Building Energy-Efficiency delivered with the Help of Improved Building Information Modelling Skills

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Abstract:

Construction industry has a wide impact on the socio-economic development of any nation. It employs a large number of population and contributes to a nation's built wealth - buildings and infrastructure. In contrast, this sector has an adverse environmental impact and is responsible for high energy use, greenhouse gas emissions, resource consumption, solid waste generation, environmental damage and pollution. Energy efficient (EE) buildings are an important and cost-efficient way today to mitigate the release of greenhouse gases. Moreover, technological changes namely building information modelling (BIM) has brought about a digital transformation in the industry and have significant interest across Europe. This has created a potential for a better digital management of energy-efficiency of buildings and – concurrently - a huge demand in new skills and competence requirements for the construction workforce - professionals, managers, labors as well as engineering students.

This paper presents the objectives and discusses the challenges and initial results of BIMEET (BIM-based EU - wide Standardized Qualification Framework for achieving Energy Efficiency) research program funded under H2020 program. BIMEET project aims to leverage the take-up of ICT and BIM through a significant upgrade of the skills and capacities of the EU construction workforce. The paper provides an overview of the BIMEET project and discusses the use cases that especially will need a description of skills related to BIM and energy-efficiency. Such descriptions should rely on the European Qualifications Framework in order to be standardized across Europe and countries' specific competencies and training schemes. The paper finally defines the purpose of the training platform aiming to widely disseminate the BIMEET outcomes. The platform will support registering labelled training offering and finding suitable BIM training in different levels of AEC sector.

Keywords: BIM, BIM training, Energy efficiency, European Qualification Framework, BIMEET.

1. INTRODUCTION

"Construction sector is one of the largest in the world economy, with about $10 trillion spent on construction-related goods and services every year" (MGI, 2017). The interactions of our built environment with the natural environment are complex and have a massive direct and indirect impact on the world around us. 45-50% of global energy, 50% of water and 80% of agricultural land are used by buildings (Willmott Dixon, 2010). Likewise, buildings in EU account for the largest share of total energy consumption of 40% and produce about 36% of all greenhouse emissions (Šajn, 2016). The European Construction sector is facing unprecedented challenges to achieve ambitious energy efficiency objectives (with the aim to generalize Near-Zero Energy Buildings). The European objectives for energy savings have been translated into stringent regulations and policies at the European and National levels. For instance, the recast of the Energy Performance of Buildings Directive (2010/31/EU) imposes stringent energy efficiency requirements for new and retrofitted buildings.

Declining productivity has been another one of the major issues in the AEC/FM (Architecture, Engineering and Construction/Facility Management) industry (Allen, 1985; Allmon et. al., 2000; MGI 2017). The industry is experiencing its digital revolution and gaining significant interests towards model based solutions - mainly Building Information Modeling (BIM) in order to overcome the issues. BIM tools and processes have been widely implemented with positive results in different types of the projects through regulations and maturity targets, which always face the traditional low-tech and informal practices of construction businesses (a fragmented sector, dominated by SMEs). BIM is seen as key for increasing construction productivity and is paving the way to more effective multidisciplinary collaborations with a total lifecycle and supply chain integration perspective. As shown in Figure 1, BIM is a model centered approach intending to generate and manage data and information of built environment during its entire life cycle form concept design to decommissioning.

