Automated Building Data Exchange between BIM and BPS Supporting Building Environmental Assessment Methods (BEAM)

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Abstract

This paper discusses a need to connect BIM (Building Information Modeling), BPS (Building Performance Simulation) and BEAM (Building Environmental Assessment Methods) like LEED, BREEAM, and DGNB, it addresses BIM use case for interfacing CAD tool with analysis tool. State of the art in each field is discussed; an opportunity to improve information exchange is founded. A novel framework for automated information exchange using BIM technologies for BPS and BEAM is proposed. Result is a solution for connecting proprietary BIM software (Autodesk Revit) with a national certification system (Chilean CES), embodied in a spreadsheet.

Introduction

In recent years, as the need for sustainable building has increased rapidly, various factors, such as energy costs, the effect of CO2 on the Earth, public and government trends, and new technology becoming available, have led to a requirement for better building performance. Several versions of BPS (Building Performance Simulation) software have been used to simulate energy demands, lighting, heat gains, CO2 emissions, etc. Many buildings are being certified on these aspects by using Building Environmental Assessment Methods, or BEAM (Burnett & Yik, 2001; IGBC, 2013), such as LEED (US), BREEAM (UK), DGNB (Germany), and CES (Chile), all of which require a large amount of complex building data to complete all required documents and forms. On the other hand, Building Information Modeling (BIM) technologies support the whole building lifecycle and have plenty of rich geometry and data that has great potential for strong support of energy analysis and energy assessment of buildings, even more so for design teams in early stages. This research addresses the automated exchange of information between these three environments.

What is the current state of the art?

Next, we discuss a state of the art for the three areas: BIM, BPS and BEAM.

BIM (Building Information Modeling)

BIM technologies are the current paradigm in practice for Building and Infrastructure (NBS, 2016; Eastman et al., 2011; Jones, 2014). Mass adoption began in 2000, and since 2003 government implementation began as a standard for public buildings such as 3D-4D BIM Program at the GSA (GSA, 2016), Government Construction Strategy in UK (Government Construction Strategy UK, 2016), Staatsbyg in Finland. Early stages of design are also fully supported (Lobos, 2011).

At present almost every BIM software vendor includes an Energy Analysis tool in its BIM commercial Package (see Table 1). For example Autodesk Revit has an Insight 360 plug-in that runs analysis for illuminance and validation of LEED v3 IEQc8.1 and LEED v4 IEQ Daylight Credit, Option 2 (Stine, 2015). The Bentley AECOsim Energy Simulator tool runs simulations that generate documentation and reports, which are ASHRAE Standard 90.1 compliant and LEED certified (Bentley, 2016). Allplan Nemetscheck provides software templates to obtain LEED SS Credit 5.1 during conceptual design (Ich_BiM, 2016). We can conclude that BIM vendors have become concerned about the integration with LEED, with most of them proposing to work within their BIM environment, but ultimately there is no strong evidence of test cases or real projects or its use among energy consultants.

BPS (Building Performance Simulation)

BPS software has demonstrated its usefulness in simulating building performance aspects (CO2 Emissions, LEED Credit Analysis-Lighting, Thermal Loads, Solar, Acoustic, etc.) with higher precision and speed. Some well-known software include DesignBuilder, TAS, Daysim, Green Building Studio, and IES_VE, among others (Crawley et al. 2005; Attia et al., 2012; Clarke & Hensen, 2015; Raslan & Davies, 2010; Best Directory, 2016). Nevertheless, their usability

requires long training and profound building energy knowledge, which complicates the real-time and continuous participation of architects/designers. Many of this software can generate LEED documents. Although BIM-BPS exchange has been proposed by many authors (Bazjanac & Maile, 2004; Calquin, Wandersleben, and Castillo, 2014; Hoffer, 2009; Prada-Hernandez, Rojas-Quintero, Vallejo-Borda & Ponz-Tienda, 2015) there is no strong evidence of their mixed use in practice.

Table 1: List of Energy Analysis tools within BIM software. Prepared by the author, 2016.

BIM PACKAGE and Vendor Company	**Built-in Energy Analysis Extension/Plugin/Software**	**LEED**	**BREEAM**	**DGNB**
Revit (Autodesk)	Insight 360	LEED v3 IEQc8.1 and LEED v4 IEQ Daylight Credit, Option 2	--	**
	Light Analysis Plugin			
Archicad (Graphisoft)	EcoDesigner Star	ASHRAE 140-2007, ASHRAE 90.1-2007 (LEED Energy)	*	**
AECOSim (Bentley)	AECOsim Energy Simulator	ASHRAE Standard 90.1 compliant and LEED certified.	--	**
Digital Project (Gehry Technologies)	--	--	--	**
Allplan (Nemetscheck)	Software templates	Template can get SS Credit 5.1 (conceptual design)		**
* Via gbXML file to DesignBuilder. ** Under research. Potential by using IFC and BIM-based Model Checking automatization. -- No Information/Evidence				

BEAM (Building Environmental Assessment Methods).

