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A MODEL FOR IDENTIFYING OWNER'S NEEDS IN THE BUILDING LIFE CYCLE

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Abstract. Building life cycle is a process which covers not only the construction phase but also the feasibility, the design and the operation phases. Identifying the owner's needs in all phases of this process is of paramount importance for achieving satisfactory results for the building project. Additionally, the owner's needs should be fulfilled by the work scope of every stakeholder involved in the project. Nevertheless, these needs are not always adequately considered in building projects. Thus, the purpose of the research reported in this paper has been to develop a model that allows for the identification of the owner's needs in all phases of the building life cycle. The article presents a six level classification system for the information required in the project and a two-dimensional model that maps the life cycle and the logical actions to be undertaken in each phase. The model has been corroborated and improved by applying the Delphi technique to a panel of ten experts in two rounds. The practical use of the model is through the systematic application of a series of questionnaires built upon the information classification system for determining the owner's needs. The paper details the operation phase of the model as an illustrative example and a case study on a residential building project of twelve apartments in Spain.

Keywords: building, information system, life cycle, need, owner, requirement.

Introduction

The construction process covers the feasibility, design, construction and operation phases (Groàk 1994; Gann, Salter 2000; Pellicer *et al.* 2014). This concept of process is equivalent to the most popular life cycle concept (Levitt 1965; Cole, Sterner 2000), which implies a set of phases beginning with the owner's initial idea and eventually finishing with the dismantlement or demolition of the built facility at the end of its life time. According to Winch (2002, 2006) the construction process focuses on transactions (rather than on production) and information flows (instead of material flows). Actually, information processing is vital for acquiring enough knowledge for starting the cycle successfully (Chan *et al.* 2002; Yu *et al.* 2010; Xia *et al.* 2014). For Tushman and Nadler (1978), processing information is twofold: identifying and capturing information, on the one hand, and classifying information, on the other hand.

Information flows affect a broad spectrum of individuals, groups or organizations involved in the project, generally called stakeholders (Winch 2003; PMI 2013). The owner is the stakeholder (agent, legal entity or physical person either private or public) who initiates the process (Kamara *et al.* 1999) and finances and operates (directly or indirectly) the construction product (i.e., the built facility). Actually, the owner (or client) is the most important stakeholder in the project (Lim, Ling 2002; Soetanto, Proverbs 2002) and has a strong interaction with the other stakeholders through communication and collaboration in order to ensure that his/her needs are met in all phases of the facility life cycle (Muller, Turner 2005; Lima *et al.* 2011).

Needs are the stakeholders' expectations concerning the construction product (Kamara *et al.* 2000a; Chua, Yeoh 2011) and must be processed and formally translated into requirements (Lima *et al.* 2011; PMI 2013). Project management ensures the understanding of the stakeholders' needs and their accomplishment by coordinating the activities of every project stakeholder (Yuan *et al.* 2010; PMI 2013; Yang, Shen 2014).

Although there is abundant literature on the management of stakeholders' needs in general (Smith, Love 2004; Takim 2009; Yuan *et al.* 2010; Jennings *et al.* 2013; Yang, Shen 2014), typical construction processes lack practical frameworks for specifically managing the owner's needs (Shen *et al.* 2004; Yu *et al.* 2010; Chua, Yeoh 2011; Yu, Shen 2013). In most cases, owners express their needs on the basis of their previous construction

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experience but the reliability of this strongly decreases with the project complexity (Kamara *et al.* 1999, 2000b; Lima *et al.* 2011). Actually, identifying the owner's needs in order to attain his/her expectations usually requires a much deeper analysis from expert consultants so that the integration of other stakeholders' needs may be achieved (Kamara *et al.* 2000b; Lima *et al.* 2011) – either owners acknowledge it or not, this is a key issue for the success of the whole construction process (Chan *et al.* 2002; Yu *et al.* 2010; Xia *et al.* 2014).

Considering the first step of information processing, as explained in the first paragraph, several authors have attempted to identify and capture the owner's needs in a number of different construction projects. Owner's needs for the design and construction phases in large infrastructure projects were analyzed and foreseen using questionnaires by Hassan *et al.* (1999). A more in-depth study was performed by Kamara *et al.* (1999, 2000a, 2000b, 2002) who developed the Client Requirement Processing Model, and applied it to concurrent engineering. This model first structures and ranks the requirements, then prioritizes the stakeholders according to their importance, and finally generates the facility design attributes. Lim and Ling (2002) proposed a different model to examine owner's needs by considering twenty attributes possibly affecting the facility life cycle, divided into five groups. On the other hand, quality management models, such as Six-Sigma (Pheng, Hui 2004), Quality Function Deployment (Akao, Mazur 2003; Lima *et al.* 2011), or the European Foundation for Quality Management (EFQM 2008), have defined quality as the fulfillment of the project owner's needs, and implement these needs as input data (Hoyle 2009). Yang *et al.* (2012) went a step further and relate quality to the definition of project requirements and its management. Nonetheless, Yu *et al.* (2010) concluded that managing the owner's needs for design and construction phases still raised a number of practical difficulties.

Shen *et al.* (2004) proposed a very interesting framework for defining client requirements at the early start of the design phase of a building project. A workshop organized by the owner, attended by the main stakeholders gathers key information through facilitation and discussion. Criteria are broken down and weighted, and acceptance thresholds are established to satisfy the owner's needs. At the building operation phase, an assessment takes place on the fulfillment of the initial requirements and building performance, thereby providing important feedback for the framework.

Other tools have had substantial development in recent years, such as the Building Information Modeling (BIM) approach that generates and manages construction information in an interoperable way, allowing users to integrate and reuse it throughout the facility life cycle (Lee *et al.* 2006); BIM helps the owner to check that requirements have been implemented in the product during the design, construction and operation phases (Eastman *et al.* 2008; Teicholz 2013), but it does not systematically identify and capture the owner's needs. Commissioning, on the other hand, is a systematic process that aims to inspect that every building system is designed, installed, and tested according to the interpretation of the owner's needs from designers and builders (Energy Design Resources 2005; ASHRAE 2006), but it cannot assure the real identification and fulfillment of those needs. Table 1 summarizes the characteristics of some models, normative and systems intended for processing and implementing the owner's needs.

