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THE ROLE OF CLIENTS AND USERS IN THE DECISION-MAKING PROCESS: AN OVERVIEW ON HOW BIM AND INFORMATION TECHNOLOGIES COULD CHANGE EARLY DESIGN PHASES

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The implementation of Building Information Modelling (BIM) methods and tools is deeply changing the AEC industry, acting on roles, relationships and interactions of stakeholders. New keywords are emerging related to collaborative workflows, anticipated evaluations and integration of knowledge throughout the building process. The paper aims to provide an overview on the role of Clients and end-Users in these innovative practices since the very early stages of the design process. Such an approach influences how design alternatives are analysed, regarding not only design costs and constructability, but also considering spatial configuration and Client and Users' requirements virtually managed and simulated. The integration of the BIM-based static validation of formal and functional requirements with a dynamic validation of how design alternatives answer to Users' behaviours and needs is investigated as necessary for an effective pre-occupancy evaluation of design alternatives into a Digital Built Environment. The aim is to highlight the possibility behind the combined use of Space Programming and rule-based Model Checking tools with Game Engines and Immersive Environments in order to coordinate and validate the simultaneous and computable interactions between Users, spaces and activities according to different scenarios and actively involving the Client and Users in the decision-making process.

Keywords: Building Information Modelling, Digital Built Environment, Requirements Management, Pre-Occupancy Evaluation, Simulation of Users' Behaviours.

Introduction

Building Information Modelling (BIM) has arrived as an epochal transition in the AEC industry, an industry historically resistant to change and late adopter of technological innovation. What emerges from the analysis of ongoing BIM mandates is that an aware application of the BIM methodology necessarily requires a process of reconfiguration of the AEC industry, as well as a review of roles, relationships and responsibilities (Rizal, 2011) among all the stakeholders involved in a project, from Owners/Clients to end-Users. As stated from the National Institute of Building Sciences in the United States (2007), a Building Information Model, as result of a Building Information Modelling and Management process, «is a digital representation of physical and functional characteristics of a facility. As such, it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life cycle from inception onward. A basic

premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM process to support and reflect the roles of that stakeholder». According to this definition, the change is on cultural, organisational and contractual levels in order to improve efficiency and effectiveness in building processes and to assure a better quality of the final product, reducing the gap between Client's requirements, Users' expectations and design solutions.

Building Information Modelling is a holistic management process that involves different phases of the building life cycle. The Owner/Client plays a key role in this process, starting from briefing and concept design (Ciribini, 2015). The proposed paper represents the first step of a PhD research project on a digitally-enabled Client/Designer interface, taking into account operational and behavioural requirements since early design phases. It focuses on the implementation of digitised procedures since the briefing phase, when requirements are captured, as well as at the conceptual design one, when designers, with a probabilistic approach, submit design solutions in order to answer to these requirements. The aim is to investigate how the static validation of formal and functional requirements by means of Space Programming and rule-based Model Checking methods and tools within a BIM environment could be effectively integrated with a dynamic validation based on Gamification and Immersive Virtual Environments (IVE) in order to simulate the answer of design alternatives to Users' needs. The importance of a collaborative workflow that actively involves Owners/Clients and Users in the briefing phase is also investigated, as well as their role in the decision-making process, including concept validation, when different scenarios are tested, and design review.

Requirements setting and management in the building process

The briefing process is the moment when a statement is prepared on how project objectives, operational requirements and performance outcome will be addressed (BS 8536-1:2015). The result of this process is a document, the brief, containing the building requirements stated by the Client and that are expected to be translated into a design proposal by the design team (Fronczek-Munter, 2014). Concept design, is the work stage when outline proposals are prepared with a probabilistic approach and defining various possible scenarios, taking into account post-occupancy and operational issues along with considerations of constructability (RIBA, 2013). Traditionally, according to a static and document-based view of the briefing process, requirements are defined only at the beginning of the building process and they do not evolve alongside design activities, effectively supporting the decision-making process (Kiviniemi, 2005). On the other hand, Blyth and Worthington (2010) stated that the briefing phase should not stop at the beginning of the building process but it has to evolve dynamically alongside the stages of a project. Kiviniemi (2005) also argued that a traditional process, usually represented by sequential phases where requirements are set only at the briefing stage, is actually a false representation of an iterative process, characterised by a «constant dialogue between ideas, analysis and evaluation». In several moments, in fact, the proposed design solution has to be checked for compliance to codes and regulations, but also against Clients' requirements and Users' needs previously defined. That is the reason why the building process and the requirements management one should be better described as parallel activities, bi-directionally linked to each other and with a fluid distinction between design phases (briefing, concept design, detail design) (Marchant, 2015).

