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# PROPUESTA PARA LA IMPLEMENTACIÓN DE LA METODOLOGIA BIM EN UNA EXPERIENCIA ÁULICA ORIENTADA A LA SUSTENTABILIDAD EDILICIA

## PROPOSAL FOR THE IMPLEMENTATION OF THE BIM METHODOLOGY IN AN CLASSROOM EXPERIENCE FOCUSED ON BUILDING SUSTAINABILITY

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RESUMEN

*Building Information Modeling* (BIM) es una metodología de trabajo colaborativo que concentra toda la información de un proyecto en un único prototipo virtual susceptible de ser estudiado a lo largo de su ciclo de vida. Una de las principales dificultades para su implementación es la escasa formación de profesionales en su uso y alcance. Por ello, esta investigación surge con el objetivo de proponer una mecánica de trabajo en tiempo real que, a partir del uso de la metodología BIM desde instancias iniciales del proceso de diseño, constituya un sistema de apoyo a la toma de decisiones en relación con la sustentabilidad edilicia. Con tales fines, se establecen lineamientos básicos para el desarrollo de una experiencia áulica piloto que integre el uso de la metodología BIM, a partir de la realización del *Building Energy Model* (BEM) de tres prototipos de vivienda social de uso generalizado en San Juan, Argentina. Como resultado, se obtiene el *BIM Execution Plan* (BEP) para la primera implementación de la metodología BIM en el Taller Vertical de Arquitectura Ambiental (TVAA) de la Facultad de Arquitectura, Urbanismo y Diseño (FAUD) de la Universidad Nacional de San Juan (UNSJ).

Palabras clave
BIM, mecánica de trabajo, experiencia áulica, BEM, BEP

**ABSTRACT**

Building Information Modeling (BIM), is a collaborative methodology that gathers all the information of a project in a single virtual prototype, which can then be studied throughout its life cycle. One of the main difficulties in its use is the limited training of professionals in its use and scope. Consequently, this research proposes a real-time work procedure where, by using the BIM methodology in the initial stages of the design process, this constitutes a support system for decision-making with respect to Building Sustainability. With this in mind, basic guidelines are set out to develop a pilot classroom experience that integrates the use of the BIM methodology, by making a Building Energy Model (BEM) of three commonly used social housing prototypes in San Juan, Argentina. The result is the BIM Execution Plan (BEP) for the first use of the BIM methodology in the Vertical Workshop on Environmental Architecture (TVAA) of the Faculty of Architecture, Urbanism and Design (FAUD) of the National University of San Juan (UNSJ).

Keywords
BIM, work procedure, classroom experience, BEM, BEP.

# INTRODUCTION

Building Information Modeling, or BIM, is a set of methodologies, technologies and standards that allow designing, building and collaboratively and through interdisciplinarity, running a building or infrastructure, throughout its life cycle, in a virtual space (PlanBIM, 2019). Salinas & Prado (2019) sustain that the standout international models for the development of BIM regulations and standards are the United States, the United Kingdom and Singapore. In South America, Brazil and Chile are the furthest ahead in BIM implementation from the public sector. In Argentina, the BIM standard came from the private sector, but with the participation of the public sector. The rest of the region has individual initiatives, without finalizing documents that reflect collaborative work (Salinas & Prado, 2019).

One of the main difficulties detected regarding BIM expansion is the lack of trained professionals. To counter this issue, the role of universities is essential (Orrego, 2017). Regarding the state-of-the-art, it is seen that Piña, Varela, Aguilera & Vidales (2017) propose revising study plans to include more competences related to BIM methodology. For this, they define an organizational chart that establishes the role of BIM agents in the different phases of the project (Design, Construction and Operation), the extent of involvement and the level of knowledge required, so that Construction Engineering students know, beforehand, what the relationships are between said players.

Meana, Bello & García (2017) and Reyes, Prieto, Cortés & Candelario (2017) also analyze the use of the BIM methodology in Industrial Engineering degrees. Meana et al. (2017) suggest the need of adapting the current educational model to the needs of professionals of collaborative models. In this sense, they propose establishing an inter-university commission that leads and unifies goals and competences regarding said methodology. Meanwhile, Reyes et al. (2017) conclude that BIM technology can be used in university teaching with a high probability of success.

Although there is a large amount of research related to the use of BIM methodology in different fields of the construction industry, its implementation in building sustainability-oriented pedagogical practices from the early stages of the design process, has not been addressed. In this line, the aforementioned authors do not outline the use of documents such as the BIM Execution Plan (BEP), or the preparation of a Building Energy Model (BEM). Likewise, the development of standards regarding BIM methodology matches its application in the public sector. However, there are no standards that guide the way this methodology must be implemented in an academic setting.

González Pérez (2015) mentions that the BIM standard is a common framework that must be carried out in the phase prior to starting the project and that it affects the proper performance of collaborative work. In PlanBIM (2019), it is said that a standard is a document established by consensus and approved by a well-known entity which put themselves in the position to help obtain an optimal degree of organization in a given context.

