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Deployment of Building Information Modelling (BIM) for Energy Efficiency in the UK

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Abstract. Continuing advancement in digitalised technology has brought about constant changes and innovations in several industries. In consttruction, Building Information Modelling (BIM) is one of these key technologies that seeks to lessen the impacts of global warming and growing environmental concern. BIM also positively contributes in sustainable life-cycle decisions for building procurement and management. The dynamic digital environment provided by BIM facilitates the effective storage, sharing and integration of all the essential building information throughout the entire life-cycle of a building within a three-dimensional computer model. Despite the major technical opportunities and benefits, however, BIM has not been fully adopted and capitalized upon yet by industry stakeholders worldwide. The lack of widespread uptake engaging all team members and more practical and achievable policies and other initiatives, substantial cost of software equipment, high training and consultancy fees, personal user behaviour, mostly regarding difficulties in changing traditional work processes and other factors represent the major barriers impeding the full BIM-productive potential which leads to many drawbacks, such as lower performance in building`s energy efficiency and qualitative properties, higher cost, resource losses, delay in time for project completion. To this end, some interiews were conducted for the purposes studying the sustainable ways of using BIM and the dissemination of its adoption in planning, consulting and contracting companies and organisations in the UK was conducted in this research. A more feasible integration of BIM for energy-simulation, but there are still many gaps to be fulfilled. Although UK-based companies appear to be willing to implement BIM, in real terms it is more likely that BIM is not being used in its full potential.

Keywords: Building, Energy Efficiency, Refurbishment, Sustainability, BIM

1 Introduction

The construction industry is expected to reach over 70% growth by 2025 [1]. Thus representing a prominent sector where energy use could be decreased, several countries have already set this target out in order to reduce their carbon emissions and to achieve improvement in energy efficiency. The aim of the UK, for instance, is "(a) 33% reduction in both the initial cost of construction and the whole life cost of assets; (b)

50% reduction in the overall time from inception to completion for new build and refurbished assets; (c) 50% reduction in greenhouse gas emissions in the built environment; (d) 50% reduction in the trade gap between total exports and total imports for construction products and materials" (ibid).

Continuing advancement in digitalised technology has bringing about constant changes and innovations in each industry [2]. As one of these key technologies aimed at lessening the impacts of global warming and growing environmental concerns, Building Information Modelling (BIM) is designed to positively contribute to sustainable life-cycle decisions with significant impact on our environmental, social and economic needs [3] and Chong et al, [2]. The dynamic digital environment provided by BIM manages to effectively store, share and integrate all the essential building information from conceptual design and pre-construction stages throughout the entire life-cycle of a building within a three-dimensional computer model [4]. Such information technologies enable the collation of exceptionally detailed but fragmented aspects and systems of a facility, and simultaneously managing to retain all the ongoing processes together within a single model, thus aiming to purposefully achieve a set target [5-6]. The very valuable virtual process of BIM for design, construction, operation and maintenance of buildings allows professionals to create and reinvent sustainable designs that improve cost-savings of a built facility, and, what is tremendously important. All the project team members (owners, architects, engineers, contractors, subcontractors, suppliers) can collaborate more intensely and efficiently together, compared to the impractical traditional processes [5, 7, 8]. Various authors have reported significant return on investments over time. This is a significant economic benefit that stresses the importance of BIM-assisted designs. The use of BIM is also perceived to be advantageous owing to "higher-quality deliverables", excellent time management, accurate cost estimation, reduced project costs and higher net savings, better understanding through real-time visualisation, instant conflict detection and low percentage of documentation errors, contingencies, risks and unexpected alterations [9, 5,7, 10].

