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Harmonized Digital Information Platform for Energy-Efficient Building Renovation

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ABSTRACT

There is an urgent need to scale up and accelerate energy-efficient building renovation in Europe for achieving the EU 2030 Climate Targets. The rise of Building Information Modelling (BIM) and the current availability of a range of BIM authoring, analytical and management tools should facilitate the process. However, until now the level of BIM adoption for renovation projects is too low. The main bottlenecks are: the lack of open and affordable digital information platforms, constraints to interoperability between various BIM tools and data, and inadequacy of techniques and skills to apply BIM for existing buildings. This paper proposes viable solutions to enable all stakeholders collaborating in renovation projects to reduce the time, effort and cost of BIM preparation, adoption and future maintenance.

Keywords: Energy-efficient building renovation; Building Information Modelling; digital platform

Rationale and literature review

The building sector accounts for 40% of the total energy consumption and 36% of CO2 emissions in the European Union (EU) (Carvalho et al., 2016). Most of the existing building stock has reached the age for renovation as 90% of the total stock was built before 1990 and 40% of this stock was built before 1960 when building energy performance standards had not yet been published. Since 2010 the renovation market has surpassed the construction of new buildings. However, even though there is an increasing trend in renovation, the rate of the renovated building stock is still very low. Moreover, projects aimed at energy-efficient deep renovation level only take 1% share. Building Performance Institute of Europe (BPIE) and the European Parliament (“Boosting Building Renovation”, 2016) indicated that only 5% of the renovation projects so far reduced energy consumption by 60–90% while renovation projects that targeted near Zero Energy consumption were negligible.

The rapid development and growing acceptance of Building Information Modelling (BIM) in the building industry can support the upscaling and acceleration of energy-efficient building renovation, and the minimization of the gap between the targeted and realized energy performance of the renovated buildings. Building Information Modelling (BIM) has many definitions, but the recurrent theme refers to a framework which standardize various

processes related to information production, exchange and management (Jung and Joo, 2011) with a specific focus on the integration of information across the entire supply and use chain of buildings (Smith et al., 2017). While BIM originally was intended for adoption to support design and engineering, it rapidly caught the attention of researchers and practitioners facing challenges during other phases of the building life cycle, such as renovation. While previous researchers reported on the benefits of adopting BIM for renovation projects (Volk et al., 2014; Aldanondo et al, 2014; Joblot et al., 2017), few renovation projects have yet adopted BIM.

The adoption of BIM for renovation projects still faces challenges in terms of: availability and affordability of digital information platforms to accommodate BIM approach; limited compatibility of the BIM tools and constraints to the interoperability of the BIM data; and lack of efficient and standardized procedures for As-Built data acquisition, As-Built and As-Renovated modelling, energy simulation, configuration of renovation design solutions, and long-term maintenance of the BIM renovation data.

Objective, type and research method of this paper

This research paper aims to analyses the actual bottlenecks of BIM for renovation projects, and subsequently propose a holistic research and demonstration approach to generate viable technical, economic, social and organizational solutions for all involved stakeholders. The research relies on an empirical method as it begins by defining the five main stages of actual BIM-based renovation projects, namely: 1) data acquisition from existing buildings; 2) renovation design; 3) building performance analysis; 4) execution of renovation works; and 5) long-term monitoring and maintenance. Subsequently, transdisciplinary innovations will be developed in the areas of: renovation process, time and resource management; ICT tools and standards; and social and legal aspects of BIM.

The proposed process innovation aims to resolve the fragmentation and segmentation within the renovation value-chain and solution development. Process re-engineering will result in a seamless integration and quick installation of Plug-and-Play (PnP) building products for renovation, which will reduce the renovation time substantially. The empirical performance of PnP renovation solutions has been proven among others in the on-going EU research project titled P2Endure (www.p2endure-project.eu). A new roadmap for BIM-based renovation that incorporates the main BIM-related renovation tasks, stakeholders' roles, required competencies and collaboration agreements will be established.

