Acoustic Refurbishment on a Temporary Auditorium: BIM Design and Interventions Influences

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Abstract

Building Information Modelling (BIM) is playing an increasingly greater role in the world of construction. BIM should combine as many stakeholders as possible during the design workflow and make it possible to manage the created object before its realization, as well as follow it during its entire lifetime. Holding together such a large number of functions is not an easy task; managing each of them in the best possible way is even more complex, especially if, as is happening today, the sectors involved in the construction of a building are becoming increasingly specialized. In order to verify (i) what the limits are that a BIM software can reach, (ii) what the most common difficulties are and (iii) in which sectors they usually appear, it is necessary to study a real project carried out in its entirety with the BIM method. For this reason, a complex case study has been chosen which would be useful in formulating a response to the previous key points. The critical aspects linked to the possible choices that should be made between the various software have been highlighted as well as the pros and cons of the possible paths that can be followed. Finally, the future scenarios of integrated software development are identified and the way in which they may be adopted to address the difficulties and weaknesses that BIM still presents, is discussed.

1. Introduction and Scope of Work

Moving from CAD (Computer Aided Design) to BIM (Building Information Modelling) includes the necessity to understand the difference between "drawing" and "modelling", handling objects instead of geometrical elements and, moreover, "intelligent" objects, carrying with themselves a certain amount of information. Thus, it is evident that designed forms are not only "shapes" anymore (Caputi et al., 2015).

BIM claim to be a unique cycle, which is able to treat in the same way most of the professional sectors involved in the design and the construction of a building, such as architectural design, load analysis, real time rendering etc. (Ciribini, 2013).

The main aim of the study is to assess and to give a clear image of how a BIM software operates in situations where it has to approach the most technical fields of buildings design, moving further than modelling as it was meant before, just virtually assembling different shapes together.

In order to develop this topic, a case study was carried out, namely the restyling of an auditorium. In this example the main goal was to link the existing edifice to the surroundings, providing a strong sound insulation system, no variations of the inner acoustics and a new lighting facility.

2. Materials and Methods

In order to better understand the importance of a comprehensive IT design, a case study was identified and studied. It consists of a real auditorium used often to host live events and located close to residential areas, in an Italian city (Fig. 1).

The primary function of the intervention included a covering body (Fig. 2), providing a solution to the problem of acoustic insulation with respect to the surrounding residential areas. The present temporary structure cannot limit the propagation of the noise, causing disturbances (Tronchin and Coli, 2015).

The existing structure is more similar to a temporary tensile composition made of steel beams supporting

Part of
Pernigotto, G., Patuzzi, F., Prada, A., Corrado, V., & Gasparella, A. (Eds.). (2020). Building simulation applications BSA 2019. bu,press. https://doi.org/10.13124/9788860461766

a polymeric frame. This construction is typical of temporary edifices; however, it is not expected to be dismantled. It is actually considered one of the main suitable locations for concerts and similar events.
The goal was the realisation of an external sound insulating covering; this whole process was carried out with the help of a Building Information Modelling software, which helped develop the entire plan, from the beginning to the end.

Fig. 1 – Project area, auditorium on the left, residential areas in the background