On the other hand, Chong & Wang (2016), Sakin & Kiroglu (2017) and Chaves, Tzortzopoulos, Formoso & Shigaki (2015) agree that BIM constitutes a reliable base to make decisions that lead to the incorporation of sustainable approaches and to the improvement of building performance, on allowing monitoring a project throughout its life cycle. Mercader Moyano Camporeale & Cózar-Cózar (2019) highlight that the consideration of environmental issues during the design stage, represent one of the greatest challenges for designers.

Upon this starting point, of the aim of this article is proposing a real-time work procedure where, from using the BIM methodology in the initial stages of the design process, it makes up a support system for decision-making regarding building sustainability. From that perspective, basic guidelines are initially defined to perform a BEM aimed at analyzing the comfort level of social housing. For this, the thermal characteristics of the materials involved for the construction solutions adopted in three commonly used social housing prototypes in the city of San Juan[1], Argentina, are taken as the starting point. In the same way, foundations are built for the diagramming of a BIM Execution Plan (BEP) directed to the first implementation of BIM methodology in a classroom setting. This will take place in August 2020, in the Environment Architecture Vertical Workshop (TVAA, in Spanish) of the Architecture, Urbanism and Design Faculty (FAUD, in Spanish) of the National University of San Juan (UNSJ, in Spanish), contributing to the development of future BIM standards in education. In short, the intention is to contribute to habitat sustainability, making future professionals aware of the importance that project decisions have throughout

1 City located in the center-west of Argentina, on the Diagonal Árida Sudamericana.

the life cycle of the building. In this regard, specifying the work procedure needed to pass from BIM to BEM allows redefining and improving, in the stage prior to the execution of the works, those technological, construction and design aspects that contribute to a greater sustainability in the building.

# METHODOLOGY

This article proposes a set of documents, capable of structuring a future teaching practice which, based on the BIM methodology, favors the integration of building sustainability variables into the design process for Architecture students. Using this as a starting point, basic directives could be defined to elaborate a Standard aimed at implementing BIM methodology in Architecture teaching in general, and in building sustainability in particular.

From this approach, the proposed methodology is based on two successive stages. In the first of these, the basic guidelines for developing the BEM are defined; then, the comfort level of the three commonly used social dwelling prototypes in the city of San Juan, Argentina, are analyzed. Here, it is important to consider that, although EnergyPlus is the standout analysis model, other software for building information modeling, like Revit and ArchiCAD, are easier to use, which favors their application for assessment in early design stages. The development of this stage includes determining the work procedure needed to go from BIM to BEM. General aspects related to the Basic Information Delivery Manual (IDM) are also mentioned, while the importance of the BIM Information Requests (SDI – BIM) is determined. In addition, the content of the evaluation reports obtained, namely, the possible output variables related to the data input in the BEM, is analyzed. From this, it is possible to determine the similarities and differences associated to the use of each software. This is interesting, so that the teacher can guide the student towards the correct interpretation of the results and, as a result, towards the determination of bioclimatic design strategies that contribute to improving the comfort level obtained in the simulation. The contents of each assessment report are analyzed following six variables (transparency, traceability, processing, comparability, complexity, and possible output variables).

In the second stage, general guidelines are established for the classroom implementation of the BIM methodology. With this purpose, a workflow is proposed, destined to incorporate sustainability variables in the initial stages of the design process. Finally, a role matrix and the Offer PEB, that guides the teaching process, are built. Figure 1 summarizes the proposed research methodology.

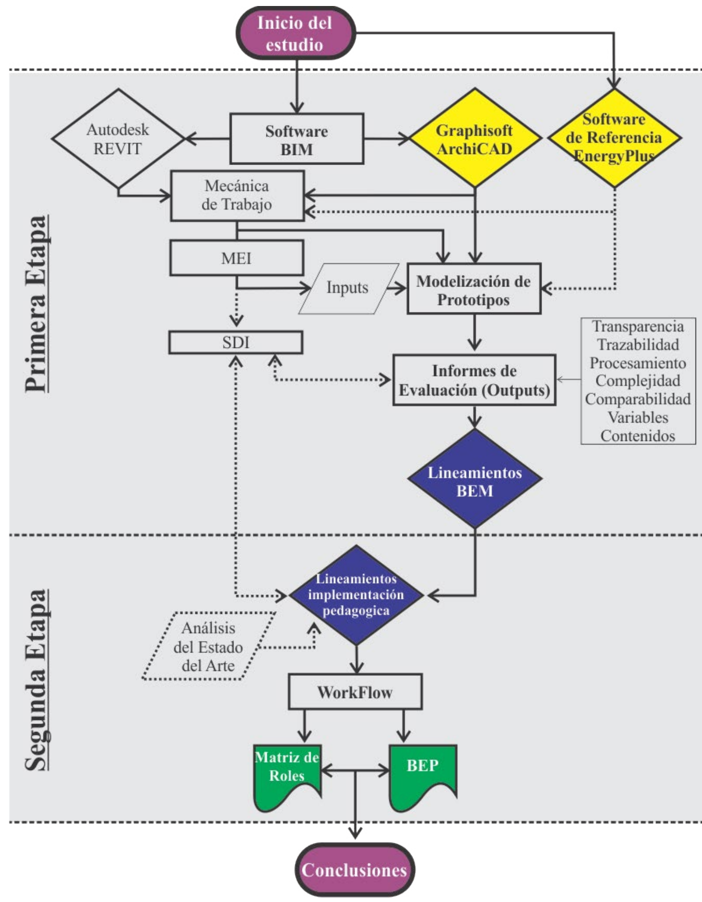


Figure 1. Flowsheet of the proposed research methodology Source: Preparation by the authors.

