Automated BIM information flow for internal comfort conditions in an historic building

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Abstract
The comfort conditions in confined environment have a great influence on well-being, productivity and quality of life. Achieving high standards of well-being for occupants inside historic buildings can sometimes be complex, which is why environmental and energy sustainability protocols can provide an efficient tool to design and verify these conditions.
The LEED Historic Building protocol allows to pursuit high internal comfort conditions, paying attention to the conservation of the building and its artefacts. This study, starting from the concept of Level Of Information Need, aims to identify the necessary data to achieve the LEED protocol credits for comfort and environmental quality. Once the necessary parameters have been identified within structured tables, it is necessary to analyse the data flow during the design phases in order to study an automatic data flow that can facilitate the design process within the BIM approach. The automation of the information flow will be set up with the use of a Visual Programming Language, which allows the automatic creation and transcription of parameters, by connecting Excel tables to BIM models. This research provides to designers a data management tool that reduce time used in exchanging information and decrease the human transcription errors. Therefore, the method developed has been applied in the retrofit design study of an historic farmstead in Milan.

Keywords: BIM – LEED – Historic Building – Internal Air Quality – Visual Programming Language

1. Introduction

Nowadays the use of a BIM approach for historic buildings retrofit is spreading in the building environment. This method allows to manage, share and check information and geometry in a much more efficient and dynamic way, developing an integrated design with cooperation between different teams. For the historic buildings, where the as built study and the cooperation are crucial, the BIM approach can be very useful, saving time and preventing human mistakes or design interferences. For this reason, the HBIM (Historical Information Modeling) approach is becoming essential for retrofit design.
The use of BIM by different disciplines leads to manage a large amount of information, which can lead to an overabundance of data, making the model heavier. There is indeed a need to create a quick and organised information flow that allows to create models easy to manage and with all the information needed, without having a surplus of data. The ISO 19650 introduces the concept of Level Of Information Need which is the description of the information deliverable to fulfil a specific purpose for which the data are required. The application of this

concept makes it possible to avoid excess of information and to provide a model with only the necessary data for the discipline under consideration.
Starting from this concept it has been possible to develop an automatic information flow able to pass information from excel tables, structured according to the Level Of Information Need, to the BIM model; in this way, information can be shared in an agile and efficient way with all the professionals involved, encouraging integrated design.
This research, in particular, deal with the passage of information involved within a sustainable retrofit project of an historic building, following the criteria of the LEED HB protocol. The design process of sustainable buildings is more complex than conventional project approaches due to the multidisciplinary design work teams that are required to address the requirements of environmental sustainability protocols. Achieving an integrated design solution prior to construction means that the design team must manage reciprocal task interdependencies and address a complex of information sharing requirements surrounding data coordination and exchange across multiple disciplines [1]
Leadership in Energy and Environmental Design (LEED), is one of the most well-known and commonly used green building rating systems, developed by the U.S. Green Building Council and it is a fundamental tool to design sustainable buildings. Italy is the first country in the world in terms of cultural, historical and architectural heritage. About 30% of Italian buildings are historic buildings, and many of these need sustainable restoration and refurbishment. GBC Historic Building certification is a rating system aimed at evaluating sustainability level of restoration and refurbishment (that comes from the Italian experience in this scenario), combined with the skills of the LEED international protocols (the most widespread rating systems in the world). This is a standard in which the recovery needed by most historical building coexists with the indications of the European targets on environmental impact reduction and existing energy redevelopment. The GBC HB rating system evaluate the sustainability in overall refurbishment activities starting from the design phase, till the construction phase and the evaluation of the efficient operation and maintenance of the building [2].
Given the large amount of information that are involved in building environmental analysis, the research has taken into account only the ones related to the internal quality conditions of the building.
In fact, the comfort conditions in confined environment have a great influence on well-being, productivity and quality of life. Achieving high standards of well-being for occupants inside historic buildings can sometimes be very complex, which is why environmental and energy sustainability protocols can provide an efficient tool to design and verify these conditions.
The paper, after an excursus on the latest scientific results about BIM information flow and its application to the LEED protocol, is structured in two main parts: the first one frames the method used to conduct the research, dealing with the definition of the Level Of Information Need for internal air quality of the LEED credits and its integration in the BIM process. The second part will show more in details the research steps and will share the results obtained by applying the method to a farmstead near Milan.