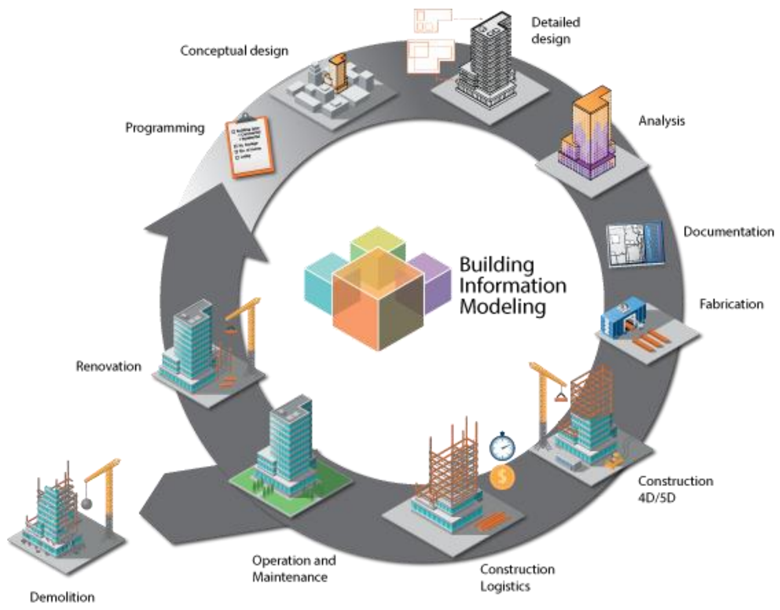

Figure 1. BIM uses across building lifecycle

2. BIMEET AND THE PROJECT GOALS

2.1 Background

BIMEET stands for BIM-based EU -wide Standardized Qualification Framework for achieving Energy Efficiency Training. It promotes the widespread use of BIM-based transversal and multidisciplinary collaborative approaches and methods in the European (and beyond) construction industry. BIMEET will raise awareness of stakeholders in the construction value chain about (a) environmental challenges, (b) current and future sustainability scenarios, and (c) energy efficiency targets with a view of delivering informed built environment interventions across lifecycle and supply chain underpinned by an effective Europe-wide BIM-based training agenda.

With the growing use and implementation of BIM and demanding EE requirements, the construction industry has a clear gap of proficient professionals. It is important to make a difference between general BIM knowledge and those specific BIM qualifications of professionals that are needed in design, construction and facility management practices. Capabilities in applying BIM are always built upon existing professional expertise; thus the own professional expertise is the precondition for successful development of further BIM qualifications. In principal, professional education should take care of providing adequate general BIM knowledge and training students in using important BIM tools. However, the final BIM qualifications needed can only be achieved in professional practices.

There are different BIM maturity matrices available in the industry to evaluate BIM knowhow and competencies both at individual and organizational levels. buildingSMART has provided a global benchmark for openBIM competency assessment. The program enables learning organizations to educate and certify individuals according to a recognized global learning framework. The program is also a proof of competence for professionals working with BIM. It is managed at international level and operated at a national level through local chapters, which adapt the learning framework for country-specific requirements. The programme structure includes individual qualification or knowledge-based learning designed to introduce the basic concepts and principles of openBIM. Professional certification or applied learning addresses the application of openBIM principles in the project environment (buildingSmart, 2017).

A recent report published by the European Commission highlights that "energy efficiency and digitalization have emerged as two of the most influential drivers affecting the need for skills" (European Commission, 2017). The same report presents the barriers to skills development, namely the low predictability in construction business, the structural fragmentation leading to a large share of SMEs, as well as the barriers specifically observed in training of building workers. Moreover, challenges in skills recognition amongst member states are pointed out. The European Qualification Framework (EQF) is foreseen as a mean facilitating the mobility of labour and promoting comparability of training offer.

In BIM training, as all the other learnings, the cores of EQF concerns eight reference levels defined in terms of learning outcomes. These ones concern what a person knows, understands and is able to do at the end of a training. These levels cover the basic general knowledge in BIM (level 1) until the knowledge at the most advanced frontier of the BIM applied to energy efficiency (level 8). A generalized EQF levels for BIMEET is presented in the table 1 below:

Table 1. EQF levels for BIMEET

Levels	Knowledge	Skill	Competence
1	Basic general knowledge	Carry out simple tasks	Work under direct supervision in a structured context
2	Basic factual knowledge	Carry out tasks and solve routine problems	Work under supervision with some autonomy
3	Knowledge of facts, principles, processes and general concepts	Solve problems by selecting and applying basic methods and tools	Take responsibility for completion of tasks, adapt own behavior to circumstances in solving problems
4	Factual and theoretical knowledge in broad contexts	Generate solutions to specific problems	Exercise self-management, supervise the routine work of others, taking some responsibility for the evaluation and improvement of activities
5	Comprehensive, specialized, factual and theoretical knowledge and an awareness of the boundaries of that knowledge	Develop creative solutions to abstract problems	Exercise management and supervision, review and develop performance of self and others
6	Advanced knowledge involving a critical understanding of theories and principles	Solve complex and unpredictable problems	Manage complex technical or professional activities or projects, taking responsibility for decision-making in unpredictable work, take responsibility for managing professional development of individuals and groups
7	Highly specialized knowledge, critical awareness of knowledge issues in a field and at the interface between different fields	Develop new knowledge to be integrated from different fields	Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches, take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
8	Knowledge at the most advanced frontier of a field	Solve critical problems, extend and redefine existing knowledge	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research.