Regarding the classifying information step, there is a number of information classification systems already in use, such as Uniclass (RIBA 1997), Construction Information Classification System (Kang, Paulson 1997, 2000), Masterformat (CSI 2004), Omniclass (Omniclass Committee 2000), ISO 13567 (Björk *et al.* 1997) and CI/SfB (Chudley, Greeno 2010), just to mention a few of the most well-known. These classification systems have been developed for different purposes, focusing on different facility types and phases. Table 2 checks these purposes for each classification system mentioned above. In summary, these systems are mainly focused on the construction phase of the process and only consider materials, processes and products, leaving out not only an important part of the other phases, but also the managerial and procurement practices. Furthermore, the classified information does not take into consideration the time dimension of the facility life cycle. Besides, levels of the classification are not developed consistently within the same system because of the varying detail of information covered. Accordingly, these classification systems do not sustain construction as a holistic perspective of the whole facility life cycle. Moreover, none of these systems explains how to get the information; they merely propose a codified organization of the targeted information.

In summary, the literature survey showed that models proposed so far attempt to handle only one of the two steps of the processing information process: either identification and capture of the owner's needs, or information classification, but not both of them. They also have a too narrow focus, namely, construction processes and products within the construction phase. Having detected this gap in the scientific literature, the goal of the research reported in this paper has been to identify and capture the owner's needs (step one in information processing), and classifying it (step two) for all phases of the facility life cycle, taking into consideration all the logical processes involved. The facilities targeted in this study, in the sense expressed by Zavadskas *et al.* (2001), are residential buildings, thus the expression "building life cycle" will be used from now on.

This paper is organized as follows. Next section briefly presents the research method used in the study. Section 2 provides a general description of the model. Then, the operation phase is explained in more detail because of its singularity. Section 4 performs a preliminary validation of the model by applying the Delphi technique.

Table 1. Main characteristics of models, normative and systems which process and implement the owner's needs

Proposal	Purpose	Sector	Phases	Owner's needs as input	Input Data Gathering
Hassan *et al*. (1999)	To identify client's business and IT requirements of large scale engineering projects	Large civil structures	Design and Construction	✓	Questionnaires
CRPM (Kamara *et al*. 1999, 2000a, 2000b)	To process the client requirement in construction	Concurrent engineering	Design	✓	Voice of the client: client vision of the proposed facility
Lim and Ling (2002)	To predict the client's contribution to project success	Construction project management	General; project performance	Five general attributes	Questionnaires
Shen *et al*. (2004)	To identify and rank the client's requirements	Building projects	Design	✓	Workshop
Building Information Modeling (Lee *et al*. 2006)	To generate and manage construction information in an interoperable way	Building projects mainly	Design, construction and operation	✓	N/A
Commissioning (Energy Design Resources 2005)	To verify that all systems and components of a building are designed, installed, tested, operated, and maintained according to the requirements of the owner.	Residential and industrial buildings	Predesign, design, construction and operation	✓	Owner's program of requirements (OPR) by the commissioning agent
Six-Sigma (Pheng, Hui 2004)	To measure and improve quality control	General-Applicable to construction	General, mostly business level	✓	N/A
Quality Function Deployment (Akao, Mazur 2003; Lima *et al*. 2011)	To help define, design and build a product which satisfies the client	General-Applicable to construction	General, mostly business level	✓	Voice of the client
European Foundation for Quality Management (EFQM 2008)	To understand the connection between an entity's work and the achieved results	General-Applicable to construction	General, mostly business level	✓	N/A

Table 2. Main characteristics of construction information classification systems

Proposal	Source	Purpose	Phases	Type of facility	Fields	Max. levels
UNICLASS	United Kingdom (RIBA 1997)	Listing construction elements, materials, products and processes; a single table of general managerial activities	Mainly the construction phase	Buildings and landscape	16	7
CICS	United States (Kang, Paulson 1997, 2000)	Classifying the facilities, spaces, elements and operations by type of construction work	Mainly the construction phase	Civil engineering	4	4
MASTERFORMAT	United States and Canada (CSI 2004)	Organizing data about construction requirements, products, materials and activities	Different phases	Mostly commercial building	43	4
OMNICLASS	United States (Omniclass Committee 2000)	Organizing and retrieving information of construction elements, materials and products	Different phases	Different construction types	16	7
ISO 13567	Switzerland (Björk *et al.* 1997)	Classifying the building elements in construction	Mainly the project (design) phase	Different construction types	Uniclass & CiSfB	Uniclass & CiSfB
Ci/SfB	Sweden (Chudley, Greeno 2010)	Classifying the physical environment, elements, construction forms, materials, activities and requirements.	A brief of planning but mainly construction phase	Residential buildings and singular buildings	4	3

Section 5 presents a case study on the implementation of the model. Finally, conclusions are drawn.

1. Research method

This research aims to develop a model that identifies, captures, and classifies the owner's needs in all phases of the building life cycle, taking into consideration all the logical processes involved. In order to develop the draft of the model, the following issues were taken into consideration by the research team: (a) literature review; (b) analysis of existing models; (c) revision of regulations (Spanish regulations for this particular case); (d) records of previous building projects; and (e) past experience of the authors. These issues were used to adjust the information classification system, which has been developed for capturing the owner's needs at all phases of the building life cycle. The draft was subsequently improved through many rounds by using the feedback of experts and professionals from the construction industry; this was carried out for checking and improving the model. The final version of the model is described thoroughly in Section 2 as a two-dimensional model that maps the phases of the building life cycle and the logic chain of project management actions (stages) within each phase by using a breakdown structure approach.

The model was validated by applying the Delphi technique through a panel of experts as can be seen ahead. It is a systematic, iterative and interactive process providing a reliable group opinion, or even consensus, from information given by a panel of experts in a specific subject (Rowe, Wright 1999; Linstone, Turoff 1975; Hallowell, Gambatese 2010; Sourani, Sohail 2014). The Delphi technique was selected for a number of reasons. Firstly, it is a sound validation tool because it can cope with complex problems involving thoughtful and judgmental analysis (Sourani, Sohail 2014). Secondly, validation requires the participation of relevant specialists who could not effectively interact in a face-to-face exchange (Hallowell, Gambatese 2010). Other techniques such as surveys would have been risky to implement in this case because the complexity of the problem to be modeled (the owner's needs in the building life-cycle) could possibly not be understood by the interviewees in a reasonable time frame. Organizing group meetings as an alternative approach would not be feasible as the time and expense of mobilizing the group would result in the exclusion of important participants. Finally, the Delphi technique has been the preferred method among expert-based studies (Rowe, Wright 1999; Hallowell, Gambatese 2010) and this has given confidence to the authors on the selection of this method for validating the model.