At the beginning of the building process, the inputs for the briefing phase are represented by the Owner/Client's requirements, formal and functional rules coming from codes and regulations, both integrated with the knowledge of the project team. The Facility Manager and the end-Users should be also actively involved in setting design requirements from the beginning, together with other stakeholders. That would mean to anticipate and take into account operational aspects since the briefing phase by means of an effective integrated and interactive process, where the demand and supply sides are involved in a mutual dialogue (Fronczek-Munter, 2014). However, some problems may arise in the communication between designers, Clients and end-Users during the decision-making process. Clients and end-Users, in fact, are not usually able to understand technical representations of a proposed design solution and they may not be able to imagine how the design will be actually used after the construction phase (Shen and Shen, 2011).

The role of Clients and Users

Clients and Users could play a key role during the entire process, especially when functional and operational requirements are defined. This theme has been stressed in various publication and research projects. The CIB W118 Working Commission, launched through the CUBES (Clients and Users in Built Environment Spaces) Workshop held in Copenhagen in 2011, aims at supporting research activities related to innovative, collaborative and multidisciplinary methods for engaging Clients and Users in decision-making processes. According to the W118 Research Roadmap Report, one of the major problems in the AEC industry is related to the «level of collaboration between Clients' organisations and the supply chain in the procurement of facilities and associated services». Clients have a central role in the implementation of innovative practices within the supply chain. Moreover, they also play as an interface between the end-Users and the supply chain into a demand-driven sector as the construction one, where the aim is to provide a better Client and Users' satisfaction (Haugbølle and Boyd, 2013). Furthermore, the building is a framework populated and activated by end-Users and their involvement should be related to every phase of an integrated process, from pre-design to operations.

The CIB Working Commission W111 about Usability of Workplaces has also highlighted the importance of briefing as means to achieve Usability. Fronczek-Munter (2014), for example, developed the Usability Briefing model to describe the role of a dynamic briefing phase and the importance of Client/User Involvement, providing an overview of how the engagement and interaction of main activities, such as briefing, stakeholders involvement, evaluation methods and design processes change over time. The Usability Briefing model developed by Fronczek-Munter (2014) highlights how the anticipation of operational requirements and Users' needs should be formalised at the briefing phase, discussed in design meetings and systematically evaluated in order to translate the brief into an effective design and construction process; that would mean to develop not only a building product, but aa service that satisfies a need (Marchant, 2015).

Collaborative workflow within a BIM environment

«BIM is an IT-enabled, open standards-based deliverable and a collaborative process» (Eastman et al., 2011) that requires the co-operation of the involved parties. According to Blakstad et al. (2010), in fact, the focus «is not only about new

methods and better processes, but it is also about the actors in the processes and their relationships». As stated by Eastman et. al. (2011), an effective implementation of BIM methods and tools «depends on how well and at what stage the project team works collaboratively on one or more digital models». Moreover, Leon et al. (2014) highlighted how the greatest potential of BIM lies in enabling a collaborative process since the early and conceptual design phases, having a greater impact on innovation and design quality. To this end, for example, Leon et al. (2014) defined a multidisciplinary Conceptual Design Stages Protocol (CDS Protocol) based on system engineering workflows applied to the AEC industry, in order to support multidisciplinary early involvement and to maximise the potentials of collaboration and coordination for the entire project life cycle. Finally, the technological advances promoted by the application of BIM, together with an informed and transparent collaboration and communication within the AEC industry, enable the implementation of digital concept validation, systematic design review and simulation of building performances, promoting the effective interaction of stakeholders and improving the final design solution.

BIM processes and Information Technologies for requirement management and simulation of Users' needs

Kiviniemi (2005) stated that one of the main problems in the current process is the lack of a bi-directional link between Owner/Client's requirements and design documents. Moreover, the visualisation of design solutions is not always accessible for Clients and end-Users that are not able to understand technical representations (Shen et al., 2012). During the iterative process of design proposals and reviews, a lack of communication in the Client/Designer/User interface may reduce the efficiency of requirements specification as well as of the design review process (Shen et al., 2012). Information Technologies play a key role in supporting the changing process from this point of view, communicating and managing both graphical and non-graphical information of the building project during its life cycle. In this context, BIM provides a collaborative and integrated environment.

