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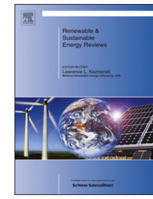

Building Information Modelling for analysis of energy efficient industrial buildings – A case study

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A B S T R A C T

Industrial buildings demand higher amount of energy than other building typologies, thus powerful modelling and simulation tools for energy-optimisation and identification of synergies-potentials between the building envelope, building services and production systems are needed.

Building Information Modelling (BIM), as emerging technology, bears promise to support processes integration thus enabling life-cycle management of buildings. BIM model serves as a joint knowledge database where data transfer between various models is possible; thereby enabling follow up studies, such as cost, thermal and structural analysis.

Adoption of BIM to BEM (building energy modelling) approach is particularly interesting for optimisation of industrial facilities. Multiple layers of interacting complex systems (building, services and machine floor layout) require careful modelling and control of geometry in terms of collisions, various adaptions due to the short product-life-cycles, as well as integrated energy performance analysis along interacting systems.

This paper explores the potentials and deficits of the modelling, analysis and optimisation of energy-efficient industrial buildings using BIM to BEM methodology, by means of case study research of two industrial facilities. Varying needs concerning the Level of Development and semantic differences in the modelling procedures of part-taking disciplines (architecture, structural engineering or analysis) were identified as problems; as well as time pressure as one of the main reasons for defects of building models. The identified deficits represent various types of uncertainties related to the integrated energy modelling, as BIM to BEM can be referred to. We conclude that as a first step of integrated modelling, an uncertainty-analysis should be carried out, and strategies how to deal with these developed. In order to minimise BIM to BEM uncertainties, not only interoperability issues of the software has to be improved (modelling uncertainty), but moreover, the redefinition of the design process and enhancement of individual capabilities is necessary (process uncertainty).

Contents

Abbreviations: AEC, Architecture Engineering Construction; BIM, Building Information Modelling; BEM, Building Energy Modelling; CAD, Computer Aided Design; ERP, Enterprise Resource Planning Software; FM, Facility Management; gbXML, Green Building Extensible Markup Language Schema; GFA, Gross Floor Area; GIS, Geographical Information Systems; HVAC, Heating Ventilation Air-Conditioning (Engineering); IFC, Industrial Foundation Classes Data Standard; MEP, Mechanical Electrical Plumbing (Engineering); TBS, Technical Building Services

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1. Introduction

Building stocks are responsible for 40% of energy consumption in the EU and for 36% of greenhouse gas emissions [1], the largest part of which occurs throughout the operation-phase. Recent research and practice has been largely focusing on analysis and optimisation of energy consumption of residential buildings [2,3], less so on public or commercial buildings (such as schools or offices) [4]. Optimisation of energy performance of industrial buildings has seldom been in the focus of research, due to the large energy-consumption of industrial production processes [5]. However, through recent policymaking – introduction of Energy Directive or Energy Performance of Buildings Directive [6], as well as to recent energy-availability issues, more integrated approaches regarding energy efficiency of industrial facilities have been proposed [7]. In this context, the balanced performance of building design, thermal envelope and HVAC systems, and use of synergies with relevant processes and occupancies has been increasingly advocated as the right approach [8]. Yet such an approach requires modelling, analysis and optimisation of complex systems, for which powerful computational tools are needed. Building Information Modelling, as "a digital representation of physical and functional characteristics of a facility" offers potentials for life-cycle modelling and management of buildings and building systems [9]. Through creation of a joint knowledge base – information rich building model – a follow up thermal, structural or cost analysis can be carried out. BIM, seen as multi-dimensional tool for life-cycle management, can be classified into 3D BIM – parametric building model, as an upgrade to a 2D CAD plan, 4D addressing time – scheduling and construction stages simulation, 5D cost – planning and estimation, 6D sustainability – thermal analysis and environmental assessment, eventually even automated building certification, and finally 7D as a fully mature, comprehensive model enabling facility management, maintenance and operation [10].

In this paper we will explore the potentials of energy-analysis and simulation on a case study of two industrial facilities using BIM to BEM (Building Information Modelling to Building Energy Modelling) approach, thereby addressing the issues of the so called 6D BIM – assessment of sustainability. We evaluated the modelling process and software-interfaces from BIM to follow up thermal simulation using BEM and tested the suitability of the models as joint knowledge base for life-cycle management of architectural, HVAC and shop-floor models. We will outline possible solutions for the minimisation of aforementioned uncertainties in such integrated modelling processes.

2. Literature review

2.1. Building Information Modelling

The common understanding of BIM terminology in the AEC industry in both practice and academia is multifaceted. Succar [11] delivers an overview of various BIM definitions. BIM terminus is originally coined by the CAD-software developer Autodesk [12], Graphisoft [13] was using Virtual Building, where as Eastman [14] introduces the Building Product Models.

BIM is defined as:

- The "new CAD" paradigm [15] – an advanced version of digital drafting tool.
- The building modelling **tool** providing possibilities of interaction with non CAD-based tools, such as quantity surveyors' or project management tools [16].
- A **methodology**:"… to manage the essential building design and project data in digital format throughout the building's life-cycle." [17] (p. 403).
- The emerging new **paradigm**: "… an emerging technological and procedural shift in the Architecture, Engineering and Construction industry." [10] (p. 357).
- Or according to the UK Government programme [18]: "… a collaborative **way of working**, underpinned by the digital technologies which unlock more efficient methods of designing, creating and maintaining our assets."

BIM is often mentioned in relation to building product modelling, a predecessor terminus to BIM, dating from the 80ies [17]. The product models address the object-oriented modelling of the data-rich building components, incorporating 3D geometries, spatial information, thermal values, and material properties; parameters upon which data interoperability builds up [19].

To the most utilised BIM Tools count Autodesk Revit (as one stop shop, offering possibilities for architectural, structural and MEP modelling and even proprietary tools for thermal and daylight analysis), Archicad by Graphisoft primarily used for architectural modelling, Tekla by Trimble, as engineering modelling tool, Allplan by Nemetschek, Microstation by Bentley etc.

BIM has often been recognised in research and practice as a suitable tool for support of collaborative planning, facilitating communication and information exchange between diverse planning process participants [20]. More practice-oriented publications often advocate BIM benefits as maximisation of efficiency, quality and reducing time effort [21]. It is largely understood as object-oriented digital representation of a building or built environment, which enables interoperability and data-exchange in digital form [22]. In this context BIM addresses primarily the process of model-building and information exchange [11].

BIM, in addition to support of collaborative processes, can through its capability of attributing both spatial and geometrical as well as non-geometrical attributes to building elements be implemented in various areas of the AEC industry, such as sustainability analysis [23], structural analysis [24], thermal simulation [25], daylight simulation [26], construction management [27], cost estimation and planning [28], fire protection [29], safety on construction site [30], facility management [31] etc.

Therefore the development of functioning and open interfaces is one of the major tasks in the advancement and successful adoption of BIM technology in the industry. One of the most important, open non-proprietary interfaces is the Industrial Foundation Classes (IFC), developed and supported by buildingSMART (International Alliance for Interoperability), which also