## STAGE 1: BEM GUIDELINES

Both for Lu, Wub, Changa & Lib (2017) and for Martin, Franco, Broock, González & Assef (2014), traditional design methods are limited in terms of sustainability analysis because of the fragmentation of the information they handle. As a result, including energy assessment in the architectonic design workflow, facilitates the creation of projects that fulfill and, even, exceed energy efficiency standards (Soltani, 2016). However, generating a parametric model requires software management skills that go beyond the three-dimensional representation and implies knowing the way in which parameters to build a functional and useful BIM model must be allocated (Mojica, Valencia, Gómez & Alvarado, 2016).

The term BEM refers to a simulation tool to calculate the thermal load and energy use in buildings, that allows predicting their use based on the architecture and the cooling, heating and air-conditioning systems (Jiménez, Sarmiento, Gómez & Leal, 2017). Therefore, to perform a correct energy assessment, the building's 3D model has to, at least, contain the envelope and carpentry structures, as well as all the main internal structures that represent a significant heat storage volume (Graphisoft, 2017).

According to Llave Zarzuela, Arco Díaz & Hidalgo García (2019), internationally, Revit and ArchiCAD are the modelling tools of building information, that include the energy assessments most used by construction professionals. They also mention that the integrated energy assessment tool of Revit is *insight 360* and ArchiCAD's is *Ecodesigner*. In addition, they mention that *insight 360* is an analytical tool lacking sufficient testing; however, the *Green Building Studio* tool can be used. Finally, they highlight that *Ecodesigner* is considered one of the most accurate energy simulation software, as it has an error range of less than 5% in energy performance assessments (Llave Zarzuela et al., 2019). Meanwhile, Blat Tatay (2016), characterizes the aforementioned software starting from their main qualities and concludes that Revit and ArchiCAD are powerful and equivalent tools that have reached sufficient maturity to be representative of the moment the BIM methodology is experiencing.

Considering the goals proposed for this research, it is necessary to highlight the importance of using tools that allow assessing building sustainability from the initial moments of the design process. Along this line, it is relevant that the software used in the development of the classroom experience, is easy to use for the students. Based on this, and looking at setting the basic guidelines to perform the BEM, the proposal is made to use the Revit, ArchiCAD and EnergyPlus software to obtain their similarities, differences and scopes, both at a user/interface level and in terms of their output variables.

ArchiCAD, version 21 (demo), Revit 18 (demo) and EnergyPlus 8.4.0 were used to make the models. The prototypes modeled are A-13, B-13, and A-12 (Figures 2, 3 and 4). The graphical information was provided by the San Juan Provincial Housing Institute (IPV, in Spanish-San Juan). In all cases, the prototypes are considered as located in a north-south facing lot with a main access their south face. This constitutes a simplification that allows considering the results using the same location conditions. Table 1 summarizes the thermal characteristics of the materials used to build the dwellings.

## STAGE 2: TEACHING PRACTICE GUIDELINES

Blasco Gutiérrez, Parant, Olivier, González Redondo & García (2017) state that the BIM methodology constitutes an evolution in collaborative work in all parts of a project and, therefore, university teaching must adapt to the current digital profile of the student, to help them distinguish the different roles of their profession, from the very beginning. In other words, BIM

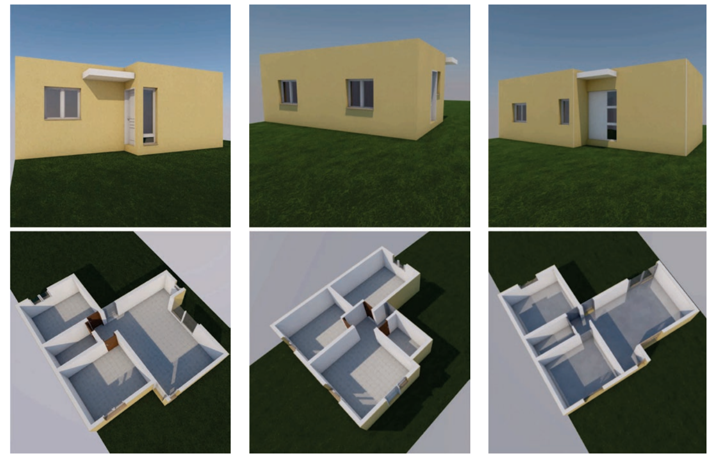

Figure 2. Prototype A-12-
Figure 3. Prototype A-13.
Figure 4. Prototype B-13.
Source: Preparation by the authors based on the information from IPV-San Juan.