The size of the panel is fundamental for the Delphi technique. The minimum number of experts varies according to each author surveyed: as stated by Martino (1972), there should be at least five, whereas Okoli and Pawlowski (2004) specified a minimum of eight experts, recommending ten for their studies. The information is obtained through questionnaires distributed by hand, post, e-mail, or web. The study facilitator selects the experts according to a minimum pattern, develops the questionnaires, analyzes the results, draws conclusions, and provides feedback to the participants. Experts give their anonymous opinions in iterative rounds led by the facilitator in order to achieve maximum consensus (Hallowell, Gambatese 2010). The four goals aimed by applying the Delphi technique in this research are:

- To measure the completeness of the information included in the classification.
- To examine the reasonability of the classification structure.
- To identify possible gaps in the classification structure.
- To collect suggestions and modifications proposed by the experts.

The draft model was developed through weekly meetings of the research team during a period of two years; expert professionals joined the meetings from time to time when their expertise was needed. Finally, ten experts have been selected for a two round evaluation of the model using the Delphi technique as explained above. After completing the model, the research team implemented it in a real case study.

2. Description of the model

The model is displayed as a matrix comprising two dimensions: time (phases of the building life cycle) and logic (project management actions to pursue in each phase). Four main phases have been considered for the building life cycle (Cleland 1999; Archibald 2004; Pellicer *et al.* 2014): feasibility, design, construction, and operation. Each matrix cell has been further broken down into additional levels of detail, for enabling a number of interactive questionnaires aiming to identify the owner's needs in all phases of the building life cycle. To achieve this end, information of technical, financial, economic, and legal nature, as well as other details, must be identified, gathered and classified.

The second dimension of the matrix is a logic chain of project management actions that should be followed in each project phase in order to materialize the output of that phase. These stages are based on project management theory (Morris 1994; PMI 2013) that proposes four stages to deal with a project: (a) start; (b) organize and prepare; (c) carry out; (d) and close. They have been adapted to the construction sector too by CIOB (2002) in a more detailed way: (a) inception and feasibility; (b) strategy and pre-construction; (c) construction; and (d) commissioning, handover and project close-out. Based on these previous contributions, and for the purpose of this research, four stages are considered: (a) planning, compiling and classifying the preparatory information for work development; (b) procurement and contract; (c) work execution according to the contract agreements; and (d) delivery of the final product to the owner. Items (a), (b), (c), and

PHASES	STAGES: PLANNING	PROCUREMENT	EXECUTION	DELIVERY
FEASIBILITY				
DESIGN				
CONSTRUCTION				
OPERATION				

Fig. 1. Two-dimensional matrix

(d) form the stages of planning, procurement, execution, and delivery, respectively. In these stages, the information directly or indirectly related to the owner´s needs is classified. If the owner is acting with in-house staff during a particular phase, then stages (b) and (d) may not be necessary and the logic chain is reduced.

Both dimensions have been combined into a matrix form, as shown in Figure 1. The two dimensions of the matrix form the first and second levels of the classification: phases correspond to the first, whereas stages correspond to the second one. Accordingly, for each cell, a combination of phase-stage is specified, using a two-level code. For example, cell 4.2 can be read as the procurement at the operation phase; this specific cell will be used as an illustrative example below.

Having defined the basic two-dimensional matrix, the next step has been to look for more detailed information on the owner's needs. The diversity and amount of possible information is huge, thus certain criteria should be established in advance:

- Legal compliance with regulations: this will vary from one country to another. The model has been developed using Spanish regulations; thus, it must be adapted when implemented elsewhere.
- Information nature: technical, economic, social, professional, legal, and so forth, depending on each of the cells.
- Owner's experience and professionalism: the more detailed the information requested, the more experienced the owner must be. The owner may be advised by a technician or even specialized firms.
- Clarity and relevance of the information and its structure.
- Supplying the right information for the right phase and stage according to the chronological development of the building life cycle.

Accordingly, four additional classification levels have been included for each phase-stage cell: field (3^{rd} level), subfield (4^{th} level), questions (5^{th} level), and answers (6^{th} level). The model could possibly go deeper, therefore providing additional levels of detail. However, feedback from experts and professionals collected throughout the research as well as the experience of the authors, advised to bring it to an end at the 6^{th} level. The researchers determined that the additional information that may be available at the hypothetical 7^{th} level would be obscured by the complexity of the model. Figure 2 shows a complete model breakdown up to the 3^{rd} level (fields).

According to Figure 2, two stages on different phases have been developed almost identically: the first one is the procurement stage at feasibility, design and construction; the second one is the delivery stage at the feasibility and design phases. De facto they follow related regulations and procedures instructed by the European Union (Directive 2004/18/EC on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts).

The 3^{rd} level (fields) is a farther dissection of each phase-stage cell. The aim of this level is to categorize the information in groups of the same nature, enabling to reach posterior classification levels. Similarly, the 4^{th} level (subfields) is the development of each item of the information included in the previous level. The 5^{th} and 6^{th} levels are the most detailed classification levels for the identification of the owner's needs and correspond to questions and answers, respectively. These two levels have the form of record sheets, which form a set of interactive questionnaires to identify and capture the owner's needs in each phase–stage cell in all phases of the building life cycle. The 5^{th} level allows for collecting detailed information on technical, financial, economic, and legal aspects of the building as well as other details, on the owner's interest. Questions categorize information allowing for alternative answering at the owner's choice. Finally, the 6^{th} level develops all the possible options regarding the information in the previous level, and also allows for recording the owner's answers corresponding to its requirements or needs.

Questions and answers (5^{th} and 6^{th} levels) have been developed per subfield in a record sheet on the format presented in Figure 3. Each record sheet is specific for each sub-field (4^{th} level) and is defined by the corresponding code (depicting the phase, stage, field, and subfield). Three basic hints are provided for each record sheet: why is this information useful (reason), what is it for (purpose), and what does it include (contents). The set of the record sheets developed for each phase-stage cell forms the corresponding questionnaire to identify and document the owner's needs in that cell.

Due to space limitations, it is difficult to present here the whole classification levels which lead to the record sheets, so that, later in the paper there is an example of a record sheet focused on the operation phase, where the development and the structure up to the 4^{th} level can be observed in Figure 5. A sample of the development of last two levels 5^{th} and 6^{th} is presented in Figure 6.

