IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

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To cite this article: F da Casa *et al* 2020 *IOP Conf. Ser.: Earth Environ. Sci.* **503** 012004

BIM for Sustainable Management in Existing Hospitals

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Abstract. The main objective of this communication is to determine the characteristics and requirements of the BIM model, in particular in relation to the BPS energy analysis, to be used as a project tool that supports sustainable management in existing hospital establishments. With this objective, BIM architectural models and environmental simulations of representative buildings in Chile and Spain were carried out to review and propose attributes of sustainable models that allow a better adaptation to growth and flexibility from the early stages of design and restructuring. This study associates low energy consumption strategies for hospital establishments. The study is aimed at the integral management of both the operation of the building and all the services involved in its use and exploitation. This will allow to discuss the paradigm changes regarding the training of the architect and the specialists involved in the design, construction and operation of more sustainable projects.

1. Introduction

Within the services sector, hospitals are characterized by their constant technological growth and complex functional programs that day after day are forced to adapt to the constant transformations and demands of the environment, thus modifying the circulations and dependencies while concentrating the uses and consumption in pavilions, developing a wide variety of activities, 365 days a year, 24 hours a day; causing with this, a high consumption of water and electricity [1]. For example, in Spain, existing hospitals consume 11% of the energy demanded by all public buildings. The distribution of the average energy consumption of the sector is 40,000 kWh / year, which corresponds to 45% of the air conditioning, 35% of the lighting and 20% in domestic hot water [2], and an average consumption of nearby water at 1,650 l / bed per day.

Along the same lines, a study conducted in hospitals in the United States showed that 27% of final energy use is used for air conditioning (heating and reheating), 21% in lighting and other electrical loads, 14% in losses of energy, 13% in fans (injection and extraction) and 10% in the energy required for cooling equipment (chillers, cooling tower fans and heat pumps) [3]. For its part, in Latin American countries such as Chile, it is estimated that said infrastructure represents approximately 15% of the total energy consumption of the public sector, around 240GWh / year [4].

And although today the new hospitals have a high level of sustainability, the challenge arises when the existing buildings are approached. Building managers do not have the opportunity to apply actions to save energy, reduce environmental impact or promote a healthy interior space, and can only make general plans for operation and maintenance [5]. In Europe, for example, more than 80% of the buildings were built before 1990 and, in general, do not have a documentation of the building in BIM format. For its implementation, reverse engineering processes are necessary, expensive and mainly manual, which could help retrieve information from the building [6].

Even so, the quality of the product obtained would not be comparable to that applied in the process in the early design stages. In the field of spatial data, quality components have been treated for more than twenty years [7], and are defined in ISO-19157. By analyzing them, you can conclude the need for a change in this process. It is worth mentioning that, for its application in Heritage buildings, the HBIM (Heritage Building Information Modeling) concept was necessary [8].

In this regard, for the management of existing hospital buildings, the main difficulties related to data collection techniques can be specified in:

- Lack of real data on the construction elements (old plans generally do not have all the information currently executed).
- Lack of real data of the facilities provided (its distribution, position and components used are not known for modifications due to extensions or repairs).
- These problems are not detectable through the regular collection of photogrammetry data or the use of 3D laser equipment.

In addition, in hospital use we find additional difficulties, such as the great complexity of current facilities. Also, a continuous evolution of the needs and requirements of these equipment. This implies a difficulty to model, and also a great effort in time and cost to reflect the changes that take place, which makes the system unsustainable. It should be taken into account that a hospital has a high potential for changes in the functioning of internal services, their interrelation, as well as with regard to new health trends, in which the patient's well-being and comfort are a fundamental factor.

One of the lines for proper management is the use of technologies in the building information modeling processes of BIM (Building Information Modeling) and its relationship with the BPS (Building Performance Simulation) (6D) energy performance analysis and management or installation of dimensions (7D) Administration (facilities management). Its application for the integral management in hospital buildings is evident, and even more so in those in which it is applied since its design, with the definition of LOD (level of geometric development) and LOI (level of development of technical information). This, to improve some key performance indicators in the execution and operation of buildings, such as: i) operating costs, ii) levels of environmental comfort (temperature, humidity, lighting, air quality, etc.) and, iii) the Required energy demand and the environmental impact of materials, among others. When working in an existing building, it is very difficult not to have all the data for conventional modeling or energy simulation, which, however, can be solved with laser scanning or similar technologies.