| Element | | Layers of the construction element | R (m²K/W) | K (W/m²K) Winter | K (W/m²K) Summer |
|---|---|---|---|---|---|
| External Walls | | Mortar | 0.01 | | |
| | | Brick | 0.22 | 2.374 | 2.374 |
| | | Mortar | 0.02 | | |
| Internal Walls | 1 | Mortar | 0.02 | | |
| | | Brick | 0.22 | 2.36 | 2.36 |
| | | Mortar | 0.02 | | |
| | 2 | Mortar | 0.02 | | |
| | | Brick | 0.09 | 3.46 | 3.46 |
| | | Mortar | 0.02 | | |
| Roof | | Asphalt membrane | 0.01 | | |
| | | Leveling cover | 0.04 | | |
| | | Pomeca (natural pumice stone) | 1.25 | 0.647 | 0.619 |
| | | Reinforced concrete slabs | 0.09 | | |
| | | Lime coated ceiling | 0.02 | | |
| Floor | | Subfloor | 0.1 | | |
| | | Cover | 0.03 | 3.29 | 2.67 |
| | | Tiling | 0.03 | | |
| External Doors | | MDF 18mm | | | |
| | | Air | Adopt: 3.50 | | |
| | | MDF 18mm | | | |
| Internal Doors | | MDF 5mm | | | |
| | | Air | Adopt: 3.50 | | |
| | | MDF 5mm | | | |
| Windows | | 3mm transparent glass | Adopt: 5.82 | | |

Table 1. Thermal Characteristics (Resistance and Transmittance) of the materials used in the analyzed dwellings. Source: Preparation by the authors.

References: Comfort levels in W/m2K from IRAM 11605 (Bioenvironmental zone III)
Summer condition: ■ A (Walls: 0.50 Roof: 0.19) ■ B (Walls: 1.25 Roof: 0.48) ■ C (Walls: 2.00 Roof: 0.76) ■ Not reached
Winter condition: ■ A (Walls: 0.286 Roof: 0.246) ■ B (Walls: 0.758 Roof: 0.642) ■ C (Walls: 1.31 Roof: 1.00) ■ Not reached

education must focus on improving the communication flow and the work sequence (Latorre, Sanz & Sánchez, 2019). For Granero & García Alvarado (2014), teaching architecture considers an essential dedication to design workshops. As a result, BIM implementation finds, in these curricular spaces, favorable conditions for its development.

Along this line, for Piña et al. (2017), running a pedagogical practice based on the BIM methodology requires identifying the different phases of the BIM project simply. These opportunities can be summarized as: Design, Construction and Operation. Reyes et al (2017) implement an Experimental Device that, starting from group work, the determination of roles, conditioning factors, and regulations to comply with, allows students to develop competences that facilitate their integration into the working world.

Likewise, the Argentinean Chamber of Construction (CAMARCO, in Spanish, 2020) mentions that BIM implementation requires planning how the transition of work will be done, as well as how to choose and develop a pilot project. At the same time, they highlight that this project must be on a small scale, with medium complexity and respond to a construction typology that the work team knows well.

Concretely, BEP is a document where the strategies, processes, resources, techniques, tools, systems, etc., which must be applied to guarantee compliance of the BIM requirements requested by the client in a given project, converge, following the life cycle phases related to this (ESBIM, 2018). Following the PlanBIM (2019), two BEP must be developed: one of the Offer (Tender) and another Definitive one (Awarded Supplier). The difference between them is based on the level of detailed information each one contains. The Offer BEP contains basic information of the project, goals and uses of the BIM, technological infrastructure and competences of the team, general deliverables, and overall collaboration strategy. The Definitive BEP, apart from having a greater specificity in the information, includes the standards and conventions that will be used.

Regarding the determination of the roles of the different participating agents, Piña et al, (2017) identify the following intervening agents in the BIM projects:

- BIM Manager: responsible for managing the team and developing and applying the BEP.
- BIM Coordinator: executive party of the BIM Manager, also responsible for developing, applying, and managing the PEB of a project.
- BIM Modeler: in charge of handling the modeling of the project.
- BIM Operator: in charge of managing the deliverables and the exchange of files.
- BIM Analyst: in charge of making simulations and analysis of the BIM models.
- Content Manager: performs the information management tasks the model contains.
- Facility Manager: carries out the building's management in the operation and maintenance phase in a BIM environment.

In this way, a role matrix, following the characteristics of a classroom implementation of the BIM methodology, must make the roles defined by the BIM standards compatible with the functions, characteristics and capacities of teachers and students, in particular. It is worth adding that, as a result of its main characteristics, it is feasible to develop an Offer BEP that allows structuring the teaching practice; while the Definitive BEP will emerge regarding the final presentation of the project, being able to include indicators that facilitate its evaluation considering the percentage compliance of the proposed goals.