Despite its major technical opportunities and benefits, though, BIM has not been fully adopted and capitalized yet by industry stakeholders worldwide. According to a research from National Building Specification (NBS), which indicates a high level of BIM-awareness in the UK, Canada, Finland and New Zealand, compared to a much lower level of current BIM-use; only in the UK is the discrepancy`s percentages highest the suggesting that 94% are aware of BIM and just 39% are actually implementing BIM. The results of the mentioned study above only confirm that due to linking challenges, obstructing its effectiveness, BIM appears to be deployed much slower than it has been anticipated in the UK [10]. The lack of widespread uptake engaging all team members and more practical and achievable policies and other initiatives, substantial cost of software equipment, high training and consultancy fees, personal user behaviour, mostly regarding difficulties in changing traditional work processes, low profitability for stakeholders, software or hardware issues and insufficiency in desirable level of integration and interoperability represent the major barriers impeding the full BIM-productive potential which leads to many drawbacks, such as lower performance in building`s energy efficiency and qualitative properties, higher cost, resource losses, delay in time for project completion [9, 5, 7].

To address this issue, a qualitative assessment was conducted for the purposes of studying the sustainable ways of using BIM and the dissemination of its adoption in planning, consulting and contracting companies and organisations in the UK. This was with the particular focs on examining the process of improving energy efficiency through developing cost-effective smart buildings. The findings of this research are envisaged to be of special interest to wide range of UK stakeholders, interested in the use of BIM in regards to optimisation of energy efficiency in operating built environment, with important insights on the current level of uptake in the development of BIM for energy efficiency in buildings, its competitive advantages and existing obstacles, associated with the implementation of BIM, as well as some featured recommendations on how future BIM-adoption could be developed [9].

2 An Overview of BIM Towards Energy Efficiency.

Due to the rising demand for energy; the public and private sectors are progressively requiring planning and construction of sustainable buildings, (i.e. with minimal environmental impact, so that next generations could be able to meet their own needs) [1]. Significant efforts have been made with regards to reducing the use of fossil fuel as the most common and incredibly polluting source of energy. Such efforts include the adoption of different sustainable processes like BIM, other planning and simulation software, effective building codes and standards. Sustainability assessments, green building rating systems such as BREEAM and LEED and a range of governmental policies and incentives [7, 2].

The two major components which when combined efficiently save considerable time and resources, based on the BIM-work process, are high level of integrated design approach and an intense/ collaborative team commitment (Ibid).

Due to the increasing importance of decisions needing to be made early; BIM gives the great advantage of the possibility for decisions in the design and pre-constructional stages to be made by the different team members involved in the project, especially when recognizing if any implications evolve during the process [7, 11]. The integration of data during the entire project can be fluid when all of the project participants use the same software to achieve the lowest possible energy consumption and to evaluate the cost and environmental impact, so undoubtedly this is one of the BIM`s greatest benefits [5, 7]. Once the model is created, all stakeholders are able to constantly refine, adjust and change the project specifications and to be instantly detected if any collisions might appear between all major systems, as BIM automatically checks for possible interferences so the team members can be ensured that the model is as accurate as possible [5].

The use of BIM from the very beginning also enables the creation of design that can analyse the impact of buildings and the prediction and optimisation of their energy performance through multidisciplinary analysis for cost-avoiding and prevention of time-consuming alterations at later stages in the project [7]. During the early or predesign stage BIM-based simulation is important for developing a sustainable building design combining many factors so that specialists could finally determine building`s internal gains and set energy consumption targets [5]. In this regard, collaborative accomplishments toward an improvement of building`s energy evaluation process and facilitation of teamwork are noted, as it is, for instance, the Object-Oriented Physical Modelling approach, developed by Kim et al. (2015), which meliorates complex data exchange between building design and energy simulation software [2]. Another excellent example represents one of the most effective ways to reduce carbon emissions through the renovation of existing buildings in order to reduce energy consumption, for the purpose of which during the post-occupancy stage Motawa and Carter (2013) has established a conceptual systematic BIM-based model to monitor building behaviour as a means of improving the post-occupancy evaluation process and meet the industry standard requirements for sustainable buildings [2]. Implementing software programs for sustainable analysis, as well as installing energy-efficient systems and optimizing strategies for minimum energy losses, such as heating systems that are power-generated from renewable energy sources, inclusion of sustainable materials and insulation from recycled or recyclable resources with high thermal properties, natural cooling and ventilation systems for best delivery efficiency are recent measures. Also, a well-orientated building design and corresponding glazing and solar shading devices for most proper day lighting and solar incidence, water-efficient systems in favour of lowering water consumption and creating more green spaces around or as a part of the building`s envelope [5, 7, 3, 12, 13]. Manual calculations at every particular location within a building to measure or to elaborate all of these factors and finding the right thermal comfort is almost unattainable. BIM-based energy simulation programs (capable of calculating all of those values accurately) we can analyze thermal performance of buildings in the most practical and optimal manner. Thus, the inextricably linked data integration and interoperability are extremely important asset when discussing BIM [4].

