

## EDITORIAL - BUILDING INFORMATION MODELING APPLICATIONS, CHALLENGES, AND FUTURE DIRECTIONS

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Organizations are currently facing important and unprecedented challenges in an ever dynamic, constantly changing, and complex environment. Several factors, including the pace of technological innovation and the globalization of the economy, have forced business and industry to adapt to new challenges triggered by an ever sophisticated society characterized by an increasing demand for customized and high quality services and products in various segments of industry (Rezgui, 2007).

The Construction industry is renowned for its complex project-based structure, reflected in its virtual enterprise like modus-operandi (Rezgui and Zarli, 2006). It is currently facing some major challenges in terms of climate change and sustainability, including the need to reduce greenhouse gas emissions from existing and new build (Rezgui and Miles, 2009). This is reflected in increasingly complex regulations (environmental, energy, waste, etc) that must be assessed and addressed by specialists to satisfy planning consents and public concerns (Hopfe, 2009). Also, the current financial downturn and the concern for quality, timely and to budget delivery against the threat of financial penalties is causing the major industry players to reduce their circle of specialists and sub-contractors represented by a large proportion of SMEs.

Moreover, the Construction industry is dominated by SMEs that exhibit a wide divergence in their capabilities. This variation reflects their different roles in the sector, some being hands-on tradespersons whilst others are in the design or manufacturing sectors. Overall, SMEs face a number of challenging issues (Barrett and Sexton, 2006; Rezgui and Zarli, 2006):

- They tend to follow conventional business models that provide traditional products and services against cost competitiveness.
- They are small independent organisations but many are highly dependent on larger industry players for their work. This can disadvantage SMEs since they can be regarded as only "piece-workers" to do tasks with little opportunity to add value.

- They tend only to be present in a project during their part of the activity and this discontinuity of involvement is a particular challenge for the industry in relation to the adoption of the right business models and modes of project operation.

The expectations and requirements of clients and users vary dramatically from one project to another as the sector is experiencing the emergence of highly demanding clients and users. Flexibility, adaptability and innovation are identified as key ingredients to sustain the competitive advantage of construction companies (Rezgui, 2009). Innovation in construction is perceived as ‘the act of introducing and using new ideas, technologies, products and/or processes aimed at solving problems, viewing things differently, improving efficiency and effectiveness, or enhancing standards of living’ (CERF, 2000).

Traditional industry process models need reconsideration and continuous adaptation to suit local conditions and frequently changing stakeholder relationships. In this context, the industrialisation of construction poses many unique challenges, including:

- Maintaining and re-using knowledge, adopting best practice, and absorbing technology.
- Integration of specialised business services for the creation of increasingly complex products.
- The ability to innovate and remain competitive in a fierce business environment which is often controlled by large key player organizations.

Moreover, the construction industry is facing a paradigm shift: a move from simple “physical” components and products towards extended IT-aware products embedding various forms of “intelligence” (Rezgui and Zarli, 2006), e.g. information and devices that support services designed to facilitate management of life cycle performance and to meet changing end-user requirements.

Industry exemplars demonstrate that manufacturing principles of mass customisation with variants of customer choice, first pioneered by the car industry, can be adapted to construction. In fact, construction is starting to adopt manufacturing industry philosophies, although there is a limit to the extent to which mass production techniques can be used to assemble the wide variety of component parts needed to produce typical construction products that are almost always unique and highly complex.

Semantic e-Construction, as an ICT-based approach for distributed engineering, has the potential to lead to a fast and flexible production of customised and industrialised complex solutions with embedded intelligence. This approach would especially rely on an extensive use of semantic construction objects and pre-defined design models.

Digital models, the so-called BIMs (Building Information Models), can serve as an efficient means for sharing rich semantic building information across different disciplines and related software applications (Rezgui et al., 2009). Digital models will allow the capture of requirements from the client, end-users, and other relevant stakeholders; the efficient and effective use of various resources needed to deliver and operate a building from a human resources, financial, and supply chain perspectives; the process and product compliance with regulations across the building and facility lifecycle; the selection of sustainable product components and processes, achieving best performance and “buildability”; and the overall improved management of facility assets during their exploitation.

The progress made so far in arriving at the BIM concept and its associated tools is undoubtedly a sizeable step forward in the management, communication and leveraging of construction project information. However, both the BIM models used by the commercial vendors and the international standards developed for construction such as STEP and IFCs still exhibit a number of shortcomings (Rezgui et al., 2009). For instance, Building Information Modelling efforts have shown limitations in their static representation of a building and its environment. Further developments are required to provide a dynamic representation of a building necessary to provide real building performance (including energetic) accounts, while ensuring the building lifelong adaptability to its usage and environment.

The pragmatic BIM approach naturally leads to a service-oriented view of the world, whereby a particular discipline (and therefore the applications that support that discipline) defines a number of services that it may offer to other disciplines, with clearly agreed semantics that can be understood by the communicating parties without having to change the bulk of the conceptualizations that they use in order to provide those services.

While web service technology underpinned by BIM presents some interesting and promising features, there are a number of issues hindering the wide adoption of this technology, including data quality assurance, quality of service (continuity and recovery plans), as well as a trust, authentication, security, validation, and certification framework (authentication and trust). Addressing these limitations would confer web service technology the industrial robustness that would promote its wide adoption on construction projects.

