How Can Building Information Modelling (BIM) Tools and Workflows Assist Architects to Optimise Their Design and Achieving Energy Efficiency Results?

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Summary

The emergence of Building Information Modelling (BIM) provides simple energy model with optimum energy requirements in the early design stage of the project. Previous works have focused on using sustainability and energy performance by architect in the design process and presenting different methods of calculating energy usage. The research proposes to further investigate the architect's role for integration BIM with energy analysing tool to get best result for efficient design that has more benefits. These proposals for using suitable methodologies which they are: Questionnaire survey to get architects' views of designing BIM and energy analysis models; and a project case study (ATRiuM 2b/ Cardiff).
This research is aimed at proposing an integrated procedure and work that link BIM and energy analysing tools by architects to achieve energy efficient building in earlier conceptual design stage.
The findings suggest that BIM-based energy analysis provides many advantages related to cost, accuracy, time, interoperability, modifications and auto-correction, generated data and simulation. In addition, the amount of energy consumed by five floors building and assessments of alternative options concerning with orientation, construction materials and glazing to determine the best energy efficiency results.

Motivation

The construction industry represents the major consumer of energy and contributes greatly to the greenhouse gas emissions[1]. These emissions and energy consuming can be minimised by architects where the most construction techniques and technologies related to efficient buildings and energy conservation can be achieved from the beginning of the design stage[2].
The aim of this research is to investigate the use of BIM energy analysing tools used by architects during the design process to achieve energy efficient and sustainable buildings. Relying upon these findings, the author will then develop the integration between energy analysis tools with BIM, as well as, a number of issues deserving further investigation.
Revit® offers the ability for architects to work and think about their designs naturally, freely, and deliver work in an efficient way (see Fig. 1). The integration between BIM and energy analysis offers integration of energy analysis functions within BIM software and interoperability among programmes to transfer data.
Applying the BIM approach, through integration between 3D BIM model and energy analysing tool, enhances the analysis process and suggests alternative sustainable options for the design by Revit and GBS to assess their impacts on the energy consumption (see Fig. 2).

Results

The first result was based on the evaluation of the used software programmes by architects and improvements that BIM has introduced to optimise energy use in buildings to achieve energy efficient designs. Moreover, the other result was describing a process of exploring different energy saving

[1] Bordass, W., Cohen, R. and Field, J. (2004). Energy Performance of nondomestic buildings: closing the credibility gap. *Building Performance Congress.*

[2] Adeyeye, K., Osmani, M. and Brown, C. (2007). Energy conservation and building design: the environmental legislation push and pull factors. *Structural Survey*, 25 (5), 375-390.

alternatives of the embodied and operating energy in the early stages of the design's life-cycle using BIM and energy analysing software programmes with regards to low carbon emissions, low impact design and low energy demands (see Fig. 3).

The data which collected by questionnaire survey from architects using BIM in their designs and project case study has shown different ideas and years' experience with BIM and energy analysing software programmes and options. Implementing BIM-based energy analysis was identified benefits, difficulties and design improvements.

Majority of the respondents agreed that integrating BIM tools and energy simulation software would improve design efficiency and quality, added to that enable architect to evaluate energy use in early design phase.

While the case study of ATRiuM 2b illustrated the possibilities and options to reduce the energy consumption by orientation, efficient materials, design size and shape, and shading surfaces (see Tab. 1 and Fig. 4).

Energy Performance Results

- Architect can perform building analysis, energy efficiency optimisation and carbon neutral by Revit and GBS.
- Architect can use Potential Energy Savings/Losses Chart to specify the most parameters could affect the energy performance of design.
- The most sensitive parameters were wall and roof insulation and can affect the energy losses.
- While, the most parameters provided potential energy savings were building orientation and window glass.

Architect and design alternatives features

- Either by using various options of parameters in GBS or by modifying the design model itself.
- With GBS, rotating the design 15 clockwise, changing roof, walls construction materials, improving glazing material and reducing window contribute in energy consumption.
- With Revit, adding elements, such as, brise soleil and window shade; or decreasing windows rate, achieved another option of optimised design by having an impact on energy losses.

BIM and achieving energy efficient and sustainable designs play an increasingly significant role in the AEC industry. The architects' works and services are required from the concept stage to the handing over stage as they represent the main contributors in AEC industry. A successful workflow from BIM to energy tools is needed to define: location and weather, geometry, materials, thermal zones, lighting and HVAC.

Figures

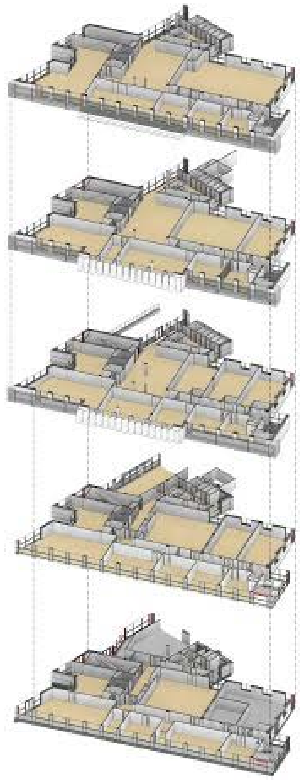


Fig. 1: Perspective plans of ATRiuM 2b

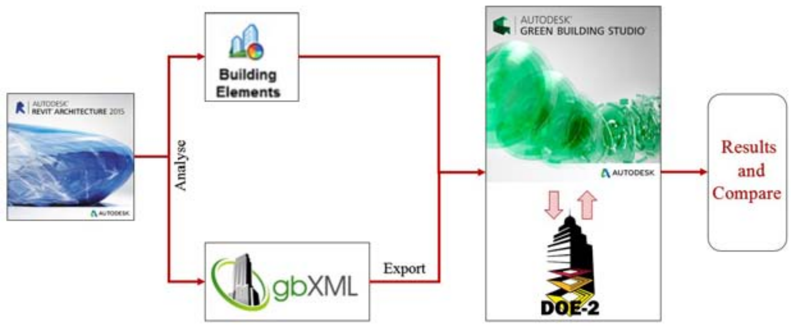


Fig. 2: Building energy analysis plan (Researcher illustration)