2.2 Project goals

The BIMEET project aims to leverage the take-up of ICT and BIM through a significant upgrade of the skills and capacities of the EU construction workforce. This Coordination and Support Action project is built around a consortium relying on educational and research expertise, robust experience of accrediting bodies, training supply chain and a wide engagement of industry led best practices. The goals of the project are listed as follows:

(a) To pave the way to a fundamental step change in delivering systematic, measurable and effective energy efficient buildings through BIM training with a view to effectively address European energy and carbon reduction targets;

(b) To promote a well-trained world leading generation of decision makers, practitioners, and blue collars in BIM for energy efficiency;

(c) To establish a world-leading platform for BIM for energy efficiency training nurtured by an established community of interest.

Its principal outputs are 1) a skills matrix related to BIM and energy efficiency and 2) a training platform contributing to widely disseminate the BIMEET EQF. These results associated with an accreditation scheme will guarantee the sustainability of the project results after its lifetime. The EQF scheme for BIM and energy efficiency developed in the project, will target blue collar workers, middle-senior level workers and governance people. The skills identified within the BIMEET EQF will be recognized on the European market and will favour the mobility and the training of workers across Europe.

3. CHALLENGES AND INITIAL RESULTS OF BIMEET

The premise of the project is that BIM can significantly support energy-efficient design, construction and building maintenance in many ways. In principal, BIM can boost and ease energy-efficient building on the basis of better data exchange and communication flows, and in practice for example by accelerating energy simulations and searching for beneficial solutions, supporting end users' involvement, requirement setting and commissioning, and by providing an opportunity for systematic maintenance management. Amidst the positive impacts brought about by BIM, AEC/FM industry can leverage BIM for greater energy efficiency in new designs as well as in retrofit and renovation projects. BIMEET demonstrates the strengths of BIM in energy-efficient building by collecting and providing use cases. The following list shows examples of use cases where life cycle applicability is aligned with eight work stages of RIBA plan of work 2013.

Use Case 1: Reduce the Gap between Predicted and Actual Energy Consumption in Buildings: KnoholEM project
Use Case Type: Research & Development
Target Discipline: Facility Management
Target Building Type: Public
Lifecycle Applicability: In Use
Brief Description of The Use Case: This study presents a novel BIM-based approach with the objective to reduce the gap between predicted and actual energy consumption in buildings during their operation stage. Due to the absence of historical energy consumption data, a theoretical simulation approach is used that takes into account a wide range of factors, including building fabric, occupancy patterns, and environmental conditions. Energy sensitive variables are then identified as well as available control variables (set points) to train and learn energy consumption patterns and behavior within the considered building. The resulting model is then used as a cost function engine (predictor) for an optimization process to generate energy saving rules that can be applied to the operating BMS (Yuce and Rezgui, 2017).
Impacts: The use of BIM has helped achieve a reduction of 25% energy compared to baseline figures.

Use Case 2: BIM-based Parametric Building Energy Performance Multi- Objective Optimization
Use Case Type: Research & Development
Target Discipline: Architectural Design
Target Building Type: Domestic
Lifecycle Applicability: Concept Design, Developed Design
Brief Description of The Use Cases: An integrated system is developed for enabling designers to optimize multiple objectives in the early design process (Asl. et. al., 2014). A prototype of the system is created in an open-source visual programming application - Dynamo, which can interact with a BIM tool (Autodesk Revit®) to extend its parametric capabilities. The aim is to maximize the number of rooms of the residential unit that satisfy the requirements of the LEED IEQ Credit 8.1 for Daylighting while minimizing the expected energy use. The geographic location of the home is in the city of Indianapolis, Indiana, USA.
Impacts: The use of a BIM model to generate a multiplicity of parametric design variations for simulated and procedural analysis is a viable workflow for designers seeking to understand trade-offs between daylighting and energy use.

