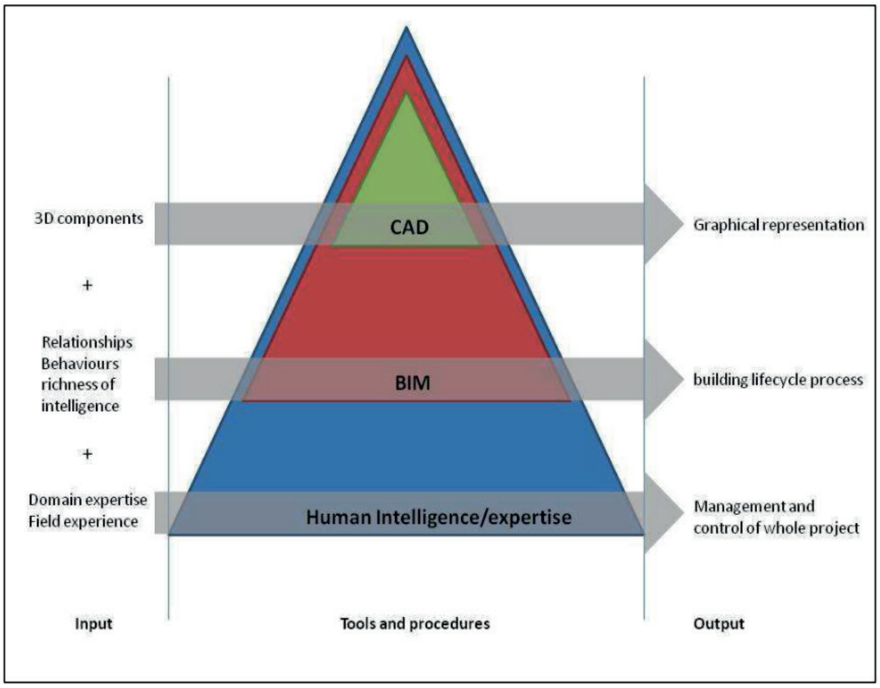



**Fig. 2**
Relation between CAD technologies and use of BIM.

According to the relevant legislation, the Procurement Directive, art. 22, paragraph 4, "for public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modeling tools or similar". As far as the Italian territory is concerned, the Code of Conduct (Dlgs 50/2016) states that one of the goals of the Code is precisely to introduce gradually the use of it and digital tools in the field of construction and infrastructure (including BIM), but responding to two fundamental features: the use of interoperable platforms and open file formats. It is not yet mandatory to use BIM, but surely it is pushing professionals to make use of BIM.

UNI 11337 is a document defining the performance characteristics of the BIM.
It encapsulates inside what will be the common language by providing univocal and interoperable information among the actors in the industry. The rule is composed in parts. Part 1 defines models, workflows and information objects for product and process. Within a BIM model there are "D" elements, where each element relates to a certain data set:

- 4D relates to scheduling information such as when an element will be built;

- 5D is cost estimating for each aspect of the building;

- 6D deals with the sustainability targets within a building;

- 7D covers the handover process to the building owner, detailing accurate facilities management and asset management data. **[2]**

The BIM will become the Big Data incubator, so you can read more in-depth reality and then simulate it to propose smart design solutions to designers.

**[2]** www.firstinarchitecture.co.uk

This is not just a revolution from a software point of view, but it will also be a generational leap in manufacturing, where with the advent of new 3D printers, new digital control technologies and new materials, it will be possible to twist the process constructive construction.

The BIM methodology should not only be seen as a set of software and technologies, but also and above all as a stream of organized and structured information.

The heart of this process is the Common Data Environment (CDE), the virtual environment where the project takes shape, where the checks are obtained, communicated and exchanged files of every kind.

The goal is to better share data and design choices between different professionalisms, without losing information from one step to another, by uploading virtual building template webs that can interact with each other.

UNI 11337 is a document defining the performance characteristics of the BIM.

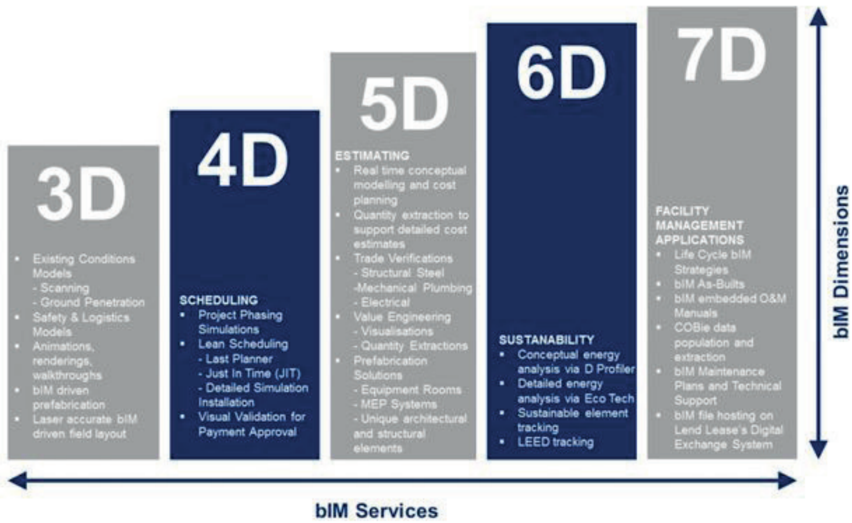



**Fig. 3**
BIM dimensions.
(www.firstinarchitecture.co.uk)

In this scenario, the Cloud technology enables project operators to have a digital platform without the need for costly system infrastructure such as computers and servers, while information is always up-to-date and accessible at any time, from anywhere, anytime. You will be able to work completely in the cloud and use the design software even on a relatively inexpensive device compared to the traditional workstations used today. With the benefit of being able to make changes in real time.

## I.1.c BIM definitions

“a Building Information Model, or BIM, utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility owner/operator to use and maintain throughout the life-cycle of a facility”

It is worth pointing out that there is no definition.

Now, we want to see what is the scenery of regulations in Europe. The Federation of European Construction Industries (FIEC) has published the “Making BIM Global Success” manifesto, in which it outlined the aims for the construction industry to be recognized as an important player in the strategy named “Industry 4.0” and to consider the BIM as an element pivotal to this strategy. It wants to promote a digital construction industry, leading the development of smart cities and smart homes, and boosting productivity, competitiveness, customer satisfaction and the image of the industry. The National Industry Plan 4.0 has as its main objectives those of encourage private investment in technologies and goods I4.0, increase private spending on research, development and innovation, strengthen finance to support I4.0 and startup. The Industry 4.0 represents the fourth Industrial Revolution, a process that will lead to increasingly automated and interconnected industrial production. It introduces the concept of “smart factory” in which cyber-physical systems control the physical processes of the company and make shared decisions through continuous and real time monitoring of all information: multidirectional, dynamic and constant communication between all actors; coordination of productive activities to respond efficiently and timely to events and unforeseen events; integrating information throughout the value chain, from supplier to consumer. **[3]**

**[3]** www.mes40.it

The FIEC vice-president, Kjetil Tonning, has declared that BIM is transforming construction and industry has to drive the effort to encourage its spread throughout the value chain and the manifesto highlights the potential of the BIM in terms of facilitating the implementation of community policy. Also, he states that BIM is changing our way of building, with benefits for economy, energy efficiency, smart cities, climate goals and employment for young people. Currently, in many countries, this technology is only used during the design phase of a building. Despite this, its use for the phases of building and management is constantly growing. The BIM is thus an opportunity for a review of the entire process investment, design, implementation and management of a product. This change will lead to the use of new work methodologies and a different assignment of role players in the building process. The BIM is a methodological approach alternative to the traditional design paper for both the design and process management part. Its introduction at an operational level necessarily requires an investment of economic resources and time by the stakeholders. Government incentives and national initiatives are strategies to support and disseminate these experimental and non-conventional projects.

## The FIEC believes that standardization is necessary.

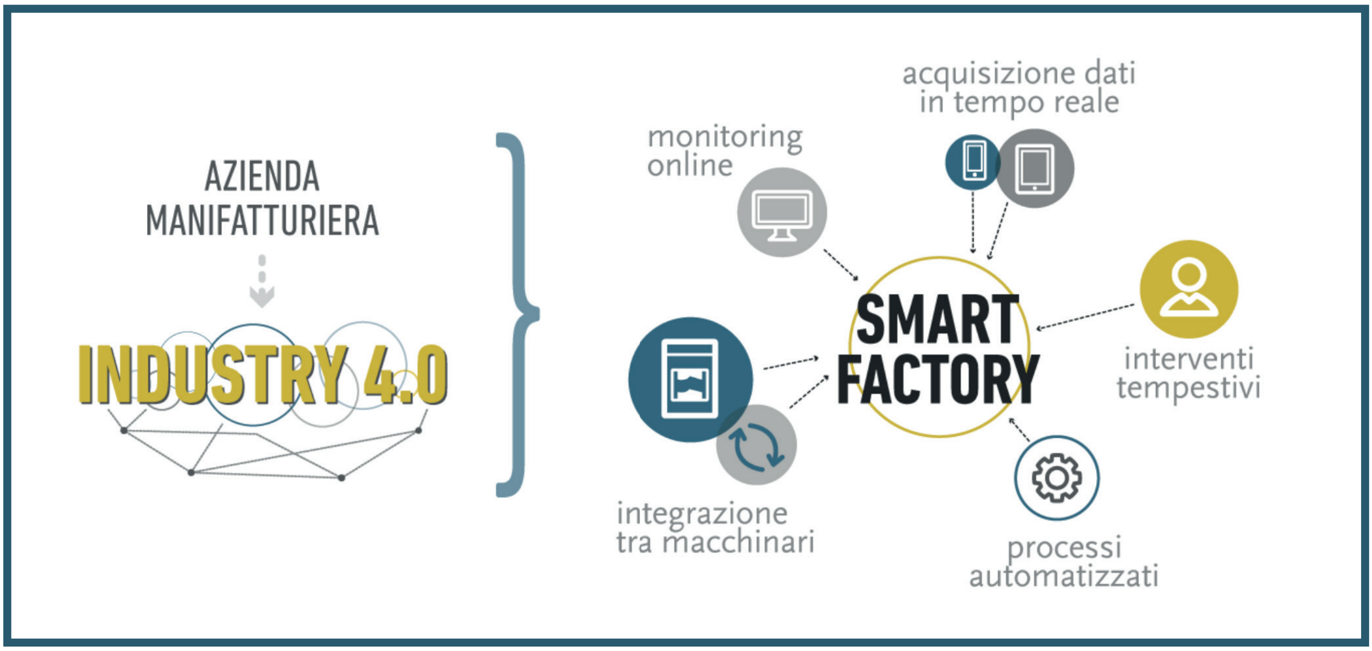



**Fig. 4**
Industry 4.0

In the field of internation, the leading nations that have adopted the BIM methodology are the following:


1

**UNITED STATES**
2007, the NBIM-US Committee publishes the National BIM Standard Version 1 - Part 1. The document contains many information on minimum standards for a traditional vertical construction and introduces a Capability Maturity Model (CMM) that reports a complete set of requirements under which the body of data could not be considered BIM.

2

**CANADA**
2011, The National Research Council of Canada publishes the Environmental Scan of BIM Tools and Standards. This report lists 79 commercial software used in the AEC industry, distinguishing three phases of the product lifecycle: Planning/Design, Realization and Management.

3

**DENMARK**
2011, obligation to adopt BIM for all projects and works over 667.000 € in public buildings (new construction, extension, renovation, maintenance)

# BIM IN THE WORLD


4

5

6

**FINLAND**
2007, the requirements for BIM from Senate Properties are detailed in 9 documents. adoption of BIM and IFC standard on all new construction and renovation projects.

**NORWAY**
2010, the Norwegian Directorate of Public Construction and Property - Statsbygg requires openBIM (IFC) in all projects. Moreover, Statsbygg has already decided to use the BIM for the entire life-cycle of the building (project, construction, management)

**SINGAPORE**
The implementation strategy for BIM solutions takes place through a combination of action plan activities: engaging the industry in e-Pian Check; implement a public training program through periodic seminars; working with training institutes better to prepare new industry operators to use BIM 3D in their own design activities.

**AUSTRALIA**
2010, the Working Group publishes a document that explores the issues related to the adoption of digital modeling technologies within the industry of Australian buildings. It includes design, planning, realization and management of commercial and residential buildings, urban environments and extraurbans as well as transport systems and public infrastructure in general.

There are other countries where BIM is only recommended, there isn’t a specific legislation. This applies to Germany, Holland, Sweden and United Kingdom.

From this global view, it is clear that the guidelines are an essential tool for understanding and integrating BIM into the life of designers and that they can only be developed by public entities that manage significant real estate assets and include the need for a well-coordinated methodology among all project participants.