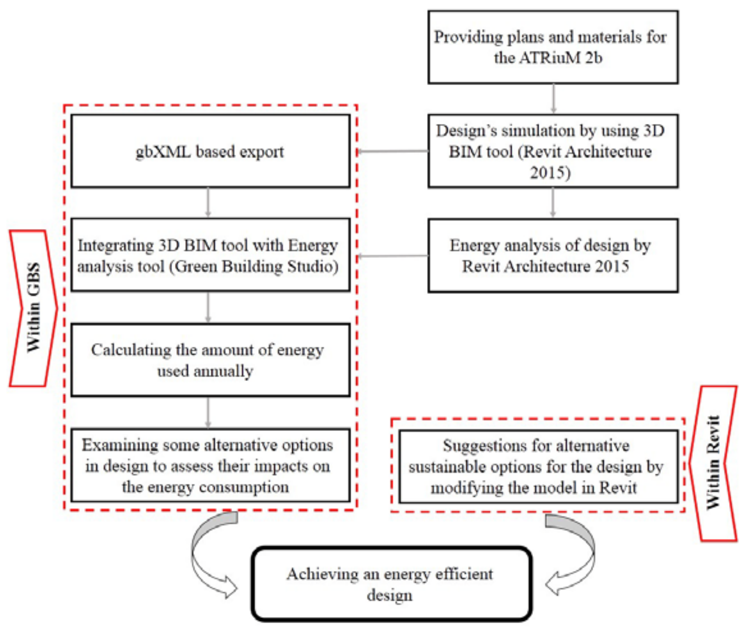
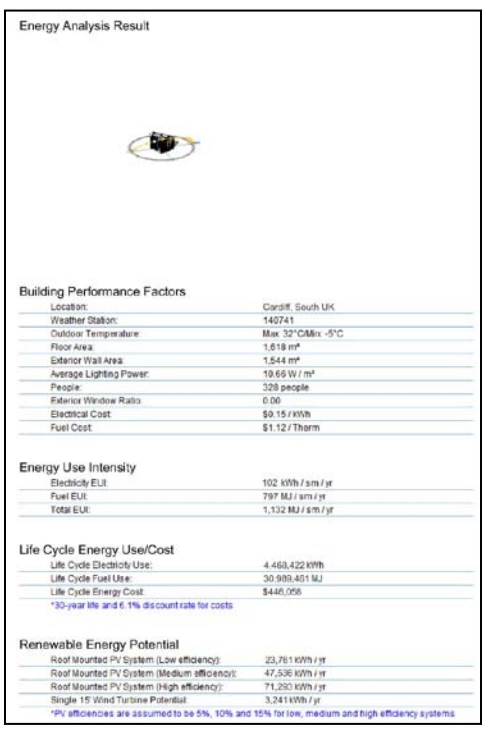


Fig. 3: Hierarchy of case study (Researcher illustration)



Energy Analysis Result

Building Performance Factors

Location:	Cardiff, South UK
Weather Station:	140741
Outdoor Temperature:	Max: 32°C/Min: -5°C
Floor Area:	1,618 m²
Exterior Wall Area:	1,544 m²
Average Lighting Power:	10.66 W / m²
People:	328 people
Exterior Window Ratio:	0.00
Electrical Cost:	$0.15 / kWh
Fuel Cost:	$1.12 / Therm

Energy Use Intensity

Electricity EUI:	102 kWh / sm / yr
Fuel EUI:	797 MJ / sm / yr
Total EUI:	1,132 MJ / sm / yr

Life Cycle Energy Use/Cost

Life Cycle Electricity Use:	4,468,422 kWh
Life Cycle Fuel Use:	30,989,461 MJ
Life Cycle Energy Cost:	$446,058

*30-year life and 6.1% discount rate for costs

Renewable Energy Potential

Roof Mounted PV System (Low efficiency):	23,761 kWh / yr
Roof Mounted PV System (Medium efficiency):	47,536 kWh / yr
Roof Mounted PV System (High efficiency):	71,293 kWh / yr
Single 15' Wind Turbine Potential:	3,241 kWh / yr

*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

Fig. 4: The impact of modifications on the design

Energy Consumption	Base Run	Alternative Run
Annual Energy Cost	$46,248	$43,669
Lifecycle Cost	$629,893	$594,774
Annual CO2 Emissions		
Electric	40.2 Mg	37.6 Mg
Onsite Fuel	71.3 Mg	65.7 Mg
Annual Energy		
Energy Use Intensity (EUI)	1,359 MJ / m² / year	1,359 MJ / m² / year
Electric	212,389 kWh	202,958 kWh
Onsite Fuel	1,430,262 MJ	1,317,489 MJ
Annual CO2 Emissions		
Electric	6,371,661 kW	6,088,731 kW
Onsite Fuel	42,907,860 MJ	39,524,670 MJ

Tab. 1: The difference between before and after design alternatives