This special issue addresses the above challenges and includes nine papers ranging from low-level implementation of BIM-based solutions to strategic reflections on recent developments in the construction sector.

In his paper, Dr Erastos Filos provides an overview of the European FP7 programme for research and development. More specifically, he discusses ways in which the AEC (architecture, engineering and construction) and facility management sectors can benefit from advances in information and communication technologies under FP7. Dr Filos argues that the technologies under development, ranging from wireless sensor networks, cooperative smart objects, plug-and-play control architectures, technologies supporting the "Internet of Things", to ICT services supporting energy efficiency can benefit not only the AEC and FM sectors, but the European economy as a whole.

Ye et al. paper argues that construction stakeholders have achieved little agreement on how to create an environment that will allow construction to move from a supply-driven to a demand-driven industry focusing on delivering extra values such as sustainability. Their work is underpinned by the quest to understand what clients, designers, contractors, end users and communities require from the buildings of the future. The authors propose a comprehensive requirement development methodology which helped elicit stakeholder requirements from seven defined stakeholder categories across Europe. Qualitative and quantitative analysis of the identified results have been interpreted and translated into six key requirement themes.

Related to the above, Chien and Mahdavi provide a set of requirements, supported by a prototype, for user interfaces of buildings' environmental controls. They argue that present occupant control actions in a building can significantly affect both indoor climate and the environmental performance of buildings. They have identified a gap in that little research has been conducted to analyze the means and patterns of such user-system interactions with building systems. Their promising work has a potential to serve as a basis for developing a new generation of user interface products to promote higher levels of connectivity between occupants and their indoor environments.

In their paper, Kubicki et al. address the issue of support for cooperative work in AEC projects. They propose a methodology to closely involve researchers and practitioners from Luxembourg in eliciting their business requirements. A generic "Sustainable Service Innovation Process" (S2IP) is applied to documents sharing in construction projects. They describe processes related to "service value" identification and to "service design". The paper presents a set of cooperative working practices related to document management, which have been mutually agreed between practitioners. This forms the foundation of their software environment currently being tested and validated.

Van Nederveen and Gielingh provide timely reflections on construction in the current economic turmoil arguing that credit-reductions by banks, as a consequence of the global monetary crisis, will hit the construction industry for many years to come. They introduce the Living Building Concept in which buildings are continuously adapted to changing user and/or client needs in the form of Product/Service combinations. Van Nederveen and Gielingh discuss the implications for building information modelling and construction ICT. They argue the need for a life-cycle modelling approach in which individual components and materials play a central role. Buildings are considered as temporary configurations of these components and materials. The functional life of buildings, which strives for higher and sustainable end-user value, becomes detached from the technical life of building components and materials, offering new opportunities for reuse, remanufacturing and recycling.

Mahdavi explores the necessary conditions for the emergence of cogitative buildings. A cogitative building is defined here as one that possesses a multi-faceted representation of its context (site, micro-climate), its physical constituents (elements, components, systems), and its processes (occupancy presence and actions, indoor climate controls). Cogitative buildings have the potential to dynamically update their representation and use it for virtual experiments toward regulation of the building's systems and states.

Paul and Borrmann propose geometrical and topological approaches in BIM. Their paper demonstrates how to derive topological relationships from "traditional" building models consisting of unconnected B-Rep bodies

using geometric processing algorithms. It also discusses the capabilities of building modelling based on topological concepts using an approach that combines relational database design principles with algebraic and point set topology. Their approach is illustrated in an application of cell-complex-based modelling, characterised by the separation of the building model into an abstract specification of building entities (sketch), a collection of possible concrete realizations of such sketch entities (details), and a specification of the details used by sketch entities.

In his paper, Medjdoub presents an object-based CAD approach for handling the schematic design, sizing and layout planning for ceiling mounted fan coil system in a building ceiling void. In order to deal with more complex geometry and real building size, Medjdoub proposes a hybrid approach combining case-based reasoning and constraint programming techniques. From the specification of the building 3D BIM model, the resulting software prototype proceeds through four steps. First, the user divides the building into zones, each zone being defined by a geometrical primitive. Next, for each zone a similar case is retrieved from the case library. The retrieval process generates a first incomplete 3D solution containing some inconsistencies. Next, the incomplete solution is adapted, using constraint programming techniques, to provide a consistent solution. Finally, distribution routes (i.e. ducts and pipes) are generated using constraint programming techniques.

Finally, Nour discusses research aimed at defining a stakeholder private workspace in a collaborative BIM environment using a central model server. The paper focuses on reducing the complexity and improving the performance of obtaining IFC early binding runtime objects from stored persistent models. It discusses and describes the various types of object-relational mappings between the IFC EXPRESS schemata and relational databases. The paper also presents the results of examining the possible serialization and de-serialization of IFC objects based on a number of parsers and interpreters developed by the author.

There is an urgent need to re-think and pave the way to a built environment adapted to the challenges of the 21st century. This requires the adoption of multi-disciplinary and multi-faceted methodological interventions that factor in people, process, and technology issues. It is hoped that the above papers will stimulate and contribute to the ongoing debate on BIM-based automation in construction. The editors would like to thank all the authors for their efforts and contributions to this special issue.

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