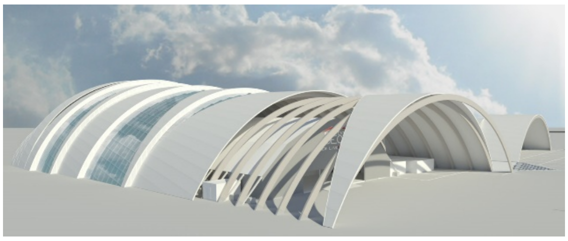

Fig. 2 – The covering roof structure

This kind of approach made it possible to separate and treat each of the working phases separately. This was the easiest and fastest way to understand in which stages of the process Building Information Modelling could actually be an advantage and, on the other hand, when adopting this alternative process could create some problems, and therefore not provide satisfying results.
In addition, an uncommon structure as the case study was chosen in order that unconventional architectural shapes could be used and particular volumes modelled. This was considered important because it was felt that all possible solutions which a BIM system provides to the user should be developed and investigated.
The different types of BIM software are similar but not equal even if they should all work in the same context (Wang et al., 2019). This is due to the fact that over the last few years, a huge number of different companies have developed their own BIM software and, although the concept behind them is more or less the same, it is still possible to identify some significant differences. The first step is therefore choosing the right software for the specific need.
It is particularly important to discriminate between two main groups of programs; their leading distinction is the way they treat the elements, namely components of the building's model (Eastman et al., 2016).
The first sample (Fig. 3) works with single constructive elements, which means that each object is independent from the others: its features can be modified one by one without having an influence on anything else.

Fig. 3 – Functioning method of the first software sample

The second sample (Fig. 4) proposes a different approach: all the elements are assembled together in order to create the entire model; they are listed in categories, or "families" and "typologies". This means that a single object belongs to a certain family and has a specific typology.

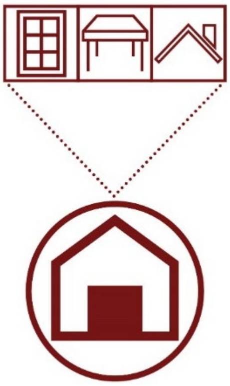

Fig. 4 – Functioning method of the second software sample

"Families" are groups of certain kinds of elements (furniture, constructive elements etc.), with the same standards. The "typologies" are the sections where slightly different objects of the same family are contained (Fig. 5) (Zhou et al., 2019); they are the same model, but with a couple of distinct features: dimensions for instance, materials or slightly different constructive characteristics (Gasteiger, 2015).

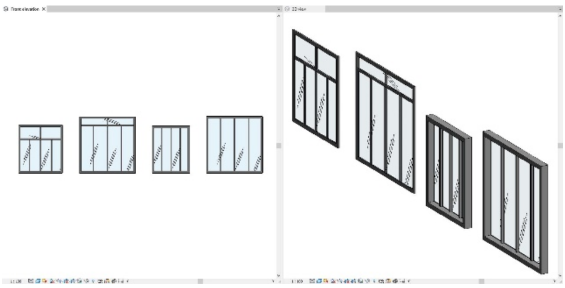

Fig. 5 – Example of more typologies of a window family

In this second kind of software, if a feature is modified, all the elements of the same type, which are already included in the file, are also adjusted too. If a customization is needed, a new typology or a new family must be created, so as to leave the other existing elements of that family unaltered (Hardin and McCool, 2015).

In this view, the first type of software could be advantageous for smaller projects, or at least when in a certain construction the number of elements is not too high. Therefore, they can still be managed without any particular difficulty by the user and, if necessary, updated one by one. In these cases, having the ability to interact with a single object, while leaving all the others unaltered, could make some processes faster to implement.

The second type is obviously the opposite, helping much more when numbers and values are increasing.

In this case, the chosen software belongs to the second group. This choice is dictated by the fact that a more in-depth parametric design could be implemented. In addition to the above-mentioned characteristics, this type of program is closer to an informatic approach and less to the world of architectural design. It means that the procedures adopted are mostly constructed following the operating mode of IT programming; thus, the software itself allows the user to access, organize and reassemble the information contained in a certain file. Parameters and data are available to the user who is able to manage an object from every point of view, not only in its external appearance. Choosing this type of software makes it possible therefore to reach the aim of the project from a more accurate perspective. Working with the first group could have possibly been faster in some steps, but, in this way, there is a wider range of aspects that are analyzed.

It is also important to point out the main differences in terms of planning between a BIM and a traditional CAD program. Building Information Modelling deals with the whole process involved in a construction, being able to follow all the different phases, from the design to the demolition or the relief and the renovation. This way of working is called "seven-dimensional planning" (Fig. 6), where each "dimension" indicates an extra field that is treated by these software, from the standard 3D spatial modelling to the 7th dimension that stays for "maintenance".

