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Innovation evaluation model for macro-construction sector companies: A study in Spain

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ABSTRACT

The innovativeness of the traditional construction sector, composed of construction companies or contractors, is not one of its strong points. Likewise, its poor productivity in comparison with other sectors, such as manufacturing, has historically been criticized. Similar features are found in the Spanish traditional construction sector, which it has been described as not very innovative. However, certain characteristics of the sector may explain this behavior; the companies invest in R+D less than in other sectors and release fewer patents, so traditional innovation evaluation indicators do not reflect the true extent of its innovative activity. While previous research has focused on general innovation evaluation models, limited research has been done regarding innovation evaluation in the macro-construction sector, which includes, apart from the traditional construction companies or contractors, all companies related to the infrastructure life-cycle. Therefore, in this research an innovation evaluation model has been developed for macro-construction sector companies and is applied in the Spanish case. The model may be applied to the macro-construction sector companies in other countries, requiring the adaption of the model to the specific characteristics of the sector in that country, in consultation with a panel of experts at a national level.

1. Introduction

The traditional construction sector, composed of companies focused in the construction phase of the infrastructures, has and currently does play an important role in the development of the Spanish economy, despite the crisis that it is currently facing. Housing construction, rehabilitation, construction of production facilities, infrastructure and public works are important elements for the modernization and maintenance of the economy, urban areas, communication infrastructure and tourism activity, promoting, on the one hand, productive and industrial activity and, on the other, the welfare of society (Free College of Emeritus, 2010; Pellicer, 2004). The importance of this sector has not been limited to its direct effect on the economy, but it has been amplified by the so-called 'tractor-effect' that the sector exerts on other economic activities, which doubles their total effect (Free College of Emeritus, 2010).

If we are to analyze the present state of the traditional construction sector in Spain, it is worth noting its high ranking over the period 2002–2010 in Europe. In 2008, the contribution of this activity accounted for 10.6% of total gross added value, including housing and civil works, and employed 12.5% of workers at a national level (Martín & González, 2010). Up until 2007, Spain built more new housing units per year than France, Germany and Italy together (Kapelko, Oude Lansink, & Stefanou, 2014). This disproportionate weight of the traditional construction sector, compared to the rest of the economy, and its consumption of so many resources means that the sector has been criticized by several authors (García-Montalvo, 2007), not least on environmental grounds.

This scenario began to change in 2006 as a result of a reduction in demand, a response to the enormous amount of new housing on the market. Although it was not the main reason, credit restrictions imposed after the so-called 'subprime' crisis intensified the recession in the market, (Bernardos, 2009). At the end of 2009, new unsold housing stock amounted to 688,044 units, in a country with 45 million inhabitants.

The crisis in the Spanish traditional construction sector was caused by a combination of the following factors: the reduction in housing demand since 2006, the 'housing bubble' that burst in 2007, the onset of the international financial crisis and drastic cuts in the budget for public infrastructure, in line with the financial

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adjustment policy of the European Union (capital provisions were reduced by 74% between 2006 and 2011 (Herrero, Escavy, & Bustillo, 2013)). From that point, the scenario for the sector in Spain changed dramatically, as its activity levels fell in the second half of the 1990s (Villegas, Carrasco, Lombillo, Liaño, & Balbás, 2012) in the face of a disproportionate supply of housing units in relation to demand. The number of companies in the sector fell from 246,271, in 2006, to 152,562, in 2010 (Laborda, 2012).

Other data showing this change of cycle are as follows, between 2007 and 2011 the sector has seen a 75% reduction in residential building production, 67% drop in public procurement, and accounts for approximately 75% of job losses in Spain (Oviedo-Haito, Jiménez, Cardoso, & Pellicer, 2013).

After the crisis and in view of the discouraging economic scenario at the national level, the largest Spanish construction companies increased their production in foreign countries. Spanish contractors are, after the Chinese, the second most successful worldwide (9% of the total), and the first in Latin America, with a 32% market share (Oviedo-Haito et al., 2013). An example of this situation is that, according to Public Works Financing, in 2009, 7 of the 10 largest global traders in infrastructure by number of operations were Spanish companies; ACS, Itínere (Sacyr), Cintra (Ferrovial), Global Vía (FCC and Caja Madrid), Abertis (OHL and Acciona) (Martín & González, 2010).

It must be stressed that growth in the construction sector depends heavily on the business dimension, the financial capacity of the most powerful companies that allows them to develop their ideal growth pattern, with more intensity than the rest, and to find ways into international markets (Martín & González, 2010).

On the other hand, when analyzing the demographics of the companies in the Spanish traditional construction sector (INE – Spanish National Statistics Institute, 2015a), it is important to mention that 97.74% of the companies in the sector are micro-enterprises (less than 10 employees) and 2.10% of enterprises have between 10 and 50 workers. Unlike large companies, most of these companies are neither of sufficient size nor have the necessary operational, financial and strategic potential to access international markets, so they are forced to compete in an increasingly complex and competitive national market. Moreover, a considerable part of these enterprises are of recent creation, launched under the favorable conditions of the expansive moment of the construction industry, prompting the emergence of multiple small new companies, especially with fewer than 6 employees (Martín & González, 2010).

Analyzing more specific characteristics, it should be said that a large part of the companies in the traditional construction sector have historically been characterized by a high degree of inefficiency (68%), associated with their poor levels of innovation (Kapelko, Horta, Camanho, & Lansink, 2015; Kapelko et al., 2014). In Spain, in terms of productivity per hour of work, the productivity in the traditional construction sector is 30% less than in traditional manufacturing industries. In addition, at least 15% of all construction costs represent the rectification of faulty work (Fundación Cotec para la Innovación Tecnológica, 2009; ISEA Sociedad Cooperativa, 2007).

As an example, it may be mentioned that the member States of the European Union (EU-27) in 2006 invested an average of 1.77% of GDP in innovation. In the case of the traditional construction sector, this rate is considerably lower. In particular, Spanish companies in this sector invested an average of 0.27% of GDP in innovation in 2007 (Pellicer, Correa, Yepes, & Alarcón, 2012). This figure is very significant, when we consider that the sector employed 12.7% of the working population in that same year, contributed to 17.9% of national GDP (Pellicer et al., 2012) and that investment in the sector stood at 58.5% of total investment in Spain (ISEA Sociedad Cooperativa, 2007). Over 2012, traditional construction sector companies were responsible for a mere 2.1% of total R+D expenditure in Spain. A figure that is far lower than total expenditure by either industrial enterprises (59.2%) or by companies in the service sector (37.4%) (Fundación Cotec para la Innovación Tecnológica, 2009).

These characteristics of the sector, along with the challenges that these companies face today, mean that awareness is growing in both the productive sector and the public administration regarding R+D and innovation, resulting in a series of actions at different levels, such as the existing tax benefits for investment in R+D and innovation (Pellicer et al., 2012) and the standardization of the innovation processes through the set of UNE 166000 standards, one of the first standards in the world to offer a certifiable standardized management system for innovation. This sets of standards, developed by the Spanish Association for Standardization and Certification (AENOR), aims to systemize innovation to stimulate R+D+I activities in general, as well as to help to achieve better management of such projects in a structured and systematic way (Mir & Casadesús, 2011, 2008). The Spanish Ministry of Development introduced another change in this direction in 2006, by which it is possible to increase the final score in bids for public tenders if R+D+I activities are introduced into the project, scoring between 10 and 25% more (Pellicer et al., 2012).

In addition and reflecting the importance of the concept of innovation as a competitive factor (LePatner, 2008), multiple innovation evaluation models exist today in the market, which aim to assess company innovation capacity and improve its management, identifying areas for improvement. In this sense, the majority of the evaluation models are generalist, designed for their application in companies from different sectors (Caird et al., 2013; Hansen & Birkinshaw, 2007; Hashi & Stojčić, 2013; Haskel, 2009), others however are designed for application in SMEs (Engel et al., 2010; Freitag & Ganz, 2011).

The above models have expanded the body of knowledge on innovation evaluation at a general level. Nevertheless, only to a certain extent some research has been made regarding the evaluation of innovation specifically in the construction industry (Toole, Chinowsky, & Hallowell, 2010; Toole, Hallowell, & Chinowsky, 2013), being a model designed for EPC (Engineering Procurement Construction) companies in the U.S.A.

In this sense, Loosemore (Loosemore, 2015) highlighted the need for specific evaluation models in the construction sector, stating that innovation in the construction sector is nowadays difficult to identify and to reflect, as the models which are available for the evaluation process are generalist and designed for companies in other sectors, leaving a lack of knowledge in this area of study. Along these lines, some other authors have also given their opinions (Barrett, Abbott, Sexton, & Ruddock, 2007; NESTA (National Endowment for Science, Technology & the Arts), 2006), stating that much of the innovation that occurs in the traditional construction sector is not captured with the current innovation evaluation models and therefore remains hidden, referring to this aspect as “hidden innovation”.

It may therefore be concluded that the evaluation of innovation has yet to be addressed at the level of the macro-construction sector, leaving a “knowledge gap” in this field of study. In this research the field of study of the macro-construction sector has been defined, in order to have a sufficiently broad view of the construction industry and because multiple agents and organizations take part in the production process of an infrastructure (a residential building, an industrial building, a public infrastructure or any other system), besides the one in charge of project implementation, which is the traditional construction company or contractor.