Through the opportunity of using data exchange in thermal simulation software and selected thermal tools that integrate such analysis building geometry (surfaces and volumes), internal loads (operating systems, equipment and occupants), weather and climate conditions, and other essential input data, affect energy consumption and cost can now be modelled thereby clearing the interoperability`s challenges between BIM and energy simulation tools. This can increase the workflow between analysis` applications and project`s deliverables [14]. According to Turk [6] the goal has always been to “make building information models understandable and model data sharable across multiple design disciplines and heterogeneous computer systems”.

Several technical barriers that BIM-based thermal simulation tools continue to face are long analytical model preparation times, missing or invalid data in architectural models and inconsistent conversion of architectural models to thermal models (ibid).

Not having the capacity to simultaneously analyze all the aforementioned green building features and systems, thus not providing sufficient analytical data for an assessment with green building rating systems like BREEAM, LEED, DGNB, Green Star, and other, is a very significant disadvantage that certainly needs to be amended [13]. If all required documentation for certification toward the level of building` sustainability could be incorporated in BIM-based analysis software, this would diminish time and resource prerequisite and simplify the assessment method, compared to the conventional approach [2].

Another persistent obstacle is that BIM is mostly used during design phase, but comparatively rarely for facility management and throughout the commissioning and operational phases, and also with highly challenging direct application in existing buildings (ibid). Hence, during the development of BIM, there must be a linking of retrievable data within the model for all the subsequent post-construction phases [4]. Although existing BIM-based software is still limited to the project design phase, there are some supporting detailed energy performance analysis designed for the operation, maintenance and post-occupancy phases, and more multidisciplinary BIM applications are indispensably expected to experience growth. The development of such extensive green BIM applications would allow a systematic analysis of the whole environmental impact of a building [13].

Last but not least, there is another shaping moderation in the ongoing adoption of BIM, affecting the user-technology relationship, namely personal attitude and perceptions, depending on factors like age, experience, motivation, voluntariness of use, social influence, terms of support and expectancy, so in order to accelerate the diffusion of BIM there should be primarily focus on individual level [9].

In general, the BIM process needs better standardization in order to define strict guidelines for its implementation. Therefore, the data exchange process for performing energy and environmental simulations engines need to become more reliable, combined with more user-friendly interface, more capable and much quicker, more up-to-date and with more advanced functionality towards current computer science technology, so that the users can integrate them more smoothly into practice [14]. Simplification and compatibility of input parameters and enhancement of data exchange solutions with more reliable data conversion based on BIM, as well as deep knowledge of thermal processes in a building, are mandatory for a meaningful and accurate energy simulation [13]. Closer integration of energy simulations with the operational performance of buildings in real terms will thus not only improve existing simulation tools, but will also enable a more energy-efficient operation of buildings.