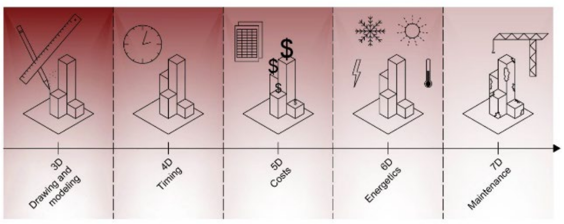

Fig. 6 – Representation of the "7D planning"

3. Results and Discussion

At this step, it can be stated that all the tasks related to the definition of the structure itself were simplified and completed more easily than if it had been carried out with other tools.

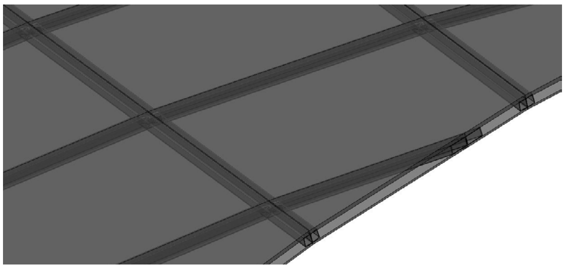

Fig. 7 – Detail of the constructive elements of the roof

The use of a parametric method is clearly advantageous (Mirshokraei et al., 2019). In this case, the designing of the external and internal shape could probably have been achieved with most computer aided modelling applications. Nevertheless, the adopted procedure seemed to be the best solution because the covering skin of the auditorium has a grid structure and is composed of individual construction elements (Fig. 7) and each of them must adapt to the required curvatures (Fig. 8).

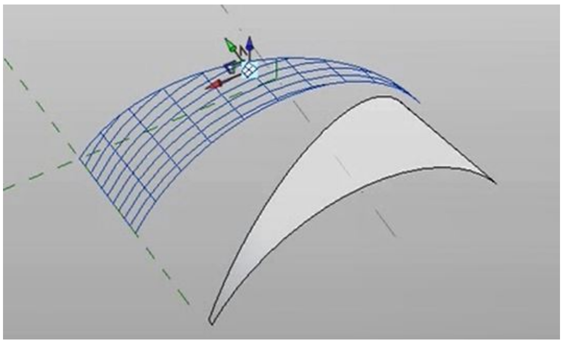

Fig. 8 – The grid adapted to the curvatures

On the one hand, the above-mentioned aspect is particularly evident in the change in size and characteristics (Fig. 9) of the frames and components: the way in which the latter adapt to the former is automatic, considerably faster and with less chance of making mistakes during the procedure.

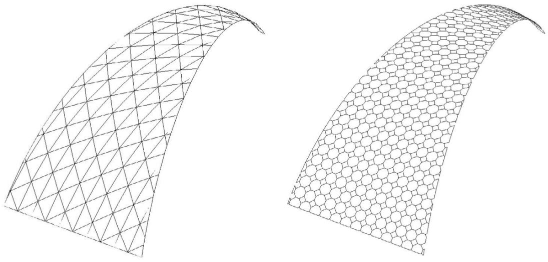

Fig. 9 – Comparison between two different frame systems, adapted to the same shape only by changing parameters

On the other hand, there is no specific section in the BIM language referring to acoustics or lighting technology. It is therefore important to understand which path to take to make it possible to solve the phases of design and subsequent assembly more easily and quickly.

It is also important to highlight that modelling in a BIM software does not always involve the same procedure. This means that the way an object is obtained depends greatly on its final function and how it will be positioned in the building and which cues and pointers it will have in its ultimate position. It is therefore very important for the user to be aware of the kind of construction element that has to be modelled and with which properties, at the very beginning of the process.

This creates the possibility of obtaining individual objects, frames, grids, modular systems and so on and each of them will adapt in the best possible way according to the function and role they play within the construction.