The objective of the text is, therefore, to determine the characteristics and requirements of the BIM model and its relationship with the BPS energy analysis to be used as a projective and comprehensive management tool in existing hospital establishments.

2. Methodology

The proposed methodology for this work begins with the definition of two significant case studies, for their exemplary value and their typological reproducibility, located in Chile and Spain. Then, a functional, constructive and energetic analysis is performed (recognition of passive and active strategies incorporated) and simulations of the buildings through the BIM software and interoperability with Design Builder). For this, it will be necessary to make previously simplified 3D volumetric models. Ending with the recognition of the characteristics and requirements of BIM modeling and its relationship with the BPS energy analysis.

IOP Conf. Series: Earth and Environmental Science **503** (2020) 012004 doi:10.1088/1755-1315/503/1/012004

2.1. Architectural, constructive and energetic characterization of the existing hospital establishments.

2.1.1. Hospital Clínico del Sur - Concepción Chile.

The Hospital Clínico del Sur (Figure 1), is one of the most important health *centres* in the Bío Bío Region (Central South of Chile), has 117 beds and 7 surgical pavilions of the highest technology; This establishment presents a first level infrastructure, a new emergency service, with 8 modern service boxes, observation room, resuscitation and procedures box and plaster box. It also has ICU and ITU that have been *remodelled*, currently with 16 critical patient beds and 4 ICU neonatology beds.

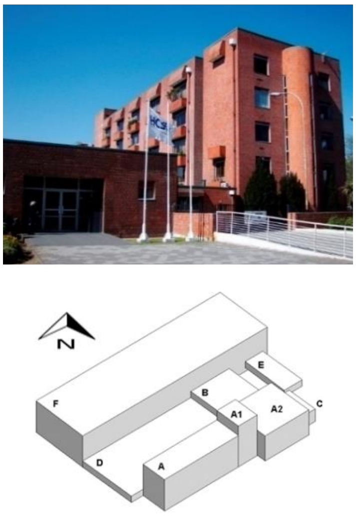


Figure 1. Clinical Hospital of southern Concepcion Chile. Taken from [9]

This compact establishment designed under a basement block typology, is located on a plot of 9,794 m² with a total construction area of 11,300 m², consists of a main building and a secondary building. The main building consisting of volumes A-A1-A2-B (Figure 1) is part of the hospitalization unit, surgical pavilions and maternity. While the secondary D-C-E is mainly intended for the administrative functions of the institution, emergency service, care box, observation room, resuscitation box and procedure box.

As an example of high concentrated consumption, the hospitalization unit (volume A-A1) was taken, which includes a total of 3,000 m² of construction, which houses 58 rooms with 117 beds, in a rectangular pavilion with northwest orientation, which has 20 meters high, 14.80 meters wide and 56.22 meters long, with a total covered area of 1,385 m². The skin materials (Table 1) do not have current regulations, and the incorporated bioclimatic and energy efficiency strategies are scarce, which influences the final consumption of domestic hot water, electricity and heating.

Table 1. Characteristics Hygrothermal hospitalization unit - Hospital Clínico del Sur (own elaboration)

Element	Materiality	U(W/m²K)
Roof material	Thermo acoustic tile	0.36
Exterior walls	12 cm ceramic brick	3.4
Internal walls	12 cm ceramic brick	1.71
Windows	Individual glass	1.05
Slab	Reinforced concrete	3.4

2.1.2. Príncipe de Asturias, Hospital of Alcalá de Henares - Spain.
Medium-sized hospital (600 beds) built in the 80s, but with a project in the late 70s. The building consists of seven floors with a total constructed area of 59,160 m² (Figure 2)

