A MODEL FOR SYSTEMATIC INNOVATION IN CONSTRUCTION COMPANIES

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ABSTRACT

The reasons that drive construction companies to innovate, as well as the processes they use, have not yet been fully explored in the specialized literature. This paper describes the “hows” and “whys” behind the push for innovation in a construction company. The research method is founded on a review of current theory and practice, as well as a case study, based on a medium-sized construction company which implemented and certified an innovation management system, as established by the Spanish standard UNE 166002. The studies conducted by the authors over a five-year period generated a set of 18 propositions reflecting an explanatory model of innovation management. This paper reports on the validation of the
model; the results fully corroborate 15 of these propositions. The conclusions of this research are limited by the small amount of experience accumulated to date about the standardization of these systems. Therefore the proposed model should be challenged or improved at a future date with a larger number of companies, more mature in innovation management, and with externally certified systems available.

KEYWORDS: Construction Company; Business Management; Innovation; Process; Standardization

INTRODUCTION

Innovation management within a company is implemented through a series of activities and decisions which increase the value of the products and services offered to external clients or other stakeholders, or that fulfill other strategic business objectives (Ko 2009, Trkman 2010). Its final goal is to strengthen the competitiveness of the company for its long term survival (Evangelista et al. 1997). However, this relationship between innovation and competitiveness is still not clearly understood by construction companies (Winch 1998, Harty 2008). This motive drove the creation of a model to explain the process and reasons which drive innovation management in a construction company, and to identify barriers that impede the adoption of innovative business strategies which would increase the competitiveness of this type of organization.
Modern companies are managed by processes which tend to transform vertical organizations, structured by functions, into horizontal organizations focused on activities which add value to the client (Vanhaverbeke and Torremans 1999). These processes are usually continuous and at least partially recurring in their activities (Tidd et al. 1997, Gann 2000, Gann and Salter 2000); therefore, these companies develop procedures to systematize and simplify them. Davenport (2005) justifies the standardization of processes, indicating that they make the company’s internal and external communications easier; they also allow resource interchangeability, which grants more flexibility, improves the efficiency of the process, and allows benchmarking. Current technologies which support these business processes are suitable for standardization and the exchange of data and information.

Innovation management can be described as a business process which is critical for an organization’s ability to compete (Tidd et al. 1997, Vanhaverbeke and Torremans 1999); it is an extremely complex and uncertain process because of its evolutionary and interactive nature (Veugelers and Cassiman 1999). Gann (2000) highlights the characteristics of companies that manage their production by processes (mainly in the construction sector) where there are additional coordination challenges which impact the knowledge management within the organization and inhibit the innovation ability of these companies. Some authors (Dulaimi 1995, Gann 2000, Gann and Salter 2000, Pellicer et al. 2008) indicate that innovation can be planned, organized, managed and controlled in the construction industry just like any other business process; however, the reality is that many companies produce innovations sporadically, rather than as part of an idea generation process that is methodical and continuous.
There are authors who indicate the low innovation ability in the construction industry which is highly traditional and closely tied to local practices (Serpell 2001, Blayse and Manley 2004, Taylor and Levitt 2004). Other contributions go into great detail about the specifics of innovation in construction (Winch 1998, Gann and Salter 2000). Problems that come up in construction sites require specific solutions or spontaneous inventions (Nam and Tatum 1992). This informal approach to innovation does not take advantage of the benefits of its systematization as a process, which provides added value to clients and other stakeholders involved in the infrastructure life-cycle, as described by Manseau (1998).

One approach that supports innovations and allows its systematization is the adoption of voluntary standards, such as the UNE 166002. The UNE 166002 standard is based on a set of sub-processes focused on generating and documenting a company’s innovation projects. These sub-processes include: (a) technological watch, (b) creativity, (c) planning and executing innovation projects, (d) technology transfer, and (e) protection of results (AENOR 2006, Pellicer et al. 2008, Yepes et al. 2010, Mir and Casadesus 2011). The UNE 166002 standard is based on continuous improvement of processes, which are part of the ISO 9001 standard for quality management (Pellicer et al. 2008). There is specialized literature which supports that adequate quality management in a company improves its ability to innovate (Perdomo-Ortiz et al. 2006 & 2009). Casadesus et al. (2011) confirm that the coordinated application of different management systems standards is beneficial for the company due to the synergies created. The advantages recently obtained by Spanish companies applying and certifying systems to manage innovation, drove Portugal (NP 4457 standard), Chile and México to also incorporate versions which were adapted from these Spanish standards (Teixeira et al. 2009).
This paper presents the final phase of a five-year research project conducted by the authors regarding innovation management. This research has been possible due to the constant collaboration with a medium-sized construction company, as well as the specific collaboration with other companies and professionals from this sector. Prior research included: (1) a complete literature review and the conception of a theoretical framework (Correa et al. 2007); (2) the introduction of the UNE 166000 standards, as well as prior research regarding innovation in the Spanish construction industry (Pellicer et al. 2008); (3) a strategic analysis of a company selected as a case study (Pellicer et al. 2010); (4) the implementation of an innovation management system in that company (Yepes et al. 2010); and (5) the explanation of the model derived from the case study (Pellicer et al. 2012).