Rating systems such as LEED (US), BREEAM (UK), DGNB (Germany), and CES (Chile) and many others have stimulated the real estate market and government by providing more confidence in the sustainability of a building (Wu et al., 2016; Ramírez-Villegas et al., 2016; Seinre et al., 2014). Normally they are based on credits for each criterion and recognize different types of buildings, stages, and certification categories. However, not all of them are strongly connected to BIM or BPS software, since many data have to be manually updated from any simulation or 3D model. Normally all efforts made in making BIM models are lost when energy consultants start assessing the building to obtain BEAM certification (LEED, Breeam, DGNB).

What are the deficiencies?

Many issues, such as BIM and BPS interoperability, the challenges in collaborative integrated design process, the lack of model and interface standards, the requirements of building performance assessment and building energy modeling are currently of concern to practitioners and researchers. All three areas (BIM, BPS, and BEAM) are not well connected. Information from BIM and BPS software is not usually shared successfully within the BEAM environment or vice versa. The first BIM and Energy efforts (Schlueter & Thesseling, 2009) did not include BEAM integration. Some recent efforts include integrating BIM and LEED systems at the conceptual design stage (Jalaei & Jrade, 2015). Nevertheless, all information required in BEAM documents must still be completed manually (USGBC, 2016) and new information must be updated manually after design changes (Kryegel & Nies, 2008) such as adding/deleting stories/areas/rooms, resizing/rotating rooms, moving walls, change of material, etc. Providing required/achieved performance information to design teams is also a failing of these software packages.

The integration

Recent market research reports reveal the great potential of integration for the industry (Jones, 2014). Bazjanac (2008) was one the first authors dealing with BIM-IFC exchange to improve energy design for buildings. There have been also some recent efforts concerning the integration of these three fields, such as integrating BIM and the LEED system at the conceptual design stage (Jalaei & Jrade, 2015), but depending on a commercial BIM package (Autodesk Revit); using cloud-BIM for LEED automation (Wu & Issa, 2013); BIM execution planning in Green Building projects (Wu & Issa, 2015); certain guidelines for using BIM for energy analysis of buildings (Reves, Svetlana, & Issa, 2015); and integrated process mapping for BIM implementation in Green Building project delivery (Wu & Issa, 2013). Remmen et al. (2015) promotes an open framework for integrated BIM-based Building Performance Simulation using Modelica. In the early 2000s Bayforrest dealt with connecting an IFC-compliant product model of a building (using Autodesk Architectural Desktop, a proto BIM software) via the internet with databases for the resource and energy requirements of building materials (Neuberg et al, 2004) not connected to any BEAM scheme. The use of BIM-based Model Checking (BMC) was proposed for DGNB Danish version (Gade, Svidt, & Jensen, 2016).

In conclusion, there is no direct method to fill BEAM forms directly from BIM software in order to speed up and make the certification process of a building more accurate. In addition, there is a lack of an intuitive interface to do this.

What methods have been applied?

A novel framework has been proposed (Figure 1), including information exchange between BIM and BEAM. In this framework we start by recognizing BEAM requirements (i.e. LEED, Breeam, DGNB, Chilean CES), then we model the BIM for architectural design (under BPS protocols), then it is evaluated in a BPS environment (i.e. DesignBuilder, TAS, Ecodesigner, Green Building Studio), changes are required, changes are made in BIM Model and then BEAM requirements are fulfilled.

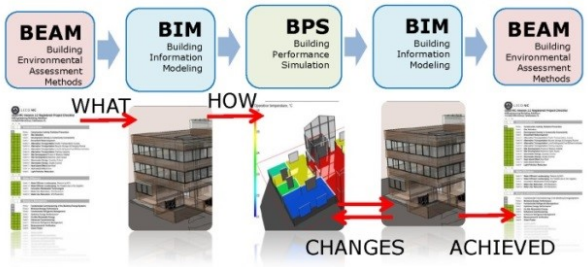

Figure 1: The proposed new framework. Source: authors (2016).

Table 2: CES criteria that can be filled out from the BIM tool. Prepared by the authors, 2016

Item	Variable
General information	Location
	Owner
	Project's name
	Customer ID
	Surface
Use and location	City Location
	Days of use / week
Definitions rooms	Numbering of enclosures
	Room name
	Description
	Useful area
	Density of Usage
	Lighting Charge
	Loads Equipment
	Regularly Occupied
Definition of Groups	Group numbering
	Groups Name
Allocation of Enclosures to the different Groups	Numbering of rooms
	Room name
	Group to which it belongs
Surrounding	Area
	Height
	Material (Walls / Ceilings / Floor)
	Thickness (Walls / Ceilings / Floor)
	Insulation (Walls / Ceilings / Flooring)
Infiltration and air changes	Infiltration and Air renewal
	Night Ventilation
Radiation	Orientation
	Dimension
	Visible Light Transmittance
	Solar Factor Glass
Features of window frames on each orientation	Facade Obstacle Dimensions
Ventilation	Room´s Area
	Height
	Use
	Occupational Density

Next a case for this framework is presented and discussed. An automated information exchange method between a BIM platform (Autodesk Revit) and Chilean certification (CES) was developed. The proposed framework was based on knowledge of both topics (BIM and BEAM), which are normally separate and rely on different practitioners. The method was to map both processes (BIM/BEAM), here a strong match between several variables was found (See Table 2). Then a database connection (MS Access) between proprietary BIM software (Autodesk Revit 2017) and a BEAM spreadsheet format (part of the Chilean CES rating system) was setup, allowing automated completion and update from the BIM model.