In the following paragraphs, some of the digitally-enabled methods and tools for supporting Clients and Users in the decision-making process are described. The focus is, on the one hand, on Space Programming and Model Checking tools for the static validation of formal and functional requirements and, on the other hand, on the implementation of virtual reality in order to simulate Users' behaviours and support interactive and collaborative review processes by means of Gamification and Immersive Virtual Environments (IVE).

Space programming and rule-based Model Checking

BIM processes and tools could change how the programmatic requirements of Clients are captured and used, improving the semi-automatic validation of design solutions. Space Programming tools, for example, organise, manage and maintain data and functional requirements for room templates, room data sheets, furniture, finishes, items, systems and components in cloud-based platforms. According to the building type, they can be used in order to create a bi-directional link between the requirements management phase and the design one (Eastman et al., 2011). Parametric Space Programming tools can improve the performance of requirements

setting and management, keeping requirements and informative content up to date throughout the project, including construction and operational phases of a building life cycle (Kim et al, 2015). At present, in order to integrate design requirements with design spaces, either a plug-in based or an open IFC-based interoperable and bi-directional link between Space Programming tools and BIM authoring platforms allows a continuous validation of compliance of design outcomes to the given formal and functional requirements.

Building quality and compliance to design requirements can be also assured by means of a BIM-based Rule Checking process. Rule Checking is a multi-domain validation framework based on parametric rules within a BIM environment (Eastman et al., 2009). It consists in a key process in order to ensure quality and internal consistency of a Building Information Model. Moreover, in an open BIM environment, based on the use of an interoperable and neutral data format, the validation phase is essential to formalise information exchange procedures, increasing transparency and interoperability of the process as a whole. To this end, a systematic control of parametric models should be implemented in own procedures by both Clients and designers in order to improve the quality of the design solutions, their consistency with the information requirements and their constructability. Clash Detection is the Model Checking use with the best effort-benefit ratio, since it does not necessarily require information-rich objects. However, in an entirely digitised building process the focus is on BIM Data Validation and semi-automated Code Checking (Ciribini et al., 2016). BIM Validation is the application of parametric rules to check geometric and non-geometric attributes embedded in a BIM model in order to validate property values and modelling procedures. For example, BIM Validation rules allow the analysis of the informative content associated to a parametric object and the validation of the correspondent Level of Information (LOI) based on what previously specified in the Employer Information Requirements (EIRs) and in the BIM Execution Plan (BEP). Finally, BIM-based semi-automated Code Checking is a specific case of rule-based Model Checking that validates three-dimensional (3D) and object-oriented design (Solihin et al., 2015) through various validation domains, comparing the parameters of the Building Information Model against current codes and regulations.

A parametric Rule Checking system can be implemented in two different ways. The former is the use of applications and plug-ins in BIM authoring platforms, which usually contain tools to perform a preliminary check of the interferences or a partial BIM validation of geometric aspects. On the other hand, at present, BIM design tools do not provide more advanced Model Checking capabilities based, for example, on customisable rule-sets. To this end, Model Checking BIM tools are required, which apply rules to Industry Foundation Classes (IFC) building model data (Zhang et al., 2013): that is one of the reasons why data interoperability remains a major issue.

Game engines to simulate Users' behaviours

Space Programming and rule-based Model Checking manage and validate formal and functional requirements, but they do not predict and validate dynamically space-use scenarios according to the computable interaction between spaces, activities and Users (Kim et al., 2015). This computable interaction is defined by building usage

