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Begoña Fuentes Giner
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AN INNOVATIVE DATA-BASED APPROACH FOR GRADUAL INTEGRATION OF BIM IN DESIGN TENDERING

Di Giuda, Giuseppe Martino[a]; Locatelli, Mirko[a] ; Pattini, Giulia[a] y Pellegrini, Laura[a]
[a]Department of Architecture, built environment and construction enginnering, Politecnico di Milano, Italy bimgroup-dabc@polimi.it

Abstract

This paper presents an improved model for design competitions management. This model has been set and improved based on Iscol@ programme, promoted by Sardinia Region that has two main goals: the reactivation of the construction supply chain at a regional level, and the reduction of education drop-out rate, through the improvement of both school building stock, and educational provision.

The proposed approach is developed on machine-readable requirements set in DIPs (Documento di Indirizzo alla Progettazione), that can be implemented in BIM-models proposed (and later on required) by the project teams taking part in tenders. The setting of quantitative requirements allows the definition of a hierarchy of clients' goals, as well as the setting of a steady evaluation for all the contestants. The definition of DIP takes into account the different disciplines involved, providing requirements related to both architecture and pedagogy.

Keywords: *Design tendering, Iscol@, school building design, project requirements.*

Resumen

Este trabajo presenta un modelo mejorado para la gestión de los concursos de diseño. Este modelo ha sido establecido y mejorado en base al programa Iscol@, promovido por la Región de Cerdeña, que tiene dos objetivos principales: la reactivación de la cadena de suministro de la construcción a nivel regional, y la reducción de la tasa de abandono de la educación, a través de la mejora tanto del parque de edificios escolares, como de la oferta educativa.

El enfoque propuesto se desarrolla sobre la base de los requisitos legibles por máquina establecidos en los DIP (Documento di Indirizzo alla Progettazione), que pueden ser implementados en los modelos BIM propuestos (y posteriormente requeridos) por los equipos de proyecto que participan en las licitaciones. El establecimiento de requisitos cuantitativos permite la definición de una jerarquía de objetivos de los clientes, así como el establecimiento de una evaluación constante para todos los concursantes. La definición de DIP tiene en cuenta las diferentes disciplinas implicadas, proporcionando requisitos relacionados tanto con la arquitectura como con la pedagogía.

Palabras clave: *concurso de diseño, Iscol@, diseño de edificios para escuelas, requisitos de proyecto.*

Introduction

Requirements are the basis of every project; they define the basis for project planning, risk management and monitoring of adjustments and changes. Their role is relevant in every step of the design process.

Design process in Italy is different from other Countries, and it is particularly difficult to trace due to the features of the construction sector (Alfieri, Seghezzi, Sauchelli, Di Giuda, & Masera 2020). The scope of this research is limited to Italian context. The legislative framework is mainly set by D.Lgs. 50/2016 as amended and DM 560/2017; public projects and private projects follow different rules, the focus is here kept on public sector.

Public projects must be carried out following three degrees of development that do not follow RIBA stages and have different contents:

1. Technical-economic feasibility
2. Concept design
3. Technical design

The legislative framework also prescribes that projects (the Public Procurement Code define not only projects, but also services) under 40,000 € can be direct awarded (Codice Appalti – Public Procurement Code); projects over that amount require a public bidding.

Public bidding of projects is therefore a relevant and crucial aspect in Public Administrations management. The basic tool for PA to structure their request in a public bidding of design competition is the Documento di Indirizzo alla Progettazione (DIP) that defines for each stage of design, the Client's needs and the objectives to be reached, the economic setting of the project.

This document should describe the needs both in qualitative and in quantitative terms, and represents the reference to evaluate design proposals. Nonetheless, it is hard to describe qualitative information through quantity, and in addition, there is currently a lack of identification, management, and traceability of requirements in design processes (Arayici & Ahmed 2006).

For this reason, the aim of this paper is the definition of quantitative requirements to be set in DIPs, that can be implemented in BIM-models, and that can help to evaluate design proposals in competitions.

1. ISCOL@ Program

Iscola@ is a program set by Sardinia region with the goal of reinforcing the school system, improving the competences and skills of the scholars a contrasting the school leaving and school disaffection. This program regards different aspect of "school improving", including teaching skills and innovative education techniques. One of the main part of the program regards the architectural improvement of existing schools and the construction of new ones, with the aim of increasing the quality of learning spaces, and the sustainability, both in environmental and in social terms.

In this context, the region has started a series of new design competitions to reach those goals.