In this sense, the goal of this research is to develop a general innovation evaluation model that can be applied in the companies belonging to the macro-construction sector. In this research, the model has been customized in the case of the Spanish macro-construction sector, but can be applied to companies from other countries, requiring nothing more than its adaption and adjustment to the specific characteristics of the sector in a particular country. This matter requires the assistance of a panel of experts at a national level, in order to regulate the relative weights of the indicators, taking into account the specific reality of the companies of the sector in that country.

Therefore, in this paper an innovation evaluation model has been developed and has been applied in the companies of the Spanish macro-construction sector, with the collaboration of an expert panel formed by two academic researchers and eight construction industry professionals. Thus, it is intended to make a general model available to companies, to assess their current levels of innovative performance, identifying relevant areas for improvement.

In the following sections, we will first describe the proposed research method. Then, we will present the conclusions of the literature review on innovation in the traditional construction sector with a literature review on the way to approach its evaluation. Then, the development process of the innovation evaluation model will be described. Next, the results of applying this model to three companies, along with the overall results of the sensitivity analysis will be described. In the Discussion section, the relation of these results to previous contributions will be explained and, in the Conclusions section, the main contributions of the research, its limitations, its managerial implications and directions for future work will be described.

2. Research method

To that end, the presented research is divided in 4 phases, as can be seen in Fig. 1. The first phase consists of a review of the scientific literature on the relationship between traditional construction sector companies and innovation, identifying the causes which hinder the development of innovations. Also, in this first phase, a literature review on innovation assessment is presented, which analyses a total of 16 innovation assessment models and their specific characteristics, to ascertain the key variables related to innovative performance and to identify the different methodologies that have been used for this purpose over time.

In the second phase and first, the theoretical framework of the MIVES methodology is presented, which describes the mathematical method to obtain an evaluation index, through a hierarchical process of requirements, criteria, sub-criteria and indicators. Having presented the theoretical framework, based on the conclusions of the previous phases, an innovation evaluation model for macro-construction sector companies will be developed. To do so, indicator and dimension selection and the assignation of their relative weights is performed using the Delphi methodology, with the participation of a panel consisting of 10 experts from the sector.

In the third phase, the proposed model is applied to three different companies from the Spanish macro-construction sector, in order to test its responsiveness and behavior. In the fourth and last phase, a One-at-a-time (OAT) sensitivity analysis is performed, in order to test the validity, stability and robustness of the results, by varying the weights of each criterion.

3. Literature review

3.1. Innovation in construction

3.1.1. Characteristics of the sector

According to various authors (Free College of Emeritus, 2010; Pellicer, 2004), if we are considering the characteristics of the construction sector, it is not an “industry of specialized production processes” that produce identical products in serial. On the contrary, it is a sector that produces heterogeneous and disparate assets, held in different places and in different media, with little automated processes and working normally “on demand” and “outdoors” with a temporary activity horizon, dependent at all times on the duration of the project in each case.

Gann and Salter (Gann & Salter, 2000) claim that the companies in the sector share some unique characteristics, defining these companies as “project-based, service-enhanced forms of enterprises”, by which the activities of these companies differ significantly from the activities in other sectors, such as manufacturing, based on more stable production systems, which

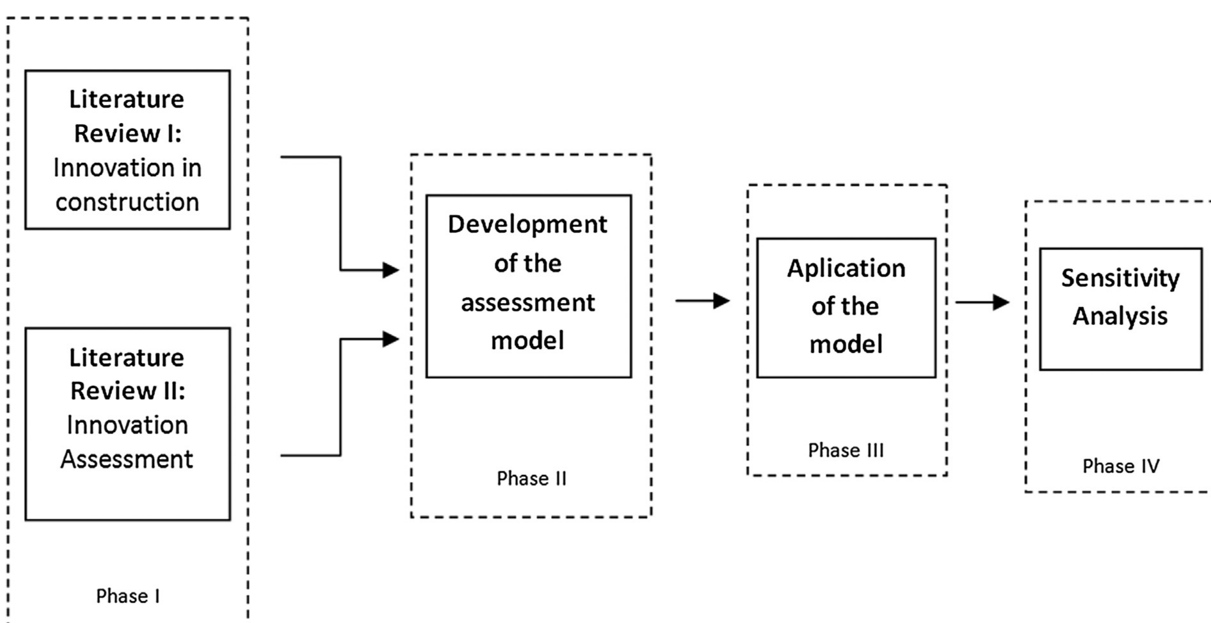

Fig. 1. Research Method.

produce products and services en masse. In project-based productive networks, linkages between firms and other institutions differ from those found in traditional manufacturing approaches, which focus on individual firms working in purely buy–sell relationships with each other. In project-based productive networks, firms have to manage networks with complex interfaces (Gann & Salter, 2000).

Along the same lines, Winch (Winch, 1998) stated that the construction industry is a "Complex Product Industry" (Miller, Hobday, Leroux-Demers, & Olleros, 1995), so that the process and the dynamics of innovation differ markedly from those of the 'conventional' Schumpeterian innovation model, which tends to assume mass production industries and relatively simple products. Unlike many other industries, innovations in construction are, typically, not implemented within the firm itself, but on the projects upon which the firm is engaged (Winch, 1998).

Additionally and according to various authors (Kapelko & Oude Lansink, 2015; Kapelko et al., 2014, 2015), there are certain features of the traditional construction sector, such as the nature of the construction product, the form of contract or the form of management, which makes the productivity and the innovative performance of these companies appear low. For these reasons, the sector has historically been criticized for "not looking right and left"; in other words, hindering the exchange of information and experience between its different actors. The sector has even been qualified as the "Cinderella industry" (Bessant, 2006).

Questioning these theses, Loosemore (Loosemore, 2015) states that despite that many researchers and governments labeled the sector as poorly innovative, there is a considerable amount of innovation that occurs in the traditional construction industry, but that it is not cached or reflected, since the models which are used in the evaluation process are designed for companies in other sectors, stating that there is a lack of knowledge of the true extent of innovation that takes place in the sector. Echoing this fact, several authors (Barrett et al., 2007; NESTA (National Endowment for Science, Technology and the Arts), 2006) affirm that much of the innovation taking place at the project level in the traditional construction sector remains hidden and is not captured by the traditional innovation performance indicators, explaining this phenomenon with the term "hidden innovation".

For all these reasons, it can be concluded that the companies in the construction sector represent a challenge to research on management and innovation (Gann & Salter, 2000). The next section will analyze the reasons for this phenomenon, identifying and describing the barriers faced by these companies when developing innovations.

3.1.2. Barriers to innovation in the traditional construction sector

The traditional construction sector, a mature industry, groups together various differentiated construction processes, although the traditional organization of the construction process is a common element. This feature, the segmented traditional organization of the construction process, has been identified as one of the major obstacles to the implementation of innovative processes in this sector (Pries & Janszen, 1995).

The temporary nature of construction, as Dubois and Gadde (Dubois & Gadde, 2002) argued, is disadvantageous for innovation in the sector and slows knowledge transfer within the company and between different organizations collaborating on a project. These relationships were qualified as "loose matches", because the business relationships between companies end as each of their collaborative projects finishes, and each company then seeks new projects on its own. Any learning process initiated in the course of the earlier project is not encoded and the information is lost.

The traditional construction process according to Barlow (Barlow, 2000) is generally managed by dividing the work into discrete parts and assigning each part to relevant specialists. Companies therefore enter into legal contracts and pass the risk to the following agent in the supply chain. This working practice limits itself to proven risk-reduction solutions, ignoring new and innovative working practice. Moreover, many small-to-medium sized companies participate in construction projects, with few resources, which mean fewer incentives to embark on expensive processes such as innovation. In addition, each company in a joint project only manages a single part of the overall process, which risks ineffective global co-ordination (Pries & Janszen, 1995). In this sense, Oviedo-Haito et al. (Oviedo-Haito et al., 2013) argued that subcontracting in this sector generates the following problems: "low-tier subcontractors use cheaper labor, equipment and materials; this means poor business practices and performance and a final product of low quality". The authors concluded that the growing number of firms involved in the process makes communication throughout the supply chain particularly inefficient. Thus, there is an additional need to coordinate and control, in order somehow to neutralize the reduction of overhead costs.

A further unique point is the foresight and planning implicit to its business management style (Pries & Janszen, 1995). Periodic economic cycles in the construction market mean that many companies adopt diversification strategies. These strategies are based on short-termism and market changes, in reaction to the circumstances at the time; a behavior that complicates the planning of medium and long-term innovation strategies.