Following on from this, it is proposed to hold, in August 2020, a BIM implementation classroom experience in the Environmental Architecture Vertical Workshop course of FAUD-UNSJ which, based on what has been set out by CAMARCO (2020), will consist in the development of a social dwelling (typology known by the students, with a small scale and medium complexity). Given that the analysis is focused on building sustainability, it is considered pertinent that the students in the pilot project work team have prior knowledge in the matter. For this reason, it is better that the experience is carried out with advanced students. In addition, to select the work team, it is proposed to make a survey beforehand, aimed at determining the level of knowledge among the workshop's students regarding BIM methodology and building sustainability.

## RESULTS AND DISCUSSION

The first stage of development of the research consists in making the BEM models corresponding to the chosen case studies. The different prototypes were prepared following the commonly used construction solutions in the housing of IPV-San Juan that, as can be seen in Table 1, do not reach the C level (minimum) established for the Bioenvironmental Zone to which San Juan belongs (IIIa), in accordance with the IRAM 11605 standard. Therefore, from a perspective focused on hygrothermal comfort, these construction solutions must be revised to respond to the current standards in Argentina, in general, and to building sustainability, in particular.

However, the importance of running these models in Revit, ArchiCAD and EnergyPlus, lies in that the basic guidelines that allow passing from the BIM to BEM model can be obtained from this task, as well as the scopes associated

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to each software.

In this sense, according to PlanBIM (2019), the Information Delivery Manual (IDM, in Spanish) constitutes a guide to prepare the BIM models. In other words, it structures the information to guarantee quality BIM deliverables and to ensure the availability and possible reuse of the information. In this direction, the development of the IDM implies:

- The same language, in order to remove inefficient tasks.
- OpenBIM IFC
- Same structure. It relates with the information systematization and coding (coherent and uniform file naming, coordinated position, matching the names corresponding to the BIM model levels, as well as the correct use of entities).
- Availability of information for future uses, resulting from the suitable use of the properties and set of properties defined in IFC.

It must be underlined that the importance of using IDM is the possibilities of improving interoperability, increasing effectiveness of task development, facilitating information systematization and, therefore, its availability for future use.

On the other hand, Tables 2 and 3 present the differences and similarities detected in the assessment reports obtained with each one of the pieces of software used in the research. In this regard, it is highlighted that, in Table 2, the content of these reports is qualified using a scale of *high, medium and low*, depending on the transparency and traceability of the results obtained and the possibility of running later relational analysis. Based on the purposes of this research, the complexity of the interpretation of results and the possibility of establishing model buildings that benefit assessing sustainability conditions that, at the same time, act as the basis to determine compliance indicators related to teaching practice, are also analyzed. Finally, the possible output variables in each piece of software are considered. Table 3 also shows a list of the contents observed in the assessment reports obtained.

On examining Tables 2 and 3, it is seen that ArchiCAD places emphasis on data transparency, referencing their origin. Likewise, the software studied present the possibility of making a comparative analysis of different construction or design options. Revit accentuates economic aspects, the use of photovoltaic energy and analysis by orientations. Based on this, it is inferred that this software highlights bioclimatic design variables. On the other hand, EnergyPlus and ArchiCAD present the results of different variables without establishing hierarchies, leaving to the criteria of the researcher, the use and establishment of data priorities. Revit presents, in addition, an analysis strongly focused on energy costs, while ArchiCAD shows an evaluation that is analog to that of EnergyPlus. Likewise, according to the bibliography consulted, Revit does not address the analysis of thermal bridges. Following on from this, Table 4 summarizes the general guidelines that allow passing from the BIM model to the BEM.

| Variable de Análisis | Software | | |
|---|---|---|---|
| | **ArchiCAD** *(Ecodesigner)* | **Revit** *(Insight 360)* | **EnergyPlus** |
| Transparencia | High | Low | High |
| Trazabilidad | High | Low | High |
| Posibilidad de procesamiento posterior de datos | High | Low | High |
| Complejidad en la interpretación de los resultados | Medium | Low | Low |
| Comparabilidad (Posibilidad de establecer edificio de referencia) | High | High | High |
| Cantidad y Pertinencia de variables de análisis para la simulación energética | Medium | Medium | High |

Table 2. Analysis of the assessment report content (general characteristics).
Source: Preparation by authors based on simulations made in Revit, ArchiCAD & EnergyPlus.

References: : ■ High ■ Medium ■ Low

| Results Analysis | Software | | |
|---|---|---|---|
| | **ArchiCAD** *(Ecodesigner)* | **Revit** *(Insight 360)* | **Energy Plus** |
| Project Data Summary | • | | |
| Results by Zones | • | | • |
| Energy balance of the project | • | • | • |
| Temperature | • | | • |
| HVAC Performance | • | • | • |
| Energy Consumption | • | • | • |
| Energy Consumption by Source | • | | • |
| Environmental Impact | • | | • |
| Energy Certifications | • | • | • |
| Base Performance | • | • | • |
| Base Energy Cost | • | • | • |
| Performance Rating | • | | • |
| Energy savings and consumption | • | | • |
| Leaks | • | • | • |
| Renewable energy usage | • | • | • |
| Lighting | • | • | • |
| Warning Reports | • | | • |