2. Literature review

The BIM approach is an important tool for all the professionals involved in the construction process: it can be applied to many disciplines and gives the opportunity to efficiently manage data exchanges throughout the whole built asset life cycle, including the operational phase. The BIM process is studied by many professionals to develop more efficient designing method that could improve the information management throughout the life cycle of the building. To this purpose were developed and studied framework and prototype for an holistic BIM for Facility Management workflow addressing information specification, verification and use. The study analyses a solution that addresses the entire BIM for FM workflow, from the definition of information requirements, through the development of the data container, to the management of the data container and its use in operation, using as main tool the Common Data Environment [3].
To achieve these goals appropriate filter and query methods and tools are required which enable the craftsmen companies to access BIM-based information resources with respect to their specific needs and working environment. Therefore, an interesting tool is to use visual

BIM query language (VBQL) to extract and query information from a BIM model [4] or to modularize a rule-checking approach using the LRML schema as the standard to represent building design rules. These studies recognized the great potential of VPL (Visual Programming Language) to retrieve information from a 5D-BIM [5]

Regarding the application of the BIM approach to sustainable design, a plug-in was developed to calculate the accumulated potential LEED credits with access to API of the BIM tool (i.e. Autodesk Revit, Google Map) and their library. The model concentrates more on predicting and calculating the other LEED points that could not normally be calculated from the design by using data mining method. Overall, this research demonstrated that BIM and LEED integration was feasible, even if with considerable constraints [6].

A study conducted by Azhar, Carlton, Olsen, and Ahmad [7] demonstrates how planners and designers may use BIM to analyse sustainability in pursuit of LEED certification by developing a conceptual framework that illustrates the relationship between various LEED credits and the related BIM-based sustainability analysis. The results of this study show that there is no one to one relationship between LEED certification process and BIM-based sustainability analysis because of the lack of LEED integration features in the used software and the analysis results can be used directly, semi-directly or indirectly to generate LEED documentation.

In this research environment, this study wants to focus on the possibility to developed an information workflow that will support the cross information with a BIM approach and will allow the designers to efficiently manage the information regarding the LEED credits.

3. Method

The first step was to define the Level Of Information Need for LEED HB protocol credits; in order to do so, the protocos manual and its schedules were studied to identify the relevant data.

Then was developed a framework that defines the extent and granularity of the information the study took into account. For this paper, were considered only the data needed to achieve the credits for the Indoor Air Quality (IAQ). The schedules were organized on Excel file to create default structured tables that could respond to the Level Of Information Need requirements and allow to automatically create and manage new information in the BIM model.

With the BIM authoring software, it is possible to customize the parameters assigned to the model's objects in order to add information to the default one. Shared parameters are definitions of parameters that you can add to objects or projects. Shared parameters are also useful when you want to create a schedule that displays various family categories. Ultimately a workflow has been studied to automate these data transfer from the Excel Level Of Information schedule to the BIM model; in order to achieve this, the VPL tool Dynamo, a plugin for Revit, that allowed to create a script that transfer data without having to manually rewrite them, was used.

A very important step is to analyse the BIM objects and choose the most suitable to be enriched with the new information in order to better manage the data and reach the goal. In fact, every BIM objects has its own properties and parameters depending on how the authoring software manage it. This decision will influence the final step, which is the definition of the BIM schedules to organize the parameter in order to answer to the LEED HB credits requirements. These schedules will show in a clear and easy way all the information needed to achieve the credits' points and will help the designer to design a sustainable building, keeping always in mind the steps and the requirements to achieve the final goal.