scenarios, which represent the set of events that describe the interaction between the Users and the building system (Simeone et al., 2015). Several researches have been developed in order to represent this interaction within a BIM Environment, integrating BIM and Gamification, meant as application of «methods and technologies dedicated to simulate human behaviour in videogame» (Simeone et al., 2013). Gamification, also meant «as the use of game design elements in non-game contexts» (Deterding et al., 2011), represents a particularly dynamic approach to integrate various no-static phenomena in a classic BIM representation, such as those related to building uses and Users' behaviours according to the surrounding built environment (Simeone and Kalay, 2012). The integration between BIM and Gamification allows the simulation of how the design proposal answers to Users' needs taking into account the computable interaction between activities, spaces and Users in a sort of Pre-Occupancy Evaluation, defined as the evaluation of building performances and satisfaction of Users at a «pre-design, pre-construction and pre-occupancy phase» (Shen and Shen, 2011). Shen and Shen (2011), for example, introduced a BIM-based Pre-Occupancy evaluation method in order to simulate end-Users' activities in the future built environment, improving the Clients' understanding about the design proposal. Simeone et al. (2013) believe that a better understanding of how people will use the building and interact with the built environment would necessarily affect the design process. The main aim of such a dynamic simulation, in fact, is the validation of design solutions in use conditions in order to support designers and Owners/Clients in evaluating the impact of their decisions on future Users' activities, anticipating this issue at early design and evaluation phases. Moreover, the use of game engines, Agent-based Modelling tools able to manage 3D models, improves the visualisation and communication of design proposals, promoting a deeper involvement of various stakeholders in the design process.

Immersive Virtual Environments to validate design alternatives

Immersive engineering is the development of innovative visualisation environments that can be implemented in interactive and collaborative review processes for the analysis of design solutions during the decision-making process, effectively involving also Clients and Users. They can be used to develop virtual prototypes of building solutions where virtual architectural spaces can be visualised and tested (Fraunhofer IAO), simulating a realistic experience of spaces that do not physically exist yet (Schaumann et al., 2015). Multi-touch displays, gesture control tools and 3D real-time positioning systems can be used with Computer-Aided Virtual Environments (CAVE) and Head Mounted Displays (HMDs): both of them are immersive environments to interact within a virtual space. A CAVE is a multi-sided projection system that gives viewers a realistic impression of the 3D model, including a downward view. It can be used for collaborative design review, inspecting the model and exploring design prototypes (Fraunhofer IAO). HMDs are wearable digital devices and Oculus Rift is one of the most known; it works with a single mobile phone display and it can be connected to other technologies, such as the Leap Motion controller, in order to track hand-inputs in relation to the virtual body position (Hilfert and König, 2015). Such devises create immersive VR systems, in which Users feel immersed in a virtual environment just as they usually feel in a real one (Rankohi and Waugh, 2013). These technologies are becoming widely adopted within the AEC industry in order to provide am effective

understanding of design solutions to Clients and end-Users by means of a better visualisation of design options. Moreover, it is also possible to walk inside a virtual built environment, testing in first person the designed spaces virtually represented (Hilfert and König, 2015). An important theme related to the implementation of these technologies within a collaborative workflow is the level of interoperability between various applications in a BIM process: usually, a Building Information Model, including its informative content, cannot be directly imported in Immersive Virtual Environments from BIM authoring platforms; first it has to be imported into a game engine. A current research theme is the use of the IFC neutral data format for an interoperable information exchange between these three steps. This opportunity would allow retaining the geometrical and non-geometrical information and attached metadata of the IFC scheme within the Immersive Virtual Environment. In this way, the interaction with the elements would enable not only to visualise building objects and to walk in virtual spaces, but also to check data and information without breaking the immersion experience (Hilfert and König, 2015).

According to Heidari et al. (2014), BIM has to evolve toward a more User-centred design in order to help end-Users «to experience their daily activity in a virtual environment and understand the space reactions». Few examples of how IVEs have been introduced in design processes are cited. The alreasy cited Hilfert and König (2015) used Oculus Rift and Leap Motion to simulate a User placed into a wheelchair in order to see and test the proposed design solution from the point of view of a disabled person. At the Centre of Virtual Engineering of the IAO, Bullinger et al. (2010) focused on the application of Immersive Virtual Environments as communication tool with non-expert Users in a User Centred Design (UCD) process in order to define an iterative design review based on the feedback of Owner/Client, end-Users, Facility Manager, Contractors and Designers after experiencing the virtual prototype. Castronovo et al. (2013) also investigated the role of Immersive Virtual Environments in the design review process, which they define as a «critical step in a pre-construction phase»; they stated that identifying design errors using Virtual and Augmented reality in the early design stages could effectively improve the overall building process. Maldovan et al. (2006) used a CAVE to involve key stakeholders in the concept design phase of a courtroom. Dunston et al. (2011) used IVE to involve end-Users in the design of healthcare facilities in order to present different design environments and get Users feedbacks to improve the design with the necessary changes according to their needs.