All in all, the volume of information that the model aims to identify and capture can be measured by the number of fields and subfields developed. Table 3 shows that the total number of fields is 102 and that the total num-

	1. PLANNING	2. PROCUREMENT	3. EXECUTION	4. DELIVERY
1. FEASIBILITY	1.1.01. Owner's basic data	1.2.01. Contract's basic data	1.3.01. Previous analysis	1.4.01. Notification
	1.1.02. Geographical location	1.2.02. Tendering	1.3.02. Objectives	1.4.02. Provisional hand over
	1.1.03. Urban planning scenario	1.2.03. Contract requirements	1.3.03. Main constraints	1.4.03. Review process
	1.1.04. Environmental constraints	1.2.04. Warranties and insurance	1.3.04. Field works	1.4.04. Reception
	1.1.05. Basic definition of the building	1.2.05. Drafting the contract	1.3.05. Owner's cooperation	1.4.05. Warranty return
	1.1.06. Financing	1.2.06. Signing the contract	1.3.06. Outsourcing	1.4.06. Finish
	1.1.07. Marketing	1.2.07. Subcontracting	1.3.07. Supervision of works	
2. DESIGN	2.1.01. External architecture	2.2.01. Contract's basic data	2.3.01. Documents	2.4.01. Notification
	2.1.02. Indoor architecture	2.2.02. Tendering	2.3.02. Constraints	2.4.02. Provisional hand over
	2.1.03. Infrastructure	2.2.03. Contract requirements	2.3.03. Field works	2.4.03. Review process
	2.1.04. Structure	2.2.04. Warranties and insurance	2.3.04. Owner's cooperation	2.4.04. Reception
	2.1.05. Installations	2.2.05. Drafting the contract	2.3.05. Outsourcing	2.4.05. Warranty return
	2.1.06. Budget	2.2.06. Signing the contract	2.3.06. Change management	2.4.06. Finish
	2.1.07. Constraints	2.2.07. Subcontracting	2.3.07. Supervision of works	
			2.3.08. Format, layout and editing	
3. CONSTRUCTION	3.1.01. Preparation of key information	3.2.01. Contract's basic data	3.3.01. Start up of the building works	3.4.01. Notification of completion of work
	3.1.02. Documentation and credentials	3.2.02. Tendering	3.3.02. Technical supervision and control	3.4.02. Inspection of completion of work
	3.1.03. Managing licenses and permits	3.2.03. Contract requirements	3.3.03. Owner's cooperation	3.4.03. Delivery type
	3.1.04. Preview of the construction site	3.2.04. Warranties and insurance	3.3.04. Administration of the building site	3.4.04. Unsuitable works
	3.1.05. Technical issues to consider for contracting	3.2.05. Drafting the contract	3.3.05. Logistics of the building site	3.4.05. Reception
	3.1.06. Technical services for supporting	3.2.06. Signing the contract	3.3.06. Occupational risk prevention at the building site	3.4.06. Warranty return
	3.1.07. Marketing	3.2.07. Subcontracting	3.3.07. Environmental issues at the building site	3.4.07. Finish
			3.3.08. Quality management at the building site	
			3.3.09. Waste management at the building site	
			3.3.10. Outsourcing	
			3.3.11. Completion of the work	
4. OPERATION	4.1.01. Nature, mode, and scope	4.2.01. Sale	4.3.01. Business management	4.4.01. Sale
	4.1.02. Requirements	4.2.02. Rent	4.3.02. Maintenance activities	4.4.02. Rent
	4.1.03. Responsibilities	4.2.03. Operation by another entity		4.4.03. Subcontract for operation or concession
	4.1.04. Administrative procedures	4.2.04. Operation by the owner		

Fig. 2. Fields per phase – stage cell

Code	Content
	PHASE / STAGE / FIELD / SUBFIELD
WHAT? (contents) WHAT FOR? (purpose) WHY? (reason)	
FIFTH LEVEL (1)	
SIXTH LEVEL (1-1)	
…	
SIXTH LEVEL (1-p)	
…	
FIFTH LEVEL (n)	
SIXTH LEVEL (n-1)	
…	
SIXTH LEVEL (n-r)	

Fig. 3. Record sheet template

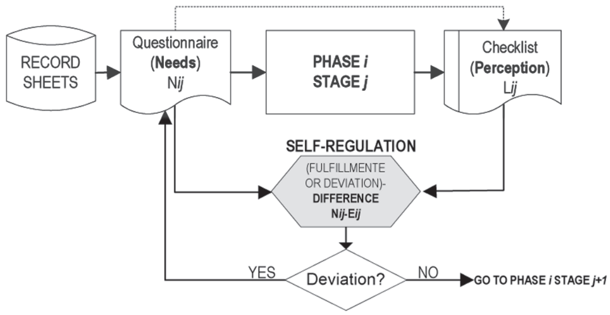

Fig. 4. Functional architecture of the model

ber of subfields is 566 (the same number of record sheets developed). The average number of needs identified per record sheet exceeds ten (see Fig. 6 as an example); thus, the model is able to identify more than five thousand owner's needs. This is comparable with the information provided by current construction information classification systems as depicted in the lasts two rows of Table 2. Masterformat, for example, deals with a maximum number of 43 fields and four levels of breakdown against the maximum number of seven in Uniclass and Omniclass.

Having described the structure of the model, its practical use should now be explained. The model is used through the systematic application of the questionnaires to the owner (or its representative) in order to obtain as much information as possible on the owner's needs. Every cell (phase-stage) of the two-dimensional matrix is to be analyzed according to each of its fields and corresponding subfields. Before the initiation of any stage at every phase (cell), the corresponding record sheets are retrieved from a data base which includes all the developed sheets and filled out by the owner or its representative. This will generate the set of owner's needs corresponding to that cell. After finishing the work on a specific cell, the owner's needs identified through the model can be used for checking his/her perception and possibly adjusted if significant deviations in the real work are detected. Then, the owner's needs in next cell (phase-stage) can be identified. Figure 4 shows the model's functional architecture.

An in-depth description of the model from this point on is beyond the scope of this paper, because of the huge volume of information handled by the model. The complete description of the model at the subfield level (record sheets) is developed in Alshubbak (2010).

3. The procurement stage at the operation phase

The operation phase has been chosen as an example in order to explain the model exhaustively, where readers can trace the progress of the classification procedure up to the record sheet. This phase is particularly interesting due to the fact that it is less considered in the literature than other phases of the building life cycle (Lai, Yik 2007), such as the design and construction phases.