Considering the specificity of the goals and of the buildings considered, the clients' requirements should be well structured and defined, in order to guarantee the quality of the final object.

Furthermore, the goals of the region in creating better structured DIP and requirements are not limited to increase the quality of buildings, but also in changing the design process.

Sardinia has peculiarities. It is the region with the highest school drop-out rate in Italy, with 21.2% of early school leavers, against a national average of 14% (Colombo 2015). The insular condition of Sardinia does not help its economy, especially considering construction sector (Balletto, Borruso, & Mei 2019). Iscol@ program has as goal the interaction of local design firms with other professionals, including pedagogic experts, sustainability designers, etc., help overcoming the sector fragmentation. The program aims at increasing the interactions between Sardinia and the rest of Italy, and stimulating the mix of competencies.

The concept is the combination of architecture/space requirements and pedagogical principles, to achieve the best quality in school buildings.

2. Methodology

This research project has been developed in accordance with Sardinia region, in the framework of Iscol@ program previously described. The aim of this research is to present the definition of quantitative criteria to evaluate and guide design proposals, in the framework of the progressive integration of BIM in design competitions.

For these reasons, several meeting with the region were organized, in order to properly understand the client's requirements and therefore to set a translation of these requirements in quantities presented in the DIPs of the design competitions. Several DIPs were analyzed, in order to define their structure and their features.

These requirements are then translated in a grid to be used during the evaluation of the design proposals; each of the requirements is combined with a score given to the proposal for each commissioner, and is assigned a weight. The grid is structured as a multi-criteria table, and allows the jury to express a quantitative evaluation of the projects.

In this sense, the client's requirements are used as a benchmark to verify the efficiency of a project proposal considering the initial requests. The evaluation of projects can in this way be carried out following clear and objective criteria.

In this context, the use of BIM models play a relevant role for two main reasons: first, it allows the designer to explore different project alternatives that fit the requirements, and allows the clients to verify in a complete and rapid way that his requirements are properly translated in projects.

It is important to underline that BIM is progressively becoming compulsory for public procurement. The proposed methodology can be applied to traditional projects, but shows its benefits in BIM-based processes. The definition of qualitative and quantitative requirements of the Clients allows the designer to incorporate those data in the BIM models (e.g., in parameters related to technical elements), and therefore to define design choices and compare different solutions. The client, on the other hands, can evaluate project proposals expressed in BIM models provided in a clear way, checking the compliance of the requirements.

Considering a BIM-based process, the DIP can be considered as part of the EIR (Employer's Information Requirements). As for the ISO 19650, the EIR expresses needs and requirements of the Clients, including the information management. The BIM Execution Plan (pre-contract) is the response of contractors or design team to the requirements of the Clients; in the context of a design competition, BEPs should be part of the project proposals.

3. Expressing client's requirements

The definition of requirements and sub-requirements has been based on Kansei engineering (Nagamachi 1996), that is a method developed in Japan by professors Yoji Akao, of the Tokyo Institute of Technology, and Shigeru Mizuno, to translate customers' requests and needs into product features, from the design phase to the production. This approach assures higher quality of a product as it perfectly fits the clients' needs.

On the contrary, the traditional approach of Quality Function Development has a limitation, as the qualitative evaluation based on Likert scale can represent different meanings depending on the user involved. For this reason, criteria are subdivided in sub-criteria so that the level of detail can help the evaluation of alternatives and the verification of their correspondence to initial goals. On the other hand, this level of detail also allows the designer taking part in the competition to better set their design principles.

The objectives set are based on the features described by SMART: specific, measurable, achievable, realistic, time-related (Mannion & Keepence 1995). In order to evaluate potential alternatives, simulation can be used to verify the correspondence to initial requirements expressed in the DIP; pre-occupancy simulations can be used to test interactions among users to assure the integration of architectural layout and pedagogical method, meaning that the design of space can effectively stimulate the interaction of scholars. Computer based simulation, based on BIM models, can also help in the understanding of projects and the efficiency of the communication between Client and designer.

In a BIM-based process, information-exchange requirements should be included in the EIR: the EIR includes the DIP and therefore all the project requirements and acts as a guide for designers to develop their proposals. To facilitate the evaluation of design proposals, it is necessary to include a table with the objectives required in the DIP and the summary of how the proposed project answers to those objectives.

4. **Criteria setting**

The setting of criteria is based on seven main areas to be furtherly divided in sub-criteria. As previously stated, these criteria represent the needs of the Client. They are meant to be used for all the design competitions regarding new schools in Sardinia. The criteria set can anyway be modified when needed, to better fit the clients' needs. It is relevant to underline that these set of requirements is the one used for the first level of project process (that is the technical and economic feasibility).