Use Case 3: Intelligent Services for Energy-Efficient Design and Life Cycle Simulation- ISES project
Use Case Type: Research & Development
Target Discipline: Architectural design / Structural engineering / HVAC engineering / Electrical engineering / Builders / Construction companies / Building managers
Target Building Type: Public
Lifecycle Applicability: In Use
Brief Description of The Use Cases: Intelligent Services For Energy-Efficient Design and Life Cycle Simulation is developing ICT building blocks to integrate and complement existing tools (STEP and BIM) for design and operation management into a Virtual Energy Lab capable of evaluating, simulating and optimizing the energy efficiency of products and facilities, in particular components for buildings and facilities, before their realization and taking into account their stochastic life-cycle nature (Balaras et. al., 2014).
Impacts: The combination of energy profile models with product development STEP models and building and facility BIM models

Use Case 4: Shopping Center using around half the energy of a typical development
Use Case Type: Real-world application
Target Discipline: Architectural design / Structural engineering / HVAC engineering / Electrical engineering / Builders / Construction companies / Building managers
Target Building Type: Commercial
Lifecycle Applicability: Preparation and Brief, Concept Design, Developed Design, Technical Design, Construction, In Use
Brief Description of The Use Cases: The project is a large shopping center and commercial development in Pori, southwestern Finland. The development was designed to LEED Gold and has won a global BIM award for its innovative use of modeling during design and construction (Skanska, 2014).
Impacts: BIM was effectively used in a project where 50 % energy savings were achieved compared with Finnish Code and 50 % savings in water consumption compared with conventional retail development in Finland. Also measured energy production of geothermal heat pumps and gains of free energy for heating and cooling have exceeded expectations.

Use Case 5: Robust decision making around building efficiency and occupant comfort
Use Case Type: Real world application
Target Discipline: Facility Management
Target Building Type: Public
Lifecycle Applicability: In Use
Brief Description of The Use Cases: Ingenuity House - a 12,000m2 highly sustainable building, is currently under construction adjacent to Birmingham's International Airport and Railway Station. The building will be Interserve's new regional HQ and is being used as a test bed to start to go beyond BIM Level 2 (BS 1192: 2007).
Impacts: Delivery of SMART building to be established once it is completed.

Use Case 6: Use of BIM for ESD Analysis of BCA Academic Tower
Use Case Type: Real world project
Target Discipline: Architectural, Mechanical & Structural
Target Building Type: Public
Lifecycle Applicability: Concept Design and Developed Design
Brief Description of The Use Cases: BCA Academy Project consists of a new 10-Storey Academic Block, with an adjoining new 6-Storey Training Workshop Block and a new Pavilion. The design aim to provide climatically responsive and incorporate active and passive features wherever possible to lower energy consumption. These includes proper orientation of the buildings, appropriate choice of materials, use of energy fittings, fixtures and devices (such as light fittings), good fenestration and daylight design, etc. Vertical greenery and roof garden are designed be provided, where possible. Building Information Modelling (BIM) plays a pivotal role in achieving the required sustainable design features.
Impacts: BIM plays a pivotal role in achieving energy efficiency by leveraging the BIM model and performing several types of energy analysis and simulations.

To this day, BIM has been implemented more and with more powerful results for some building types. Especially certain cases of retail and office buildings provide good examples how BIM has supported demanding requirement management, simulations and searching solutions for ambitious energy targets. For instance, availability and use of BIM data aid towards 25% of energy reduction in facility management (use case 1). Likewise, BIM has been effectively used in the Shopping Center (use case 4) using around half the energy of a typical development, results associated with commercial buildings report about 50% energy saving and 50% saving in water consumption.

In other hand, using RIBA Plan of Work for lifecycle applicability we can observe also associations between lifecycles and BIM impact on energy efficiency. It reflects increasing requirements for sustainability and BIM and it allows simple, project-specific plans to be created. The RIBA Plan of Work organizes the design process into different stages including briefing, designing, constructing, maintaining, operating and using building. According to these stages, various ways of use and levels of impact can be identified for the use of BIM for energy efficiency.

4. DISCUSSION

The construction industry presents a major opportunity to reduce energy demand, improve process efficiency and reduce carbon emissions; it is also traditionally highly fragmented and often portrayed as involving a culture of "adversarial relationships", "risk avoidance", exacerbated by a "linear workflow", which often leads to low efficiency, delays and construction waste. BIM can facilitate more effective energy modeling and multi-disciplinary collaborations with a total lifecycle and supply chain integration perspective. BIM has significant potential to deliver energy savings in the built environment from the outset of the design process through to the operation of the resultant construction. Whilst often portrayed as solely a digital model, BIM is a construction process that enables the development of construction information in a coordinated and structured fashion. An appropriately coordinated implementation of BIM which incorporates and recognizes the key factors of energy efficiency around design, construction and operation has extremely significant potential to drive energy efficiency through improved brief setting, more integrated and optimized design solutions, better specification and site delivery, and better efficiency in the operation during building in use.(Petri et.al, 2017). The use cases have multiple objectives however; the most common objective identified through use cases is to minimize energy consumption. Likewise, the most common impact of utilizing BIM for energy efficiency is intended to increasing energy saving.