From the owner's point of view, the operation phase deals with the management of the facility as a business, as well as maintenance activities. The first one refers to economic, financing, and administrative activities that also involve the users. The second one seeks to ensure all elements, both structural and functional, in terms of stability, safety and habitability. Thus, various types of maintenance should be performed at periodic intervals.

The procurement stage at the operation phase comprises four fields, each of which is developed in subfields as described in Figure 5. The four fields are the following:

- Sale (home buyer): once both parties have fulfilled their contractual duties, the property title is passed on to the buyer, and the owner is relieved of its responsibilities (except for hidden defects).
- Rent (home lender or tenant): after fulfilling their contractual duties, the property title keeps on the owner's. In this case, only the temporary use is given to the tenant.

Table 3. Number of fields/subfields per phase-stage cell

	Planning	Procurement	Execution	Delivery	TOTAL
Feasibility	7 / 35	7 / 46	7 / 20	6 / 22	**27** / **123**
Design	7 / 54	7 / 46	8 / 35	6 / 22	**28** / **157**
Construction	7 / 29	7 / 46	11 / 74	7 / 28	**32** / **177**
Operation	4 / 24	4 / 47	2 / 14	5 / 24	**15** / **109**
TOTAL	**25** / **142**	**25** / **185**	**28** / **143**	**24** / **96**	**102** / **566**

- Operation by another entity: the owner subcontracts the building operation (or part of it) to a specialized entity, taking legal form of facility management or concession.
- Owner's direct operation or use: it may also include a transition time before a final decision for the definitive use of the facility has been set up.

Regarding the procurement at the operation phase, the nature and scope of the four different options have to be considered. Each one of them carries different requirements, responsibilities, and administrative paperwork. Nevertheless, considering the subfield "Conditions", the questions stated are almost the same for the first three options above (sale, rent, and operation by another entity), namely: price, payment form, place and date, expenses, condominium (master deed and rules of governance), obligations, confidentiality, modifications, resolution, extinction, deadlines, renewals, jurisdiction, penalties, and arbitration. A complete record for questions (5th level) and answers (6th level) is shown in Figure 6 corresponding to the subfield "conditions", field "sales", stage "procurement", and phase "operation".

4. Preliminary model validation: Delphi technique

A preliminary validation of the model was carried out by using the Delphi technique. A panel of ten experts was set up according to the following criteria: experts should hold a university degree in the construction field with a minimum of 15 years of practice and be available to effectively participate in the Delphi study. An invitation letter was sent to a group of 24 experts, 10 of them responded positively. The final panel consisted of four civil engineers, three architects, two industrial engineers, and one economist. Six of the experts had MSc degrees and the other four held PhD degrees.

Experts were asked to assess the items considered in the model up to the 4th level of classification. Three aspects for each item were inquired: importance, completeness, and suggestions for improvement. The first two aspects were evaluated quantitatively and analyzed statistically; the latter was only assessed qualitatively.

In order to achieve a consensus, two rounds were planned, with a possible third, if the convergence would be unsatisfactory. Each expert received a document pack that included a cover letter, an expert-profile questionnaire, an introductory explanation of the model, the outlines of classified information up to the 4th level, and the Delphi questionnaires. According to Best (1974), feedback from the experts greatly improves the accuracy of last rounds; thus, previously to the second round, the panel was individually informed about the results achieved that far. Subsequently, the experts received the second questionnaire and were asked again about every topic of the model.

A five-point Likert scale (Cohen *et al.* 2011) was used to measure the experts' level of agreement or disagreement regarding the importance and the completeness of the item included in the classification system. The scale had the following alternatives: strongly agree, agree, neutral, disagree, or strongly disagree. A score is given to each of the choices, from 1 (strongly disagree) to 5 (strongly agree); thus, responses to these questions can be analyzed statistically by calculating their mean and standard deviation.

The convergence of the experts' opinions was measured by using the Cronbach's Alpha coefficient. This ratio is a measure of the squared correlation between observed scores and true scores; the reliability is measured in terms of the ratio of true score variance to observed score variance (Yu 2001). The Cronbach's Alpha coefficient is calculated according to Eqn (1), where K is the number of items, δ_X^2 the variance of the observed total test scores, and $\delta_{Y_i}^2$ the variance of item i for the current sample:

$$\alpha = \frac{K}{K-1}\left[1 - \frac{\sum_{i-1}^{K}\delta_{Y_i}^2}{\delta_X^2}\right]. \quad (1)$$

4.2.01. SALE	4.2.02. RENT	4.3.03. OPERATION BY ANOTHER ENTITY	4.3.04. OPERATION BY THE OWNER
4.2.01.01. Contract nature	4.2.02.01. Contract nature	4.2.03.01. Entity	4.2.04.01. Use type
4.2.01.02. Awarding procedure	4.2.02.02. Awarding procedure	4.2.03.02. Contract type	4.2.04.02. Management
4.2.01.03. Aim	4.2.02.03. Aim	4.2.03.03. Awarding procedure	4.2.04.03. Advertisement
4.2.01.04. Conditions	4.2.02.04. Conditions	4.2.03.04. Aim	4.2.04.04. Information
4.2.01.05. Guarantees	4.2.02.05. Guarantees	4.2.03.05. Time	4.2.04.05. Contract type
4.2.01.06. Contract writing	4.2.02.06. Contract writing	4.2.03.06. Bidding procedure	4.2.04.06. Awarding procedure
4.2.01.07. Contract signature	4.2.02.07. Contract signature	4.2.03.07. Conditions	4.2.04.07. Aim
4.2.01.08. Technical specifications	4.2.02.08. Subcontracting	4.2.03.08. Guarantees	4.2.04.08. Time
4.2.01.09. Registry	4.2.02.09. Technical specifications	4.2.03.09. Contract writing	4.2.04.09. Conditions
4.2.01.10. Final close-out	4.2.02.10. Registry	4.2.03.10. Contract signature	4.2.04.10. Guarantees
		4.2.03.11. Subcontracting	4.2.04.11. Contract writing
		4.2.03.12. Technical specifications	4.2.04.12. Contract signature
		4.2.03.13. Registry	4.2.04.13. Subcontracting
			4.2.04.14. Technical specifications

Fig. 5. Classification structure up to the 4th level in operation-procurement cell