## I.2 Smart construction

Experts have said that by 2050, global population living in urban areas will double and 70% of the earth's inhabitants will reside in cities. This exponential increase in urbanization in such time will have to be managed to ensure a good quality of life, efficiency and environmental sustainability.

Smart city is an urban area developed and designed to create economic development and high quality of life through the use of integrated technology and resource optimization, mainly in the following key areas: mobility, communication, economy, work, environment, administration and construction.

The concept of smart city is linked to an ambitious project in 2008: IBM has launched a Technology Promotion Plan to create a smart approach to the issues that affect economic growth for a smarter planet. It was therefore intended to stimulate investment in capital, so that European cities would be stimulated to become "smart".

These projects were born, and still being promoted, to an eco- sustainable approach to urban development, to the reduction of energy waste and the drastic reduction of pollution, thanks also to an improvement in urban planning and transport. The smart city definition is centered on "network infrastructure utilization to improve economic and political efficiency and enable social, cultural and urban development" **[4]** where the infrastructure term refers to business and residence services to leisure, quality of life and ICT (fixed and mobile phones, satellite TV, computer networks, electronic commerce, internet services).

Sustainability, in general, is seen as an important strategic component of the intelligent city. Environmental sustainability is important in a world where resources are scarce and where cities are increasingly relying on their development and wealth on tourism and natural resources: their exploitation must guarantee the safe and renewable use of the natural heritage. You have to design smartly to have intelligent cities.

BIM, understood as a smart 3D model with the inclusion of all the data that characterize it, becomes the starting point for entering the complex world of simulations. It is about cognitive design, where the goal is to simulate human behavior, acoustic performance, comfort and habitat of elements and spaces through advanced algorithms and software tools. New software technologies allow to query our computers to achieve and get the "ideal solution" to realize our ideas.

**[4]** Quote from article: *"The concept of Smart Cities; A literature review and a proposed framework for analyzing and enriching dimensions of the "smartness" of a city"*

The main project idea is to reduce the energy consumption and the $CO_2$ emission through a sophisticated system of monitoring data coming from different operators: facility manager, energy manager and energy provider.

## I.3 BIM for DIMMER

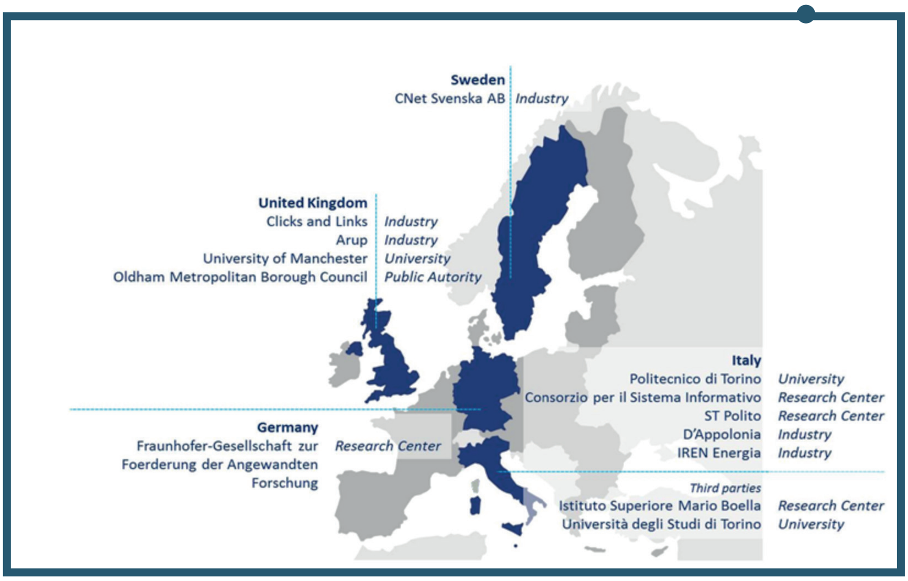



**Fig. 5**
Institutes adhering to the consortium head of the DIMMER project. (www.dimmerproject.eu)

District Informatioin Modeling and Management for Energy Reduction, which acronym is DIMMER, is a smart-city project financed from European community lasting three years, where the Politecnico is at the base of a consortium of relevant importance in collaboration with Manchester University and with north and south Europe. It has been working on setting up a work methodology based on the integration of BIM and GIS. To do this, it was necessary to think about standardizing this process, by modeling the District Information Model (DIM).

BIM models are the starting point for DIM models, whose aim is to spread realtime data about the architectural and geomatic aspects.

DIM methodology is an approach based on simulation of systems that include urban data and architectural data. At the urban level, domains have been created identifying the different districts. DIM models thus created are considered as a "basis for modeling, simulation and control systems, always in real time, to motivate community dynamics based on data interoperability".

Several buildings have been selected, both by type of construction, by orientation and by year of construction. Once identified, sensors have been inserted into the environment with possible scenarios. This has enabled, on the one hand, to get simulation results related to the scenery selected, by BIM modeling and energy simulation, and on the other, to quantify actual energy savings with the actual data being measured. These results were optimized from the point of view of the interoperability of the information, so that they were legible both through the tools applied and both within the software used. The creation of a platform middleware validated through two sample pilot cities in Turin and Manchester is the final result. In this way is possible compare the consumption data before and after the energy efficiency definition at the urban district level, and subsequently, create new policy of intervention.

The process of construction starts from the requirement of manufacture, construction or transformation, and its related to the entire design, construction, operation and maintenance.

## Traditional method

The traditional method provided, at first, the freehand drawing, subsequently, we have used CAD digital design; where all information comes from documents that remain separate from each other.

## Innovative method

The innovative approach, however, is based on interoperability between software and data, typical of the BIM. This methodology in many realities is a common and consolidated practice, but in Italy it is still in the process of being approached. The innovation of this system is that the information comes from the same database. There is no longer any building processor who works on his own documents, but all actors search, draw and provide information within the same database. Instead, they exchange that information through interoperability using automated and digitized processes.

## To make this step, from the traditional method to the innovative one, we need to rethink the entire constructive process.

BIM

Two different definitions of BIM are used:

- BIM, as Building Information Model, "a model needs 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, and second, it must include some information in the model or the properties about the objects beyond the graphical representation"; **[5]**

- BIM, as Building Information Modeling, "is a method that is based on a building model containing any information about the construction". **[6]**

INTEROPERABILITY

Interoperability allows to exchang information to get a representation of the building where you have both the architectural part and the part of the energy simulations. Referring to international literature, the definition of interoperability is as follow: "Software interoperability is seamless data exchange at the software level among diverse applications, each of which may have its own internal data structure". It represents the ability to exchange data between different applications automatically without loss of information.

This way, the actors can continue to operate with the software who usually uses, but at the same time the software share the interchange format, which must become standard; so that everyone works with their own tool, but using the info of colleagues and transmitting their work to others.

**[5]** National Guidelines for Digital Modelling, CRC construction Innovation
**[6]** *"Handbook of Research on Emerging Digital Tool s for Architectural Surveying, Modeling and Representation",* Stefano Brusaporci
**[7]** National Building Information Modeling Standard: *"Transforming the Building Supply Chain through Open and Interoperable Information Exchanges"*

## I.3.a Presentation of case study

Whitworth Park is student residence of the University of Manchester, builded in 1976 and designed by Building Design Partnership and built in 1973-74. It is centrally located on the University campus, close to sports centre, libraries and Students Union. It comprises Aberdeen, Acomb, Burleigh, Derby, Dilworth, Garstang, Leamington and Thorncliffe Houses for single undergraduate and postgraduate students.


**Fig. 6**
Localization of Whitworth Park Aberdeen House from Google maps.

Whitworth Park comprises eight buildings containing one to three story flats for groups of seven, eight or nine students. Each accommodation has single study bedrooms, with shared kitchen, lounge and bathroom in each flat.

**Fig. 7**
Photographic representation of the studied building.

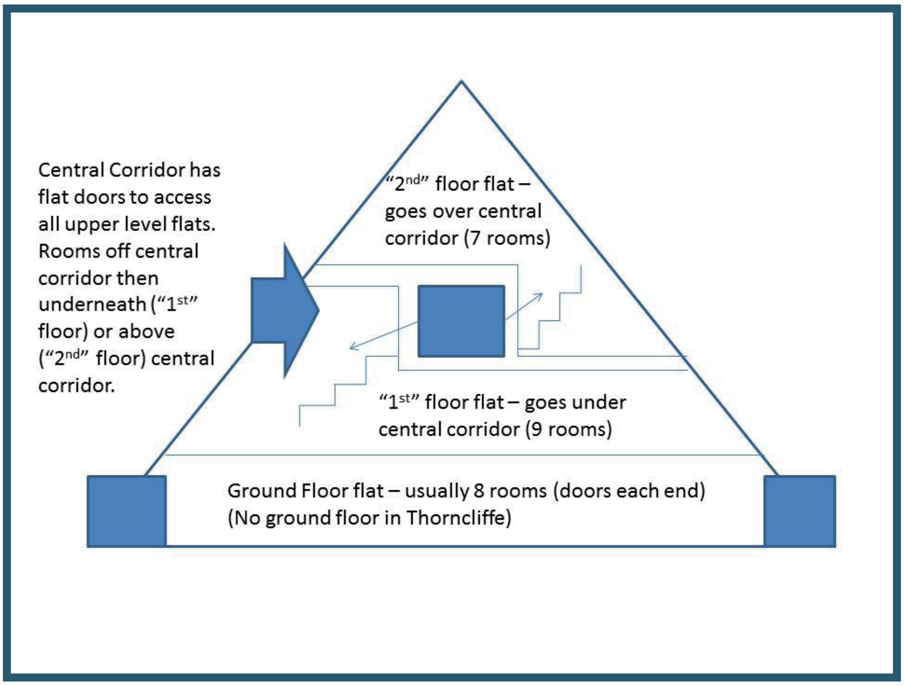
Among the eight buildings, the one assigned to them is the Aberdeen House, consisting of two bodies, each with five floors above ground, for a total of 48 accommodations.

The ground floor has 16 lodgings, the first and second floors are characterized by 12 lodgings, while the third and fourth floor contain twostorey apartmentsforatotalof8lodgings.

Each flat has a shared bathroom (or separate toilets and showers) and kitchen/living room; besides room sizes can vary.

The two factory corridors are connected by open spaces, such as terraces, which contain fire extinguishing stairs. It is a typical red brick building and thick walls, featuring an imposing roof, embellishing the nickname of “toblerone”.

The inside area is structured as follows:




The blue squares mark the doors (ground floor) or the central corridor through the building (upper floors).

**Fig. 8**
End view of a typical Whitworth Park building. Facebook page of Whitworth Park Student Residences.

# Chapter II

# Interoperability

The following chapter was written in the beginning of a difficulty: saving the architectural model of the building, made with Archicad software in gbXML format, and then proceeding with the energy simulation phase.

The version used by Archicad does not allow the file to be saved in .gbXML format, so you have to opt for an alternative solution for your work to be missed. Indeed, it has been of interest to us, as it has been identified in other designers who will probably have encountered the same problem; so we wondered how to overcome this situation.

From here the interest, study and deepening in order to facilitate communication and data transfer, finding both valid solutions and to the benefit of the project, and the same time the issues of interoperability between software.

## II.1 The age of parametric software

The necessity from architects and designers to push boundaries of forms, customization and construction, has allowed to improve and create new digital fabrication tools.

Information technology has given to designers and architects the tools to analyze and simulate the complexity observed in nature and apply it to structural building shapes and urban organizational patterns. In 1980s architects and designers started using computers running software developed for the aerospace and moving picture industries to “animate form”. For this reason, they have need of computer-aided design systems, that are increasingly parametric, in fact they represent designs that change with their input data. Such systems give more control and capability to designers.

The idea behind is to optimize certain design goals against a set of design constraints. The idea behind is to optimize certain design goals against a set of design constraints.

Architects use Cad to help them visualize their ideas. Parametric design is a fast-growing development of Cad that lets architects and designers specify the key parameters of their model and make changes interactively.

Every time the 3D model is modified it will automatically update. The next level is where the parameters determine the behavior of the elements. Beyond that is where the parameters of the elements determine their interactions with each others and further where global environmental parameters influence those interactions. The strength of this parametric philosophy is that works with defined “objects” and not with simple lines as AutoCAD: it has some parametric features but does not seem to have full functionality in 3D; so, AutoCAD does not seem to be a fully capable parametric modeling software.

Today exist many parametric software like Revit, Allplan, Archicad, Dynamo, ecc.

The approach “smart” of parametric software, immediate and fast, is technologically important, because in one job file contains the entire project: opening a single document, in fact, you can access to view and study tables without need to produce, process and store more files, shortening design time and process management. Also, they are developed for the BIM parameters, in particular ArchiCAD end Revit.