The information workflow starts from shared scheduled that can be consulted and modified by all the designer involved in the project, in order to collect all the needed data in an organized and fixed structure; then, the information are automatically transferred in the BIM model as shared parameter due to VPL scripts that associate Excel table with BIM objects. Finally, the shared parameter can be organized in schedules where are listed the needed parameter and their quantity in the project: all the information required by the LEED protocol will be displayed to be checked and consulted during all the design phases.

To make the VPL scripts more adaptable and user-friendly was used Dynamo Player, that provides a simple way to execute Dynamo scripts in Revit. It displays a list of Dynamo scripts in a specified directory, along with the current status of each script giving the possibility to open and modify it.

It is possible to design user input and output to be assigned before running the script. Once the input data are defined, the script will run by clicking on play and it will be possible to check immediately its success by the output data.

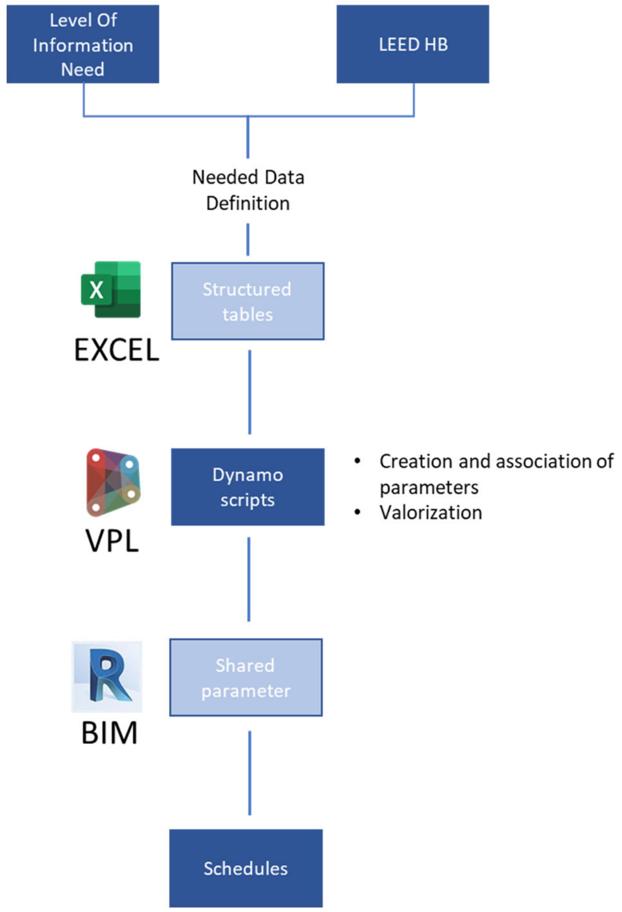

Fig. 1: Information Workflow scheme

4. Workflow application

This information flow (Fig. 1) was applied to the study design for the manor house of farmstead Sella Nuova, near Milan, a building existing since the 15th century. A redevelopment and reuse project was studied to create a social gathering place for the neighbourhood. The manor house is the heart of the project to create social relationships with common areas, bar and classrooms where people of all ages can learn and socialize (Fig. 2).