CODE: 4.2.01.04.	CONTENT: Operation / Procurement / Sale / Conditions
WHAT? To define the conditions to be set in the contract that apply to both parties that sign it. WHAT FOR? To determine the responsabilities and rights of each party. WHY? To write the contract correctly.	
4.2.03.04.01. PRICE	4.2.03.04.06. OBLIGATIONS
Monthly price (€):	Indicate:
Yearly price (€):	4.2.03.04.07. CONFIDENTIALITY
Value Added Tax (€):	Indicate:
Total (€)	4.2.03.04.08. MODIFICATIONS
4.2.03.04.02. PAYMENT FORM	Indicate:
Bank transfer	4.2.03.04.09. RESOLUTION
Direct debit	Indicate:
Cash	4.2.03.04.10. EXTINCTION
IOU	Indicate:
Check	4.2.03.04.11. DEADLINES
Other	Indicate:
4.2.03.04.03. CONTRACT	4.2.03.04.12. RENEWALS
Place:	Indicate:
Date:	4.2.03.04.13. JURISDICTION
Time:	Indicate:
4.2.03.04.04. EXPENSES	4.2.03.04.14. PENALTIES
Charged to the developer:	Indicate:
Charged to the client:	4.2.03.04.15. ARBITRATION
4.2.03.04.05. CONDOMINIUM	Indicate:
Master deed:	
Rules of governance:	
Role of the developer:	

Fig. 6. Record sheet corresponding to subfield 4.2.01.04: conditions of sale contract at the operation phase

The stopping criteria for the Delphi rounds iteration were established to include the following points: (a) Cronbach's Alpha coefficient greater than 0.8 (minimum reliable value); (b) no response value of 1 or 2 in any case; and (c) an overall average attained greater than 4.5. The statistical analysis of the two rounds contains the average response of the experts, regarding the importance and completeness of the information included in the classification. Importance aims at measuring the perceived relevance of information that should be collected, whereas completeness relates to the amount of significant data in each project phase. Table 4 shows the average response of the experts for each cell (phase-stage) for the importance and the completeness issues. Regarding importance, the experts considered the execution of the design and construction phases and construction procurement as the most important cells; whereas the less important ones were the design delivery, and the procurement, execution and delivery at the feasibility stage in addition to planning and execution at the operation phase. Completeness, on the other hand, was worse considered for the execution of the feasibility and operation phases. On the other hand, procurement and execution at the design and construction phases, as well as design planning, were the ones considered more complete. In general, it can be deduced that experts are more comfortable with the construction phase, and less so with the planning and operation ones. The more in-depth knowledge of the experts of the construction phase, plus the difficulty of standardizing the feasibility and operation phases because of their greater variability, can be a reason for these results.

The non-statistical analysis corresponds to the modifications and suggestions proposed by the participating experts. The classification content was updated in accordance with these modifications. In the second round, the three stopping criteria items were completely achieved; hence, no more rounds were performed.

5. Case study

The complete implementation of the model required selecting a case study from its initiation to the full operational phase. This set of activities could take many years, maybe even decades. Therefore, the authors implemented the model in a residential building project at the feasibility and design phases only. The project owner was a private company that always works with the same architect (a local consulting firm) for design and construction work

Table 4. Average response for the importance and completeness facets per cell (phase-stage)

PHASE-STAGE	IMPORTANCE		COMPLETENESS	
	1st Round	2nd Round	1st Round	2nd Round
Feasibility – Planning	4.5	4.6	4.1	4.6
Feasibility – Procurement	4.4	4.5	4.5	4.8
Feasibility – Execution	4.3	4.4	4.2	4.5
Feasibility – Delivery	4.4	4.5	4.5	4.6
Design – Planning	4.6	4.7	4.3	4.9
Design – Procurement	4.4	4.7	4.3	4.8
Design – Execution	4.6	4.8	4.5	4.9
Design – Delivery	4.1	4.2	4.5	4.6
Construction – Planning	4.4	4.6	4.3	4.7
Construction – Procurement	4.6	4.8	4.3	4.8
Construction – Execution	4.7	4.9	4.2	4.8
Construction – Delivery	4.5	4.6	4.7	4.7
Operation – Planning	4.1	4.4	4.4	4.7
Operation – Procurement	4.5	4.7	4.3	4.8
Operation – Execution	4.5	4.5	4.3	4.4
Operation – Delivery	4.5	4.6	4.1	4.7
Average	**4.44**	**4.59**	**4.34**	**4.71**
Cronbach's Alpha	**0.814**	**0.937**	**0.849**	**0.867**

inspection – this outline is typical of the Spanish residential building sector (Pellicer, Victory 2006). The case study consists of a 12-apartment building. Each apartment is comprised of three or four bedrooms, two bathrooms, a living room, a kitchen, and a parking box on the basement. The ground floor is for commercial stores. The building is located in one of the urban neighborhoods of Valencia (Spain). This building was chosen as a case study for four main reasons: (1) it reflects a typical Spanish building project due to its architecture, materials, contract, and management features; (2) the timing was right because the project was just starting; (3) the project team had proven experience in this field; and (4) the owner and architect agreed to participate in the research (four other similar building projects declined). Instead of the typical brief of the owner to the architect (Shen *et al.* 2004), the feasibility phase of the model was implemented in this case study. In the same way, the design produced by the architect was based on the implementation of the design phase of the model. The procurement stage was not implemented in any of these phases as the designer was already employed directly by the owner from the very beginning as mentioned above. If that were not the case, the identification of the owner's needs for the procurement stage should have taken place.

It was agreed with the owner to implement the model in order to define his needs for the feasibility and design phases. The owner representative was the architect who advised the owner on how to fill out the questionnaire for the feasibility phase. Subsequently, the architect filled out the questionnaire for the design phase. After each phase, the fulfilled questionnaires were analyzed by the owner, the architect and the research team (who acted as facilitator in the process) for checking if the owner's needs were really detailed for both phases. Table 5 describes the model implementation process for this case study.

As shown in Table 3, the total number of record sheets (subfields or 4th level of breakdown in the model) is 123 for the feasibility phase and 157 for the design phase; these figures include the procurement stage, which was not applied in any phase, since the architect was directly employed by the owner. According to Table 6, a total of 83 owner's needs were identified in the feasibility phase, and 203 in the design phase. The subfields responded totaled 44% for the feasibility phase and 79% for the design phase. In the feasibility phase, because the procurement stage was not considered due to the aforementioned reasons, the percentage is low. In the design phase, however, the owner left unanswered the remaining 21% of the subfields for two reasons: either to leave the designer some freedom for design options, or because those were considered irrelevant by the owner and beyond the scope of the project.