An additional factor is that many companies in the traditional construction sector overlook the problems that arise in projects, according to Vrijhoef and Koskela (Vrijhoef & Koskela, 2000), categorizing them as "normal characteristics of the business" that are accepted and seen as unavoidable. Without sufficient attention, no solution can be found. Oglesby, Parker and Howell, G.A. (Oglesby et al., 1988) provided further evidence of these management failings, observing that everyday problems are resolved 'on the fly' by management that occupies a large part of their time and effort.

Staff promotion in traditional construction companies is geared to project completion and as Pries and Janszen (Pries & Janszen, 1995) observed, management positions are filled by people that, in their words, have 'mood' in their feet; a positive attribute in traditional construction firms. In other words, people should start from the bottom, from on-site work, before ascending to a management role. Unqualified managers and engineers represent nearly all of the company executives in this sector (95%) and reach management positions after time spent in a working environment and after technical training, where short-term (project) management dominates. Known as the "paradigm of the engineer" (a technical product and process-based approach), its effects on management are found everywhere. So, Pellicer et al. (Pellicer et al., 2014) cited the two most relevant constraints on innovative developments in these traditional construction companies: senior management that prioritizes production processes and that fails to recognize the potential competitive and strategic value of innovation.

Limited innovativeness in the traditional construction sector is also linked to its procurement systems, which work against the acceptance of non-traditional products and processes in construction companies (Kumaraswamy & Dulaimi, 2001). The authors argued that this adherence to traditional approaches, which views different working practices as impinging on potential benefits, is harmful to innovation. Some examples could be a preference for project completion and solely price-based systems, strict delineation of responsibilities and engaging unhostile and self-protective behavior.

3.2. Innovation assessment models

Reflecting the relevance of the innovation concept in company competitiveness (Şener & Sarıdoğan, 2011; Carter, 1988; Isaksen, 1999; Lenihan, 2011), there are multiple innovation evaluation models available in the market.

The purpose of this section is to develop a review of the scientific literature on innovation evaluation by relevant authors, identifying the key scientific variables that reflect innovative performance and that may be used in practice for its analysis and measurement. A total of 16 innovation assessment models and their specific characteristics were analyzed and the results are presented in Table 1.

A number of databases –Sciencedirect, Scopus, EconBiz, Google Scholar, IEEE Xplore, IScirus and SpringerLink- were searched with the following combination of keywords: “innovation”; “assessment”; “evaluation”; “methodology”; “model” and “tool”. All the references were checked and in some cases the authors were contacted for additional information.

Analyzing the results, it must be said that each model has its specific characteristics and are applied in several sectors. For example and in relation to the number of indicators used when measuring innovation, there are significant differences, ranging from the 13 indicators in the Hansen and Birkinshaw’s Capability Measure model to the 213 indicators in the TCW – Innovationsaudit model. In each case, the number of indicators gives us an idea of the time required to complete the evaluation. The majority (65%) of the models have less than 50 indicators, ranging between 10 and 50.

A mere 6% of the models employ solely qualitative indicators to assess innovation, while only 25% employ solely quantitative indicators. In all, 69% of the models employ both qualitative and quantitative indicators, in accordance with the dimension measured in each step of the evaluation process.

Table 1
Innovation assessment models.

	Name	Author/Year/Nature	Country	Application area	No. Indicators	Type of Indicators	No. Dimensions	References
1	Innovation Maturity Model	CII (Construction Industry Institute)/2010/PRIVATE	USA	EPC organizations	61	Qualitative	8	(Toole et al., 2010; Toole et al., 2013)
2	Innoscore	Fraunhofer Institute/2008/PUBLIC (1/3)	Germany	Industrial SMEs	26	Quantitative	8	(Freitag and Ganz, 2011)
3	The Community Innovation Survey 2010	OECD – European Union/every 4 years since 1992/ PUBLIC	EU-25	All kinds of organizations	120	Quantitative	11	(Hashi and Stojčić, 2013)
4	The Solvay Business School Survey	The Solvay Business School/2000/PRIVATE	Belgium	All kinds of organizations	85	Qualitative & Quantitative	12	(Peeters et al., 2003)
5	The Open2-innovation	The Open University – U-STIR programme/2013/ PRIVATE	UK	All kinds of organizations	28	Qualitative & Quantitative	4	(Caird et al., 2013)
6	Innovation Quick Scan	Syntens, Business Innovation Network/2009/PUBLIC	The Netherlands	All kinds of organizations	1	Qualitative & Quantitative	6	(Van der Meer, 2006)
7	Hansen And Birkinshaw’s Capability Measure	Morten T. Hansen and Julian Birkinshaw/2007/ PRIVATE	UK	All kinds of organizations	13	Qualitative & Quantitative	6	(Hansen and Birkinshaw, 2007)
8	Organisational Innovativeness Construct	Catherine L Wang and Pervaiz K Ahmed/2004/PUBLIC	UK	All kinds of organizations	20	Qualitative & Quantitative	5	(Wang and Ahmed, 2004)
9	Analytic Hierarchy Process To Evaluate Organizational Innovativeness	Ming-Ten Tsai, Shuang-Shii Chuang and Wei-Ping Hsieh/2008/PUBLIC	Taiwan	High-Tech Industry	58	Qualitative & Quantitative	5	(Tsai et al., 2008)
10	Innocert	MIGHT (Malaysian Industry-Government Group for High Technology)/2010/PUBLIC	Malaysia	All kinds of organizations	52	Qualitative & Quantitative	4	–
11	Imp3rove	European Commission – Directorate-General for Enterprise and Industry/2005/PUBLIC	Europe	SME-s	47	Quantitative	5	(Engel et al., 2010)
12	Tcw–Innovationsaudit	TCW Transfer-Centrum GmbH & Co. KG/2007/ PRIVATE	Germany	All kinds of organizations	213	Qualitative & Quantitative	6	(Herstatt et al., 2007)
13	Nesta Innovation Index	NESTA (National Endowment for Science, Technology and the Arts)/2009/PUBLIC	UK	All kinds of organizations	16	Quantitative	3	(Haskel, 2009; Roper et al., 2009)
14	RKW–Innocheck	RKW Kompetenzzentrum/2000/PUBLIC	Germany	SME-s	27	Qualitative & Quantitative	7	(Lohmann and Blaeser-Benfer, 2011)
15	Hamburger Innovationsaudit	Handwerkskammer, der Innovationsstiftung Hamburg, der HSU Helmut-Schmidt-Universität, TU Hamburg-Harburg und der Universität Hamburg/ 2007/PUBLIC	Germany	All kinds of organizations	39	Qualitative & Quantitative	10	(Herstatt et al., 2007)
16	Irish Innovation Index	The Innovation Foundation and UCD GEARY INSTITUTE/2010/PRIVATE	Ireland	All kinds of organizations	26	Qualitative & Quantitative	n/a	(Carney and Ryan, 2010)

Similarly, the concept of "innovation" has a different scope in each model. Some models evaluate a reduced number of dimensions or families; for example, the Nesta Innovation Index uses 3 families or dimensions. Other models employ a larger number of dimensions in the measurement of a broader conceptualization of innovation. The Solvay Business School Survey employs 12 dimensions in its assessment process. The majority of models (87%) organize the indicators under various dimensions ranging from 3 to 10.

In relation to the innovation quantification process, the models that have been presented apply different techniques to select indicators and dimensions, to assign their corresponding weights and to perform the final evaluation. One of the most consistent techniques used between models is the Analytic Hierarchy Process (AHP); for example, AHP in the model developed by Tsai et al. (Tsai et al., 2008) has proved to be of great interest in the resolution of these kinds of evaluation problems (Cheng, Ryan, & Kelly, 2012; Doloi, 2007; Pan et al., 2012) and is used in the present research. Other models, such as for example the model developed by Wang and Ahmed (Wang & Ahmed, 2004) used Confirmatory Factor Analysis to select the indicators and dimensions and to assign their respective relative weights. In the case of the research by Toole et al. (Toole et al., 2013), the Nominal Group Technique (NGT) was used for this process.

Whatever the evaluation technique, various aspects (criteria, dimensions, and indicators) are evaluated by the existing models, which can mean different measurement units based on weighted scoring systems for different parameters. Hence the utility of multi-criteria evaluation techniques in the innovation evaluation process. The final result ties in with the evaluation of various indicators, grouping measurable aspects with heterogeneous units.

These decision-making models are also tools for decision-making in the construction industry: health and safety (H&S) issues (Reyes et al., 2014), building sector technologies (Pan et al., 2012), productivity and worker motivation (Doloi, 2007), social problems (Cheng et al., 2012) and costs and quality (Gambatese et al., 1997).

4. Innovation evaluation model for macro-construction sector companies

4.1. Proposed evaluation model

The evaluation model in this research is based on MIVES methodology (Alarcon, Aguado, Manga, & Josa, 2011), a Multiple-Criteria Decision Making (MCDM) method with AHP-based value functions. Their incorporation adds homogeneity to different indicators with different measurement units. An appropriate hierarchy tree is therefore extremely important with a none-too excessive number of indicators (Alwaer & Clements-Croome, 2010).

In the present research, the selection of indicators and criteria and the assignation of their weights have been conducted under the guidelines defined by the Delphi method, with the participation of a panel of 10 experts and based on the "Analytic Hierarchy Process (AHP)" technique, proposed by Thomas L. Saaty. AHP (Saaty, 2008) considers various aspects (criteria, indicators, etc.) and their weights in a project assessment, through a logical and structured working approach, which optimizes complex decision-making problems (Pons & Aguado, 2012; Raslanas et al., 2013).