They are able to perform energy analysis and delight, and looks like a basic tool for the design of sustainable architecture. It goes in this direction also the ability to export project information to Green Building Extensible Markup Language (tha acronym is gbXML), to carry out building energy analysis.

Sometimes is necessary the collaboration between more software and, to allow the interoperability, is possible save the file in an accessible language for both. This format is IFC (Industry Foundation Classes). Before going to the IFC topic, we wanted to make a premise about setting differences between Archicad and Revit.

## Archicad

The language of geometric description at the base of Archicad, developed from Graphisoft is the Geometrical Description Language (known as GDL). It is used for build the library elements of different type, from more simple twodimensional symbols to more complex spatial forms. Each elements of library is composed from one or more script that generate the solid and its planimetric symbol.

The GDL is a real programming language, in fact each script is a organized collection of instruction for the creation of 3D geometrical forms. Every object is the result of a sort of little software in which are memorized a series of operations, properties and calculations to allow the generation in plan and in 3D of element. But, Archicad provides a standard library of elements, in fact there are many different typologies of objects, like Window Object, Door Object, Generic Object and Attribute Object; they are parametric object.

Instead, Wall, Slab and Flap are graphic entities, not defined from any default list.

Each tool of drawing uses a group of variables or parameters necessary to realize the element considered. There are two management mode of settings of a tool: “set default parameters” and “modify parameters selected elements”.

Each tool has its setting window divided in:

- Plant and section attributes (line type, board type, mesh type);
- Model attributes (materials to be assigned to the model);
- List attributes (ID of the element, component assignment and description);
- Parameterized attributes.

In this way, it’s possible to personalize the elements that characterize the building.
The library of Archicad objects is organized in arguments. Being a directory can be placed anywhere you want.

## Revit

Revit is a relational database: virtual creation of an object that will later become real. The organization of objects is different in this software. Every element is a family, that is divided in three main categories:

- system families;
- loadable families;
- local families.

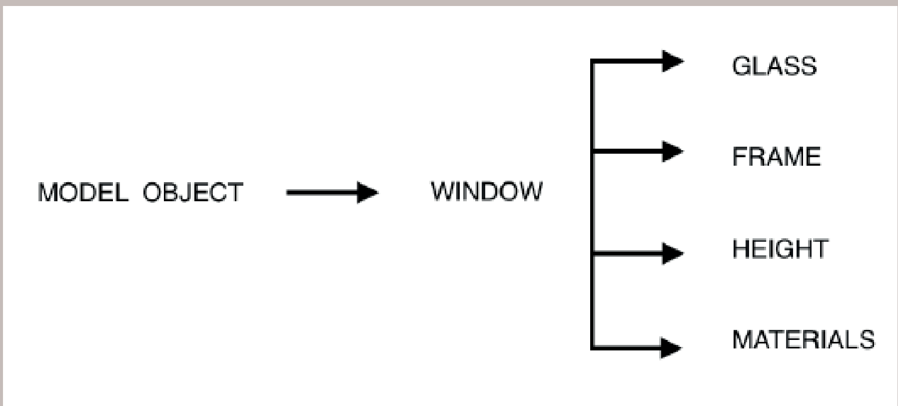
Each family belongs to a category or macrocategory, because allows an immediate and univocal identification of every object.

The .rvt file is a database in which are memorized all parametric informations of the project and all objects that constitute it. There are three subdivisions for the objects, like:

- model object;
- annotation object;
- views.

For each category exists a sub-category, that defines, in a specific way, the graphic aspect of the family.

For example:




The views are cameras with fixed parameters, that is the scale of representation, detail level and orientation. Family is a parameters set with different values and for each set of parameters we have a type, that is the "modulation" of a family. For example, the walls can be a part of same family, but can be of different types. But, only "locals families" haven't the types. For each type there is an instance, that identifies exactly the position of the object in the project. The parameters determinate the aspect or the behavior of the element and there are two different categories, like the "type parameter", defines the characteristics of each specific type, and the "instance parameter", that has effect only on the selected element.

Exist also intelligent relations between parametric elements, named twodimensional relations; they coordinate the changes made to the virtual model.

## II.2 What is an IFC?

The design and realization of a building involve various figures, that each operating within its own area of interest. Suppose, therefore, the strategic importance for the various parties involved the opportunity to exchange information in order to effectively collaborate to the realization of a shared project. And therefore the need for a standardized format allowing interoperability and interchange of data safely, without errors or loss of information. This is the aim of the IFC.

**Industry Foundation Classes** (IFC) is a particular format of data, created to ease the interoperability between different operators.

Its format is ISO certified. It was developed and managed by buildingSMART International (from 1996 to 2008, called IAI, International Alliance for Interoperability).

Its strength is the worldwide network: it has access to governments all over the world andtokeyplayersintheindustries. IFCs are open and neutral data formats for openBIM, independent of the software used.

The IFC has been designed to process all the information of the building through its entire life cycle, from feasibility through construction and maintenance, as well as various design and planning stages. This results in higher quality, error reduction, cost reduction and saving of time, with consistent data and information in the design phase, implementation and maintenance.

The structure of the IFC database is delivered from the STEP format, described in ISO 10303. The STEP format serves as a reference in the industrial building industry and allows the exchange of geometry and data required for the construction. It is a structured data model, a system of classification and description that reported not only the physical components of the article such as walls, doors, floors or their attributes as transmittance, masses, but also to abstract concepts such as quantity, cost and time sequences of operations. The IFC define a single object-oriented data model of the article, “interoperable” among all compliant applications: is a format of open data, public and independent from any software company and, therefore, you can exchange the artifact information simply exchanging files in “.ifc” between the various applications.

There are various versions of the format which, evidently, is continuously developed emergenceof users’ needs: the most widespread is the IFC 2×3.

## II.3 IFC Property set

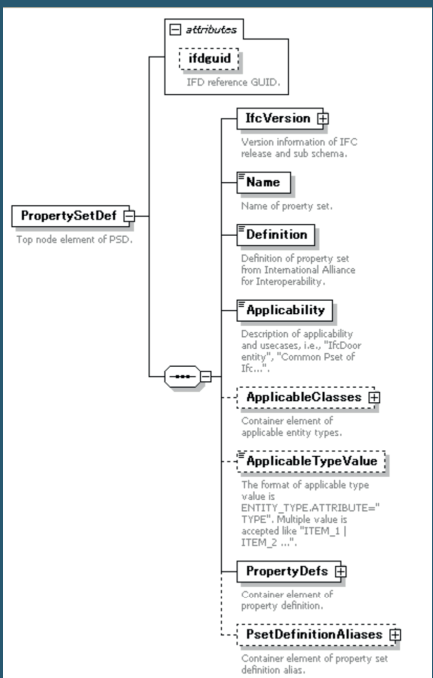



**Fig. 9**
IFC property scheme

IFC defines multiple file formats that can be used, supporting various encodings of the same underlying data:

- IFC-SPF is a text format defined by ISO 10303-21 ("STEP- File"), in which each row typically consists of a single registered object and has the extension ".ifc". This is the IFC format most widely used, with the advantage of having a compact size but with a more readable text;

- IFC-XML is an XML format defined by ISO 10303-28 ("STEP-XML"), with the extension ".ifcXML". This format is suitable for the interoperability of XML tools and the exchange of partial building models. Due to the large size of typical models of a building, this format is less common in practice;

- IFC-ZIP is a compressed ZIP format consists of an IFC-SPF file embedded and with the extension ".ifcZIP".

IFC defines an entity-relationship-based EXPRESS model consists of several hundred hierarchically organized entities based objects. Examples of entities are constructive-geometric elements, such as for example IfcWall.

IFC divides all entities in "rooted" and "unrooted". Entity become entrenched as IfcRoot and have a concept of identity, along with the attribute name, description, and revision control. Entities not have a rooted identity and instances exist only if you refer, directly or indirectly, for instance rooted.

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

- **IfcObjectDefinition:** catching appearances and types of material objects;

- **IfcRelationship:** captures relation ships between objects;

- **IfcPropertyDefinition:** captures dynamically extensible properties on objects.

***IfcObjectDefinition*** is divided into appearances of objects and object types. ***IfcObject*** describes the presence of the object such as the installation of the product with the serial number and the physical location in the building space. ***IfcTypeObject*** capture type definitions as the type of product that has a particular model number and commonly that particular shape. Instead, ***IfcRelationship*** describes the relations between the objects.

*IfcPropertyDefinition* capture sets of extensible properties dynamically. A property set contains one or more properties that can be a single value, a limited value, an enumeration, a list of values, a table of values or a structured data. While IFC defines several hundred sets of properties for specific types, custom property sets can be defined by application providers or end users.

*IfcPropertySet* represents a set of properties associated with an event object or type of object. The IFC Property Set defines all dynamically extensible properties. The property set is a container class that holds properties within a property tree.

These properties are interpreted according to their name attribute. Property sets, defining a particular type of object, can be assigned an object type, they are assigned to objects through an objectified relationship. If the same set of properties applies to more than one object, it should be assigned by a single instance to a set of related objects. Those property sets are referred to as shared property sets. IfcPropertySetTemplate [IFC2x4] captures definitions of properties and data types.

*IfcProject* encases a global project and indicates the project name, description, default units, currency, coordinate system, and other contextual information. A valid IFC file must always understand exactly IfcProject instance, from which all other objects have direct or indirect relationship. A project may include more buildings, more participants, and/or more stages according to the particular use.

## II.4 Horizontal interoperability

The building, subject of study, was initially created with the Graphisoft's Archicad software and subsequently saved in IFC format by entering the following settings.

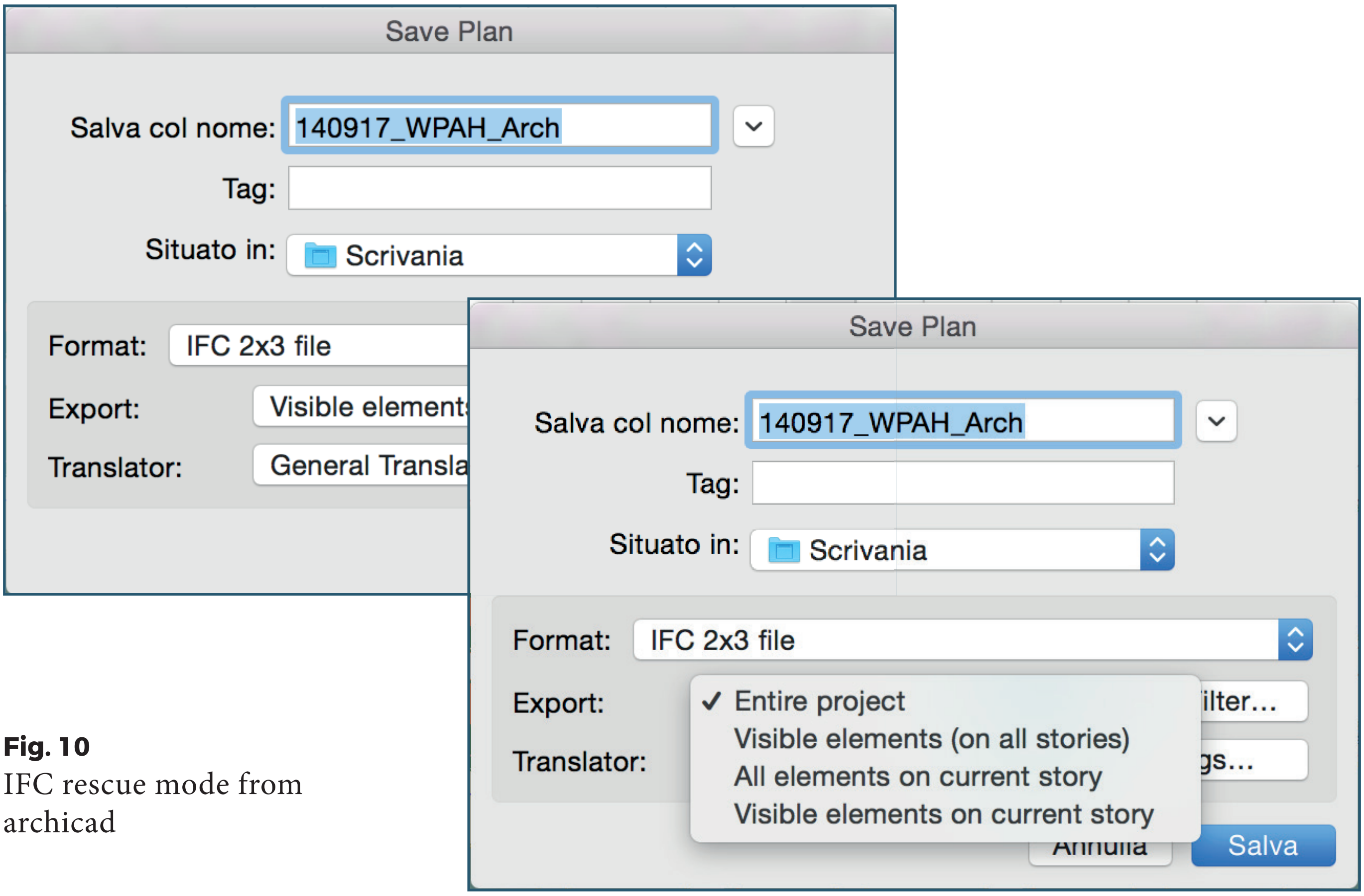



**Fig. 10**
IFC rescue mode from archicad

The IFC file saved as "140917_WPAH_Arch" was reported in Autodesk Revit software.