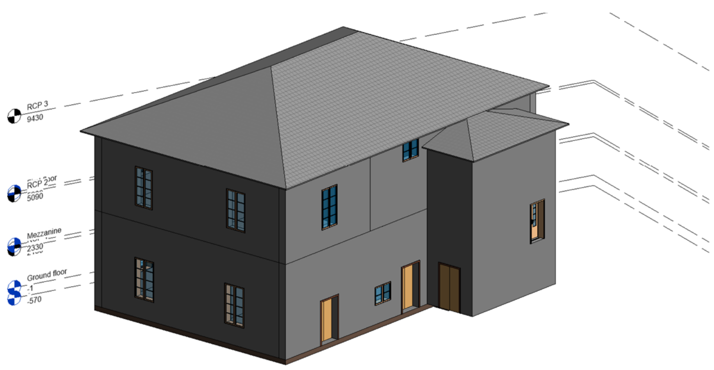

Fig. 2: Manor house of Sella Nuova farmstead, BIM model

The definition of the Level Of Information Need started from the study of the LEED protocol in its detail, to identify which data were necessary to achieve the desired credits. Once the necessary data was identified, the research moved on structuring the Level Of Information Need table to meet the requirements described in ISO 19650, where were identified the BIM objects to which the parameters were associated, the usage model, the author of the board and the purpose, i.e. for which discipline, the board was defined. For this paper, credits related to Indoor Environmental Quality were analysed. The area is structured into two possible paths: on one hand the goal of conservation and preservation of historic architecture, on the other the fulfilment of occupants' conditions of comfort and indoor air quality. This dual approach allows user to respect the historic environment by protecting surfaces and high-quality materials and, at the same time, to achieve the highest levels of comfort and indoor air quality attainable taking advantage of the potential offered by the boundary conditions.
Below it is shown the Level Of Information Need for the 6.2 LEED HB credit, regarding the control and management of the systems for the thermal comfort. The Level Of Information Need is the frame which defines the extent and the granularity of information to be exchanged and can be answered by a combination of geometrical information, alphanumerical information and/or documentation, as described in the UNI EN 17412-1. To specify the Level Of Information Need and how information is going to be delivered, it is useful to consider:

- The purpose for the use of the information to be delivered;
- Information delivery milestones for the delivery of the information;
- Actors who are going to request and actors who are going to deliver the information;
- Objects organized in one or more breakdown structures.

A schedule was defined to answer to these concepts, which specifies the Level Of Information Need and defines the granularity of the information needed (Fig.3).

<table>
<tr><td>OBJECT (*)</td><td colspan="3">#Room</td></tr>
<tr><td>COMMERCIAL BENCHMARK</td><td colspan="3">Not applied</td></tr>
<tr><td>PRICE LIST ID Code</td><td colspan="3">Not applied</td></tr>
<tr><td>PRICE LIST ID</td><td colspan="3">Not applied</td></tr>
<tr><td>COMPILER (**)</td><td colspan="3">-</td></tr>
<tr><td>MODEL USE</td><td colspan="3">Sustainability</td></tr>
<tr><td>PROJECT PHASE</td><td colspan="3">Design</td></tr>
<tr><td>(*) Trade name unified by "Hashtag" method (**) Appointed by the BIM Coordinator</td><td colspan="3"></td></tr>
<tr><td rowspan="5">Modeling information</td><td colspan="2">Detail</td><td>Rapresentation with shape and dimensions</td></tr>
<tr><td colspan="2">Dimensionality</td><td>3D</td></tr>
<tr><td colspan="2">Localization</td><td>Relative</td></tr>
<tr><td colspan="2">Look</td><td>None</td></tr>
<tr><td colspan="2">Parametricity</td><td>Yes: x, y, z</td></tr>
<tr><td rowspan="4">Alphanumerical Information</td><td rowspan="4">Sustainability</td><td rowspan="4">LEED HB cr. 6.2 IAQ</td><td>HB_cr6.2 Type of occupation</td></tr>
<tr><td>HB_cr6.2 Presence of thermal comfort control system</td></tr>
<tr><td>HB_cr6.2 Type of thermal comfort control system</td></tr>
<tr><td>HB_cr6.2 Shared/multi-function room</td></tr>
<tr><td>Documentation</td><td>Documentation</td><td>LEED HB cr. 6.2 Attachments</td><td>HB_cr6.2 Floor plan - Thermal comfort control system location</td></tr>
</table>