So, a specific problem, shown in Fig. 2 –the evaluation of innovation- is divided into a subset of simpler criteria and then evaluated on a case-by-case basis, to determine their influence on the final objective, as defined by the MIVES methodology (Ministerio de Ciencia y Educacion, 2010). The models based on the MIVES methodology are described in the works of Del Caño and de la Cruz (del Caño & de la Cruz, 2002), Manga (Manga, 2005), San José (San José et al., 2006; San-José et al., 2007), Reyes (Reyes, 2008), Hosseini (Hosseini, de la Fuente, & Pons, 2016a; Hosseini, de la Fuente, & Pons, 2016b), Alarcón et al. (Alarcon et al., 2011), Cuadrado et al. (Cuadrado et al., 2015, 2016), drawing from the works of Saaty (Saaty & Vargas, 2012).

The following steps are required to prepare the innovation assessment:

Step 1: An evaluation tree with criteria and indicators: a balanced number of criteria in the requirements tree is essential.

Step 2: Relative weights for the evaluation of each different stage; the indicators in a dimension, and the set of dimensions that

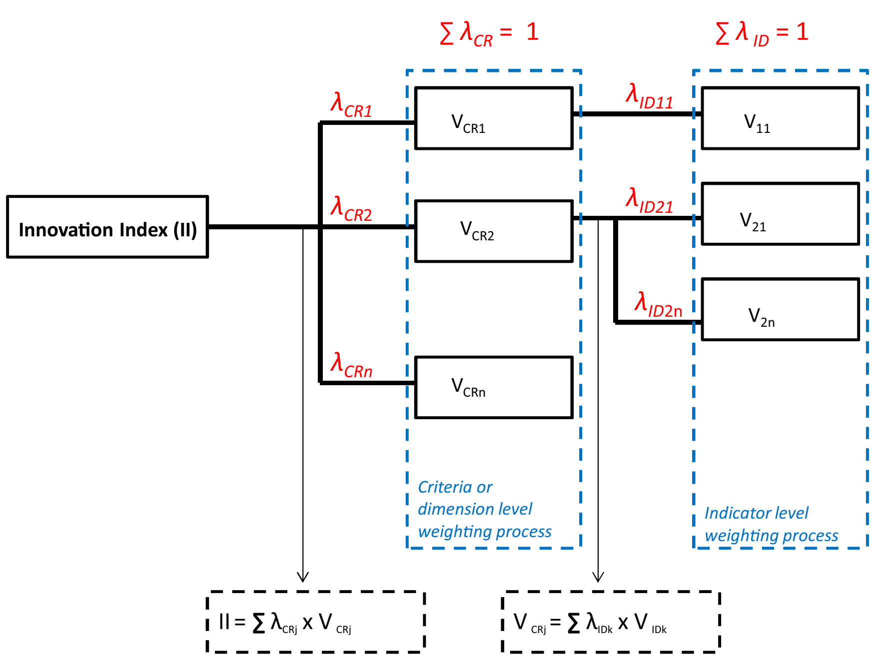

Fig. 2. Innovation Index (II) hierarchy diagram.

constitute the Innovation Index (II) are all assigned to different levels of the evaluation tree.

Step 3: A value function attached to each indicator, offering a range of possible solutions, a set score or an output register, between a minimum value of “0” (the worst of the solutions) and a maximum value of “1” (the best of the proposed solutions).

Step 4: Partial results and the value of the Innovation Index (II) may be progressively generated by requirements, through the completion of the set of output registers, according to the weighting system that is proposed at each stage. All these values are in turn defined at some point between 0 and 1.

4.2. Selection of criteria and indicators

The first task in the systematic approach for building the hierarchy tree (Fig. 1) is, as previously mentioned, to select the criteria and indicators and to estimate their corresponding priorities, through the assignation of weights at the respective hierarchical levels (indicator, dimension, and global Innovation Index). As well as permitting quantification and simplification of the object of study, the definition of the indicators and dimensions must reflect the changes that take place in the system. Additionally, it should not be forgotten that the indicators and the criteria are very dependent on the context (in this case, the macro-construction sector), so they also need to be very carefully selected on the basis of their usefulness.

In this study, the Delphi method was used to select the indicators and the criteria and the assignation of their weights, which involves a group of individuals (Expert Panel) who address a complex problem (Linstone & Turoff, 2002). In its standard definition, the Delphi method structures an effective process of group communication. It allows a group of individuals, working together, to approach multi-faceted problems (Linstone & Turoff, 2002). As opposed to the brainstorming method, where experts seek consensus, the Delphi method avoids the imposition of the opinions of a specific person or collective on the rest, as it permits experts to respond anonymously in the early rounds of the process.

This method attaches greater value to the specific experience and views of qualified members than it would to the views of a larger panel of experts, whose statistical contribution could be more extensive. Moreover, the qualitative techniques apply to samples that are structural and social rather than statistical. Thus, the selection of panel members should not be superficial; they should be chosen for their skills, knowledge and independence (Reid, 1988).

In this study, macro-construction sector professionals formed the Panel of Experts and their selection followed the guidelines defined by Hallowell and Gambatesse (Hallowell & Gambatese, 2010). These authors postulated an ideal Panel of Experts, formed of a highly qualified and diverse group, ranging between 8 and 16 individuals. In this case, a database of 72 professionals in the construction sector from 30 different organizations (public and private companies, research centers and universities) was used for the selection of the experts and finally 10 experts were selected, as described in Table 2.

In this systematic process and in the initial round of the investigation, a total of 149 innovation evaluation indicators for construction sector companies were presented to the Expert Panel, which were selected on the basis of information collected in both phases of the literature review. Based on this initial sample of indicators, panel experts were given the task of selecting the most relevant ones, by assigning their relative weights and grouping them into their corresponding criteria. It is noteworthy that the experts were entrusted to select a minimum number of relevant indicators, in order to be able to work with a small core of key indicators, so as to design an agile, practical model for companies, because these companies often have insufficient time for complex assessments, which require large amounts of information.

In the second round, these results were compiled and presented to each expert, together with their own answers. The experts then decided whether to alter their own answers, in the light of the responses from the whole group. This process of sharing the answers of the Expert Panel so as to give each expert a further opportunity for consensus was repeated twice. In the final phase, the results were collected and the means of the relative weights assigned to each indicator were calculated. All indicators with relative weights of less than 5% were eliminated; 131 indicators were removed, leaving 18 final evaluation indicators grouped into 5 criteria, as can be seen in Fig. 3.

Additionally, in order to certify that the 18 selected indicators were considered essential by all the panel experts, the Content Validity Ratio (CVR), developed by Lawshe (Lawshe, 1975) was

Table 2
Professional experience of the Expert Panel.

Expert	Description
1	A mechanical engineer with 9 years of working experience, who works as a managing director of a company manufacturing concrete products for public works, sanitation, urbanization and buildings. He also works as a part-time professor at a public university.
2	A holder of a PhD in Mechanical Engineering with 11 years of working experience, who works as a consultant engineer in a company dedicated to the design of energy-saving solutions in domestic and industrial installations. He has previous experience as a researcher in the Division for Sustainable Construction of a research centre.
3	A mechanical engineer and the director of a multinational construction company dedicated to the implementation of “turnkey” projects in (conventional and renewable) energy, steel and mining sectors, with 20 years of working experience.
4	A holder of a PhD in civil engineering, working as professor in the civil engineering department of a public university, with over 30 years of research experience in the fields of concrete technology, special concretes and the analysis of concrete structures: reservoirs, deposits and tunnels. The author and co-author of 115 journal publications.
5	A holder of a PhD in civil engineering, with a working experience of over 20 years, working as professor in a public university with over 18 years of research experience in the fields of organization and management of construction projects: quality, health and safety and innovation. The author and co-author of 35 journal publications.
6	A holder of a PhD in mechanical engineering and a director of the Division for Sustainable Construction at a research centre employing over 1400 employees, with more than 30 years of working experience.
7	An economist with 10 years of previous experience in a multinational consultancy company, and 5 years as a consultant in a public agency, the mission of which is to promote the launch and development of spin offs.
8	An architect with over 10 years of working experience currently working as a Building Project Manager in a public company attached to a regional-level Employment and Social Policy Department, the main objective of which is to promote quality public housing.
9	A holder of a PhD in mechanical engineering with 19 years of working experience in a multinational engineering company, with expertise in applied mechanics, structural design, electronics & control.
10	An economist with over 15 years of working experience, who is the Director of a regional-level Construction Cluster, the main objective of which is to launch, develop and manage initiatives that improve the competitiveness of Construction Sector companies.