Once the questionnaires corresponding to the feasibility and design phases were filled by the owner representative, the facilitators extracted each answer (selected or written down) along with the items in all previous corresponding classification levels, showing a series of items separated by slashes that started with a unique code and finished with the answer of the owner representative. The final code is formed by the sequential codes corresponding to the items of the classification levels up to the question level. Each expression corresponds to a single owner's need with the following structure: Code: Phase/Stage/Field/Subfield/Question: Answer.

Table 5. Model implementationw process in the case study

Role	Task
Owner Research Team	First contact and understanding of the model and roles assigned
Owner Representative	Reception of the model questionnaire for the feasibility phase Response to the questionnaire for the feasibility phase
Research Team Owner Representative Owner	Questionnaire assessment for the feasibility phase
Owner Representative	Brief (output for the feasibility phase)
Owner Representative	Reception of the model questionnaire for the design phase Response to the questionnaire for the design phase
Research Team Owner Representative Owner	Questionnaire assessment for the design phase
Owner Representative	Normative and specifications appraisal Conversion into specific requirements Calculations, drawings, technical specifications and budget
Owner Representative	Design documents (output for the design phase)

Table 6. Quantitative data of the case study implementation

	Feasibility Phase / Design Phase				
	Planning	Procurement	Execution	Delivery	Total
# Subfields (model)	35 / 54	46 / 46	20 / 35	22 / 22	123 / 157
# Subfields (answered)	25 / 42	0 / 0	12 / 25	17 / 21	54 / 88
# Extracted needs	46 / 128	0 / 0	18 / 43	23 / 32	87 / 203
# Owner's needs per Subfield (answered)					1.6 / 2.3
% Subfields (answered)					44% / 79%

Figure 7 shows a sample of the owner's needs gathered for the design phase, which is formulated according to the breakdown structure of the model. The input is displayed in the last two levels: the owner's answer (6th level) to the corresponding previous question (5th level). These needs belong to different natures: technical, economical, contractual, managerial, etc. Note that although these needs are specific for this case study, they may be recurrent in other similar projects.

The following two owner's needs are examples to understand Figure 7:

- 2.1.01.04.02: Design / Planning / Exterior Architecture / External Doors / Material: Metal. The external architecture design should be carried out considering the owner's requirement of installing external doors of metallic material.
- 2.1.01.04.03: Design / Planning / Exterior Architecture / External Doors / Type: Armored. The external architecture design should be carried out considering the owner's requirement of installing armored type external doors.

Figure 7 shows that the owner's needs were identified and codified in the case study by applying the model developed and reported in this article. Each need is unique and formed by seven parts: a single unique code and six classification items. All owner's needs identified in the case study were expressed by the predefined items included in the levels developed for the classification system. This provides a unique terminology that expresses the needs; in turn, all participants along the building life cycle will understand and allocate the needs in the same way. This situation prevents possible misunderstanding and loss of information.

The number of needs is proportional to the phase complexity and relative importance: 203 needs were identified for the design phase and 87 for the feasibility phase. This means that the owner pays more attention to the design stages, and intends to participate more in the definition of the design details than in other phases.

The owner and the architect showed a high level of involvement and cooperation throughout the research period. After the model was already implemented, both were interviewed in depth by the research team. They considered the application of the model as a reliable way to identify both explicit and implicit needs intended to obtain a final better product (the building). The owner stated that the collection approach of project data was greatly facilitated by the model, and further realized that most of his implicit needs were detected and specified in the design documents; in previous projects these needs did not become explicit from the beginning and had to be put forward to the architect at the very end of the design

