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Implementation of an interoperable process to optimise design and construction phases of a residential building: A BIM Pilot Project

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ABSTRACT

Building Information Modelling (BIM) represents a long-term investment that could allow time reduction and a cost enhancement by means of optimised design and construction processes. The paper focuses on the first official Italian Public Pilot Project, dealing with the implementation of BIM-based validation and construction optimisation in a construction process. The case study concerns a residential building located in a dense urban district, causing a confined construction site affected by space shortage and coordination issues. The research aims to implement an interoperable IFC-based process in order to support the design and construction phases, performing advanced Model and Code Checking and analysing the construction phase through 4D BIM. Architectural, structural, and MEP models have been enriched with alphanumeric attributes as required by semi-automatic validation processes. An auto-matching between BIM objects and construction activities was also achieved. The early results showed the possibility of a BIM-based semi-automatic validation of design choices and an improved coordination between design disciplines. Moreover, the construction site simulation allowed the comparison of different layout options and baseline schedules. The research also tested the joint use of Model Checking and 4D BIM tools in order to analyse construction progresses by exporting an IFC-based construction site configuration directly from the 4D BIM tool. The tested process created an open, interoperable, and multi-disciplinary approach. The main findings concerning the domestic special constraints are described and analysed.

1. Introduction

Building Information Modelling (BIM) has been conceived and perceived as a transformational game changer by various governmental strategies in Europe and elsewhere [1–3]. A profound shift is needed during this transformational process, indeed: Public Clients have been often involved in BIM-based Pilot Projects over Northern and Central Europe, depending on the nature of their government mandates. Several EU-28 Member States have already implemented BIM in their construction strategies in order to transpose the European Union Directive 2014/24/EU on Public Procurement stating that "for public works contracts and design contests, Member States may require the use of specific electronic tools, such as of building information electronic modelling tools or similar" [4]. UK, Germany, France, and Spain have already started to include, with different levels of maturity, Building Information Modelling methods and tools in their governmental strategies [5–12]. On the other hand, the implementation of information-based methodologies and technologies in the Italian AEC industry is just at the beginning and it lacks an effective BIM-oriented strategy.

The proposed paper focuses on the first official Italian BIM Pilot Project managed on behalf of a Central Public Body. The aim was not to implement BIM during the bid process and in the Public Procurement framework [12], but to support the Public Client in order to test advantages of BIM compared to traditional design and construction management practises and to improve coordination and collaboration between different disciplines and phases of the construction process. The Pilot Project aimed to introduce the Public Client to a different approach rather than the traditional one it currently uses, from both a methodological and technological point of view. It can be said that the focus was based on the education to BIM of the Public Client in order to transform it in an effective co-author of the project and originator of the process [13].

A BIM approach can be implemented in any tendering route, improving the overall process [1,12]. During either the design phase or the construction one, in fact, there are clear benefits in using the BIM methodology [12,14]. In the proposed Pilot Project, the chosen Public Procurement method was the Design-Bid-Build (DBB) one: the Public Client developed the preliminary and detail design, while the awarded contractor was responsible for the construction phase and had to evaluate construction costs as well as to develop the construction

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documents, including the schedule. This kind of procurement, on one hand, helps the Public Client to have a better idea of the costs, but, on the other hand, this also leads to a certain level of separation between the design phase and the construction one [1,12]; as a result, the process is characterised by a lack of knowledge and collaboration.

In a DBB procurement method, it would be possible to create a Building Information Model during the tendering phase in order to allow the bidders to fully understand the complexity of the project and to extract quantities in a semi-automatic way [12,14], leading to a better control of quantities and a more accurate cost estimation. The bidders may also link the parametric model to the construction schedule in order to better optimise the construction phase. Moreover, a more coherent and coordinated documentation could be extracted from a federated model rather than starting from traditional 2D drawings, avoiding mismatching information and controversies [12,14].

Anyway, the use of BIM in traditional procurement routes loses an important part of its positive disruptive benefits [12,15] and they may also represent a limit to an effective implementation of the digitalised process [16]. In the last few years, innovative procurement methods based on the collaboration and co-operation of the involved parties have been developed [12,17]; one of them is the Integrated Project Delivery (IPD): in this case, the use of BIM can effectively support the required level of collaboration [12,18–20].