In order to reduce data inconsistencies and to increase the number of projects where energy simulation within BIM can be not only productively used but, more importantly produce reliable results. It is thus hereby suggested that practitioners should engage themselves in further research and development process for finding such BIM-based solutions. Hence, software vendors should be encouraged to improve tools that support practical needs [15]. Furthermore, professionals willing to effectively integrate BIM in their designs should commit to its widespread implementation and to the development of standards, enabling continuous improvement not only toward the conceptual modelling, but also into deeper research into more efficient integration of energy simulation during commissioning and operational level (ibid). Accordingly, companies should also invest more in training of their employees, so they could acquire indispensable and valuable skills and learn how to take full advantage of all BIM-benefits. As building industry shifts towards finding a way to successfully adopt BIM, the education system should also take as well a more thorough and collaborative educating approach towards the way of teaching and assessing sustainability topics in undergraduate and graduate degrees, as well as research objectives for doctoral programs. This will facilitate the attainment of the benefits of BIM alongside the progressive benefits from the UK Government`s mandate relating to the use of "fully collaborative 3D" BIM in all contracts awarded since 2014 in order to reduce costs and errors [8]. Although the dissemination of BIM constantly rose during the last decade and it is likely to continue its growth as long as the challenges could be overcome. Research opportunites therefore continue to abound as precursor to stimulating the supply chain to start working more collaboratively through the use of BIM in order to achieve higher levels of energy efficiency and sustainability of projects.

3 An Exploration of Industry Perspectives

The literature reviewed formed the basis for this study. It helped to identify existent gaps and challenges in the overall dissemination of BIM in the UK. The research thus set out to establish the extent of the current BIM-adoption for energy efficiency within the UK construction industry, with relation to project delivery.

An interview of the willing organisations was conducted to obtain opinions and information on the current level of BIM-use for improving energy efficiency in UK-based construction companies and organizations. For the intended purpose, an online questionnaire was first distributed through e-mail invitations sent to randomly selected architects, designers, engineers, surveyors, contractors, officially operating on the UK territory. The prepared questionnaire included basic questions that allowed the consenting, voluntary participants to indicate willingness to participate in a structured interview.

Based on the responses from the survey, three interviews were conducted as part of this phase. The interviews sought to provide information on issues such as how profitable and compatible is BIM for optimizing energy efficiency in the UK built environment, what are the major barriers toward such BIM-uptake and how these obstacles can be overwhelmed. After the data was collected it was processed for further analysis and then through discussion and stated assumptions, as well as with the aid of utilizing the option "analyze results", provided by the built-in platform of SurveyMonkey.

A systematic review approach was adopted to analyse the feedback from the survey. Although the three respondents believe that BIM offers advantages to an overall sustainable building design and that the sustainable construction practices are of importance within their company, they all considered that the energy efficiency aspect do not primary apply in their BIM projects as a pre-determined performance target, but rather as a design applying to environmental performances standards, such as BREEAM and LEED. They also believe that BIM helps to properly define client's brief requirement and ensure compliance to Building Regulation Part 'L' requirement. The interviews also revealed that BIM can significantly and effectively, or at least satisfyingly, aid in performing complex building energy performance analysis to predict and ensure an optimized building design.

With respect to BIM-interoperability, two of the respondents agree that energy-simulation tools strongly support BIM, but both agree that that there is significant room for improved BIM-support. There appears to have been a lot of excitement about the potential of BIM, but as per being an enhancement of best practices for energy efficiency in the conceptual, design and construction and operational stages this opportunity is limited. Full unanimity is observed when answering what the major barriers within the respondent`s organisation are to the uptake of BIM with regards to energy efficiency improvement, where everyone stated “no client's demand”. It is mostly agreed that respondents positively will or probably may suggest innovative upgrades of the BIM process in order to optimize energy efficiency in buildings. They also affirmed that it is absolutely essential, or worth considering, that the government should actively encourage the use of BIM through policies and other initiatives in the Private sector similar to the 2016 UK Government BIM Mandate for Centrally procured government projects.