Fig. 3: Level Of Information Need schedule for LEED HB credit IAQ 6.2

This table, structured following the requirements listed above and specified by the UNI EN 1742-1, was shared with the entire project team in order to allow its valorisation and consultation by the designers. In fact, not all data will have to be delivered by the same

designer, but it is up to the BIM Coordinator to define the different information responsibilities at the beginning of the process. Through an interdisciplinary information synopsis table, the BIM Coordinator designated the designers responsible for providing the necessary information [8].
To define the Level Of Information Need was important to identify the most suitable BIM object to which the information applies; for the 6.2 credit was chosen the object Room, because it is the element that can describe the entire environment of a building space and can give the right degree of specification required by this credit. Once the object was defined have been created as many schedules as rooms present in the building; in this way all the spaces could be described and, later, a summary schedule can be organised on Revit to have a global look to all the required parameter to achieve the protocol's credit.
Once the tables were filled, it was possible to transfer them to the BIM model as shared parameters. To make this step automatic, two scripts have been developed, via VPL, to link the excel table and the BIM model. It was created another schedule (Fig. 3), linked to the Level On Information Need one, which contains all the information necessary in the right order to create shared parameters.

Share Parameter Name	Share Parameter Group	Parameter Type	Parameter Group	Instance	Reporting	Value
HB_cr6.2 Type of occupation	IFC SustainableData	Text	PG_IFC	Yes	No	Bar
HB_cr6.2 Presence of thermal comfort control system	IFC SustainableData	YesNo	PG_IFC	Yes	No	1
HB_cr6.2 Type of thermal comfort control system	IFC SustainableData	Text	PG_IFC	Yes	No	Air temperature
HB_cr6.2 Shared/multi-function room	IFC SustainableData	YesNo	PG_IFC	Yes	No	0
HB_cr6.2 Floor plan - Thermal comfort control system lc	IFC SustainableData	URL	PG_IFC	Yes	No	C:\Users\maryr\Politecnico di Milano\Ar

Fig. 4: Excel schedule to create the shared parameters

The first script creates and associates the parameters with their Revit categories (Fig. 5). The second one valorises the respective parameters with their specific values (Fig. 6). The method of individualization of the "room" objects to which associate the values happens through direct selection from the model; in this way it is possible to value a single room or more rooms at the same time, according to the project requirements. In order to link the right values and create the parameters, the excel file has to be divided in different lists, one for each column; then every list it is connected with the node that will create the parameter in the BIM model. The check groups were added to verify immediately if the scripts have run properly, selecting all the wanted elements and adding the right number of parameters.