Results and discussion

The proposed paper is the result of an initial overview on how BIM and Information Technologies could change early design phases. The aim has been highlight and investigate several research topics (Table 1) to be integrated in a coherent design and validation framework in order to assure a better quality of the final product, reducing the gap between Client's requirements, Users' expectations and final design solutions. Some open issues have been detected (Table 2), and they may represent the starting point for future developments of this research project.

Table 1Analysed research topics

Research topics
• Role of briefing and concept design in the building process
• Client and Users Involvement in the decision-making process
• Collaborative workflow within a BIM Environment
• Anticipation paradigm and Pre-Occupancy Evaluation
• BIM processes and Information Technologies for design review

Table 2 Detected open issues to be further investigated

Open issues
• Client/Designer communication interface, anticipating operational issues
• Role of Users (FM and End-Users) in the briefing process to formalise In-Use needs
• Evaluation of User Involvement for different types of Users, processes and facilities
• Lack of collaboration and implementation of BIM only as a technology
• Need to define a validation framework to integrate static and dynamic design review

Future developments should contribute to define a process map that could link within a BIM Environment the main topics emerged from the proposed overview and that can be summarised in the following keywords: Digitally-enabled Clientship, User Involvement, Collaborative Workflow and Information Technologies as a support for the AEC industry. The aim should be an effective connection between the initial requirements, computationally defined, and the physical building (Figure 1) in order to assure building quality and compliance to upon-agreed needs and specifications. To this end, a continuous link between requirements and design solution has to be implemented and managed throughout the whole building process, matching the briefing phase to the In-Use one. An iterative design review within a BIM Environment, supported by collaborative procedures and effective involvement of digitally-enabled Clients and Users should be implemented in every project stage.

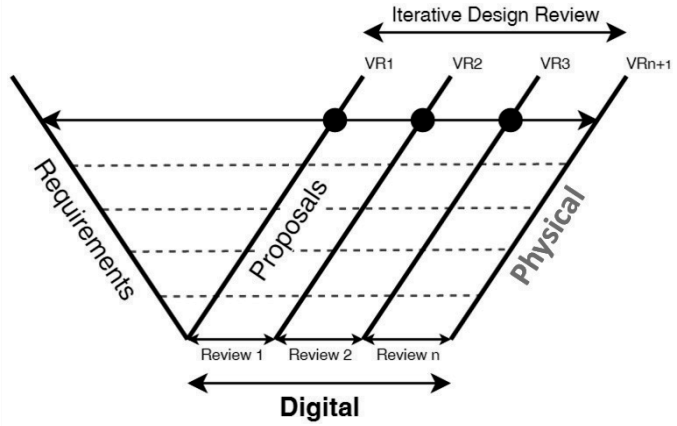

Figure 1 Preliminary representation of the link between the phase of information requirements setting/management with the iterative design review and decision-making process within a digital built environment

Conclusions

Building Information Modelling stands for collaboration, anticipation and integration of knowledge among the multiple actors involved and transversally in the different phases of a building process. That is the reason why Space programming,

Model Checking, Gamification and Immersive technologies should not be used to validate design options into a traditional framework, but they should be effectively implemented into collaborative workflows and integrated procurement systems. This is an essential aspect of a process that should start considering operational and In-Use requirements since the briefing and concept design phases. In the briefing phase, the Client can use BIM tools and processes in order to digitally define its functional objectives and needs by means of computational methods. Designers have to answer to these requirements, translating them into spatial configurations with a probabilistic perspective. Finally, end-Users will act in the proposed building framework, probably in a different way if compared to what Clients and designers initially imagined. These three worlds have to dialogue and they could do it within an interoperable BIM Environment. Anyway, even if technologies are fundamental, they are reductionist if compared to the change in roles and responsibilities that is taking place. Looking at international experiences, in fact, it seems to be necessary to start from the processes in order to mitigate the risk and increase the knowledge. The Client plays an important role in this transition since it is asked to become co-author of the project and originator of the process. There is the need to modify organisational models and procurement systems, having in mind that the maximum value is the operational phase.

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