It is possible to consider the reading of files IFC exported from ArchiCAD and imported in Revit through two different way.

In the first process, open the file IFC like a new project and at its opening, Revit reports a series of alerts: much of the structure is reported as it was created in Archicad, at least from the point of view of the layout and insertion of architectural elements and applied materials.

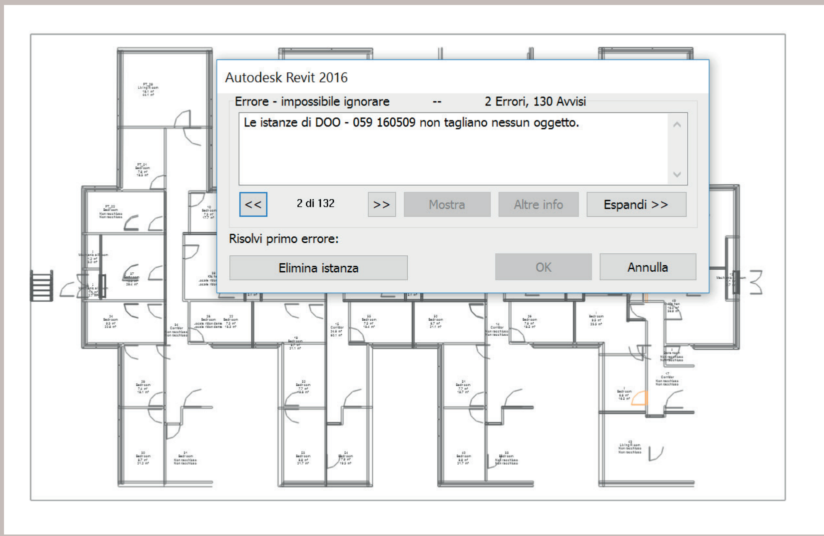



**Fig. 11**
Error - Import file IFC from Archicad to Revit

It is to be noted, however, that by selecting the “walls”, “floors”, “roof” families, for example, these elements are no longer editable but are identified by an IFC Guid: it is a 22 character code that compresses individual info elements (Fig. 12).

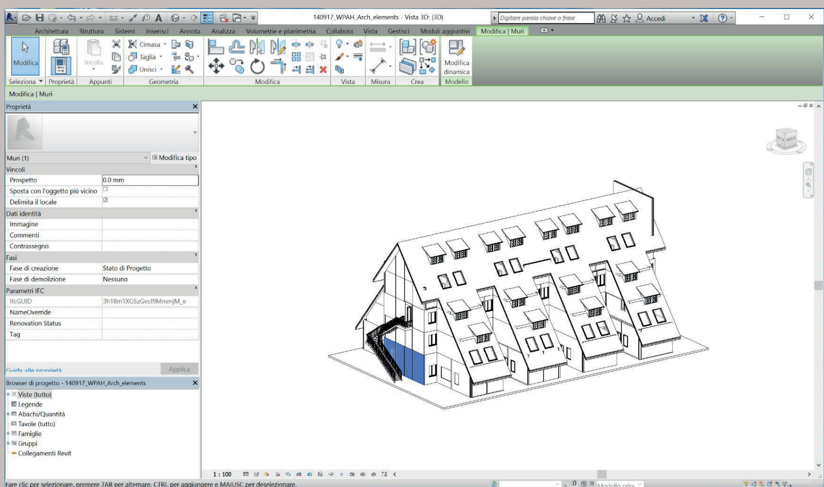


**Fig. 12**
Import model IFC from Archicad to Revit

The generated GUID is compressed for exchange purpose following a published compression function. The compressed GUID is called “IFC-GUID”. For file-based data exchange, a methodology was devised to compress these GUIDs to conserve space when physically exchanging IFC models through various media.

Given that each IFC object instance required a unique identifier containing a 128-bit number, a base 64 character encoding was devised. The resulting IFC-GUID is a fixed 22 character length string. Software implementations will need to use an algorithm that converts standard GUIDs to and from this encoding for compliance with the IFC specifications (The compression of the GUID for IFC file based exchange had been introduced back in 1996 for version IFC 1.0. Today compression of a GUID would be considered unnecessary but due to backward compatibility issues it is still enforced). **[7]**

One fundamental aspect that has been noted in reporting the IFC file from Archicad to Revit is the fact that it is not possible to modify the elements that make up the model.

In the second mode, you follow the passage:

**INSERT —— LINK —— IFC**

You will see that nothing will appear. This is because this procedure is used as reference information for a new template.

The software uses the IFC file to create the following files:

- an intermediate Revit model named <ifc_ifc>.ifc.rvt;
- a log file named <ifc_ifc>.ifc.log.html;
- a shared parameters file named <ifc_ifc>.ifc.scharedparameters.txt.

The software then links the intermediate IFC-based model to the host model. **[8]**
This option is recommended for inserting IFC models into the current Revit project as references. Only if you upgrade the original IFC file further, the Revit model will reflect the changes when you download the IFC file using the Shortcut Manager command, from Insert menu.

**[7]** Description of IFC-GUID from Building Smart (International home of openBIM)
**[8]** www.knowledge.autodesk.com

## II.5 Vertical interoperability

The mass is a category. It is useful for create objects that aren't in Revit library. There are two principal utilizations: for massing and for tracking of other objects (like facade systems, roofs, walls etc).

In the first case, it is used for the conceptual study of the shape of the building and the global visualization of other volumes; the two commands can coexist, in fact it's enough to add specific project parameters that will be used from filters for turn off what does not make use.

On the other side, the objects create with "surfaces" lose the capacity to be modified manually because they are hooked to the faces of masses; but they could be recalculated if you change the dimensions and the shape of the mass. The masses, like other categories, can be created in specific families. It is possible create a conceptual mass and afterwards loaded it in the project; or, instead, you can make a mass "in-place" already in the project.

The difference consists in the nomenclature: the local mass is created only for the specific utilization, contrariwise the conceptual mass where you create a family that you can be reuse in a second moment for an other project.

After explaining the distinction between the two types of mass that can be created in Revit, you want to point out how they are interpreted in IFC format, through a viewer.

## - CASE 1 - Conceptual mass with materials

The first step was to create on Revit a mass, generic form, and embellished the same materials adopted for the creation of Aberdeen House. The file has been saved in the IFC format. When opening the viewer, selecting one of the ground surfaces results as a property “Pset_WallCommon”; similar case if you select the cover you get “Pset_RoofCommon”.
As already mentioned, instances of IfcPropertySet are used to assign named sets of individual properties (complex or single properties). Each individual property has a significant name string. That naming convention “Pset_xxx” applies to those property sets and shall be used as the value to the name attribute. **[9]**

## - CASE 2 - Conceptual mass without materials

If the same conceptual mass, without the association of materials, comes opened in the viewer, you can see that nothing mass appear on the visualization.

### - CASE 3 - Mass in-place

Appear the same situation of case 2).

### - CASO 4 - Conceptual mass like furniture

For the mass is displayed in IFC format and, in general, from any viewer, is foundamental that it is associeted to a material (like the first case) or it is associated to a family type of Revit. This argument, however, was not deepened in the thesis.

# Chapter III

# METHODOLOGY

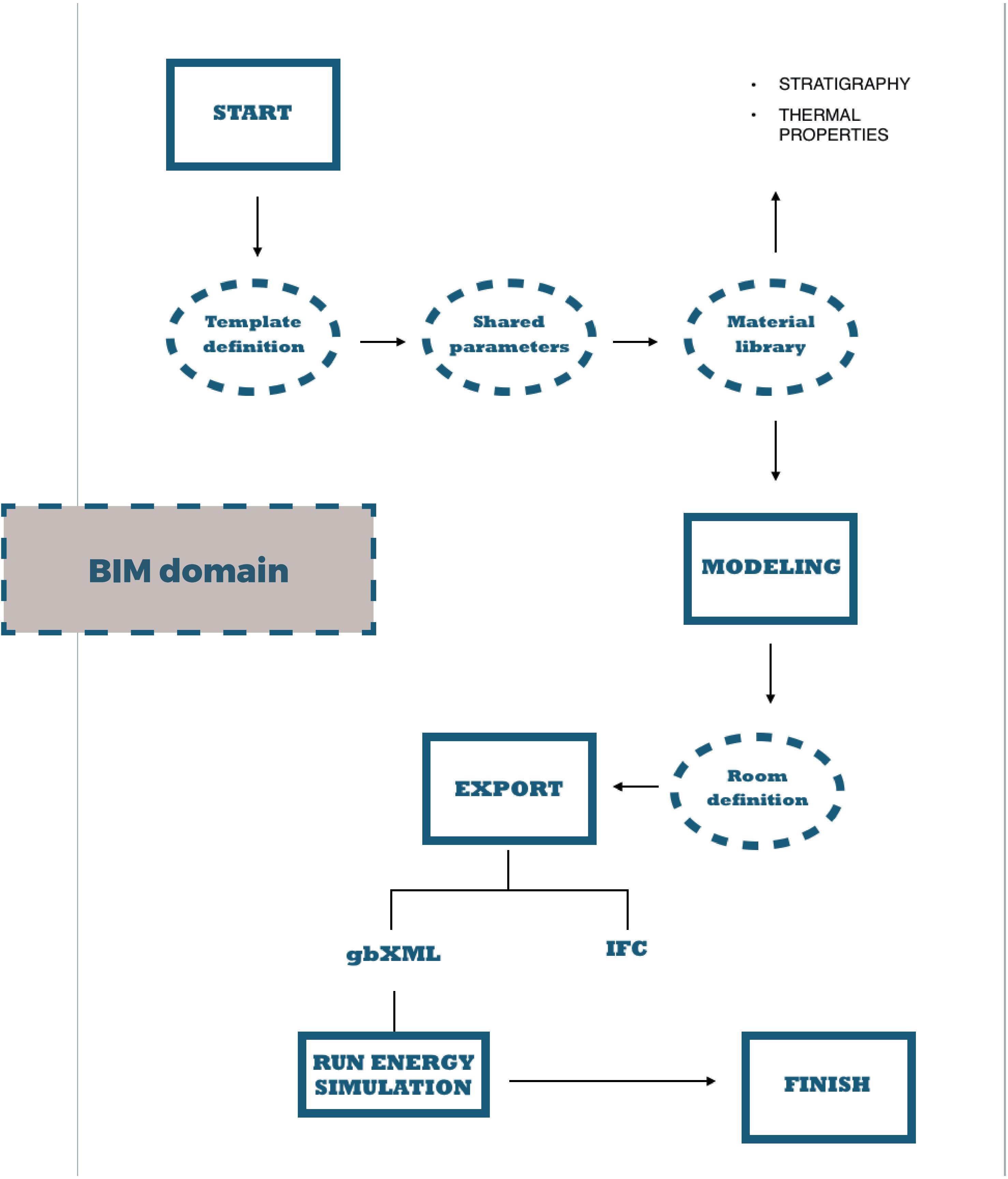
The purpose of this thesis is to be a research work related to the themes of integrated BIM design. The methodological development of the work involved the following phases:

- analysis of the graphic works of the Whitworth Park Aberdeen House;
- three-dimensional modeling in Revit representing design choices, a template containing the information of each technical element;
- managing a single model accessible by all the professional figures involved;
- using the model for the entire life cycle of the building.

In addition, the structured BIM model will be made available for development further elaborated to complete the project by using supplementary plug-ins for a later phase that is the one based on energy analysis.

Obtained the architectural model, we will extract the energy model and enter the settings related to the type of heating system present, the occupation hours, when it is used, the use of electricity and of lighting, all data that give us an idea of energy performance of the building. The goal is to propose alternative solutions with the result of reducing energy consumption and $CO_2$ emissions.

Regarding the BIM domain, the Dimmer project's workflow was synthesized according to a schema:



## III.1 The modeling step

The first step for modeling was collecting data and information provided by the University of Manchester, related to the spaces distribution (DWG files containing only floor plant), type of materials and their thermal properties. This information concerns the transmittance values of the roof, the external wall and the internal floor; but to complete the composition we have used the *Tabula* database, a site that has constructive building types based on the site, year of construction and uses destination. We have chosen compositions that can best reproduce the state of fact.
The heights are calculated roughly considering the number of steps and photographic documentation.