The goal of this research is to propose an evidence-based explanatory model of innovation management in a construction company, using a case study methodology. The research contributes evidence which allows construction companies to understand how innovation develops in their companies, the factors it is dependent upon, and its main barriers. Thus, this paper is organized in five sections. First, propositions are created from theoretical and empirical evidence, using case study methodology based on an innovation management model. Second, there is a description of the research method used to validate the propositions. Then the results of the validation are described and discussed, to finalize with conclusions and suggestions for future research.

A MODEL FOR INNOVATION MANAGEMENT
Innovation management includes all the necessary activities to efficiently implement an idea for a product or a process which will increase the ability of the organization to compete (Eaton 2001). Tidd et al. (1997) advise that innovation management should be understood as the generation of the necessary conditions within an organization in which technological, strategic, or organizational changes are made in situations of high uncertainty. Innovation management can be implemented in the construction sector at varying levels, and to a greater or lesser extent (Correa et al. 2007): (a) the national research and development (R&D) system (Gann 1997); (b) within the company (Gann and Salter 2000); (c) in projects or products (Tatum 1987, Nam and Tatum 1992); and (d) throughout the construction process (Kangari and Miyatake 1997).

The process for innovation management in construction companies has been studied by multiple authors. Manseau (1998) encourages industry to adopt a systemic, broad perspective so as to understand and expand innovation in construction. Most theoretical proposals evaluate innovation in construction companies based on the appropriate response to environmental and internal factors, using the reference of the general systems theory. The most noteworthy models, based on literature reviews, are mentioned here.

Manseau (1998), and Seaden and Manseau (2001) propose a general model which is applicable to each sub-sector but focused on the company. It considers the whole infrastructure life-cycle including all the stakeholders and the different types of interactions among them. For Winch (1998), innovation in construction companies comes from the mutual relationship between construction projects and companies. Gann and Salter (2000) develop this idea into a model highlighting six dimensions: companies, supply chains, projects, technology, institutional regulations, and knowledge transfer. Seaden et al. (2003)
proposes linking the environment and business strategy, since both of them affect the
innovative capacity of the organization. Sexton and Barrett (2003) define a model based on
the innovation process, as well as the internal and external context in which it occurs. The
internal context includes business strategy, market positioning, work organization,
technology and human resources; the external strategy includes the various business
environments and their interactions. Dikmen et al. (2005) proposes a systematic model for
innovation made up of five basic elements: objectives, strategies, environmental sources and
barriers, as well as organizational factors.

The model which explains innovation management in construction companies is presented in
Figure 1, and it is aligned with the proposal of Seaden and Manso (2001) regarding
company-focused knowledge systems; they propose that the company is the center of a
network of suppliers, clients, competitors and resources. This model also incorporates
previous proposals of the authors (Correa et al. 2007, Pellicer et al. 2012). Construction
companies generate new ideas which turn into innovation projects. However, the success of
this process rests on a business strategy which is clearly aligned and focused on generating
innovation. The strategy which supports innovation must be solidly supported and integrated
into the business environment, mobilizing all the organizational capabilities of the company
toward reaching its goals. Also, the strategy should embrace the distribution of information
and communication throughout the organization. Therefore, this innovation strategy supports
the results of the innovation projects which impact not only the company but also the
construction projects.

The results of the research focused on a construction company, as well as the observations
and data obtained from other companies and professionals generated 18 propositions that are
shown in Table 1 (Pellicer et al. 2010, 2012). These propositions were organized according to key aspects of the innovation management process (Correa et al. 2007, Pellicer et al. 2012): drivers of innovation, results of innovation, innovation system, business environment, and organizational capabilities (see Figure 1). Table 1 also includes bibliographic references which support the formulation of each one of the propositions in the case study. This qualitative research was developed following the procedure proposed by Yin (2003). The chosen company is referred to as Lambda, so as to not disclose its true identity.

An innovation management system transforms drivers into specific results and benefits. The system is influenced by the business environment and the organizational capabilities of the company. Innovation management begins with the identification of opportunities which are derived from the requirements of the stakeholders (employees, clients, suppliers, and the environment), as well as from difficulties which come up during the construction project. The best ideas are selected by the upper management to become innovation projects. The department responsible for innovation organizes and designates the necessary resources, as well as implements and oversees the projects. These innovations are evaluated and codified, becoming lessons-learned which can be transferred to future projects. The innovation results are applied to construction projects or to the company; these results are a fundamental feedback loop for continuous improvement. This process for innovation management is described in detail in Yepes et al. (2010).
VALIDATION OF THE PROPOSITIONS

The case study research process follows the guidelines proposed by Yin (2003). This process includes six steps: (a) literature review, (b) design of a logical model, (c) data collection, (d) data analysis, (e) report of results, and (f) validation of results. To ensure the quality of the research, Yin (2003) proposes four design tests: (1) construct validity, (2) internal validity, (3) external validity, and (4) reliability. Its application in this research is explained below.