When analyzing the acoustic issue, the problems may be presented in a slightly different way. This includes many variables, which need to be predicted and analyzed in the best possible way (Farina and Tronchin, 2013; Ruggeri et al., 2015; Tronchin and Fabbri, 2017), even if realized using gypsum panels (Piana et al., 2014). It is not only necessary to consider the porosity or the surface impedance or airflow resistivity of the different materials (Fig. 10), but also the intensity and size of the different sound waves. These are not direct factors that can be included in a BIM software and some of them are impossible to manage to the last detail, especially because they may require a dynamic situation to be analyzed.

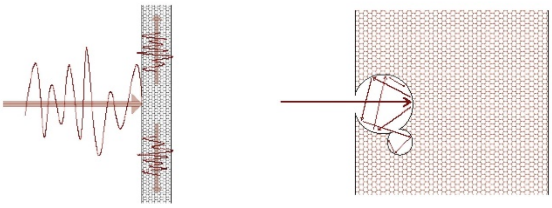

Fig. 10 – Sound-absorbing surface and soundwave interaction

In this way, another process must be adopted to simulate the diffusion of sound waves inside and outside the auditorium structure. In this case study, there were no other choices of importing the model into an external 3D ray-tracing acoustic software (Fig. 11), consequently losing all the included BIM-information.

Even if the procedure is not actually too long, the problem comes from the fact that for the first time in the design flow, other programs have to be involved, meaning that the model is leaving the BIM environment (Tanaka et al., 2019; Wu and Zhang, 2019). This causes the digital format to be changed.

It is easily understandable that this kind of method could solve a task, but at the same time it would create a dead branch of the process as well. The exported and modified model would not be usable for other purposes except for the one it was created for (e.g. acoustic simulations).

This fact is exactly the opposite of what happens with BIM objects, involving the same model in as many sectors and professional areas as possible, without the necessity to export or to change any digital format, creating a two-way procedure.

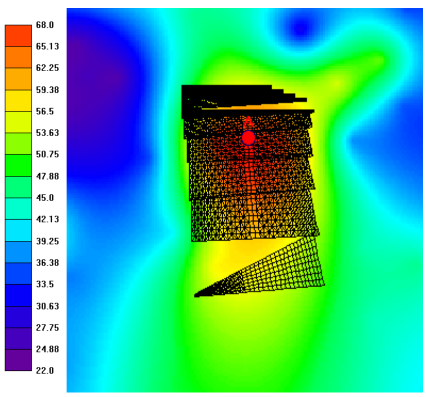

Fig. 11 – Sound insulation virtual simulation of sound pressure levels carried out without a BIM software. "A" indicates the noise source position

Further difficulties arise when analyzing the lighting tasks. This time the problem is not related to the model or its format. It is more about the way certain aspects are handled by the software: there is a lack of BIM tools that approach light as a dynamic aspect (Nawari, 2019).

This project involved the theme of light (Fig. 12) as a sign that makes it possible to understand from outside if the auditorium is hosting an event or not. This means that it becomes a variable, not only in the two directions "on or off" (what usually happens in an ordinary "day and night" situation), but in more cases. This implies the need to add a certain number of parameters more or less linked to each other, to be able to control these variations.

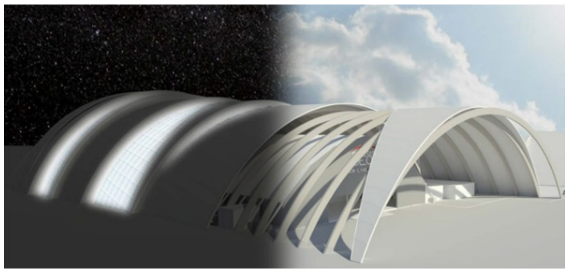

Fig. 12 – Day and night circumstances

BIM software include this possibility for a number of aspects, but have not been able to handle them during the flow of time so far.