The DIMMER standard requires the application of a specific nomenclature and encoding with respect to all work stages. A Revit file has been imported into the .adsklib file, which is a library containing the materials used for other Dimmer Studio cases to be used as a reference. Refer to the deliverable D3.1.3 *District Information Modeling: Implementation and Standard Definition* on the dimmerproject.eu site.

As said in the beginning, part of the work focuses on software interoperability and, also for modeling, two models have been performed: one with Archicad and one with Revit.

# III.1.a Modeling with Archicad

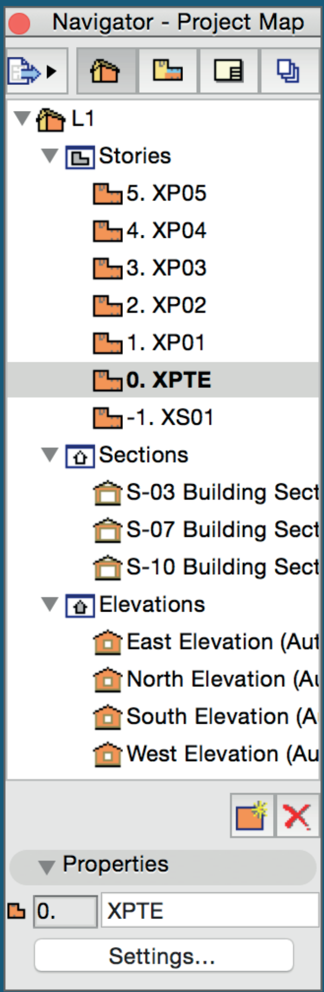



**Fig. 13**
Example of Archicad Navigator

First of all, we reported the dwg floor plants in Archicad; the building has 5 floors and already from this phase the DIMMER standards apply.

The Aberdeen house dates back to the early 1970s, being an old building with walls of varying thickness, but to simplify the architecture of the model, it was chosen to include only one type of element with a thickness that was the same for all. Also for the label of rooms, it was been assigned a code that contains number,

The insertion of the premises is necessary for the subsequent execution of the energy analysis, as this command allows the detection of areas and volumes.

With regard to the construction elements, have been chosen one type of external wall, floor, inner wall, roof and reduced to two types of windows while maintaining the same thermal characteristics. The roof has a two-sided structure and it is characterized by skylights and dormers.

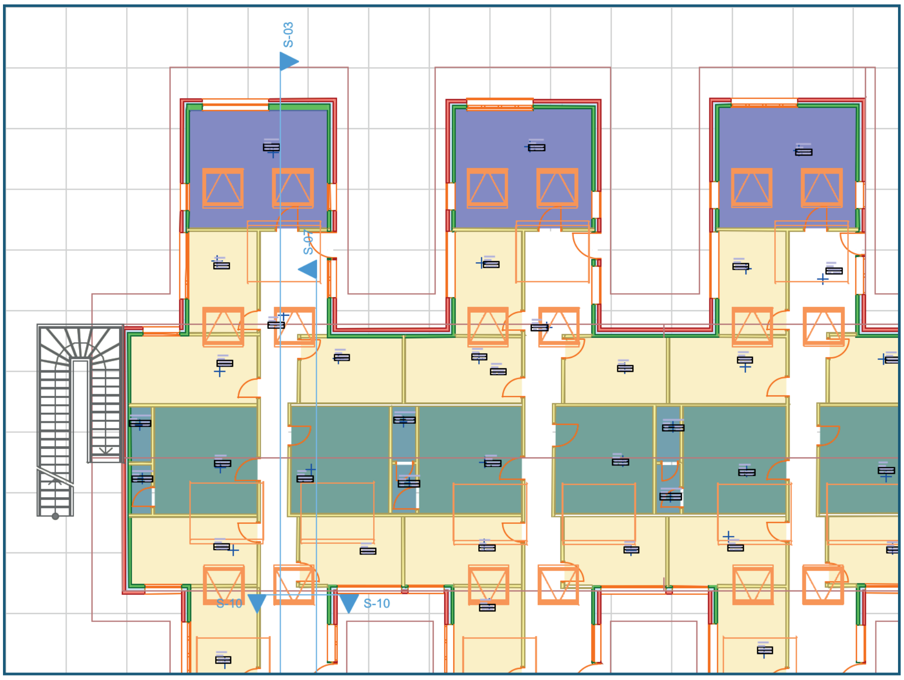



**Fig. 14**
Archicad -
Insertion of the equipment and their labels

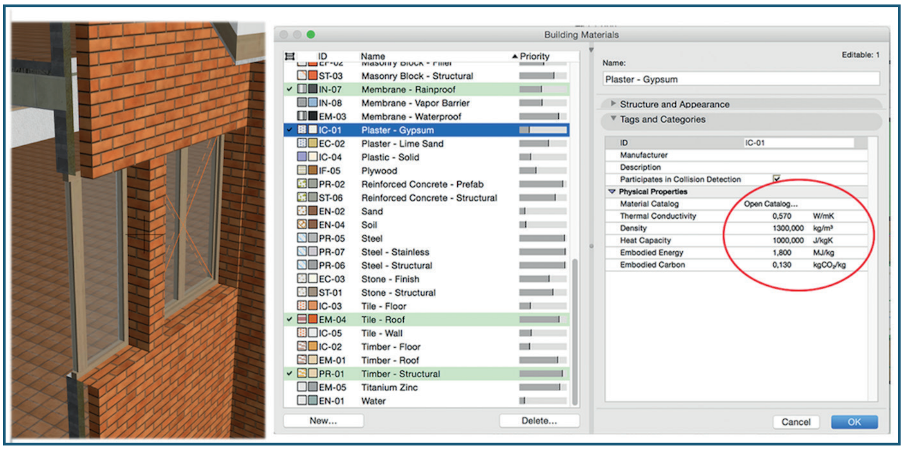



**Fig. 15**
Archicad -
Insertion of materials

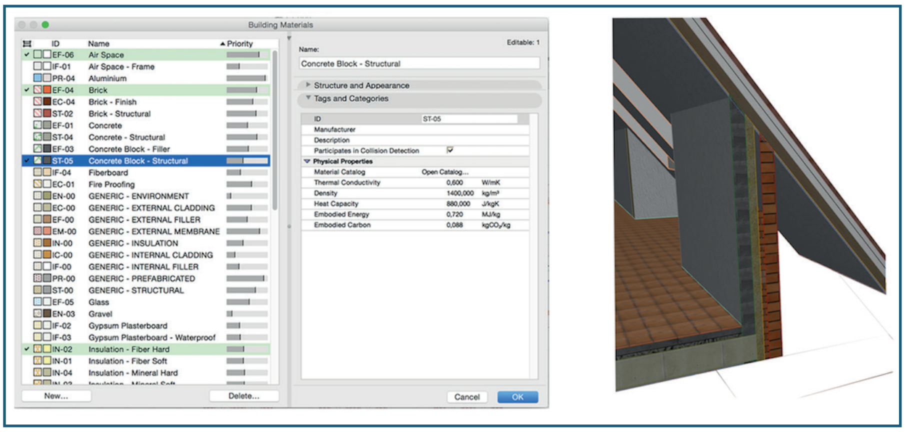


**Fig. 16**
Archicad -
Physical properties

As provided by the DIMMER guidelines, a thermal value has been assigned to each layer: in Archicad it is possible to enter the thermal conductivity value, but we do not provide the thermal transmittance value of the finished element.

At the end, the final result is the follow:

**Fig. 17**
Archicad -
3D Aberdeen House

Then, in order to start the energy analysis, we wanted to export the Archicad file (.pln format) and import it into Revit. This step involved an intermediate phase through the IFC format.

The IFC container is an entity that does not assume its body geometry, but whose components contain all the data about geometry and structure.

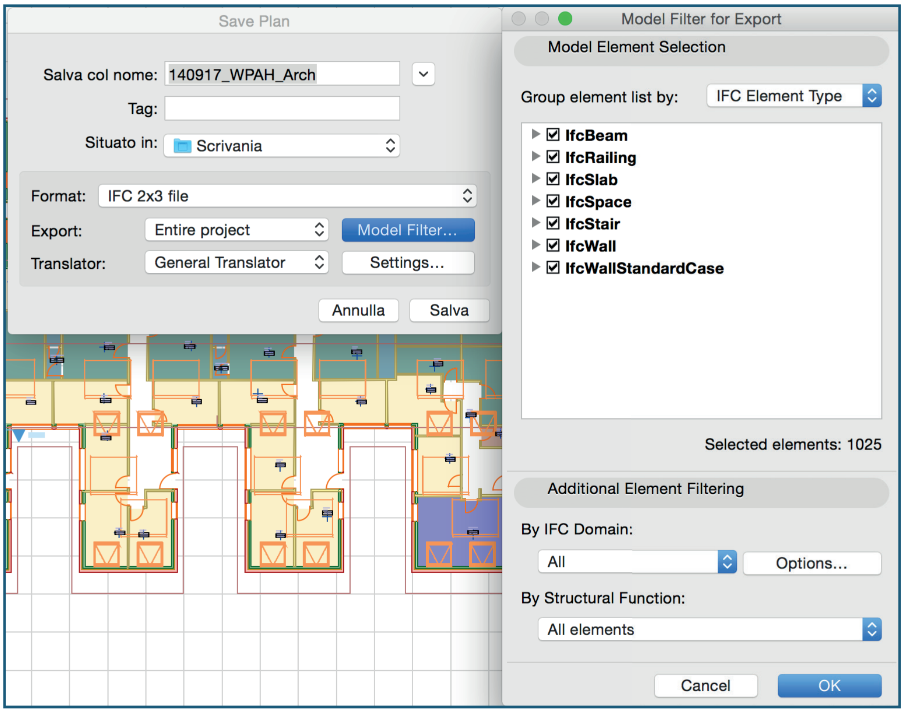



**Fig. 18**
Archicad - IFC Element type

As seen in Chapter II.3 IFC Property Set, in an IFC model, project information is represented by a set of IFC entities such as elements, surfaces, and their interrelations.

Each IFC entity (for example, an IfcWall) includes a number of fixed attributes, plus any number of additional IFC properties. Entity-to-entity and entity-to-attribute matches are automatically mapped when the IFC is being generated or exported, or when imported.

In fact, at the opening of Revit containing the IFC model, if we select the wall it will be identified with a code, which means that that element will no longer be editable. This has a limit.

At the same time, there was also a problem with the import of local geometries, varying area and volume values. Since these were basic data for extracting the analytical model, it was necessary to proceed with modeling the building with Revit.

## III.1.b Modeling with Revit

In the Revit modeling were repeated the same steps done in Archicad, following strictly the DIMMER standard. The first thing is been to locate the layers and report the dwg files; after this, it was recreated the library of materials, for example see the formation of the external wall.

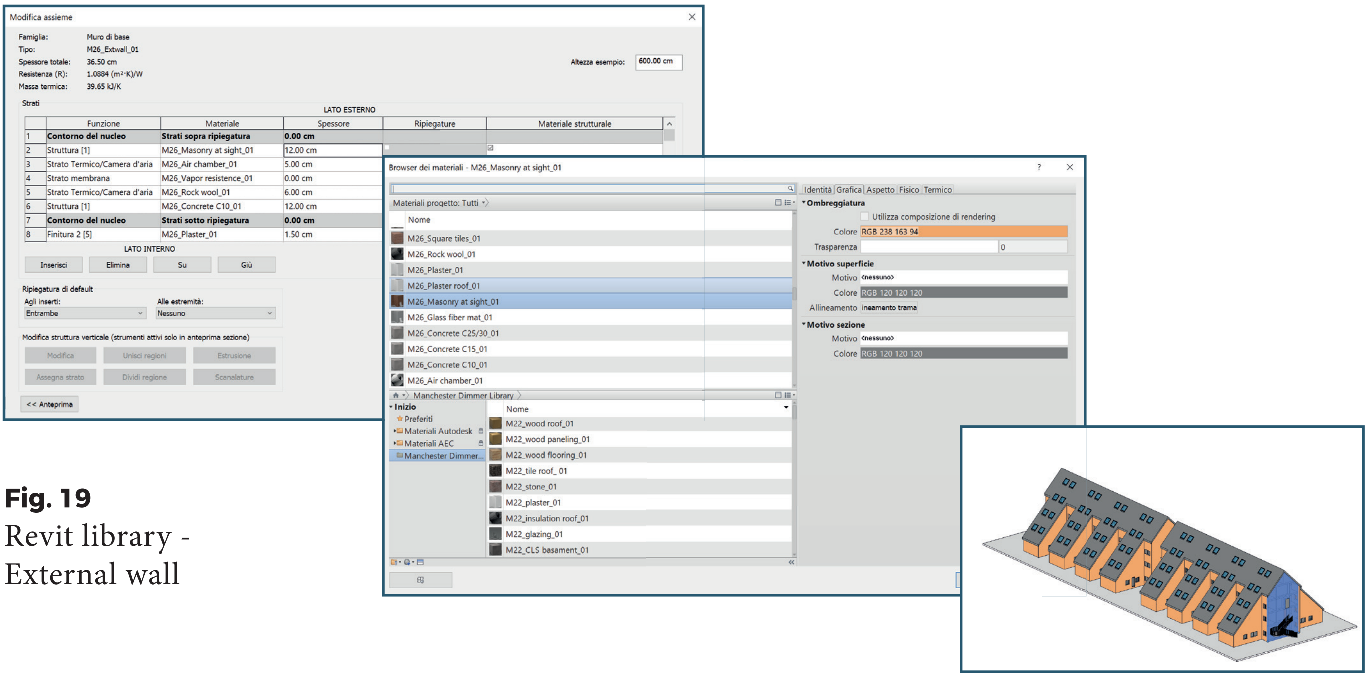


**Fig. 19**
Revit library -
External wall

Unlike Archicad, in Revit library, when we choose the composition of our element, it will also be possible to know the value of thermal transmittance; a fundamental parameter in view of a thermal and performance study of the building.