Table 3. Analysis of the content of the assessment reports (specific characteristics)
Source: Preparation by authors based on simulations made in Revit, ArchiCAD & EnergyPlus.

| Modeling Opportunities | Item | ArchiCAD *Ecodesigner)* | Revit *(insight 360)* | EnergyPlus | Observations |
|---|---|---|---|---|---|
| 1 | Integrated 3D Modeling | • | • | – – | EnergyPlus uses SketchUp and OpenStudio. |
| 2 | Determination of thermal zones | • | – | • ? | |
| 3 | Definition of materials | • | • | • ? | ArchiCAD and Revit have integrated Calculation engines that take the data From the model. EnergyPlus uses IDFEditor. |
| | Determination of building packages | • | • | • ? | |
| | Configuration of thermal Blocks / Climatization Systems | • | • | • ? | |
| 4 | Personalized User Profiles | • | – | • ? | Revit has use profiles by default . |
| 5 | Selection of climate file | • | – | • ? | ArchiCAD and EnergyPlus accept Climate files: (*.epw). Revit obtains data of closest meteorological season |
| | Output variables | • | • | • ? | In EnergyPlus, the *"fatal errors"* require the revision of the model. In Revit, session must be started in Autodesk and be in the 3D window ArchiCAD, requests the correction of inconsistencies before simulating<br>EnergyPlus and ArchiCAD, have compatible output variables. Revit makes an analyzed based on energy efficiency and use of renewable energies. |
| 6 | Results for later processing | • | – | • ? | ArchiCAD and EnergyPlus allow the later data processing |
| | Results Report | • | • | – – | Revit, does not permit later analysis of the results |

Table 4. Similarities and differences detected in the different modelling instances, of the software analyzed.
Source: Preparation by authors based on simulations made in Revit, ArchiCAD & EnergyPlus.

The guidelines for running the BEM are obtained from the analysis of Table 4, as well as the particularities inherent to its process, following the characteristics of the software chosen for the task. In this context, it is relevant to clearly establish the goal the model is made for. Thus, if the valuation of the building sustainability emerges in the design stage or, as is the case of this research, to set up a decision-making support system from the early stages of the projection process, it is better to use Revit or ArchiCAD due to their easy application and the speed results are obtained. Now, if the project requires an in-depth analysis about the energy behavior of the building, the use of specialized software, like EnergyPlus, is suggested.

Regarding the results obtained in the second stage, it is highlighted that, for Mercader Moyano et al. (2019), the environmental, social, and economic sustainability has the design stage at its core. For this reason, the proposed teaching practice to be held during August

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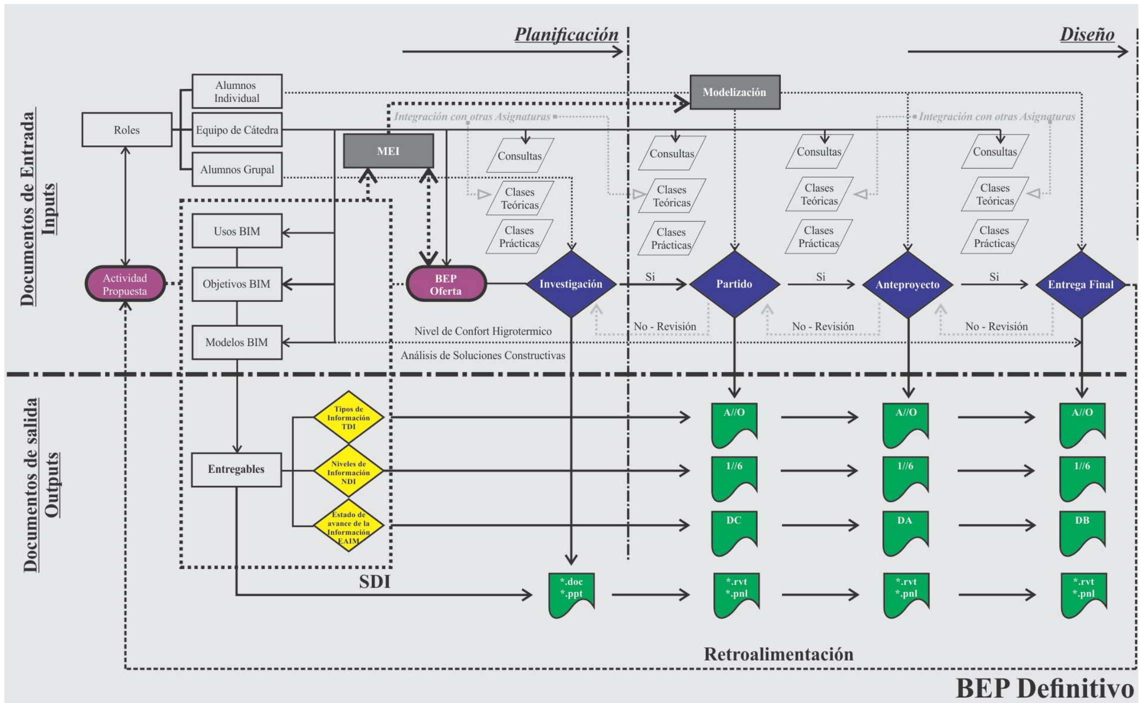