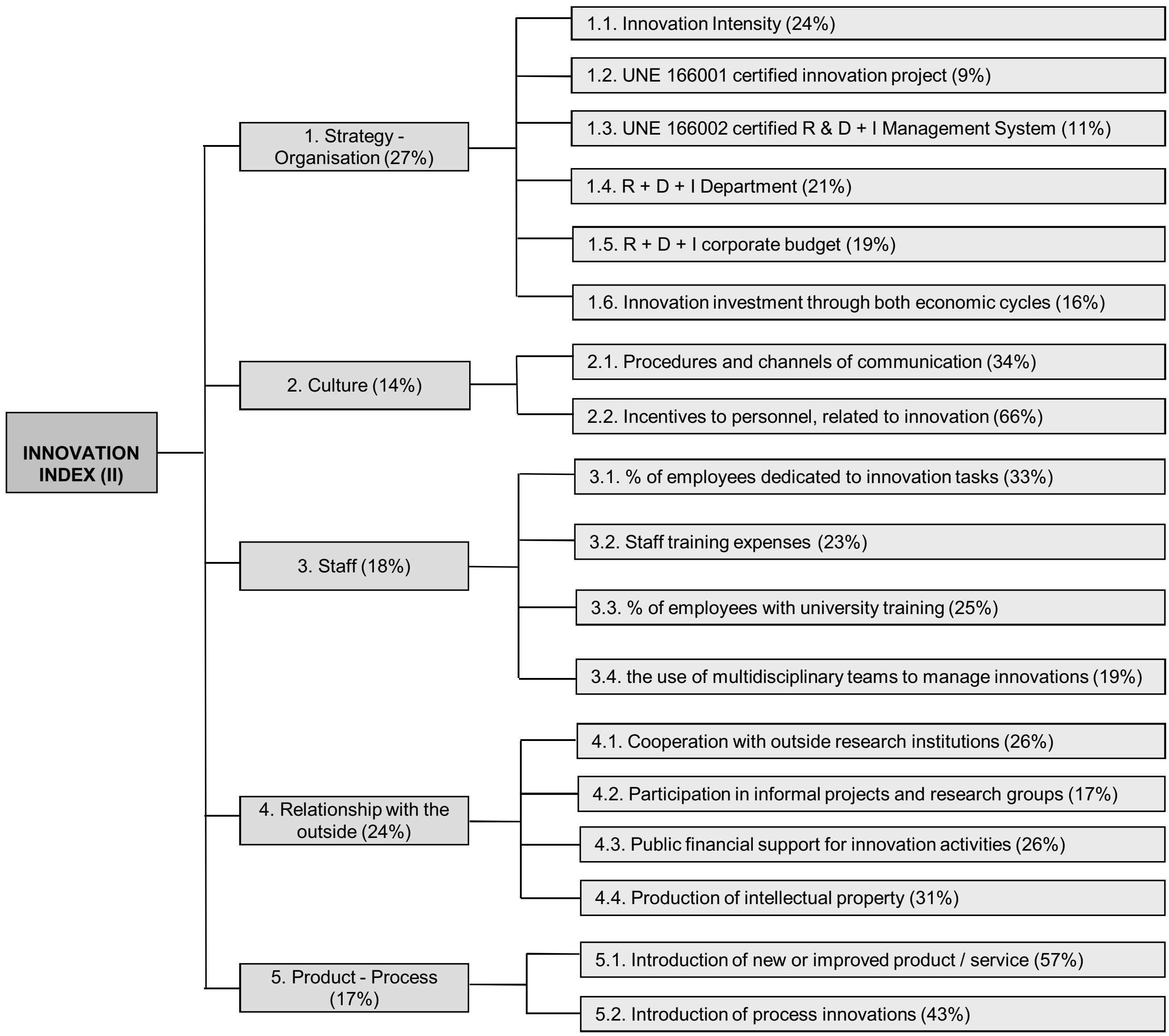

Fig. 3. Evaluation tree of the Innovation Index.

calculated for each indicator, which is a method for gauging agreement among raters or judges regarding how essential a particular item is, through the following Eq. (1):

$$\text{Content Validity Ratio (CVR)} = \frac{n_e - \frac{N}{2}}{\frac{N}{2}} \quad (1)$$

Where,

n_e = the number of panel experts indicating that an item or indicator is "essential"

N = the total number of panel experts

In this case, the ratio reached a value greater than 0.62 for each of the 18 indicators, which, according to Lawshe (Lawshe, 1975) and Wilson (Wilson et al., 2012), certifies the relevance and appropriateness of the 18 indicators in this field of study.

The final and definitive evaluation tree composed of 5 criteria and of 18 indicators is represented in Fig. 3.

4.3. Innovation index (II) for macro-construction sector companies

The final objective of the proposed model is to establish a means of evaluating the innovative performance of a company in the macro-construction sector. Once the respective values and weights at the indicator sublevel have been defined, the additive value function is applied. Subsequently, the evaluation process at the lowest level (indicators) yields an innovation value (scale [0–1]), and so on until the highest hierarchical level is reached: firstly criteria or dimension level and, finally Innovation Index (II), as shown in Fig. 2 (general overview) and in Fig. 3 (specific case study).

Therefore, the Innovation Index (II) is obtained by adding up each of the adimensional values (Vcr) of the 5 criteria or dimensions, which have to be previously corrected according to their own final weight (λcr), as shown in Eq. (2).

$$\text{II} = \sum_{i=1}^{j} \lambda_{CR_i} \times V_{CR_i} \quad (2)$$

Where,

II: Innovation Index (II) for macro-construction sector companies

λ_{CR_i}: Weight of the criterion i

V_{CR_i}: Value of the criterion i

j: Total number of criteria

Each of the adimensional values (VCR) of the 5 criteria is obtained by adding up the adimensional value functions (Vi,k) of the 2-to-6 indicators of each criteria, which have to be previously corrected according to their own final weight (λi,k), as shown in Eq. (3).

$$V_{CR_k} = \sum_{i=1}^{j} \lambda_{i,k} \times v_{i,k}(x_{alt}) \quad (3)$$

Where,

V_{CR_k}: Criterion k value
$\lambda_{i,k}$: Indicator weight i of criterion k
$v_{i,k}$ (x_{alt}): Indicator value i of criterion k
j: Number of indicators hanging from criterion k

The indicators are valued through a value function. This score is obtained with the mathematical expression defined by Alarcón et al. (Alarcon et al., 2011). The value functions (Vi) vary from 0 to 1 (respectively, the minimum and the maximum score of each indicator) and depend on several parameters related with the function shape and the way in which that indicator value corresponds to an adimensional scale ("value"). The selected value function (mathematical expression) is presented in Eq. (4).

$$V_i = A + \frac{1}{B} \times \left[1 - e^{-k_i \times \left(\frac{|x_{alt} - x_{min}|}{C_i} \right)^{P_i}} \right] \quad (4)$$

Where:

C_i: Abscissa value at the inflection point on curves with $P_i > 1$.
x_{min}: The minimum reference point on the indicator scale. Indicator response generated = 0.
x_{max}: Maximum reference point on the indicator scale. Indicator response generated = 1.
x_{alt}: Response to the assessed alternative regarding the respective indicator, value between x_{min} and x_{max}. Indicator response generated = V_i (x_{alt}).
P_i: Form factor defining whether the curve is: concave, convex, straight or "S" shaped. Concave curves imply $P_i < 1$. Convex or "S" shaped curves imply $P_i > 1$. Straight lines $P_i \approx 1$.
D_i: Abscissa value at the inflection point (curves $P_i > 1$).
K_i: Ordinate value of point C_i.
A: Value of response "x_{min}", A = 0 or A = 1 (usually A = 0).
B: Factor for maintaining value function in range [0–1] and the best response equal to 1 (see factor B below).

$$B = \frac{1}{1 - e^{-k_i \times \left(\frac{|x_{max} - x_{min}|}{C_i} \right)^{P_i}}} \quad (5)$$

A relationship between the value of the indicator and the dimensionless response is established by means of this formula, which may present any of the following trends: from a straight line, passing through concave or convex curves, with an "s" form and even upward or downward, as shown in Fig. 4. The selection of the trend is done with the help of the Expert Panel and by identifying the key issues. This systematic working approach and the application of this formulation of great potential has already been used in different areas, both in research (Cuadrado et al., 2012; San-José & Cuadrado, 2010) and for normative purposes (Spanish Ministry of Development, 2008; Spanish Ministry of Development, 2011).

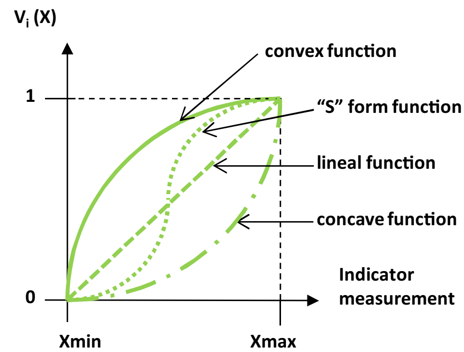

Fig. 4. Value function shape.

4.4. Example of the assessment process in the "Innovation Intensity" indicator

In the following section that describes an example of indicator assessment, only the assessment of the "Innovation Intensity" indicator within the "Organization – Strategy" criterion will be presented, because this is the indicator with the highest weight and due to limitations on the length of the paper.

By definition (Arundel & Bordoy, 2005; INE – Spanish National Statistics Institute, 2015b), the "Innovation Intensity" indicator measures spending on innovation activities, expressed as a percentage of the turnover. The following innovation activities are considered for the assessment of this indicator, as seen in Table 3.

The value of this indicator is calculated by adding total expenditure in innovation activities performed by the company over the past year and dividing this value by the turnover in the same period of time, according to the following formula (Eq. (6)):

$$\text{Innovation Intensity} = \frac{V1 + V2 + V3 + V4 + V5 + V6 + V7}{Turnover} \quad (6)$$

The next step in the assessment process is to introduce the value of the Innovation Intensity indicator into the value function that has been defined for this specific indicator, to produce a value between 0 and 1. This value represents the quantification of the indicator and, in this case, follows the strategy of enhancing spending on innovation activities. Thus, the curve yields a higher score as greater spending effort is made in this regard; insofar as the innovation intensity is greater. In this case, as may be appreciated in Fig. 5, a concave downward function is suggested, to incentivize higher expenditure on innovative activities.