EQF's qualification levels from 1 to 8 cover the whole supply chain and targets to set a common framework for EU in order to support the skilled BIM workforce, the labor market, as well as common way of working with BIM. As a project result, the BIMEET training platform will be an EU wide dissemination portal with the features of (a) self-assessment of skills in line with BIMEET, while providing tailored recommendation, e.g. for a company or an architectural office, (b) assessment of skills at project-scale, in particular for supporting meetings where all practitioners involved in the construction team have to define a BIM strategy and protocol, and (c) registering of training modules provided by training institutes and potentially further allow experts to review and deliver a BIMEET labelling or accreditation.

5. CONCLUSIONS

Already on the basis of the initial results of BIMEET, the project has gathered evidence that there is a clear role of BIM in relation with Energy Efficiency through the whole lifecycle of buildings. This definitely requires upscaled skills regarding the whole value chain. BIMEET partners, advised by an External Expert Advisory Board, will devise a competency matrix, aimed at covering EU-scale requirements. This matrix will end up in the setup and further delivery of innovative training offer, focusing on both BIM as an essential mean for conducting digitized design and construction processes, as well as a central repository for improving Facility Management, and in particular energy optimization, in design, construction and operational stage. The BIMEET training platform is under development and will consist an EU wide dissemination portal.

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REFERENCES

Allen, S. G. (1985). ''Why construction industry productivity is declining.'' Review of Economics and Statistics, 117(4), 661–665.

Allmon, E., Haas, C. T., Borcherding, J. D., & Goodrum, P. M. (2000). US construction labor productivity trends, 1970–1998. Journal of construction engineering and management, 126(2), 97-104.

Asl, M. R., Bergin, M., Menter, A., & Yan, W. (2014). BIM-based Parametric Building Energy Performance Multi- Objective Optimization. In eCAADe Education and Research in Computer Aided Architectural Design in Europe. pp. 455–464.

Badrinath, A. C., Chang, Y. T., & Hsieh, S. H. (2016). A review of tertiary BIM education for advanced engineering communication with visualization. Visualization in Engineering, 4(1), 9.

Balaras, C., Dascalaki, E., Baumgärtel, K., Gudnason, G., Katranuschkov, P., Hoch, R., & Klinc, R. (2014).

ISES D9. 2: End user report on the Virtual Energy Lab pilot©. ISES Consortium, Brussels.
buildinsSmart (2017). buildingSMART Professional Certification - The global benchmark for openBIM training. buildingSmart International. https://www.buildingsmart.org/compliance/professional-certification/ (Last accessed: January 30th, 2018)
European Commission, (2017). Analytical Report - Improving the human capital basis. European Construction Sector Observatory. https://ec.europa.eu/docsroom/documents?documentsIds=24261_native&iframe=true&locale=en&languagesExpanded=true&autoHeight=true. (Last accessed February 1st, 2018)
GCP, Global Construction Perspectives and Oxford Economics, (2015). Global Construction 2030 : A Global Forecast for the Construction Industry to 2030; Global Construction Perspectives and Oxford Economics: London, UK.
MGI - Mckinsey global institute, (2017). Reinventing construction: a route to higher productivity. McKinsey & Company 2017.
Petri, I., Kubicki, S., Rezgui, Y., Guerriero, A., & Li, H. (2017). Optimizing Energy Efficiency in Operating Built Environment Assets through Building Information Modeling: A Case Study. Energies, 10(8), 1167.
Šajn, N. (2016). Energy efficiency of buildings–A nearly zero-energy future. Brussels: European Parliament Briefing.
Skanska (2014), Case study 132 - Puuvilla Shopping Center, Finland. http://www.skanska-sustainability-case-studies.com/index.php/latest-case-studies/item/232-puuvilla-shopping-center-finland (Last accessed: February 17th, 2018)
Willmott Dixon. (2010). The Impacts of Construction and the Built Environment, Briefing Notes, Willmott-dixon Group.
Yuce, B., & Rezgui, Y. (2017). An ANN-GA semantic rule-based system to reduce the gap between predicted and actual energy consumption in buildings. IEEE Transactions on Automation Science and Engineering, 14(3), 1351-1363.