Figure 5. Workflow of classroom experience based on BIM methodology.
Source: Preparation by the authors.

| Phases of the Life Cycle | Role | | Planning | Development | Construction | Operation | Lead | Revise/ Evaluate | Model | Coordinate | Manage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Project Stages | | | | Function | | | | |
| Design | BIM Manager | Course Head | ● | | | | ● | ● | | ● | ● |
| | BIM Coordinator | Course Team | ● | | | | ● | ● | | ● | ● |
| | BIM Modeler | Student | | ● | ○ | ○ | | | ● | ○ | ○ |
| | BIM Operator | Student | | ● | ○ | ○ | | | ● | ○ | ○ |
| | BIM Analyst | Student | | ● | ○ | ○ | | | ● | ○ | ○ |
| | Content Manager | Student | | ● | ○ | ○ | | | ● | ○ | ○ |
| | BIM Information Manager | Student | | ● | ○ | ○ | | | ● | ○ | ○ |
| Construction | Construction BIM Manager | Student | | ○ | ○ | ○ | | | ○ | ○ | ○ |
| Operation | Facility Manager | Student | | ○ | ○ | ○ | | | ○ | ○ | ○ |
| End of Life | Facility Manager | Student | | ○ | ○ | ○ | | | ○ | ○ | ○ |

Table 5. Tentative roles matrix for the classroom implementation of the BIM methodology.
Source: Preparation by the authors based on Piña et al. (2017).

References: ● Main Role ○ Role subject to model's target

2020, in the Environmental Architecture Vertical Workshop (TVAA), takes as a starting point, a social dwelling design phase. The goal here is providing students with knowledge that allows them to suggest a sustainable design by checking the results, from the beginning of the classroom experience.

From that point of view, apart from the work procedure and the IDM, the following general pedagogical guidelines are suggested: forming work groups; making the sustainable design of social housing (simplified design experience) using a BIM software; brainstorming; comparison of the experience with the traditional design practice; determination of benefits and difficulties in the implementation of the BIM methodology during the design process; and preparation of group conclusions. It is pertinent to mention that the BIM Information Requests (SDI BIM), known in European standards as EIR (*Employer's Information Requirements*), are documents that include: targets, uses, type and levels of information (TDI and NDI), deliverables, collaboration strategies (Shared Data Setting – CDE), state of progress of the information (EAIM), and organization of the models (PlanBIM, 2019). As a result, their definition prior to the preparation of the BEP, is advisable.

**BEP Tentativo de Oferta**

| | Ítems | Característica | Variables | % de Cumplimiento |
|---|---|---|---|---|
| A. Información de Proyecto: | Llenar con la Propuesta Pedagógica | | Nivel de competencia | |
| B. Introducción | Listado de Alumnos/ Equipo de Trabajo - Declaración de sus competencias previas | Arquitectura | ● | |
| | | Estructura | ● | |
| | | Instalaciones | ● | |
| | | Otros: | | |
| C. Información del Modelado | Objetivo | Ej. Vivienda Social Bioclimática | Recursos / Capacidades / Experiencia Previa | |
| | Usos BIM | Ej. Consumo Energético | ● / ● / ● | |
| | Desafíos del Modelado | | | |
| | Oportunidades del mode | | | |
| | Nivel de Desarrollo | | LOD 100 / LOD 200 / LOD 300: x / LOD 400 / LOD 500 | |
| | Estrategias de modelado | | | |
| | Verificación del Modelado | | | |
| | Verificación de Interferencias | | | |
| D. Información de Referencia (INPUT) | Nombre del Archivo | Contenido principal | BIM: x / CAD / PDF / JPG / XLS / GIS / Otro; Planificación: x / Desarrollo / Construcción / Operación | |
| E. Roles y Funciones | Jefe de Cátedra | | Dirigir: x / Revisar/ Evaluar: x / Modelar / Coordinar: x / Gestionar: x | |
| | Equipo de Cátedra | | Dirigir: x / Revisar/ Evaluar: x / Modelar / Coordinar: x / Gestionar: x | |
| | Alumno (Individual) | | Modelar: x | |
| | Alumnos (Equipo) | | Modelar: x | |
| F. Cronograma | Ej. 10-06-2020 | Ej. Diseño Urbano | Investigación / Esquicio / Idea Partido: x / Anteproyecto / Entrega Final / Otro | |
| G. Información a producir/ Entregables | | | BIM: x / CAD / PDF / JPG / XLS / GIS | |
| H. Sistema coordinado para la Recopilación/ Gestión e Intercambio de Datos (CDE: Entorno de Datos Compartidos) | | | | |
| I. Conclusiones | | | | |

Table 6. Offer Tentative BEP
Source: Preparation by the authors based on PlanBIM (2017) and SIBIM (2019).