A similar scheme is proposed for the entire set of indicators, in all cases establishing the proposed objectives, the approach to the indicator valuation, as well as the proposed strategy, by means of different value functions.

5. Application of the model

5.1. Data

The proposed model was applied in three different companies, each company belonging to the Spanish macro-construction sector, in order to test its responsiveness and behavior:

- Company A: a traditional construction company or contractor
- Company B: a precast and building materials supplier
- Company C: an engineering consulting firm

A general description of each company is presented below.

Table 3
Innovation activities.

Innovation activities	
V1	Internal R & D
V2	Acquisition ofR & D (external R & D)
V3	Acquisition of machinery, equipment and advanced hardware or software and buildings
V4	Acquisition of other external knowledge for innovation
V5	Training for innovation activities
V6	Introduction of innovations in the market
V7	Design, other preparatory activities for production and/or distribution)

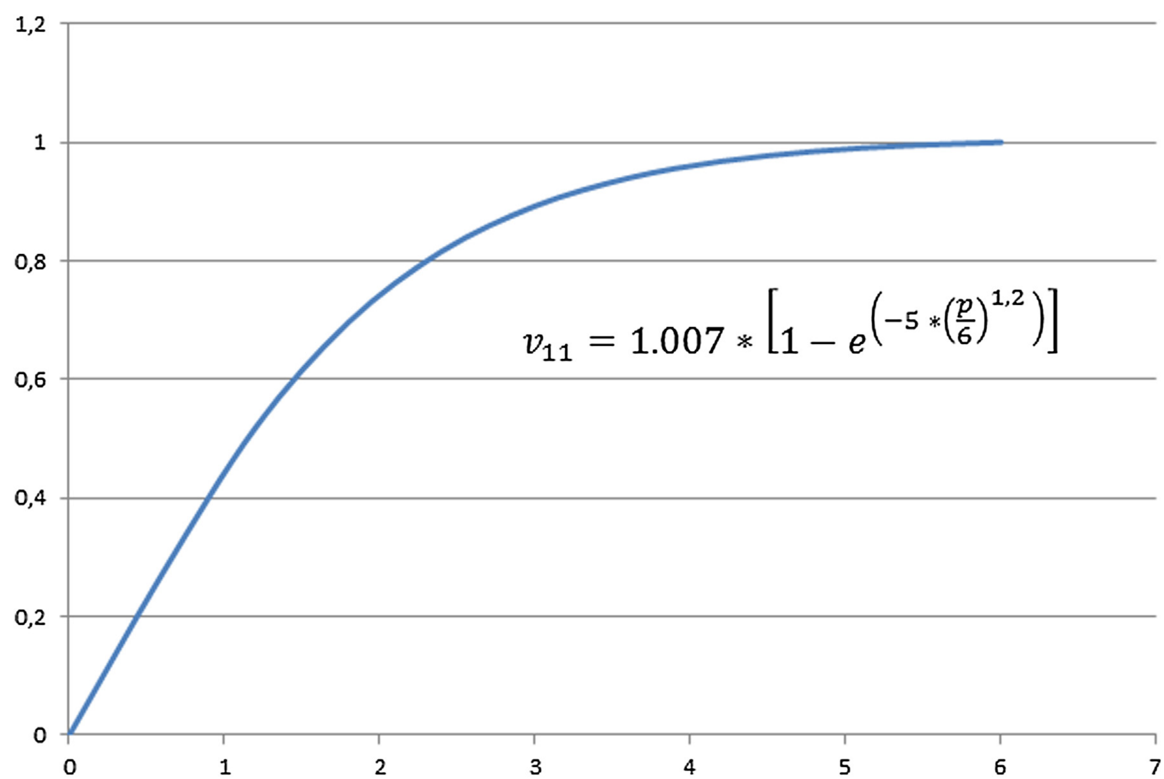

Fig. 5. Value function associated with the 'Innovation Intensity' indicator.

5.1.1. Company A

Company A is a traditional construction company active for over 32 years in the Spanish market. It has 3 offices in Spain, through which it provides nationwide services. The areas in which it conducts its activities are: industrial and logistics, residential, tertiary and endowments, rehabilitation and civil works.

Company turnover in 2014 was €57,026,759, while its spending on innovation activities amounted to €113,468 in the same year; an innovation intensity rate of 0.19%. The company has no certified innovation project in accordance with UNE 166001 standards, nor does it have a certified R+D+I management system in accordance with UNE 166002 standards. However, it has its own R+D Department and invests in innovation through both economic cycles (upward and downward).

Its staff number 121 people who work in the company, of whom 75% have a university degree and 5 people are engaged in innovation activities in FTE (Full Time Equivalent). There are no incentives for staff, related to innovation in the company (bonuses, recognition, awards, and permissions) and the participation of the staff in informal projects and research groups, such as the visits to other companies and participation in forums and clusters is uncommon.

The company has collaborated with external institutions and universities on innovation activities over the past year and has received public funding for these activities from the Spanish Government. It has introduced a process innovation, but no product innovations and has produced no intellectual property over the past 3 years.

5.1.2. Company B

Company B is a small company active in the manufacture and marketing of precast concrete products for public works, such as piping, wells, containment systems, manholes and blocks. The company has performed these activities for 61 years and sells primarily in the domestic market (6.32% of sales outside Spain).

The most recent figures for company turnover, corresponding to the year 2014, totaled €2,735,538 and spending on innovation activities amounted to €260,047 in the same year, resulting in an innovation intensity rate of 9.5%. The company neither has certified innovation projects in accordance with UNE 166001 standards nor certified R+D+I management systems in accordance with UNE 166002 standards. In this case, the company does not have an R+D Department, because of its size. However, it conducts R+D activities and invests in innovation activities throughout both economic cycles (upward and downward), as it has its own budget to finance these activities.

Regarding the staff, 22 people work in the company, of whom 23% have a university degree and 1.8 people are engaged in innovation activities in FTE (Full Time Equivalent). There are no innovation-related incentives for company staff (bonuses, recognition, awards, and permissions) and, in this case, the participation of staff in informal projects and research groups, such as the visits to other companies and the participation in forums and clusters, is common.

The company has collaborated with external institutions or universities for innovation activities in the last year, especially with a technology centre specialized in research on construction sector sustainability. It has received public funding for R+D activities, from the Regional Government.

Regarding the production of intellectual property, the company has made a record of industrial design or model in the last three years. In that period it has also introduced a product innovation and a process innovation.

5.1.3. Company C

Company C concerns an engineering consulting firm specializing in the execution and management of turnkey projects in energy sector (conventional and renewable), in the mining and the steel industry. The company has carried out this activity for 29 years and clearly has an international client base, as 80% of its turnover is from foreign clients.

The most recent turnover figures, from 2014, totaled €18,457,243 of which in the same year €803,074 was spent on innovation activities, resulting in an innovation intensity rate of 4.35%. The company has neither certified innovation projects in accordance with UNE 166001 standards nor a certified R+D+I management system in accordance with UNE 166002 standards. It has its own R+D department, its own budget to finance innovation activities and invests in innovation in both (upward and downward) economic cycles.

Regarding the staff, 44 people work in the company, of whom 89% have a university degree and 2.3 people are engaged in innovation activities in FTE (Full Time Equivalent). There are innovation-related incentives for staff; specifically, a variable part of the salary, which takes into account the contributions of the workers on issues such as the generation of ideas and innovations. Also, procedures and channels of communication of ideas through projects and disciplines exist in the company.

The company has collaborated in innovation activities with external institutions and universities over the past year. Specifically, it has a cooperation agreement with a School of Industrial Engineers, with whose undergraduate and PhD students it is involved in various research projects. It has received public funding for R+D activities, from the Regional Government, as well as public funding for costs associated with trade missions and market prospecting, because of its international character. In the last three years the company has introduced a product innovation and process innovation.

5.2. Results of the assessment

Having applied the model to each of the three companies, the hierarchical breakdown of each criterion with their corresponding indicators is presented in the Appendix A.

Table 4 shows the final values of the Innovation Index (II) and the values of the different criteria or dimensions, which are used to obtain it.

These results can be represented in a spider diagram, in which the strengths and weaknesses of company may be clearly observed, as seen in (Figs. 6–8).

Table 4
Values of the different criteria that create the II.

Criteria (CR)	Company A	Company B	Company C
Strategy–Organization	0.350[a]	0.608	0.740
Culture	0.000	0.148	0.578
Staff	0.687	0.870	0.901
Relationship with the outside	0.662	0.799	0.724
Product – Process	0.473	1.000	1.000
Innovation Index (II)	0.457[b]	0,703	0,787

[a] $V_{CR_i} = \sum \lambda_{i,k} * v_{i,k}$.
[b] $II = \sum \lambda_{CR_i} \times v_{CR_i}$.

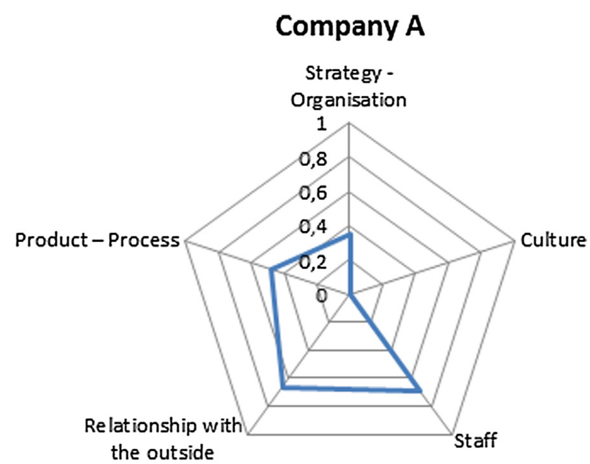

Fig. 6. Results of Company A.