In this Pilot Project, BIM was implemented in order to improve coordination and collaboration between different design disciplines and to validate the design phase. Model Checking was used to control the quality of the model in a semi-automatic way [21,24] and check compliance against codes and regulations at national and local level [21–23]. Moreover, this methodology was also implemented in the construction phase to create a 4D Building Information Model, which consisted in a simulation of the construction process over time. A 4D BIM is created by linking construction activities defined in a schedule to 3D objects in a Building Information Model. Developed at different stages of a construction project, a 4D BIM allows the analysis of a proposed design and its constructability, as well as the validation of construction planning and monitoring the construction progress [25–27].

2. Methodology

The proposed case study was the first official Italian Public Pilot Project for the implementation of the BIM-based validation and construction optimisation into a construction process. The Pilot Project followed a comparative approach and it was developed according to the sequences and frames devised by the Ministry of Justice in the United Kingdom [13,28] and Statsbygg in Norway [1,29].

2.1. The BIM Pilot Project framework

The experimentation took six months between 2013 and 2014; the Public Client decided to not integrate BIM directly in the Public Procurement process, but between the detail design phase and the construction one. The validation phase had already started according to the traditional, manual methodology when the BIM experimentation was introduced. This choice inevitably led to some limits in exploiting the potential benefits of the BIM implementation [30]. Anyway, the entire design and construction management processes were simulated, with a focus on the role of BIM in design validation and construction optimisation.

The aim of the Pilot Project, in fact, was to test advantages of BIM compared to traditional practises of a building process as a long-term investment for the Public Client to better control the entire process, but also to effectively improve coordination and collaboration between different disciplines and phases of an integrated process. The actors involved in the case study were the Public Client, both owner and design reviewer, an ICT partner, and the BIM research group of the Department of Civil, Environmental, Architectural Engineering and Mathematics (DICATAM) of the University of Brescia, which supported the implementation of the BIM process.

The case study was related to the BIM-based validation and construction optimisation of a new three-floor residential building with a two-floor underground car park. The architectural, structural, and MEP designs were modelled in dedicated BIM authoring software and then merged into a federated model through the Industry Foundation Classes (IFC) interoperable and neutral data format [31]. The aim was to simulate the co-operative approach implemented elsewhere in order to validate its own reliability within a confrontational environment. An IFC-based interoperable process was implemented to perform Model Checking, including compliance checking to codes, regulations, and client's requirements, and to effectively manage the construction phase linking the construction schedule to the Building Information Model into a 4D BIM. The BIM environment included two BIM platforms and two BIM tools [19]. Nemetschek Allplan 2014 was used for structural and architectural models, while DDS-CAD of the Norwegian Data Design System, currently a Nemetschek company, was the BIM authoring tool used for modelling MEP systems. Model and Code Checking was implemented through Solibri Model Checker (SMC) in order to check quality, internal consistency, and regulatory compliance of the Building Information Models. Synchro PRO was the software chosen for 4D Building Information Modelling (4D BIM) and construction management.

Moreover, geometrical and alphanumerical attributes were defined and added in the Building Information Models to be used for further BIM-based analyses.

2.2. Building model preparation according to defined BIM uses

Model Checking and 4D Building Information Modelling are the BIM-based analyses conducted during the experimentation. The purpose was the implementation of an interoperable and semi-automatic IFC-based process aimed to perform advanced Model and Code Checking and to effectively manage the construction phase through 4D BIM. To this purpose, the Building Information Model was enriched directly in the BIM authoring tool of all the informative content needed to proceed to the next phase of the analysis. An outline BIM Execution Plan (BEP) defined BIM-goals as a function of which geometrical and, above all, alphanumerical attributes were embedded in architectural, structural, and MEP models in order to answer the information requirements [32] of the Public Client that, for the first time, implemented a BIM-based process in its own procedures.

In order to provide the information model with the needed informative content [33] and to achieve a certain level of automation, a careful and detailed modelling and information management phase was performed. A deep analysis of the alphanumeric attributes to be added in BIM objects and of the suitable granularity of the parametric model was needed. In fact, building model data had to be effectively structured in order to successfully validate the informative content, geometrical and non-geometrical one, against various rule-based domains and to automatically link parametric objects, filtered by construction activity, to the construction schedule in a 4D BIM tool [25]. For both these analyses and BIM uses [34] the necessary attributes to be included in the informative content of the Building Information Model were defined [24].

Allplan native data were exported to Microsoft Excel, where the required attributes were added directly in the spreadsheet. The bi-directional link between the authoring tool and the spreadsheet allowed the informative content to be automatically modified and integrated with the necessary requirements. Moreover, the external link to the Allplan database allowed the easy management of the necessary BIM requirements for checking the model against BIM Validation and Code Checking rules. According to the Level of Development (LOD) [35] of a Building Information Model, in fact,

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