The seven main criteria are:

1. Architectural quality
2. Learning space quality
3. Furniture quality and flexibility
4. Environmental quality of the building
5. Technical and technological innovation of the project
6. Technical and economic feasibility
7. Work team

As stated, the criteria should be divided in order to provide an increase in detail of the requirements. This approach helps both the designers as the project proposal development can be structured and based on solid requirements, and the jury to evaluate the effective incorporation of them in the proposals.

Architectural quality is hard to evaluate (Marans & Spreckelmeyer 1982); for this reason, this criterion has been split in sub-criteria that are easier to control and to evaluate: architectural value (that is the overall quality of the intervention); spatial and volume integration with the surrounding, that measures the way the building is connected with the building site and with the town; green areas design; and layout quality. This last aspect includes the flexibility and modularity of the layout and school spaces. This is particularly relevant taking into account the legislative framework that requires flexible and easy to modify spaces.

The second criterion, that is the learning space quality, measures how the internal spaces of the building are suitable to their specific use. Sub-criteria include the acoustic quality, thermal comfort, lighting strategies, and the possibility to modify the spaces for the scholars to increase their sense of belonging (van Merriënboer, McKenney, Cullinan, & Heuer 2017).

The third criterion, that regards furniture, is evaluated through three sub-criteria, measuring the usability for both single and group activities and the potential to create new spaces through the furniture. It also keeps into account the adaptability depending on physical needs of scholars and teachers (Panagiotopoulou, Christoulas, Papanckolaou, & Mandroukas 2004), and the economic and environmental sustainability of the furniture in the entire Life Cycle .

Environmental quality of the building is split in the use of materials, process, and building methods that encourage the use of renewable materials; general strategies to evaluate quality and sustainability of the

building site; and the ability to increase the general quality of the landscape and the urban area where the building is located.

The fifth criterion, regarding innovation, evaluates the quality of data distribution and power supply systems in terms of building automation, the use of innovative materials and ease of maintenance, and the quality of the structural design especially considering seismic design.

Technical and economic feasibility also considers the reliability of the information provided in the project, and takes into account all Life Cycle Costs, including maintenance costs, that play a relevant role in the building operation phase.

The last criteria group measures the coherence of the work team to the project proposal. At least one of the member of the group should have expertise in learning space design, and one should have certified expertise in sustainability design.

5. Design proposals evaluation

Each of the sub criteria is evaluated with a score from 0 to 1 from the members of the jury. Following multi-criteria method (Bana e Costa, Ensslin, Cornêa, & Vansnick 1999), the Client's has defined the relevance of each of the criteria in terms of a weight assigned. The combination of jury's scores and criteria weights allows creating a classification of design proposals based on their quality and their correspondence to the requirements set in the DIP.

This method has been applied in several competition, and has proven to be easy to use, complete, and to help the jury's members to express their ideas in a structured way. As previously stated, this set of requirements is intended for technic and economic feasibility level; it is possible to increase the criteria set depending on the needs. Weights of the sub-criteria can also be varied depending on their relevance for the clients.

6. Conclusions and further development

The proposed approach is currently in use as part of ISCOL@ program, and has been specifically designed for that use; once enough data will be collected it will be possible to measure its effect in terms of quality of the design proposals. The proposed method can be applied to other building typologies, and other client's needs and provide valuable results in terms of requirements management.

As stated, ISCOL@ program is not yet completely based on digital and collaborative procedures, but gradual introduction of BIM processes is underway. The requirements of the Client are not defined in EIRs, but expressed in the DIP. The shift from traditional to collaborative process starts with the definition of clear requirements in terms of project results and data management. The proper structure of BIM processes involves careful information management throughout all the phases; the definition of clear and detailed client's requirements is necessary for the development of the EIR that acts as base of the whole process. BEPs responding to the client's needs, together with the project proposals, are part of the evaluation process by the jury.

In the specific case of ISCOL@, where design teams include different professionals, the application of a collaborative approach can help and facilitate the communication among team members and the client. Actors' roles, competencies, and responsibilities in each phase of the process should be included in the BEP.

The integration of the proposed requirements in a BIM-based procedure could be crucial to properly manage and trace the requirements while integrating them in a recognizable and measurable way in the design process. The use of BIM models could also play a relevant role in the definition of analyses and simulation to check and monitor design alternatives and compliance with the Client's needs. Stakeholders of the process would be aware of the impact of any change during the design process.

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