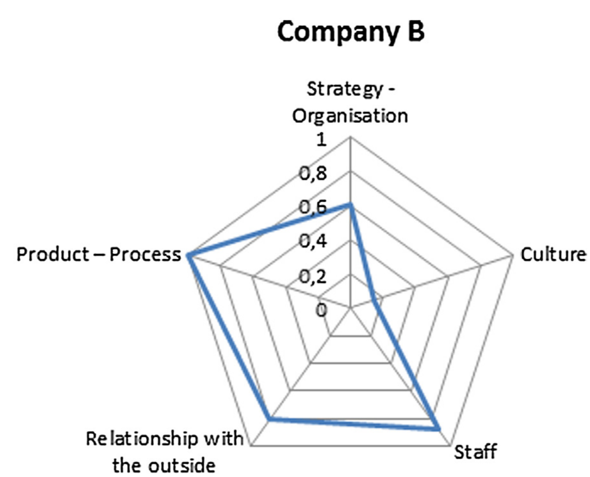

Fig. 7. Results of Company B.

In the comparison of the 3 proposed examples, the engineering consulting firm, which is not strictly speaking a productive company, obtained the highest scores for Strategy – Organization, Culture, Staff and Product – Process criteria. This assessment is conditioned primarily by the particular characteristics of the companies in this subsector in Spain (Rastrollo Horrillo, Martín Armario, & González Pachón, 2014): they are structured on the basis of highly specialized multidisciplinary teams providing knowledge-intensive services, combining knowledge from various disciplines. They also have highly qualified human resources and a high degree of internationalization, partly due to the stagnation of the Spanish market, which forces companies to face unknown markets and to gain the resources to overcome uncertainties,

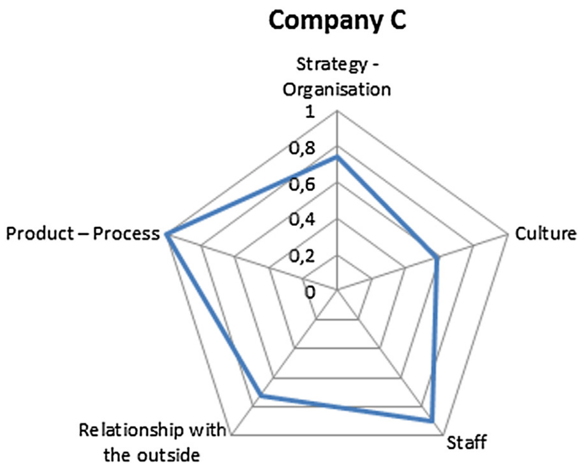

Fig. 8. Results of Company C.

complexities and risks, all of which are associated with international activity; and there is a close relationship with the customer, who has a high degree of demand and involvement in these kinds of projects.

It is also important to mention that the precast concrete supplier obtained a very good score on the Product – Process, Relationship with the Outside and Staff criteria, especially in view of the size of company with only 22 workers. This good score is due in part to the commitment of management to innovation, reflected in the fact that it has a corporate budget for R+D activities, which is unusual in companies in this subsector in Spain (INE – Spanish National Statistics Institute, 2015b). It is reflected in the value of the innovation intensity indicator, which reached a value of 9.5%, far higher than the average of its subsector (INE – Spanish National Statistics Institute, 2015b), especially taking into account that this innovation investment was in a downward business cycle, due to the economic crisis, with a 36% reduction of the turnover of the company. It should also be mentioned that the company is actively linked to external agents, such as universities and technology centers and that it has been able to attract public funding for innovation activities, which is not simple, taking into account the budgetary restrictions of public administration in times of economic crisis.

In third place, there is the example of the traditional construction company that obtained the lowest Innovation Index (II) value. It also obtained the lowest values for each of the criteria separately, which is in line with the conclusions of the National Statistics Institute (INE) report (INE – Spanish National Statistics Institute, 2015b), which observed that companies belonging to this subsector have the lowest innovative performance throughout the Spanish macro-construction sector.

In the traditional construction company example, this rating is a very important and striking fact, as it is the largest company on turnover and number of workers and, in theory, should have more resources to invest in innovation activities. An explanation of this reasoning is mentioned in Literature Review, which concludes that the traditional construction subsector erects most barriers to innovation, works in the worst conditions, with procurement systems that give preference to project costs and to the urgency of its date of delivery, establishing very strict responsibilities and promoting hostile and self-protective behavior. This fact must be added to the oversupply that exists in this subsector, in a country that has suffered a drastic reduction in public and private tenders, in which the number of companies remains high and the companies themselves are generally not actively seeking entry to international markets. With this market ecosystem and these difficult working conditions, it is difficult to give space and prominence to innovation in the day-to-day management of these companies, especially because the strategy of obtaining contracts is based mainly on price.

5.3. Sensitivity analysis

The final Innovation Index (II) values relate to the weights attached to the main criteria and their indicators. Slight changes in

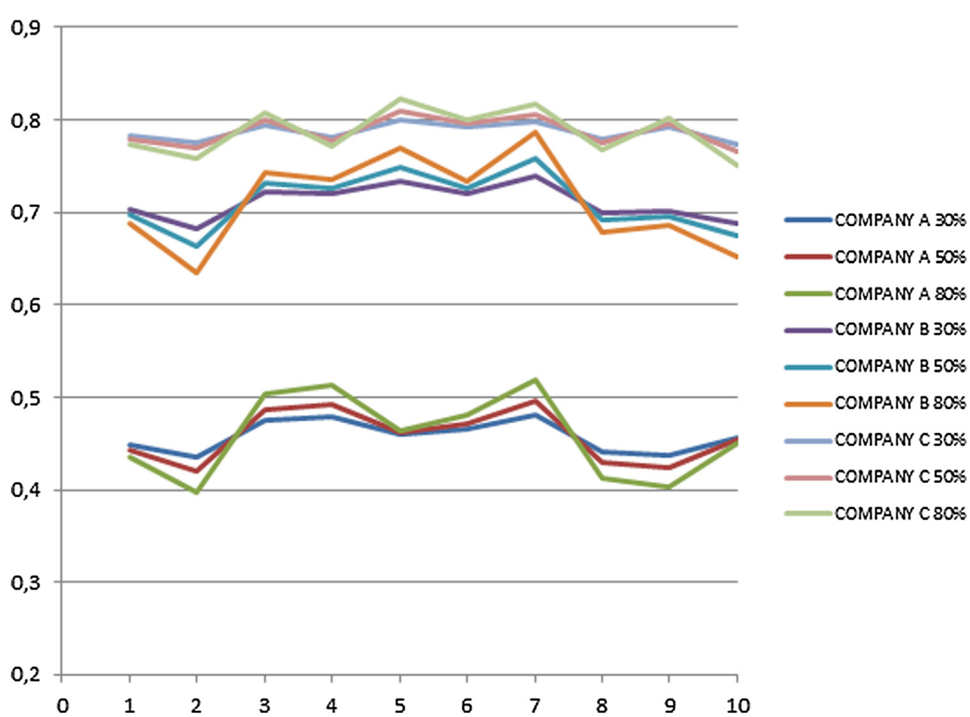

Fig. 9. Sensitivity analysis results.

the relative weights can therefore prompt major changes in the final value of the assessment (Chang, Wu, Lin, & Chen, 2007; Delgado & Sendra, 2004). These weights are the result of subjective assessments by the members of the Expert Panel, so the validity, the stability and the robustness of the Innovation Index (II) results must be tested by means of a sensitivity analysis, by varying the criteria weights. Hence, the one-at-a-time (OAT) sensitivity analysis approach, one of the most popular sensitivity analysis approaches in the literature on AHP-based models (Chen & Kocaoglu, 2008), was selected, because it is a simple, computationally light method, that is easily developed, with easily understandable results (Chen, Yu, & Khan, 2013).

This analysis provided information on the validity and stability of the innovation assessment model used in the study. If the results are highly sensitive to small changes in the criteria weights, a careful review of the weights is recommended. To do so, the criteria weights must be separately and independently adjusted, with changes of ±30%, ±50%, and ±80% respectively, through the definition of 10 new scenarios for each change. Proportional adjustments to the weights of all the other criteria meant that their total sum was always 100%. So, the resulting new Innovation Index (II) rates of each company (Fig. 9) and the percentage of Innovation Index (II) rate variations (Table 5) could be calculated by independently increasing or decreasing the weights of the criteria through the 10 new scenarios.

When the results are very similar, even with significant variations in the weights of the criteria, it can be concluded that the assessment model is correct (Barba-Romero & Pomerol, 1997; Chen, Yu, Shahbaz, & Xevi, 2009). In our case, the maximum variation of the Innovation Index (II) rate was 13.30%, which can be considered quite a small variation, taking into account that it was generated as a consequence of an extreme variation of the requirements (80%).

The results of the sensitivity analysis with the agents involved in the development of the model also needed to be analyzed and validated (Delgado & Sendra, 2004). The results were therefore presented to the Expert Panel, suggesting the possibility of modifying the final weights of the requirements, in the light of the results. After a round of consultation and discussion on this issue, the Expert Panel concluded that on the basis of such information, there was no justification for changes in the requirements weights, so the original weights remained in place.

5.4. Discussion

The worldwide traditional construction sector has historically been criticized for its low innovative performance. Its level of productivity and efficiency is also low compared with other sectors, such as manufacturing, and there are many reasons that explain this behavior. If we focus on the Spanish traditional construction sector and except in some success cases of several major companies, these negative features are maintained.