It is not generally possible to create a dynamic model that can therefore help to understand how proper characteristics change over time (for example, distinction between day and night hours, or events presence). Even if the "time" variable is important in a BIM procedure, it is usually meant as a condition, not as a dynamic flow: the user can only modify the status of the project in the digital environment, in order to be able to predict how the real structure will react to wear. For these reasons, it was necessary to adopt a static solution (Fig. 12). It was therefore not possible to verify changes in the designed lighting during the different hours of the day, but several different static situations had to be created to distinguish how the structure would react to different lighting conditions (Fig. 13). In terms of final results, the quality was not lower, and it was still possible to analyze how the scenario would be in many different situations, but it was extremely time consuming.

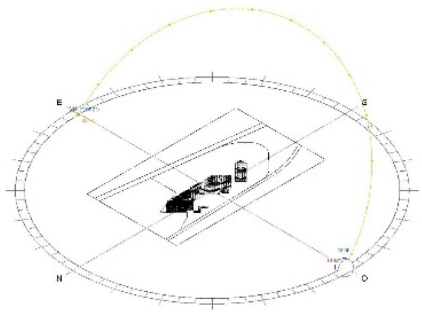

Fig. 13 – Solar light settings in a BIM software

In order to somehow include more aspects into BIM environments, software developers have adopted multiple and often different solutions. Most of the companies have included in their software the possibility to add external parts and sectors, which are useful to strengthen and to improve a certain aspect of the planning. These implementations belong to two main categories: tabs and plug-ins.
Plug-ins are likely more complex and complete. They are extra software, based on and working with the main BIM program. On the other hand, tabs are often better connected and easier to use, because there is no need to leave the main software, since they are actually tools already integrated in the main software's environment.
Although BIM is not free of shortcomings and lacks, the whole issue must be seen in its entirety: this type of IT tool is still young and is probably in its main phase of development and growth. Furthermore, fields such as construction science and design have also been evolving very rapidly in recent decades. This fact therefore means that both sides most likely need time to adapt to each other.
The main goal then has to be to reach a complete "open BIM" situation: this term indicates a scenario in which all the different BIM software would be able to collaborate with each other without limitations, including output formats. This plan naturally requires a common digital standard, and for this reason the IFC (Industry Foundation Classes) format was created (Di Martino et al., 2020). This would be the way to connect all stakeholders who have to deal with a project together (Fig. 14), limiting the loss of time and of information between the different stages of its development. As the example shows, a good variety of tasks could be completed with the help of an appropriate parametric setting; this is the best way to deal with aspects that may still present some interface difficulties, such as acoustics or lighting.

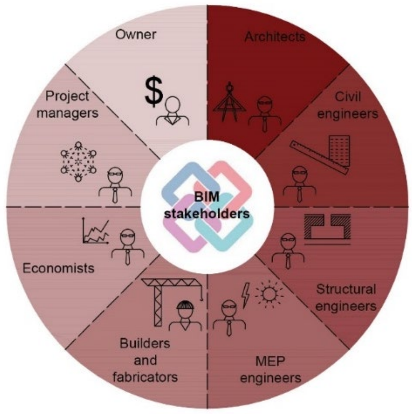

Fig. 14 – Possible stakeholders

Finally, in the authors' opinion, it is necessary to have a common framework, a standard format that can be used for the development of possible plug-ins of the main software. In this way, the different companies could have a common base to work on during the programming process. This fact could facilitate the interaction between the BIM software and its plug-ins and also highlight any areas not adequately covered by the various proposed tools.

4. Conclusions

In this paper, the problem of using the BIM method for complex structures involving acoustics and lighting properties has been addressed. The pros and cons of the various BIM modelling methodologies were analyzed and a complex case study was carried out to identify a possible way to implement these features, which are currently absent, in Building Information Modeling.
Finally, the possible improvements were highlighted, which are desirable in order to make the best use of this tool, which today still lacks many technical aspects related to building physics such as (i) the acoustic aspect of materials and components and (ii) the simulation of lighting in dynamic mode. A possible solution is represented by "open BIM", where the software can fully interact with other external programs and can be also implemented by

tools, able to resolve issues by taking full advantage of this type of virtual design.

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