Building Energy Performance Analysis of an Academic Building Using IFC BIM-Based Methodology

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Abstract:
This paper discusses the potential to use an Industry Foundation Classes (IFC)/Building Information Modelling (BIM) based method to undertake Building Energy Performance analysis of an academic building. BIM/IFC based methodology provides a mechanism for providing quick and cost-effective feedback to building users. The paper discusses the need for IFC and BIM-based analysis of existing buildings. A case study of Building Energy Performance Analysis of an academic building is presented with a detailed discussion on various interventions undertaken to calibrate the model. The paper concludes that BIM/IFC based approaches provide a feasible alternative to conduct energy analysis of existing buildings provided various correlations are built into the model.

Keywords:
Building Information Modeling, Building Energy Performance Analysis

1. Introduction
Building operations consume massive amount of energy and account for 40% of global Green House Gas (GHG) emissions (UNEP, 2006). As result of increasing awareness of environment impact of buildings and rising prices of fossil fuels, the need for enhancing building performance through energy consumption reduction is increasingly being realised. Reducing the energy consumption in our residential and commercial buildings will have a huge impact on UK’s total energy savings.

Existing approaches for building energy performance (BEP) analysis are either prohibitively expensive (e.g. detailed energy audits by BREAM certified experts) or inadequately granular and not providing enough energy feedback (e.g. carbon calculators, energy benchmarks, ROI curves). This is also constrained by limited availability of building energy performance experts. Also, traditional approaches to BEP analysis incur huge time delays in energy model preparation before useful information is made available to support building operations or retrofit decisions. Huge costs, complexity and time delays incurred in producing BEP results mean that it is not commonly used in building operations. Thus, there is need to complement high budget and time consuming traditional BEP analysis approaches with low-cost innovative methods to meet carbon reduction goals.

IFC/BIM Based methodologies for Building Energy Performance (BEP) simulation provide a mechanism for quick feedback to users. Also, use of IFC/BIM based BEP methods are driven by UK government agenda to make usage of BIM mandatory (UK Government Construction Strategy, 2011). Usage of BIM based BEP simplifies the process by using existing Building Information Models, where available. Thus, IFC/BIM approaches have a significant potential to reduce simulation time and improve model accuracy.
This paper presents a case study of BEP analysis of an academic building using IFC BIM-Based Methodology. Initially the need for IFC and BIM-based analysis of existing buildings is discussed. This is followed by discussion of a case study that discusses the energy analysis process in detail and various interventions undertaken to calibrate the model. Final Section discusses various technical and cost challenges associated with energy consumption feedback and using such analysis to support retrofit decision making.

1. Case Study Description

For the case study, an academic building at University of Salford campus was chosen (Figure 1). There is a tremendous interest within University of Salford in the area of sustainability and energy efficiency improvements. University has also launched Carbon Management Plan with an aim to reduce Carbon emissions by 30% in comparison with 2005/2006 levels over a 5 years period. A BIM model of Maxwell building was produced (Figure 2), representing accurate building mass and envelope. Accurate representation of building materials such as insulation used for building envelope is essential for correct calculation of heat losses. Energy analysis software (Autodesk, 2013) were utilised to undertake preliminary environmental performance assessment. The software uses building mass to predict energy intensity (kWh/square footage) of a particular building. Data from nearest weather station was used to collect climatic data such as highest and lowest temperatures over the year, amount of rainfall on average for the region, wind forces, solar radiation etc. Such climatic information serves two pronged objective. Firstly, it helps achieve accurate calculations for energy use prediction. Secondly, it helps in computation of potential renewable energy gains resulting in more sustainable and efficient building. Building data related to operating schedule, details of HVAC system and actual electricity and fuel consumption data was obtained from estates department at University of Salford. Results from energy simulation such as electricity/ fuel consumption rates, carbon emissions, life cycle energy use/ cost etc were benchmarked against actual consumption rates obtained from the building operations team.

The first iteration showed a wide variance of results between the actual building energy consumption data and results obtained from BIM based energy simulation analysis. From the numbers provided by the Estates Department at Salford University, the annual electricity consumption for the case study Building was estimated to be approximately 3,690,116 kWh, while annual gas consumption is estimated as 3,622,900kWh. However, the results from energy simulation analysis indicated an annual consumption of 5,360,000 kWh, an over-estimation by 1,650,000 kwh. It was important to calibrate the energy simulation results leading to this accuracy.
In order to correct the inaccuracy, various energy settings available within the software were investigated. Revit Architecture provides the user with a choice of different HVAC
systems. Each system would impact differently on the energy consumption rates. A list of all possible choices was explored working with building operations team. The HVAC system used in the building is of type 12 SEER/0.9 AFUE Split/Packaged Gas, 5-11 Ton. There is no HVAC option available in the energy analysis tool that actually matched installed HVAC system in the building. However, the option that closely matched the system that is installed was chosen. This substantially reduced the variance between the estimated and actual energy consumption results.

Software results were further calibrated through accurate input of building operating schedule. Initial energy calculations used the assumption that building operates throughout the year on a 24/7 routine, with an exception of couple of day’s closure during Christmas holidays. Thus, an operating schedule of 24/7 building usage for 363 days was used for initial energy simulation results. However, discussions with estates staff at University of Salford showed that building opening hours do not correspond with actual energy consumption, which is much lower during weekend and night hours, when most of the building occupants have left. Thus, amount of energy (electric, light, electric equipments) consumed at night time is lower than that used in morning hours. Even during winters, the heating is not switched on 24/7, rather operates in a 19/7 cycle for 6 months of the year. Based on discussions with building operations team, building operating routine was set equivalent to a facility operating 12 hours per day and 7 days a week. This resulted in further improvements in results accuracy, by lowering down the building energy consumption estimate to 4,106,000 kWh, in comparison with actual energy consumption data of 3,690,000 kWh, as provided by the Estates Department.

The case study building was constructed over 50 years ago and few corrections were made to correct target glazing percentage inside the building. It is important to use correct glazing levels of the building as most of the heat is lost through openings such as windows. BIM model of the building, alongside actual digital photographs were used to accurately calculate the glazing percentage for the larger façade of the building, which was calculated to be approximately 55%. Since the glazing does not take up the same percentage from every wall, some additional calculations were made to determine that the glazing percentage of the entire building façade is approximately 51 %. Changes in the glazing percentage resulted in energy consumption estimates of 3,864,000 kWh. This meant that the energy intensity (kWh/square foot) results as predicted by BIM based energy analysis software were within 5 percent of the actual energy consumption data.

2. Discussion and Conclusions

The research has demonstrated that BIM/IFC based approaches provide a feasible alternative to conduct energy analysis of existing buildings, provided various correlations are built into the model. The approach does not require specialist energy assessor, auditor or a software expert. After initial calibration, results were obtained within a 5% margin of accuracy. The results could be used for preliminary energy analysis and for exploring various alternatives to enhance building performance using renewable energy.

One of the key limitations of conventional methods and schemes for environmental performance assessment of buildings is that they do not adequately take into account actual building operations data. Thus, there are many cases where buildings rated BREEAM Excellent or having outstanding performance actually use more energy than the old buildings
they have replaced. Some of the promising features of BIM-based energy performance analysis is that it helps predict key data related to building energy consumption. Also, the approach is visually appealing with graphs and images providing an engaging mechanism to provide feedback to building users on building energy consumption reduction and carbon-neutrality potential and for quick comparisons to be made with actual energy consumption data. There is a potential of deployment of such approaches on projects where quick input on various energy related retrofit decisions are required.

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**References**