Reflecting this concern, various actions have been launched at national level, with the aim of improving the sector's performance in relation to innovation, such as the existing tax benefits for investment in R+D+I and the UNE 166000 R+D+I management standards, which aim to standardize the innovation processes. Additionally, there are multiple innovation evaluation models on the market that may be used to improve the management of innovation through performing a diagnosis of the company. Most existing models are applicable in different sectors and use generalist innovation evaluation indicators, without being specific to a particular sector or industry.

Given the unique characteristics that the construction industry presents and due to its nature as a “Complex Product Industry”, the process and the innovation dynamics differ markedly from those of the ‘conventional’ Schumperterian innovation model. For this reason, generalist indicators fail to reflect the actual extent of innovation in this sector, with the result that part of the innovation that takes place remains hidden. Therefore, the goal of this research has been the design of a specific evaluation model for the companies in the macro-construction sector, to respond to the existing “knowledge gap” in this field of study. Therefore, in this research it has been essential to determine and identify the specific indicators linked directly with innovative performance in the macro-construction sector companies. In this way and through the application of the Delphi method to a panel of sector experts, 18 specific indicators for the companies in this sector have been selected and have been grouped in the following dimensions: Strategy-Organization, Culture, Staff, Relationship with the outside and Product-Process.

The evaluation model which has been developed in this research provides results in the form of aggregated global and partial indexes; it quantifies each indicator, criterion and result and has been configured and especially adapted for this area of study, being a model which did not exist so far in this field of study. Thus, it is possible to ascertain the strengths and weaknesses of each company, identifying those indicators and criteria that may need improvement.

Furthermore, the results obtained from the application of the model to three companies in the Spanish macro-construction sector are in line with the findings of the “Survey on innovation in enterprises” report (INE – Spanish National Statistics Institute, 2015b) conducted by the Spanish National Statistic Institute (INE),

Table 5
Percentage of II rate variations.

30%	SCEN. 1	SCEN. 2	SCEN. 3	SCEN. 4	SCEN. 5	SCEN. 6	SCEN. 7	SCEN. 8	SCEN. 9	SCEN. 10
COMPANY A	−1.88%	−4.99%	3.73%	4.48%	0.54%	1.88%	4.99%	−3.73%	−4.48%	−0.54%
COMPANY B	−1.22%	−4.03%	1.68%	1.34%	3.12%	1.22%	4.03%	−1.68%	−1.34%	−3.12%
COMPANY C	−0.62%	−1.40%	0.96%	−0.73%	1.71%	0.62%	1.40%	−0.96%	0.73%	−1.71%
50%	SCEN. 1	SCEN. 2	SCEN. 3	SCEN. 4	SCEN. 5	SCEN. 6	SCEN. 7	SCEN. 8	SCEN. 9	SCEN. 10
COMPANY A	−3.13%	−8.31%	6.21%	7.46%	0.91%	3.13%	8.31%	−6.21%	−7.46%	−0.91%
COMPANY B	−2.03%	−6.71%	2.79%	2.23%	5.20%	2.03%	6.71%	−2.79%	−2.23%	−5.20%
COMPANY C	−1.04%	−2.34%	1.60%	−1.22%	2.85%	1.04%	2.34%	−1.60%	1.22%	−2.85%
80%	SCEN. 1	SCEN. 2	SCEN. 3	SCEN. 4	SCEN. 5	SCEN. 6	SCEN. 7	SCEN. 8	SCEN. 9	SCEN. 10
COMPANY A	−5.00%	−13.30%	9.94%	11.93%	1.45%	5.00%	13.30%	−9.94%	−11.93%	−1.45%
COMPANY B	−3.24%	−10.74%	4.47%	3.57%	8.33%	3.24%	10.74%	−4.47%	−3.57%	−8.33%
COMPANY C	−1.66%	−3.74	2.56%	−1.96%	4.55%	1.66%	3.74%	−2.56%	1.96%	−4.55%

in reference to the differences in terms of innovation performance, depending on the subsector to which each company belongs.

6. Conclusions

6.1. Main contributions of the research

Through the development of this research, 18 specific factors that are directly related to the innovative performance of macro-construction sector companies have been identified based both on the findings of the literature review and the opinions of an expert panel, who participated in the research. Once these indicators have been selected, an innovation evaluation model, specific for this companies has been developed, taking into account their specific characteristics and idiosyncrasy. Therefore, the main contribution of this research is that it presents a model which did not exist until now in this field of study, which allows to evaluate the current levels of innovation of these companies, identifying the strategic aspects to which they should attend.

6.2. Relevance to practitioners

Until the onset of the global financial crisis and the collapse of the housing market, the companies in the Spanish traditional construction sector have had favorable market conditions to the development of its activity, with a high demand for projects and easy financing for customers. These working conditions favored that many companies did not identify innovation as a key factor in business strategy, simply because they did not see necessary. The form of recruitment of the sector also influenced this fact, which was often based solely on project execution time and price. As a result, budget allocations directed to the development of innovations were considered too expensive and they were usually classified as "doubtful return" investments.

Today the situation in the Spanish traditional construction sector is radically different: market conditions are complicated, there is still little demand for private projects, and there are still budgetary constraints by the public administration for investment in public works, in addition to the existing financing restrictions. This situation forces companies that want to survive to leave aside the strategy of focusing exclusively on short-term project objectives and their achievement, ignoring innovation opportunities. So, if these companies want to remain in the market, it is necessary to create a long-term business strategy, where innovation plays a strategic role.

The innovation evaluation model that has been presented in this paper could favor these changes in companies from this sector, because it produces a diagnosis of the situation of each company in relation to their levels of innovation, shows the strengths and weaknesses of each case, and marks the direction in which efforts towards improvement should be directed. In addition, it presents a novelty in this field of study, in view of the absence of any other evaluation model that is especially adapted to macro-construction sector companies, at both a global and a Spanish level.

6.3. Limitations and future research

Although the model has been designed to serve as a global model, applicable to macro-construction sector companies of different countries, it has been applied and tested in the Spanish case. In this sense, it would be possible to apply the model to companies from other countries. To do so, the only requirement would be to form a national-level Expert Panel, in order to analyze the specific characteristics of the macro-construction sector in this country and to take this information into account when adapting and adjusting the weights and the relative importance of each indicator to its own reality. This stage is necessary, as the relative weights of the indicators depend on the characteristics of the macro-construction sector in each country.

Additionally, it would be interesting to apply the model to a larger sample of companies, of different dimensions, belonging to the different subsectors which compose the macro-construction sector. Thus, the question could be considered of whether existing differences in innovative performance, depending on the subsector and company size, may be generalized to the entire macro-sector.

In this sense, future lines of research could be oriented in these two directions. First, the exportation of the model together with its working method to the realities of other countries; and, second, the application of the model to a significantly large sample of companies in the macro-sector, to analyze whether the differences between them are maintained and are in line with the characteristics of the macro-sector nationwide (INE – Spanish National Statistics Institute, 2015b).

7. Lessons learned

Having completed this, it was concluded that a preliminary pilot evaluation test with direct personal contact and support from the evaluator was needed, to validate the evaluation model. To that end, several companies were invited to perform a self-evaluation pilot test, with the objective of checking the behavior of the evaluation model. With this objective in mind, the preliminary evaluation model was distributed to a number of companies by email, followed by a telephone call, through which the project was presented. Perhaps as a consequence of the everyday working conditions of these companies, with insufficient time for activities not directly linked to production, the response rate and the commitment shown to the project

were not very satisfactory at this stage. Therefore, personal contact was established with the companies, through visits to their facilities and meetings with management and by doing so, the results improved considerably. The lessons that have been learned are therefore in that area and stress the importance of personal contact and support from the evaluator in the development of the pilot evaluation process in each company.

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Appendix A. Breakdown of each criterion (CR) in their corresponding indicators (ID)

	Company A	Company B	Company C
Strategy – Organization (CR 1)			
ID 1.1 Innovation Intensity	0.077	0.295	0.268
ID 1.2 UNE 166001 certified innovation project	0.000	0.000	0.000
ID 1.3 UNE 166002 certified R+D+I Management System	0.000	0.000	0.000
ID 1.4 R+D+I Department	0.178	0.000	0.129
ID 1.5 R+D+I corporate budget	0.000	0.214	0.201
ID 1.6 Innovation investment through both economic cycles	0.094	0.097	0.140
Culture (CR 2)			
2.1		0.000	0.148

(*Continued*)

	Company A	Company B	Company C
ID 2.1 0.078	Procedures and channels of communication		
ID 2.2 Incentives to personnel, related to innovation	0.000	0.000	0.499
Staff (CR 3)			
ID 3.1 % of employees dedicated to innovation tasks	0.308	0.406	0.219
ID 3.2 Staff training expenses	0.000	0.175	0.264
ID 3.3 % of employees with university training	0.379	0.288	0.303
ID 3.4 the use of multidisciplinary teams to identify innovations	0.000	0.000	0.112
Relationship with the outside (CR 4)			
ID 4.1 Cooperation with outside research institutions	0.306	0.314	0.371
ID 4.2 Participation in informal projects and research groups	0.089	0.089	0.082
ID 4.3 Public financial support for innovation activities	0.266	0.301	0.270
ID 4.4 Production of intellectual property	0.000	0.094	0.000
Product – Process (CR 5)			
ID 5.1 Introduction of new or improved product/service	0.000	0.618	0.549
ID 5.2 Introduction of process innovations	0.473	0.424	0.555

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