CODE	DESIGN (PLANNING)
2.1.01.02.01	Design/planning/exterior architecture/façades/type: **Cladded**
2.1.01.02.02	Design/planning/exterior architecture/façades/material: **Industrial plates**
2.1.01.02.03	Design/planning/exterior architecture/façades/color: **Light azure and black**
2.1.01.02.04	Design/planning/exterior architecture/façades/technical criteria: **Maintenance, thermal isolation, cleaning and security**
2.1.01.03.02	Design/planning/exterior architecture/windows/profile material: **Aluminum**
2.1.01.03.05	Design/planning/exterior architecture/windows/geometry: **Rectangular**
2.1.01.03.06	Design/planning/exterior architecture/windows/opening mechanism: **To inside**
2.1.01.04.02	Design/planning/exterior architecture/external doors/material: **Metal**
2.1.01.04.03	Design/planning/exterior architecture/external doors/type: **Armored**
2.1.01.04.06	Design/planning/exterior architecture/external doors/opening mechanism: **To inside**
2.1.01.05.01	Design/planning/exterior architecture/terrace & balcony/category: **Vertical gate with hanging balcony**
2.1.01.05.02	Design/planning/exterior architecture/terrace & balcony/geometry: **Rectangular**
2.1.01.05.04	Design/planning/exterior architecture/terrace & balcony/walling material: **Glass**
2.1.01.06.01	Design/planning/exterior architecture/rooftop/type: **Flat roof**
2.1.01.06.02	Design/planning/exterior architecture/rooftop/material: **Reinforced concrete**
2.1.01.06.03	Design/planning/exterior architecture/rooftop/technical criteria: **Impermeability; thermic, acoustic and vibration isolation**
2.1.01.06.04	Design/planning/exterior architecture/rooftop/color: **Light azure**
2.1.01.06.05	Design/planning/exterior architecture/rooftop/parapet: **Façade continuation (80 cm)**
2.1.02.02.01	Design/planning/interior architecture/distribution/spaces: **4 sleeping rooms model**
2.1.02.03.01	Design/planning/interior architecture/partitions/type: **light weight brackets**
2.1.04.01.01	Design/planning/structure/column/geometry: **rectangle**
2.1.04.01.02	Design/planning/structure/column/positioning: **embedded (not visible)**
2.1.04.05.01	Design/planning/structure/stairs/geometry: **Strait**
2.1.05.07.03	Design/planning/installation/heating/system: **Radiation**
	DESIGN-PROCUREMENT
	N/A
	DESIGN (EXECUTION)
2.3.01.01.01	Design/execution/project documents/type/type: **Basic and design project**
2.3.01.01.02	Design/execution/project documents/type/studies: **Health and safety plan, environmental impact assessment**
2.3.01.02.10	Design/execution/project documents/content/model: **CTE (Spanish Building Code) and the designer**
2.3.03.01.01	Design/execution/field works/type of data/technical: **Construction class, use, archeological limitations, needed installations**
2.3.03.01.01	Design/execution/field works/type of data/urban: **Needed urban permissions by City Council**
2.3.03.01.01	Design/execution/field works/type of data/environmental: **Environmental impact, assessment and prevention**
2.3.04.01.01	Design/execution/owner's collaboration/range/documents: **Property certificate, legal situation of land site, topographic map**
2.3.04.01.04	Design/execution/owner's collaboration/range/assistance: L**icenses and permits**
2.3.04.02.01	Design/execution/owner's collaboration/means/personal: **Project manager**
2.3.04.02.03	Design/execution/owner's collaboration/means/logistical: **Access to work site**
2.3.05.01.01	Design/execution/outsourcing/externalized works/type: **Site investigation and tests**
2.3.05.01.02	Design/execution/outsourcing/externalized works/level: **Partial**
2.3.05.02.01	Design/execution/outsourcing/limitations/economical: **10% of the total design budget**
2.3.06.03.01	Design/execution/change management/responsible/maker: **Designer**
2.3.06.03.02	Design/execution/change management/responsible/approval: **Designer and owner representative**
2.3.06.03.03	Design/execution/change management/responsible/assurance: **Designer and owner representative**
2.3.07.01.01	Design/execution/project quality control/range/subjected work: **Totality of design works**
2.3.07.01.02	Design/execution/project quality control/range/delimitation: **According to the applied normative**
2.3.07.02.01	Design/execution/project quality control/normative/quality: **UNE normative**
2.3.07.02.02	Design/execution/project quality control/normative/technical specification: **CTE (Spanish Building Code)**
2.3.08.02.02	Design/execution/layout and edition/calculations/structural design program: **CYPE software**
2.3.08.02.05	Design/execution/layout and edition/calculations/normative: **CTE (Spanish Building Code)**
2.3.08.04.05	Design/execution/layout and edition/budget/presentation: **Tables**
2.3.08.07.01	Design/execution/layout and edition/document support/physical: **Paper DIN A4 and A0 folded according to UNE**
2.3.08.07.02	Design/execution/layout and edition/document support/electronic: **CD Rom**
	DESIGN (DELIVERY)
2.4.01.01.01	Design/delivery/notification/date/date: **dd/mm/yyyy**
2.4.01.02.01	Design/delivery/notification/form/model: **Written letter signed by the designer**
2.4.02.01.01	Design/delivery/provisional delivery/place/address: **Owner's firm address**
2.4.02.03.01	Design/delivery/provisional delivery/corresponding payment/quantity: **xxxxxxx €**
2.4.03.01.01	Design/delivery/procedure/meeting revision: **Between owner representative and the designer**
2.4.04.02.01	Design/delivery/reception/certification/need: **Needed**
2.4.04.02.02	Design/delivery/reception/certification/cost: **Paid by the designer**
2.4.04.02.03	Design/delivery/reception/certification/documents to certify: **All projects and studies**
2.4.04.02.04	Design/delivery/reception/certification/absence of certification: **Economical penalty, designer issues certification in 14 days**
2.4.06.03.03	Design/delivery/close out/payment/effect: **Contract close out**

Fig. 7. Sample of owner's needs in the case study

phase or during the construction phase. Therefore, the model revealed adequate both for data collection and for supporting effective design specification. The architect agreed that some "given for granted" client needs were not confirmed on the model output, and this greatly facilitated his work and prevented misinterpretation and redesigning. Accordingly, it was agreed by both of them that the required outputs (brief for the feasibility phase and design documents for the design phase) were effectively improved through the model. Therefore, in spite of the partial limitation of the model, its implementation in this case study confirmed that it can be properly applicable to current building projects, increasing project efficiency.

Conclusions

The owner is the most important stakeholder in the building life cycle while other stakeholders perform their tasks in order to comply with the owner's needs. Thus, these needs must be identified, captured, and classified (previously to their transformation into requirements of the final product). This is the goal of the research reported in this paper, which has been pursued through a model that considers the building project as a temporal process (feasibility, design, construction, and operation) developed through a set of four logical stages (planning, procurement, execution, and delivery) within each phase of the building life cycle. It is necessary to break down the information further up to a certain level that enhances a reasonable identification and classification of the owner's needs; to this end, the simplification of the problem facilitates their identification.

Thus, the proposed model considers additional levels, namely field (3rd), subfield (4th), questions (5th), and answers (6th). The model is implemented by a systematic application of the questionnaires (record sheets at the 4th level including the questions and answers levels) to the owner in order to capture his/her needs regarding the project at hand. Before each phase-stage cell, the corresponding questionnaire must be filled out generating a set of owner's needs. Once the work associated to each cell is completed, questionnaires are used to check the owner's perception on the work performed against his/her needs. This produces feedback information for additional adjustments, if necessary.

The model identifies the owner's needs in a systematic and comprehensive way, allowing for interactive generation of information and back-feeding. It gathers wider detailed information for the same level of classification than other methods surveyed. The model has been corroborated and improved applying the Delphi technique using a panel of ten experts and two rounds. It has been implemented in practice in a case study that was carried out on a residential building project of twelve apartments in Spain. After its preliminary validation and implementation, it can be concluded that the main strengths of the model are: action mapping for logic stages within each phase, time/logic approach bringing up the same relevance to all phases and actions in the building life cycle, adequate criteria for collecting information for every phase-stage, sound coding system for information classification, and a question-answer approach for information retrieval.

One of the limitations of this research is that the volume of information that the model can identify is huge: more than five thousand owner's needs. Thus, computerization of the model is required so that it may become more operational and the authors are already pursuing this line of work. Even though the proposed model has been validated by a Delphi panel and it has been applied to a real project, additional empirical investigation is needed. To achieve this goal, this model should be further tested in more building projects. However, given the time needed to complete a project from its inception to its operation, this path will deliver results very slowly. Alternatively, the model will be partially tested for the construction phase through a similar process as described for the case study. Results of this process will show the trends in the number of client claims for inconsistent design, the amount of reworking during the design phase, the number of architect claims for client change orders and other variables. Data collected will be compared to typical figures obtained by clients and architects involved in the testing project and this will hopefully evidence the benefits of using the model instead of the current procedures. Adaptation of the model to other sub-sectors (educational buildings or civil engineering works) is another challenge of this line of research; using the methodology purported in this paper, the last three levels of the model can be adapted to each scenario.

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