As will be explained in the next chapter, the insertion of the rooms within our model has undergone variations, due to the excessive number of areas it has been reduced, essentially distinguishing the generic heated spaces (bedroom, lounge, etc.) from the services that provide different occupation and use (kitchen and bathroom).

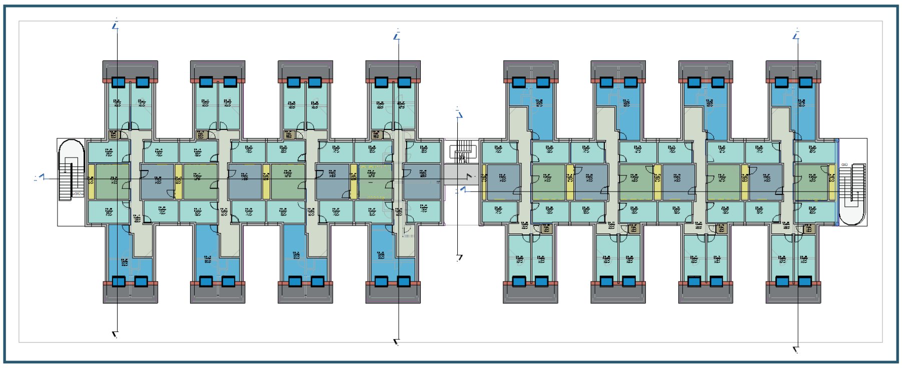


**Fig.20**
Revit - Identification of all rooms (six typologies)

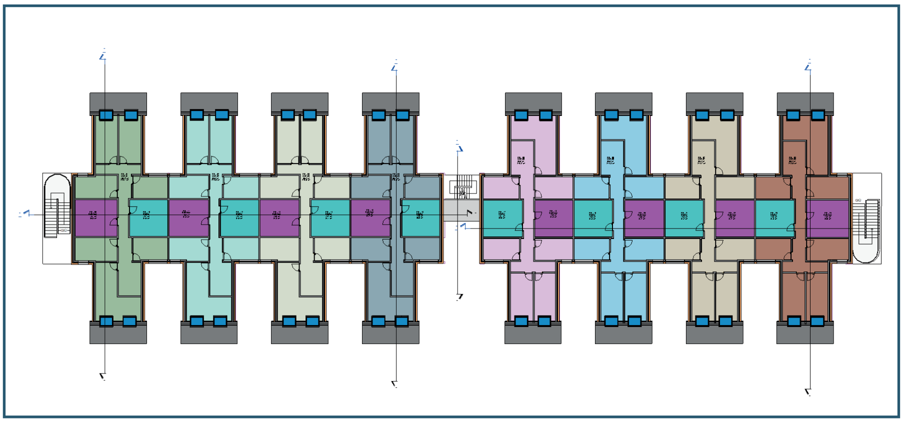


**Fig.21**
Revit - Room reduction to only three destinations

Once the latest parameters have been set up, the energy analysis is performed for extrapolation of the analytical model of the residence. Sometimes, at this stage, errors can be reported, possibly due to an incorrect localization of the premises, the presence of abnormal protrusions or recesses between the walls between one floor and another, the co-existence and crossing of the walls. These are all issues that involve refinement of the architectural model, often involving simplifications.

In this case, the building has simple geometries, so at this stage no errors were found.

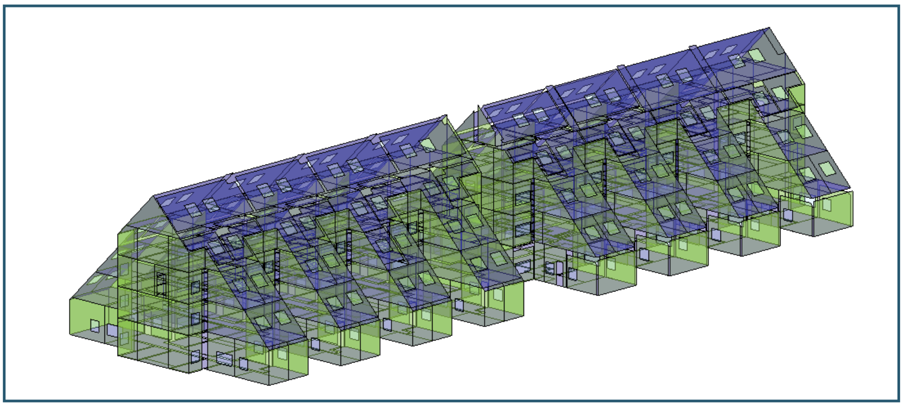


**Fig.22**
Revit - Analytical model

# III.2 Energy model extrapolation

For the part devoted to energy simulation, the development analysis was continued in the footsteps of the DIMMER project guidelines. Also in this case, it was intended to summarize in a diagram the different steps for the creation of the Energy Analysis Model (EAM). Revit extracted the energy model and inserted it into Design Builder software. In this application you enter the type of system, modeled according to the needs of users.

The energy model transforms the existing 3D surfaces into planes, so the surfaces of our EAM model will disintegrate for a percentage of the surfaces of the architectural model, up to a maximum of ±10%.

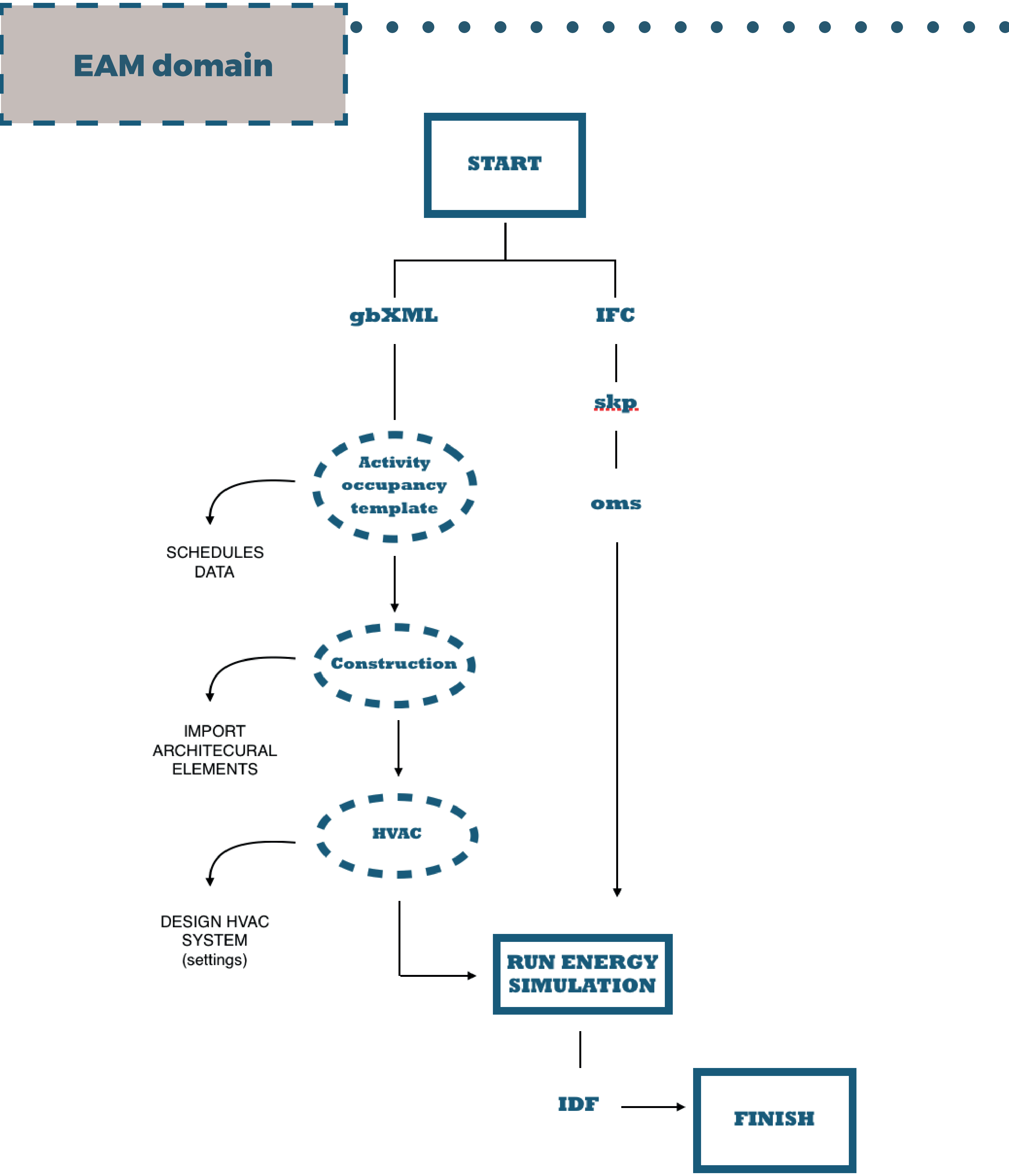
| EAM Components | BIM | EAM | DIFFERENCE |
|---|---|---|---|
| | | | |
| Spaces - Floor area ($m^2$) | 2366,62 | 2541,63 | -7,39% |
| Spaces - Volume ($m^3$) | 10167,46 | 9097,15 | 10,53% |
| Surfaces - Open windows ($m^2$) | 427,52 | 408,69 | 4,40% |
| Surfaces - Exterior walls ($m^2$) | 2751,29 | 2736,80 | 0,53% |
| Surfaces - Interior walls ($m^2$) | 4358,22 | 2883,99 | 33,83% |
| Surfaces - Interior floors ($m^2$) | 4237,90 | 3651,07 | 13,85% |
| Surfaces - Roof ($m^2$) | 1663,69 | 1381,62 | 16,95% |
| | | | |
| | | | 12,15% |

**Fig.23**
Table of differences of quantities between BIM & EAM surfaces

The biggest problem was found in roof modeling, as they are missing parts from the analytical model.

To solve this problem, different solutions have been made: reducing the roof surface by limiting the roof portion that protrudes from the perimeter wall, thus reducing the value of m2 to the "shadow" item, the same quantity that was added to the analytical calculation of the roof.

This procedure has been applied because Revit in the EAM model tends to catalog certain items in the BEM model belonging to other families. In this way, the percentage difference between the architectural and analytical surface has been reduced much from previous attempts, although it has not been completely solved, in fact, a difference of more than 10% is shown in the table.


EAM domain
START
gbXML
IFC
skp
oms
Activity occupancy template
SCHEDULES DATA
Construction
IMPORT ARCHITECURAL ELEMENTS
HVAC
DESIGN HVAC SYSTEM (settings)
RUN ENERGY SIMULATION
IDF
FINISH

Another step taken to facilitate reading the analytical model was to reduce the amount of rooms. Since the license granted by Design Builder allowed us to analyze a number of spaces smaller than expected, we split the environments into "units" (identifying the connecting spaces and bedrooms), kitchen and bathroom.

Thus, 89 rooms were identified.

At this point, it was possible to export from Revit the analytical model in .gbXML format and imported it into Design Builder.

This is because the .gbXML identifies a series of dimensions dimensionally defined by the premises (ie the volumes) previously obtained from the parametric software.

It is necessary to ensure that all environments are well-defined to avoid any errors.

Once you import the file into DB, you are creating a new work file. We import the BIM model and set up a calculation template based on the destination and location (info about climate and morphological data).