The proposed ICT innovation focuses on multi-dimensional BIM development and application, to be introduced as "10D BIM toolset for renovation". It covers: renovation project initiation and programming (1D); document management (2D); building and aerial scanning, modelling and technical clash detection (3D); time scheduling (4D); cost estimation (5D); Building Energy Modelling (BEM) and sustainability analysis (6D); facility management and post-renovation maintenance (7D); long-term monitoring and processing of real-time data (8D); connection from buildings to the surrounding environments, energy grid and local regulations (9D); and continuous updates of buildings', occupants' and energy performance in BIM Renovation Passports (10D).

This innovation goes beyond the state-of-the-art concept of 7D BIM, which presents a fully mature, comprehensive model for maintenance, operation and for facility management. This encompassing digital model contains all project relevant information of the entire process (planning, execution, management, operation and use). (Redmond et al., 2012; Georgis & Kovacic, 2016). The sixth and seventh dimensions are often not distinguished due to their contextual proximity. However, the lack of agreement on labelling BIM for facility management dimension as 6D or 7D, drives researchers toward avoiding the use of a specific label. Other than that, BIM for facility management has been on researcher radar for

a while (Becerik-Gerber et al., 2011). Current trends indicated the need of expanding BIM dimensionality to allowing smarter ways of collecting, processing and using the information through the building life-cycle towards creating a digital representation of the real-word asset, coined as “digital twin”.

Such a multi-dimensional application of BIM for renovation should take certain social and legal aspects into account, most importantly the privacy, ethics and security of BIM data compliant to the European Union's new General Data Protection Regulation (GDPR) that comes into force on 25 May 2018. Therefore, social and legal innovations related to BIM for renovation will build upon the theory by Hoepman (2018) on “the 7 principles of Privacy-by-Design” and implement “the 8 Design Strategies for software design based on Privacy-by-Design”.

Empirical research will also be conducted in testing, validation and demonstration of the proposed innovations in real building renovation projects. This paper describes the selection of the case studies, definition of the use cases of BIM for renovation, and plan for pilot implementation of the research outcomes. The main goals of this empirical research activity are to implement the innovative BIM solutions in real renovation projects; to measure the real impacts with regards to energy-efficiency performance and user comfort; and to establish the evidence of the level of adoption and best practices of BIM for renovation.

Empirical results and practical / managerial implications

The expected main results from research as described in this paper is a “harmonized digital information highway” for energy-efficient building renovation, which consists of: a cloud-based BIM platform that is open, affordable and user-friendly; a set of inter-operable BIM tools –existing and new ones– connected through the BIM cloud platform; and validated and standardized procedures for BIM-based activities throughout the whole renovation process. The information content for this digital information highway will be derived from the BIM data of the case studies and will include preliminary BIM Renovation Passports.

This paper presents the preliminary empirical results of BIM for renovation from real case studies in Spain, Italy and Poland. The real case in Spain is performed in conjunction with a large-scale EU innovation project under Smart Cities program. Several residential building blocks in Vitoria-Gasteiz, Basque Country, Spain are being retrofitted to achieve than 60% energy savings at deep renovation level according EU Energy–Efficiency Directive (EED) and European Commission document SWD(2013 143 final). This paper discusses the follow-up steps to accelerate the BIM adoption process at district renovation scale using the new digital information platform and associated tools. The other case studies (in Italy and Poland) are conducted within the EU research project P2Endure. In these cases, As-Built BIM has been created based on 3D laser and thermal scans, the Plug-and-Play renovation products have been configured using a BIM parametric modeler, and a preliminary energy calculation has been performed. Particularly for the Italian case, two different methods, each with a specific software for BEM, have been applied. This paper discusses the findings and lessons-learned from each method, and recommends optimization solutions to reduce the required time for BIM-to-BEM.

This paper finally presents the plan for wide-scale replication of the pilot experience and industrial exploitation of the newly developed and validated BIM solutions. There main pathways for such an upscaling action have been paved. The first one will accommodate immediate replications among the existing building stock owned by the clients and stakeholders involved in the real case studies. The second one will promote replications in future renovation projects which will be selected through a pan-European “BIM for Renovation Competition”, which will be organized by involving clients aiming to set up plans for BIM-based renovation, design and construction firms aiming to carry out the renovation

projects, and BIM consultants and software vendors aiming to provide their services and products to the clients and stakeholders in renovation projects. Finally, the third one will encourage embedding the knowhow in professional trainings and practices of architects, HVAC engineers, energy specialists, and construction firms through the European and national professional associations.

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