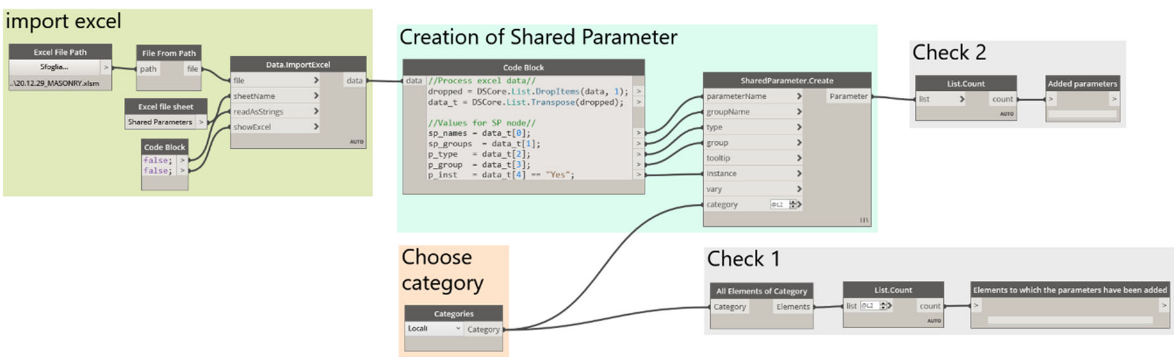

Fig. 5: Dynamo script to create and associate shared parameters

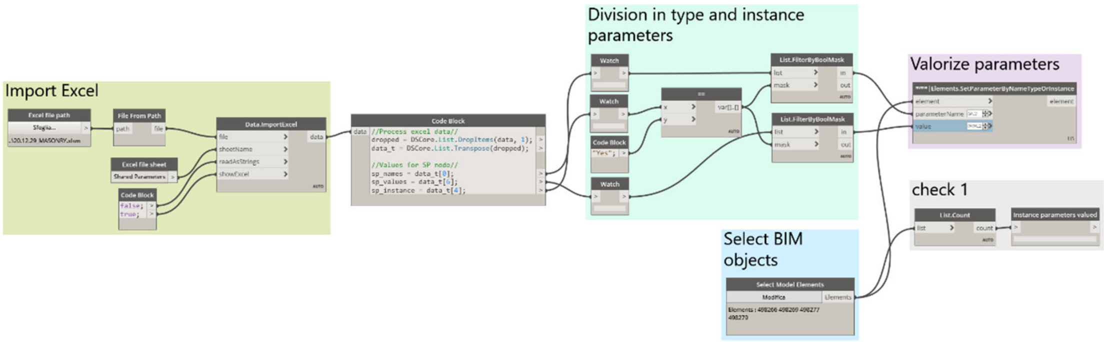

Fig. 6: Dynamo script to valorize the shared parameters

This tool allows to add only the parameters needed and update them throughout the design process without having to manually rewrite the data (Fig. 7). Once the parameters have been valorized it is possible to reorganize them in customized schedules to make them easily consultable in the BIM model; in this way it is possible to modify and control the LEED requirements during all the project cycle.

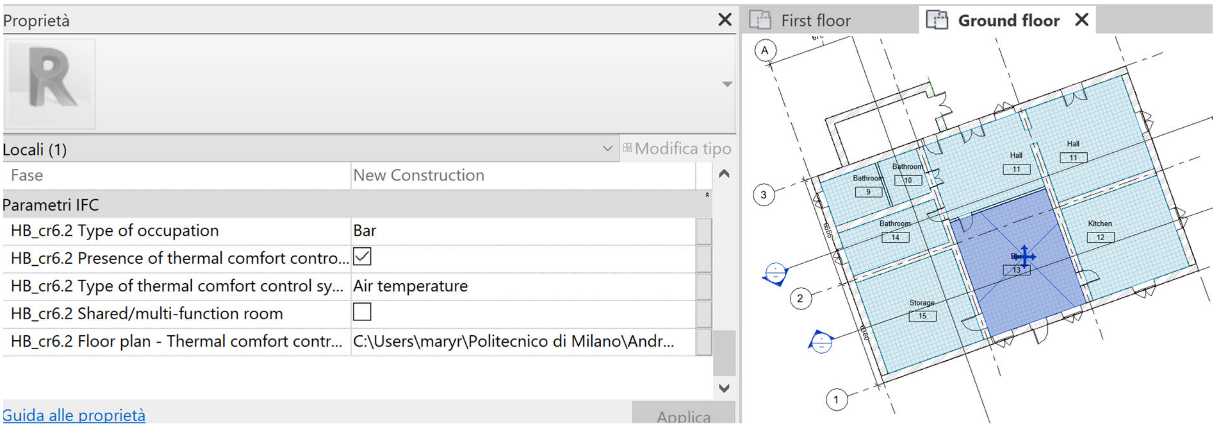

Fig. 7: Room parameters automatically created in the BIM authoring software

The schedules were organized to reflect the structure of the protocol requirements, so the information could be managed to facilitate matching the data needed to obtain LEED credits (Fig. 8-9). At the end of the process you have, therefore, a BIM model enriched with the necessary information to obtain the certification and design a sustainable building in every aspect.