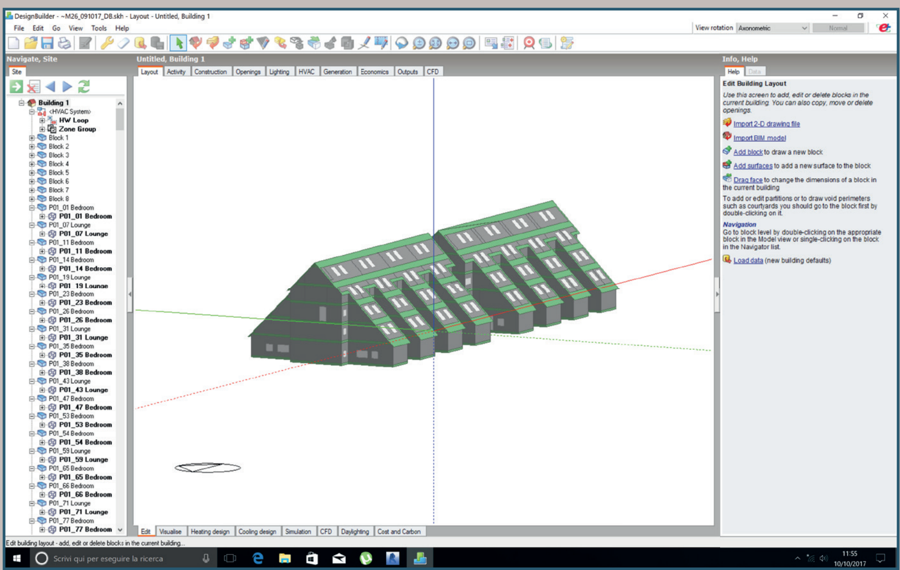


**Fig.24**
Import file .gbXML in Design Builder

From the opening screen of the software you can notice a number of areas in which fundamental parameters will have to be defined. These areas are divided. into Activity, Construction, Opening, Lighting, HVAC. We will look at step by step the various stages of this process in depth

## Construction

In this section, the different stratigraphs made in Revit are imported, easily recognizable thanks to the identification code assigned to it.

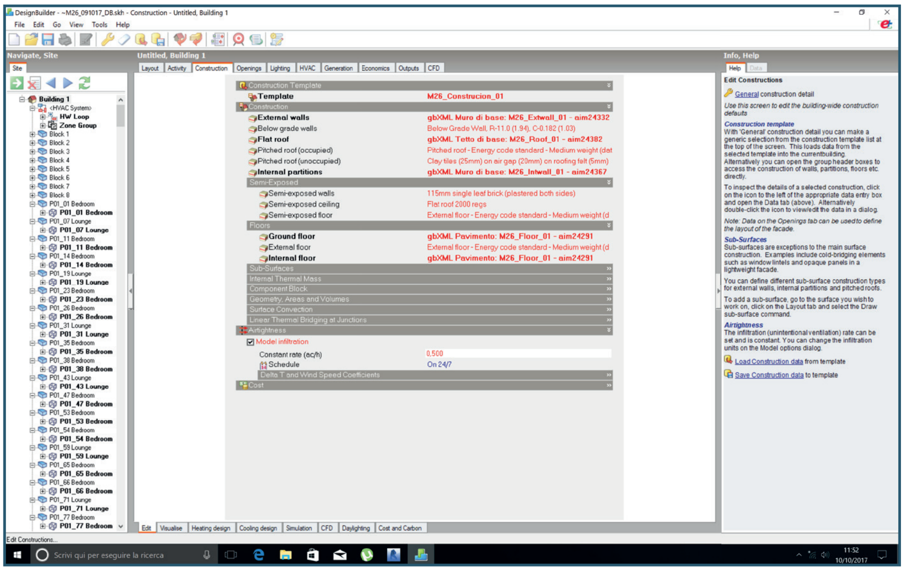


**Fig.25**
Design Builder - Construction schedule

## Opening

The openings are also considered, so it is imported the type of glass adopted in the state of art. The underlying item selects a layout with “no openings”, this is because the software is pointing to the software not to insert other openings outside of the present ones.

## Activity

The following section will include parameters related to kind of activity, type of employment (according to the timetable provided), inputs supplied by electrical components (computers and office items) and energy inputs provided by lighting.

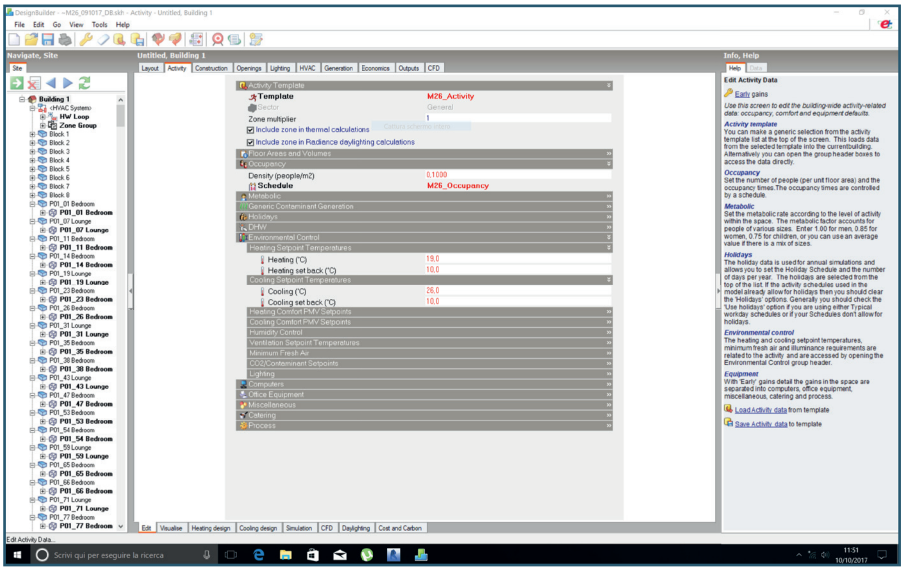


**Fig.26**
Design Builder - Activity schedule

## HVAC

It is about the modeling part of the plants. In our case study, the only reliable data is the type of plant, radiator with boiler. Ventilation is of a natural nature. We did not give any value to the power consumption of the structure and this prevents us from going to the next step, that is, the validation part.

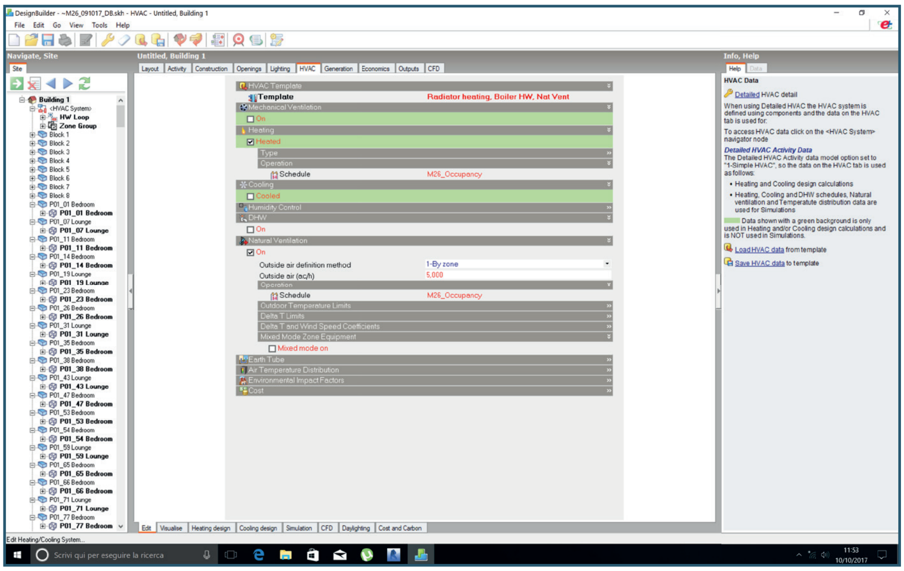



**Fig.27**
Design Builder -
HVAC schedule

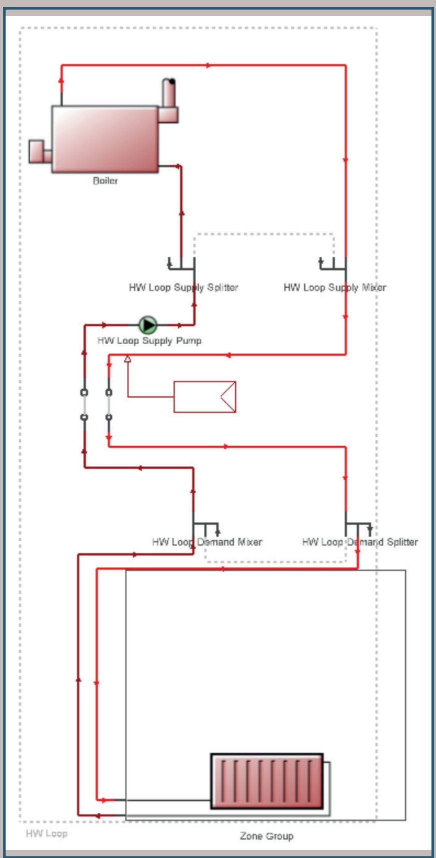



**Fig. 28**
Design Builder -
HVAC implant

The modeling takes place through a layout where the premises and the plant are schematically depicted.

For each heated room, the values provided by the Revit table, such as Flow rate (kg/s), Maximum water flow rate (m3/s) and Nominal capability radiator (W) were entered.

The HVAC can be set to Simple or Detail. When set to simple, Design Builder simplifies the size of the equipment, removing the burden on Energyplus.

In the detail case, Energyplus fully deals with the detailed calculation of the plants. In the detail case, Energyplus fully deals with the detailed calculation of the plants.

In the Activity, the set-point temperature for heating and cooling is also defined, is the temperature below which it is necessary to activate the heating and the temperature above which it is necessary to activate the cooling.

At the end of their completion, simulation can be started.

Initially, the simulation was carried out for a limited period, from 11 November to 17 November, and then for the whole year.

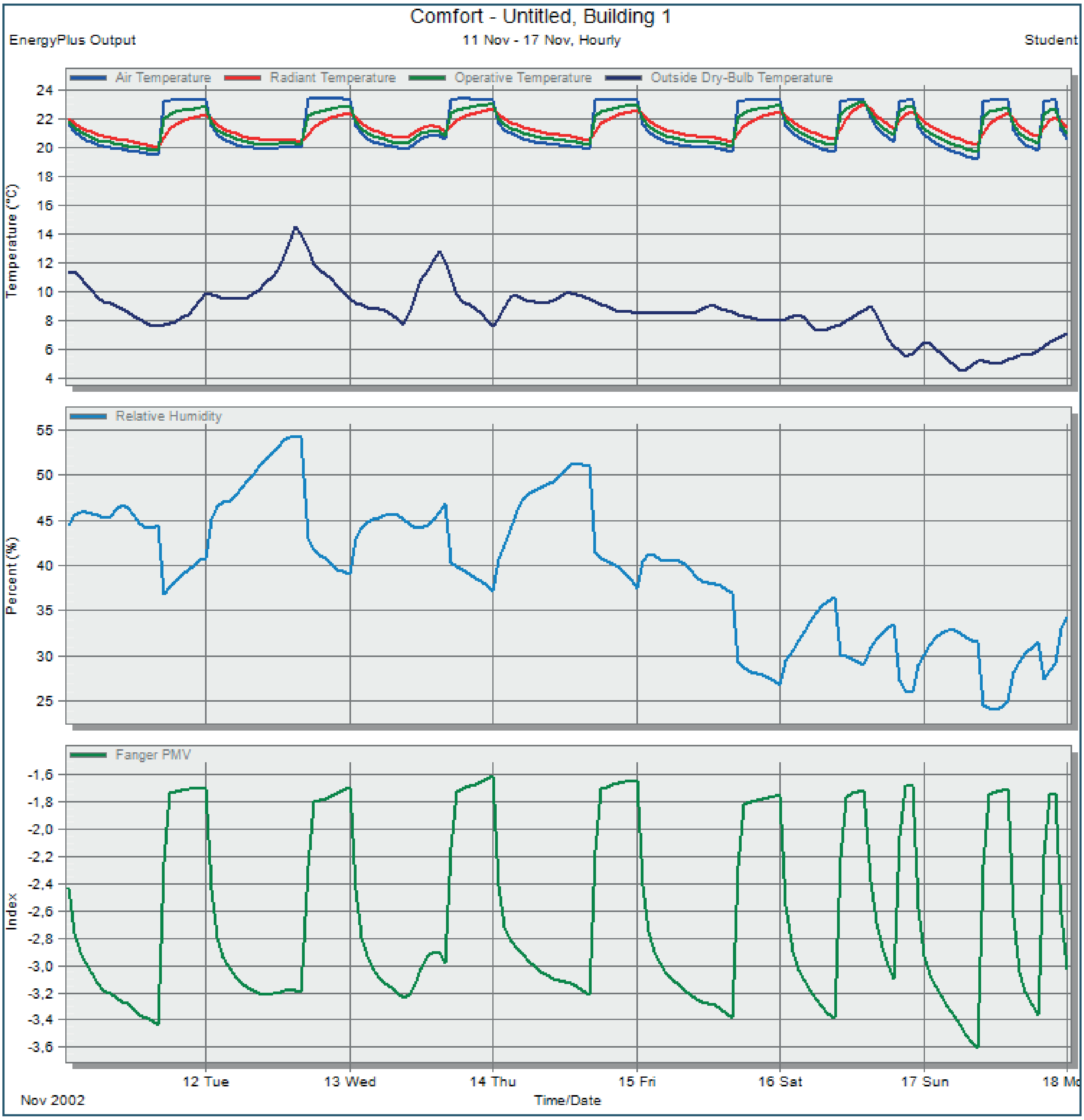



**Fig.29**
Sample of outputs generated by design Builder simulations

It can be seen from the first graph of temperature, that the indoor temperature of the rooms (15 ° C) does not reach set point values (20 ° C), without allowing the occupants' environmental comfort. In fact, the Fanger PMV chart confirms that people feel a cold feeling. This discomfort could arise from multiple causes, such as poorly performing constructive elements (remember that the building dates back to the early 1970s), or loading a weather file that does not represent the current climatic situation. However, a correct operation of the system is reported as the chart follows an upward trend around 15:30 (system start-up time) and a constant trend throughout its operation up to a deceleration near the " off time. Outbound data are represented by graphs showing visually the temperature, relative humidity and consumption trends. Outputs can also be listed as Excel tables in variable time ranges: monthly or yearly, daily, time and sub-hours. From the graphs and the final data, therefore, it is possible to predict the consumption of the building and how much it is energy-efficient.