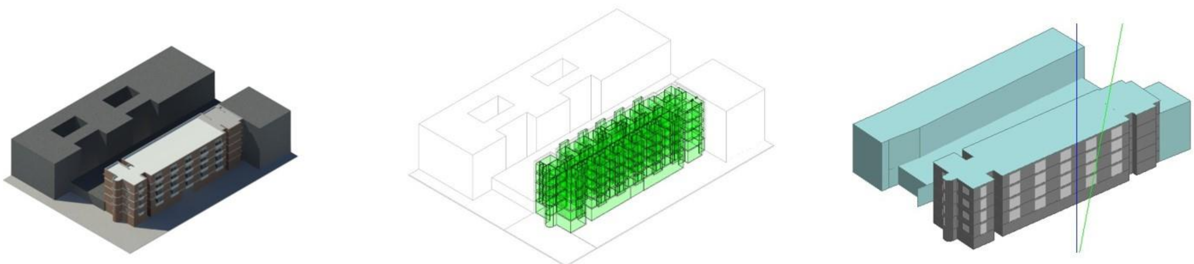
Figure 2. 3D image prior to the energy simulation of the Principe of Asturias Hospital of Alcalá de Henares [10].

It is a building with a common basement and four parallel blocks between courtyards with north-south orientation, and longitudinal facades to the east and west, which implies a certain adaptation to the environment, since it allows sunbathing on the most extensive facades of the morning. and late It is characterized by being a fairly compact building, which minimizes losses.

Vertical wrap construction systems, although not complying with current standards, are within a medium quality range at this time, with a U value of around 1.43 Wm²K

2.2. BIM / BPS modelling and energy simulation
The first part of the methodological development of this research was based on the development of BIM models in Revit Architecture 2019, which respected the shape, architectural distribution and orientation of each case study. Then, as shown in Figure 3, make energy models through thermal zones and export to Design Builder version 5.5.2 007 through the gbXML format, software developed by the US Department of Energy, which uses Energy Plus as a calculation engine.

Therefore, having the volumetric corrections, the next step was to create in the Template Builder template libraries (enclosures, occupation schedules, performance curves, etc.). The latter allowed to significantly accelerate the definition of the models, having already predefined elements in BIM.



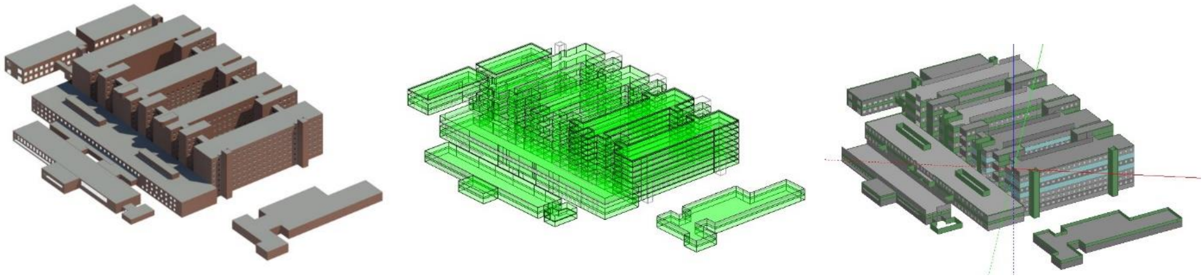


Figure 3. Modeling of case studies in Revit, configuration of thermal zones and export to Design Builder using the gbXM format (own elaboration)

3. Results

3.1. BIM / BPS simulation results

In the first approximations, for the Prince of Asturias Hospital of Alcalá de Henares of Spain, a total consumption of 25,376,120 KWh was obtained as initial data, which means a ratio of 457,205 Kwh / m² / year (95,156 Kwh / m² / year for ACS, 322,080 kWh / m² / year for air conditioning and 39,967 kWh / m² / year for lighting). More relevant is the average annual expenditure per bed, which stands at 70,489 Kwh / bed, values within the general average of hospital energy expenditure in Spain for hospitals of this dimension. With respect to the Hospital Clínico del Sur and its hospitalization unit, the consumption per unit area is 461,643 Kwh / m² / year (99,797 Kwh / m² / year for ACS, 131,583 Kwh / m² / year for air conditioning and 230,263 Kwh / m² / year for lighting).

For the Hospitalization Unit of the Southern Clinical Hospital, the results of the energy simulation show a consumption corresponding to 99,797 kWh / m² / year for ACS, 131,583 kWh / m² / year for air conditioning and 230,263 kWh / m² / year for lighting.