What are the results?

The result was a novel flow of information from BIM to BEAM. Once the initial setup is finished (names, paths, and locations of files), all changes made in the BIM model are transmitted to the BEAM spreadsheet through the database link. This means that after every design change (floor, rooms, sizes, and names) made in the BIM model, all of the required information is automatically transmitted to the BEAM spreadsheet. A list of the criteria taken from BIM to BEAM can be found in Table 2.

```
▼<Rooms>
  <Id>215169</Id>
  <IDdefase>86961</IDdefase>
  <Perímetro>10682.1989720597</Perímetro>
  <Nivel>694</Nivel>
  <Área>6.81929931475202</Área>
  <Número>225</Número>
  <Nombre>Women</Nombre>
  <Alturasinlímites>2438.4</Alturasinlímites>
  <PhaseId>86961</PhaseId>
  <Perimeter>10682.1989720597</Perimeter>
  <Level>694</Level>
  <Area>6.81929931475202</Area>
  <Number>225</Number>
  <Name>Women</Name>
  <UnboundedHeight>2438.4</UnboundedHeight>
</Rooms>
```

Figure 2: Room data from BIM model turned into XML information. Prepared by the authors, 2016.

Most of the data is turned into XML schema (Figure 2) and then recognized as tabulated information and translated into CES spreadsheet form. This allows to huge amounts of information to be shared from BIM to BEAM and it also allows the independence of any specific BIM software, since all of them are able to produce these types of files.

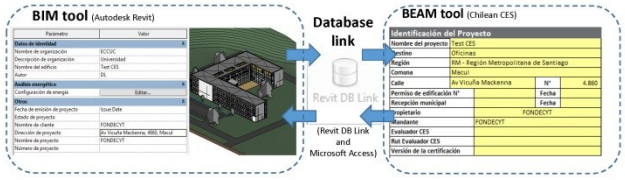

Figure 3: the BIM Model and basic data transferred to BEAM tool. Prepared by the authors, 2016

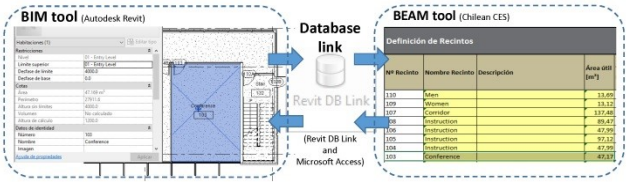

Figure 4: changes to BIM Model (room size and name update) transferred to BEAM tool. Prepared by the authors, 2016

What is the lasting contribution?

Currently, BEAM documents must be completed manually. BIM models collect a lot of useful information for BEAM documents and only a few articles deal with this problem and address it partially. The proposed workflow creates a new automated connection between BIM information and BEAM documents. Providing required/achieved performance information to design teams is also a significant contribution of this work. This case shows the use of the proposed framework in a specific workflow (Revit-CES), it could be applied to Archicad-LEED, Bentley-BREEAM or any other combination.

Conclusions

The research shows that a lot of useful information added to BIM models can be reused in BEAM schemes. Currently there is no real integration between the BIM-BPS-BEAM fields. Government BIM mandates normally do not include clear BEAM specifications or any application to link them. An exception is the GSA 3d-4d BIM Program that includes clear guidelines to support building energy modelling and simulation from BIM Models. BIM mandates and BEAM schemes must work together more clearly. Regional assessment schemes such as Chilean CES are not applicable in other regions, but the exchange method is valid for other schemes (LEED, Breeam, DGNB, etc.).

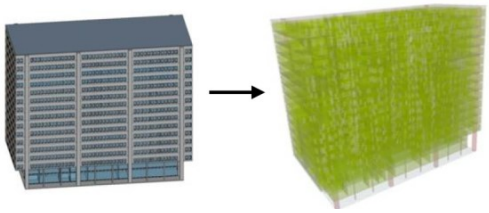

Figure 5. A GSA energy guidelines example: a BIM-based energy analysis starting with a BIM model exported to a model checker. Source: GSA (2016).

Outlook

Some extended aspects should be addressed in future work, such as: case study, web integration, government building energy policies compliance, ease of use, a more comprehensive interface to other BIM software (Archicad, Bentley, Allplan, Digital Project), exchange of information from/to BPS (Design Builder, IES_VE, TAS) may be addressed, IFC compliance for promoting OpenBIM standards, more direct linkage to Energy+ engine. Some potential problems such as operational delay and crossing information must be discussed as a risk to this kind of frameworks.

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