Bearing this in mind, Figure 5 is prepared, which summarizes the proposed workflow for developing a classroom experience based on the BIM methodology. From its analysis, it is inferred that holding said experience requires the determination of the roles each one of the players involved in the design process fulfills (Table 5), as well as the documents prior to the presentation of the Offer BEP (Table 6) and later Definitive BEP. In addition, it presents the inherent complexity for the implementation of the BIM methodology in a teaching practice, given that this requires the prior establishing of documents that structure its development. In this sense, the collaborative work of the course's team and of the work team represented by the students, is essential.

The main structure of the tentative Offer BEP proposed in this research (Table 6) was prepared based on the BEP, for the public sector of the BIM standards, developed by SIBIM (2019) and PlanBIM (2019). The items indicated in red correspond to contributions that must be completed following the characteristics of the academic practice being implemented. Given that this is a double entry table, the columns corresponding to "Variables" indicate the degrees of specificity that the model must reach to fulfill the suggested targets. To complete said variables, the traffic light method, as applies, is used, or the desired characteristic is indicated for the item with a cross. According to the state-of-the-art, in the case of using methodology for pedagogical ends, the indicators used correspond with the percentage compliance reached. In response to this, the BEP incorporates a column that allows the BIM Manager/Course Head to assess the level reached by the student or work team in each item considered. In this way, the use of this BEP, apart from contributing to structuring the pedagogical practice and fostering collaborative work, facilitates the evaluation, and as such provides traceability and transparency.

It must be underlined that the proposed classroom experience corresponds to one of the first implementations of the BIM methodology in FAUD-UNSJ. Therefore, its results contribute to the preparation of professionals with competences related to the BIM methodology and collaborative work, in what González Pérez (2015) characterizes as Big BIM, apart from the handling of BIM tools (Little BIM). Likewise, on focusing on building sustainability, it contributes to the use of the methodology as a support system for decision-making that places a value on this variable in the early stages of the design process.

Among the main limitations for the implementation of the BIM methodology in a classroom experience aimed at building sustainability, is the human capital one has for this. In fact, the determination of the level of previous knowledge students have is essential to guide the goals of the pilot project and the environmental and compliance indicators being evaluated. For this, before holding the classroom experience, a survey must be made that makes it possible to determine said level. It is important to give feedback about the pedagogical practice, identifying positive experiences and those that can be improved. From this, the guidelines are obtained to standardize positive practices, redefine those needing improvement and detecting deviations or inefficient ways to work on over time, which leads to the continuous improvement of the teamwork (CAMARCO, 2020).

## CONCLUSIONS AND FUTURE WORK

The study above allows inferring that the use of the BIM methodology in an academic setting is not only necessary for the preparation of professionals with specific competences in this but it is also highly feasible. The proposed BEP, whose structure follows the BIM standards developed in Argentina and Chile, facilitates planning a teaching experience aimed at incorporating building sustainable variables in the initial stages of the collaborative work-based design process.

From this perspective, simulating three commonly used social housing prototypes in San Juan, Argentina, allowed determining the work procedure needed to pass from BIM to BEM. In this task, the particularities of the use of a given software are obtained, which benefits that both the teacher and the student quickly detect errors made while making the model. In parallel, getting to know the scope of the results obtained in Revit, ArchiCAD and EnergyPlus allow the student to carry out the proposed activity (pilot project) in the software of their choice without compromising the validity of the results.

The role matrix, BEP and proposed workflow generate a structure that facilitates the transition from the current educational model to collaborative models. In addition, focusing on the analysis of the BEM development, there is a positive contribution to the use of the methodology as a support system for decision-making related to sustainability variables from the initial stages of the design process.

In this sense, the BEP presented in this article contributes to the development of specific standards that guide the way the BIM methodology is implemented in academic settings which, at the same time, guarantee that the student, regardless of the academic team and the BIM software, develops competences in a way that increases productivity and contributes to the sustainability of the construction industry. In this way, it helps to make future professionals aware of the importance that decisions made during the design process have on the future energy behavior of projects, as well as their environmental impacts, or on the level of indoor comfort of their spaces and, with that, the quality of life of their occupants.

For the purposes of feedback of its structure, in the second stage of this research, the proposal presented in the TVAA of the FAUD-UNSJ will be validated. Likewise, it must be underlined that the classroom implementation of the BIM methodology, as an active part of the design process, requires determining the documents that exceed the scope of this first research stage. In this regard, and looking into the future, the need is outlined of addressing analyses that include the determination and characterization of the human capital one has, as well as the definition of the possible assessment indicators considering the interests and targets of each design subject, the normative study (ISO 19650), or the development of documents other than those mentioned in this article like: AIR (Asset information requirements), CDE (Common data environment), OIR (Organizational information requirements), PIR (Project information requirements), among others. Later, work in more depth must be made in the development of the IDM, SDI and BEP, guidelines in line with the academic level of the student, which involve in their structure, the exchange of information with other courses and laboratories. With regards to the latter, it is of interest to look further into the interoperability between BIM and GIS, to prepare a City Information Model (CIM, in Spanish), that contributes to decisions regarding the urban environment. With this, the pedagogical practice would be enrichened as a result of addressing the course concepts like “urbanism” or “installations”.

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