Furthermore, interview results revealed that, the determining characteristics and conjectures about BIM are mainly positive experience, advantages in sustainability and prediction of energy performance of buildings, satisfying level of operability and ease of use towards energy-simulation tools. However, BIM does not appear to be desirable enough in implementing best practices for energy efficiency throughout the building`s life-cycle, diversity among stakeholders in attitude, expectancy and benefits toward BIM. More upgrades should be in focus, more subsidised policies and incentives should be applied by the Government in order to facilitate the adoption of BIM in the UK construction industry. Findings of the research are revealing that BIM is expanding within the construction industry and practitioners think it is the future, while moving to sustainable buildings. Overall, the collected data from the survey show that the disadvantages when using BIM towards energy efficiency and sustainability are generally less relevant than the positive effects of implementing BIM. Many obstructions were identified, though, in BIM-adoption for higher energy efficiency, and the most important barriers to uptake are: low level of awareness, difficulties in embracing innovations, lack of strict policies, lack of training and experience and relative disconnection between different construction industry`s branches.

Substantial efforts were carried out in order to obtain a more feasible integration of BIM toward energy-simulation tools, but there are still many gaps to be filled. UK-based companies and organisations are presumably willing and trying to implement BIM in an effort to meet the government deadlines, but in real terms it is more likely that BIM is not being used in its full potential. The results from this study (though limited) reveal that although there has been a significant amount of research and development about the use of BIM during various project phases, little work has been conducted about how it could be more effectively applied in order energy efficiency in buildings to become a driving aspect in new designs and refurbishments BIM-processes. Finally, the research indicates that the main reason for slowly deploying BIM relates to the lack of client`s demand and clear and strict requirements, which in turn leads to lack of expertise within private and public companies and organisations.

Although of good quality the number of respondents to the interviews introduces a limited scope to the findings. With this relatively low number of responses, drawing sensible conclusions is very difficult, and so the reason could be postulated as a result of either apparent disinterest, or low adoption percentage of BIM by professionals in the UK. The relationship between all the variables characterizing BIM evidences in general terms how individuals in the industry are currently perceiving the BIM-concept, thus the outcomes of this survey prove a lack of interest in pursuing energy efficiency.

4 Conclusion and Recommendations

Although energy efficiency measures are recognized as an important matter and the possibilities of their application are expansive; it appears that the task of assuring stakeholders of the BIM-benefits remains a challenge. Due to the many identified barriers faced as part of the process, such as: lack of time, internal capacity and resources to explore energy efficiency options; it is proving more difficult to adopt and implement energy efficiency measures. The necessity to balance profitability and competitiveness with limited resources is even tougher for many SME`s focusing on energy efficiency and other environmental concerns. Moreover, energy efficiency is indeed rarely viewed as a priority, especially among people with low income. If the investment will result, though, in other improvements beyond a sustainable way of life, such as savings, productivity, value, quality, safety, then people are more likely to be attracted and motivated to increase their investments towards energy efficiency practices.

Nevertheless, the industry is not clear enough yet on the application of BIM for optimising energy efficiency, which urges the need more significant actions to be taken by the Government and to be provided more stimulating incentives to all construction value chain stakeholders regarding the benefits of BIM towards achieving higher energy efficiency. BIM-process adaptation offers great opportunities for encapsulating rich data within the model at the earlier stages of the building life-cycle (design and construction) and such data as well for asset maintenance, so higher education institutes and other providers of educational and training courses must also collaborate more closely with practitioners to fully embrace this concept of a life-long learner in order to avoid knowledge redundancy and should be augmented with far greater industry-academic collaboration and education.

Transforming and decarbonizing the built environment is entirely possible with significant processes like BIM through which, using their full potential can be predicted and facilitated the optimal energy performance of buildings and to improve best practices for energy-efficient and high-quality construction can be improved - thus improving the quality of life. Despite the significant barriers of implementation, BIM will ultimately be driven by clients, and since acceptance is an individual act based on personal perceptions, we have to know that raising awareness about environmental challenges, leading to behavioral change. Likewise, as of a perspective, computers will continue to become faster which could allow representations of more complex relationships and futuristic BIM-approaches..

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