According to the DIMMER method, there would be a further step in Energy Plus, an open source software of DoE (the US Department of Energy), is expected to improve the level of detail in the simulation so that results can be closer to real results. As mentioned above, in the absence of real data, it was not possible to perform this last phase. Energy models will output building energy use predictions in typical end-use categories: heating, cooling, lighting, fan, plug, and process. Another way to carry out an energy simulation is by starting from an IFC exported by Revit (see diagram *III.2 Energy model extrapolation*).

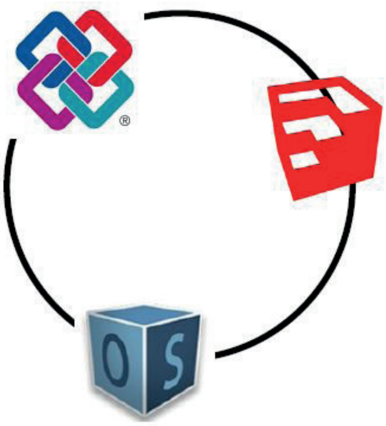


**Fig.30**
Interoperability between IFC - Sketchup - OpenStudio

At this stage, we are proposing an alternative to Design Builder, by first performing an IFC file import into Sketchup, from which a surface-compliance check is performed so that the IFC's entities and attributes are read correctly, then exported in a format .skp and inserted in Open Studio.

OpenStudio is an open source. Its graphical applications include the SketchUp Plug-in, the stand alone OpenStudio application, the ParametricAnalysisTool, RunManager and ResultsViewer.

The OpenStudio application is a graphical energy-modeling tool. It includes visualization and editing of schedules, editing of loads constructions and materials, a drag and drop interface to apply resources to spaces and zones, a visual HVAC and service water heating design tool, and high level results visualization. As with Design Builder, through this tool we can have a general framework of consumption and performance. At this point, however, we have not been able to deepen this aspect, but it may well be introduced to somebody else.

## III.3 BEM Analysis

It has been found that the architectural model (BIM of the university residence has undergone, during the thesis, a series of changes that have simplified it, until reaching the BEM model (Building Energy Model).

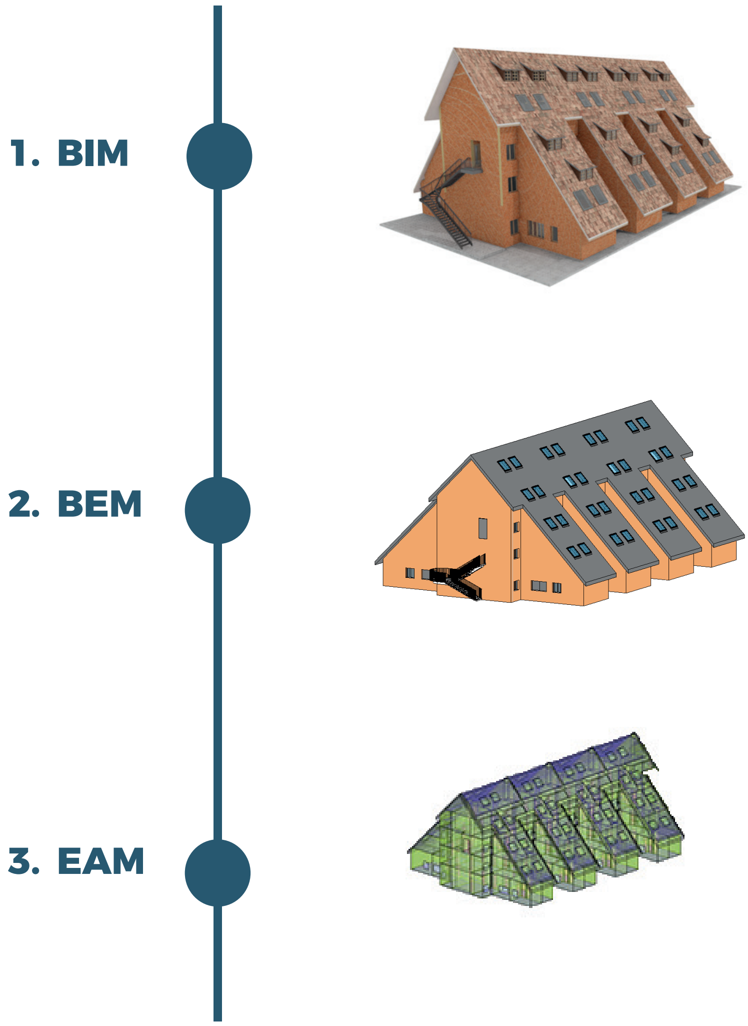



**Fig.31**
Step from BIM to EAM

In the modeling with Archicad, all the features of the building were initially respected, both from the exterior and the interior composition, while maintaining the different recesses and protrusions of the exterior walls, the presence of dormers, the insertion of cords and stairs. As it has been proceeded, problems have arisen in the reading of these elements, especially in the energy phase, as there was a crossing of the walls or a nonperfect overlap of them, creating voids (in terms of energy favoring thermal bridges).

This simplification is necessary for several reasons, both because it allows us to export the file more easily and to start the energy study, and because many architectural elements are not needed for this purpose, rather "weight" the exported model, resulting in slowdowns in the simulation phase could even increase the number of errors.

To avoid this problem, simplifying the model is achieved, reaching those geometries and information that really are of interest to the achievement of the predetermined goal.

# Chapter IV

# RESULTS

The following chapter discusses the difficulties encountered during the thesis, starting from architectural modeling of the building, interoperability between the software used and the energy study.

## IV.1 BIM for DIM

With regard to parametric modeling, no major difficulties were found, architectural is quite geometric.

The element that may have created more problems was definitely the roof due to its unusual configuration for us and due to the missing sections that were not provided. Another constraint is represented by the dormers, as in Archicad it was enough to insert an element from the library; in the Revit model, initially tried to create one but was having problems with the roof attack.

In addition, it would cause further slowdowns in the energy part, so it was decided to put skylights in place of the dormers, ensuring lighting and ventilation within the environments for the next step.

ventilation within the environments for the next step.

The party that has been involved in energy simulation has certainly been the one that has caused many difficulties and much commitment.

The BEM model was subject to various modifications to achieve an EAM model as error-free as possible. What has been found, thanks also to comparison with other projects, is the lack or not always correct connection between the vertical partition with the horizontal partitions, causing the voids to appear on the energy model. As mentioned earlier, three-dimensional elements are read as surfaces, creating a substantial percentage difference between the two models.

## IV.2 Interoperability issues

A substantial part of the thesis focused on IFC, an open file format that allows collaboration in the AEC industry. Even at this stage, some of the positive aspects of IFC's purpose have come to be understood as an element that allows a common language between architects and engineers; but, at the same time, there are critical assessments. From an architectural point of view, it was found that the IFC file exported from Archicad and imported to Revit has all the attributes assigned, with some alterations in element geometry. Chapter II.3 shows IFC properties and it has been said that structural elements are read as entities that contain attributes; when an IFC is opened in another parametric software, these entities can no longer be edited (except in the source file) and this defines a limit. Instead, you can make changes to the premises by altering areas and volumes, allowing another type of study.

| | ARCHICAD | REVIT |
|---|---|---|
| GRAPHIC INTERFACE | INTUITIVE | COMPLEX |
| MODE UPDATE TIMES | SLOW | FAST |
| CREATING NEW ELEMENTS | GDL PROGRAM KNOWLEDGE | MASSE CREATION |
| THERMAL CHARACTERISTICS (U, λ, R) | DATE VALUES | U = DATE VALUES<br>λ, R = MODIFICABLE VALUES |
| ENERGY MODEL | DOES NOT use an open source computing facture | DOES NOT use an open source computing facture |

**Fig.32**
Differences between Archicad and Revit

Given the work done between the two parametric software, Archicad and Revit, we wanted to highlight the differences between the two through an illustrative table.

The not success of the operation of simulation is also due to software limitations. Often, it has happened to have to repeat the steps because there were problems of incompatibility between one version and the other in the program or even the lack of updating of the data contained therein. We think, for example, of the result of the building's consumption and the lack of internal temperatures due to the fact that the Weather file date back to 2002.

The methodology proposed by the DIMMER project is certainly valid to the attainment of the objectives introduced in the beginning, but there are still some aspects to improve in terms of interoperability and processing of individual software.

# Conclusion

At the end of this thesis, believes that the use of BIM is necessary, if not fundamental, in the construction industry, particularly in the public sector it is necessary to use a standard planning and design method that will allow more people to collaborate on the same idea while covering a different role.

In the first part of the thesis, a preparatory speech was made to better understand the potential of the BIM, demonstrating its value through a global view of the world, which led to the need for guidelines to be followed and how to Italy, unlike other countries, needs an incentive to open up their own horizons and adopt new design criteria.

This is the intent of the DIMMER project, namely to provide guidelines to give a lifecycle criterion not only to a single building but to an entire district, exploiting today's available technologies that allow us to constantly improve, achieving high levels of precision. As already stated, there are still some aspects to improve, especially from the point of view of communication and interoperability, so experimental research is important. Beyond the thesis, this European project has given the opportunity to form figures that can divulge and raise users to a new approach to work, going beyond the roots of classical design.

The study case of the University campus Whitworth Park Aberdeen House was the product of that work and the DIMMER method its key reading.

The first step was to create an architectural model through two parametric programs: the first, Archicad, made it possible for an immediate simpler modeling, with the exception of the roof, and more faithful to reality, replicating all the architectural aspects characterizing the " building; the other, Revit, has slowed down, both because of the lack of preparation for the software, but also because the model was recreated according to a few things.

For these two programs to communicate, they focused on their interoperability through an open file format, the IFC. IFC is, a very valuable tool because it allows for strong synergy, but at the time of the limitations, as it does not allow to modify the files once they are imported; you might consider it as a read-only file.

The next step was to extract the analytical model from the architectural model to be able to proceed with energy simulation and then study the performance and consumption of the building. To do this, we had to include thermal parameters in both Archicad and Revit; look that Revit has been very easy since the data is editable, which was not possible with Archicad. For this reason, we have proceeded with the procedure indicated by the DIMMER project.

Then, from the BIM model, it passed to a simplified prototype, BEM, from which the EAM analytical model was extrapolated. Then, from the BIM model, it passed to a simplified prototype, BEM, from which the EAM analytical model was extrapolated. The final part of the dissertation was surely the most complex because of the onset of problems associated with Design Builder, a modeling and energy simulation program. In our case, a .gbXML file was imported.

Afterwards insert all the data on the type of stratigraphy adopted, the hours of occupation, the use of electrical equipment and finally the type of implant.

The results obtained were unsatisfactory and before reaching them there were problems that were not always solvable by criterion, but sometimes intuitively: for example, according to the language (ing/ita) the software implied the stratigraphies of the building.

In conclusion, the result of the simulation was not what was expected in part because of the insufficient data available, but also because the Weather file, which indicates the average temperature of the site, needs an update. Obviously, being an experimental work, it is necessary to emphasize the need to implement software, especially energy simulation, to provide a better service in terms of reliability and performance. Anyway, I trust the potential of this project and its improvement.

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