<LEED HB Credit IAQ 6.2>						
A	B	C	D	E	F	G
Numero	Zona	HB_cr6.2 Type of o	HB_cr6.2 Presence	HB_cr6.2 Type of t	HB_cr6.2 Shared/	HB_cr6.2 Floor plan - Thermal c
Ground Floor						
13	Ground Floor	Bar	☑	Air temperature	☐	C:\Users\maryr\Politecnico di
Bar: 1						
9	Ground Floor	Bathroom	☐	-	☐	C:\Users\maryr\Politecnico di
10	Ground Floor	Bathroom	☐	-	☐	C:\Users\maryr\Politecnico di
14	Ground Floor	Bathroom	☐	-	☐	C:\Users\maryr\Politecnico di
Bathroom: 3						
11	Ground Floor	Hall	☑	Air temperature	☐	C:\Users\maryr\Politecnico di
Hall: 1						
12	Ground Floor	Kitchen	☑	Air temperature	☐	C:\Users\maryr\Politecnico di
Kitchen: 1						
15	Ground Floor	Storage	☐	-	☐	C:\Users\maryr\Politecnico di
Storage: 1						
First Floor						
1	First Floor	Bathroom	☐	-	☐	C:\Users\maryr\Politecnico di
2	First Floor	Bathroom	☐	-	☐	C:\Users\maryr\Politecnico di
3	First Floor	Bathroom	☐	-	☐	C:\Users\maryr\Politecnico di
Bathroom: 3						
6	First Floor	Classroom	☑	Air temperature	☐	C:\Users\maryr\Politecnico di
7	First Floor	Classroom	☑	Air temperature	☐	C:\Users\maryr\Politecnico di
8	First Floor	Classroom	☑	Air temperature	☐	C:\Users\maryr\Politecnico di
Classroom: 3						
5	First Floor	Hall	☑	Air temperature	☐	C:\Users\maryr\Politecnico di
Hall: 1						
4	First Floor	Hallway	☐	-	☐	C:\Users\maryr\Politecnico di
Hallway: 1						

Fig. 8: Revit schedule in which the parameters are organized to answer the protocol requirements

Identificazione zone (o gruppo di zone)	Tipologie di occupazione	Tipologia di controllo del comfort termico	Numero totale di spazi	Spazi dotati di controllo individuale
Ground Floor	Bar	Temperatura dell'aria	1	1
Ground Floor	Bathroom	-	3	0
Ground Floor	Hall	Temperatura dell'aria	1	1
Ground Floor	Kitchen	Temperatura dell'aria	1	1
Ground Floor	Storage	-	0	0
First Floor	Bathroom	-	3	0
First Floor	Classroom	Temperatura dell'aria	3	3
First Floor	Hall	Temperatura dell'aria	1	1
First Floor	Hallway	-	1	0
Totale:			14	7
Postazioni di lavoro provviste di sistemi di controllo termico [%]:				50
Conformità dei sistemi di controllo individuale del comfort termico: *Nota: La conformità del credito è possibile garantendo la presenza del controllo individuale del comfort termico per almeno il 30% degli occupanti.*				SI

Fig. 9: LEED HB schedule with the Italian protocol requirements for the credit IAQ 6.2

5. Conclusions

In conclusion, the developed method saves time, avoids transcription errors and does not burden the model with unnecessary information. The workflow is automatic and easy to manage, in fact, thanks to the use of dynamo player, the scripts can be launched with a few clicks. In this way it can be used even by designers with little experience of Dynamo. Thanks

to the selection of input and output is also possible to change the categories to which assign the parameters and be able to modify the workflow to best meet the project's needs. The method developed is, in fact, replicable and versatile and can be applied to different disciplines and become a useful tool for information management. Scripts can be linked to any BIM model, creating the necessary parameters. Using the schedules, information can be easily managed and reorganized to better meet project phases and needs.
Information management is especially important in historic building design, where the ability to organize data and transfer it securely and automatically is critical.
It is important to specify, however, that was not possible to convert all the information required by the protocol in shared parameters and schedules, due to the complexity of the data requested or the difficulty to identify the BIM object to which assign the parameters. It could be interesting to study more precisely the connection between the LEED protocol and the BIM software in order to collect all the information required in one file.
This method provides a starting point for applying the workflow to different disciplines and design phases. It can be developed to meet other needs, such as those related to systems facility management, where automatic information flow is critical. It will be necessary to continue to develop the concept of Level Of Information Need in different disciplines and for different categories, to be able to apply it to all the life cycle of the building. In this way it will be possible to have all the required information, but to import in the model only those necessary for the analysed phase or discipline.

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