3.2. Characteristics and requirements of the BIM / BPS model for the sustainable management of hospitals

Sustainable management in existing buildings, such as hospitals, must be addressed through a comprehensive execution plan and methodologies such as BIM, where the conditions of materiality of the envelope, orientation, volumetric ratio, glazing ratio, air conditioning equipment, electricity and sanitary hot water. , among others. , can be reviewed and analyzed parametrically throughout the life cycle and particularly in the design phases (initial stage, preliminary draft and project) to achieve adequate energy efficiency and environmental comfort, at the lowest possible cost in the construction and operation stages . In this direction, this research presents the characteristics and requirements to address sustainability management through BIM in the design and operation stages, associating the levels of geometric and technical development to consider.

The impact of the first design decisions on the sustainability of the building must be understood. It is necessary to address the characteristics and requirements of a geometric and technical level of a BIM model (to achieve sustainable management) to the attributes and levels of geometric and technical details mainly associated with architectural spaces, thermal zones, enclosures and facilities. (see table 3). In existing buildings, laser lifting tools can contribute to a better understanding of the building, with respect to the geometric, constructive and architectural conditions necessary for environmental and energy modeling and management.

Table 2. BIM characteristics and requirements (LOD and LOI) for the efficient management of existing hospitals (own elaboration).

	Architecture room	**Thermal space**	**Skins**	**Installations**
Characteristics	-Use of the room -Builded surface -Number of levels -Project phase - Room name -Terminations - Termination surface - occupants - Number of beds	-Volume -Conditioning expenses / m² -Lighting expenses / m² - Use of space - outdoor air flow - Specified rancid air flow - Estimated average lighting	Exterior walls rooftops Windows Slabs Interior walls Roofs Surface finishes	Mechanical installations Electrical installations Water Potable sewage water Other
Requirements of the design stage (initial stage, preliminary draft and project)	modeling LOD: 100 LOI: 300	modeling LOD: 100 LOI: 300	modeling LOD 100 LOI 100	modeling LOD 100 LOI 100
Operation stage requirements (As-build) New building	modeling LOD: 300 LOI: 300	modeling LOD: 300 LOI: 300	modeling LOD 300 LOI 300	modeling LOD 300 LOI 300
Operation stage requirements (As-build) Existing building	Modeling based on terrestrial laser scanning or similar LOD: 300 LOI: 300	Modeling based on terrestrial laser scanning or similar LOD: 300 LOI: 300	Modeling based on terrestrial laser scanning or similar LOD 300 LOI 300	Modeling based on terrestrial laser scanning or similar LOD 300 LOI 300

4. Conclusions

The experiences developed in the architectural and energy analysis of two cases of existing hospital establishments in Chile and Spain, demonstrate in principle, the similarity of the challenges, both for the magnitude and complexity of these constructions, for their social relevance and high energy consumption and, due to the potential for reduction and improvement of the environmental quality involved. Although the constructive solutions and the particular functional conditions of each national reality certainly differ.

On the other hand, the need for a sustainable management approach in both cases is warned to ensure an adequate operational provision, both in cost reduction and in the ecological impact on energy consumption. What should be considered from the initial stage of the architectural design and planning of the rehabilitation or project of a new plant, through integrated models of specialties such as BIM platforms, with a particular conception. This approach refers to the organization of thermal blocks that relate the construction characteristics, to the provision of air conditioning equipment and networks, which allow balancing the actions of passive and active improvement, including the ability to dynamically analyze energy, both demands as eventually active. collection through solar panels. Then, move towards a dynamic and particularized construction data structure, to confront these establishments with their due complexity and linkage requirements and sustainable management potentials. This goes through a standardization of the information of different specialties and a workflow, as well as the interoperability of different software tools or work modules and a BIM execution plan, duly agreed upon and established by the work group. To achieve this, ensure high quality architectural and environmental health care.

Sustainable management in existing buildings, such as hospitals, must be carried out through a comprehensive execution plan, with methodologies such as BIM and laser tools, so that the characteristics of materiality, orientation, volumetric ratio, glazing ratio, air conditioning, electricity and heat The Facilities Administration can verify water health equipment, among others, parametrically in the maintenance stages to achieve adequate energy efficiency and environmental comfort, at the lowest possible cost during the life cycle of the building. In this direction, the conception of BIM models and the seventh dimension (7D) must consider in their digital construction a level of geometric detail (LOD) and technical information (LOI) acceptable for review, supervision and decision making).

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