The validity of the constructs was assured using many information sources and generating chains of evidence; both were applied during data collection. Internal validity refers to the causality logic of the qualitative study. According to Yin (2003), this is achieved in two ways: building explanations of the phenomenon being studied (“explanation-building”), and contrasting what the theory predicts with the observed reality (“pattern-matching”). External validity is the main goal of the research discussed in this paper. The reliability was achieved with the development of a protocol prior to this case and a database containing all the information and evidence collected.

As indicated previously, the research process requires an external validity (Yin 2003). This entails corroborating the propositions so the model can be generalized to the universe of construction companies with an innovation management system. To achieve this, interviews were conducted with managers of seven Spanish construction companies which had an innovation management system certified by the UNE 166002 standard (see Table 2). There were a total of eight certified companies at that time, so the sample was considered to be representative. The managers interviewed included directors of the department in charge of
innovation (being four of them also responsible for quality management), with a minimum experience of 15 years in the construction sector and university degrees in civil engineering (in 4 cases) or industrial engineering (3 cases). These interviews were structured in three stages:

1. Obtaining basic data describing the company (summarized in Table 2).
2. Validating the propositions with a questionnaire survey (included in the Appendix).
3. Using a guided interview, lasting a minimum of 120 minutes per company, to explore the barriers and benefits of the innovation process.

Eight directors of the Lambda company were also interviewed (internal validation) as well as nine construction industry experts, who were independent of this company. Managers of the Lambda company were all department directors with a minimum of ten years of experience in the construction sector; seven of them were civil engineers and one was a chemical engineer. The experts include representatives from different organizations: material supplier, consultant, real estate developer, government, city council, professional association, certifying body, and university professor; they had a minimum of 20 years of experience working in the sector. Seven of them were civil engineers and two of them were architects. The interview was tested and refined with a pilot interview done with three university professors, who had more than 20 years of professional experience in the construction industry.
The degree of acceptance of these propositions resulted from the analysis of the responses from the groups interviewed: certified companies (7), managers from Lambda (8) and, experts (9). The appendix includes the complete questionnaire.

The possible responses were scaled so that the mean could be computed for each group. Questions with possible answers of "high," "medium," and "low" received a value of 2, 1, and 0, respectively. However, answers to questions with alternatives such as “strongly agree,” “agree,” "disagree," and "strongly disagree" had designated values of 2, 1, -1, and -2, respectively. Using these values as a reference, an average was calculated for each proposition and group. A proposition was rated as “strong” (S) when the average was over 1.3, and "weak" (W) when the average was less than 0.7. For intermediate situations, the proposition was categorized with an evaluation of “medium” (M).

RESULTS

All the propositions received a “strong” rating by all the groups that were interviewed, with the exception of the propositions shown in Table 3. This table indicates the specific proposition (by code) and the level of support received from each interviewed group: strong, medium or weak. The results are shown in a graph (Figure 1) as follows: (a) strong (bold text and heavy line); (b) medium (regular text and heavy line); and (c) weak (cursive text and narrow line).

<TABLE 3 HERE>
Table 3 shows that the results obtained by the companies and Lambda’s managers are in full agreement. This indicates an alignment between the company’s reality and its managers’ views regarding innovation. However, there are discrepancies with the experts, since they valued four of the propositions with a lower rating, and only proposal P4 with a higher rating (medium). It is worth noting that this proposition P4 was the only one that had a weak support from the group of certified companies.

Other interesting results were obtained from the interviews that were not directly related to the model’s evaluation, as highlighted below:

- Four companies indicated that certification bodies associate innovation with scientific research. This uncertainty regarding the scope of the standard makes it difficult to justify simpler technological innovations.
- One aspect which was reiterated by companies is the conflict which occurs when clients’ needs are different than the standard or customary construction practices.
- There is evidence linking innovation, quality and knowledge management. Two of the companies used teams of specialists to implement innovation on site. If these innovations provided results, they generated new procedures that were added to the quality management system of the company with a feedback loop of lessons learned.
- Companies highlight the need for, and importance of, technological watch for the generation of innovative ideas, in spite of its difficulty.
DISCUSSION

An analysis of the results shows that the proposed model is highly supported, since 15 of the 18 propositions were strongly rated; two had a medium validation, and only one had a weak validation. Figure 1 includes a graphic representation of the results; they were supported by managers of external companies and those of the company under study. A review of this section focuses mainly on analyzing the propositions which were assessed as medium and weak, and also analyzing cases where there was a slight discrepancy between the response of the external experts and the managers of the construction companies.

There is overall consensus regarding the influence of the drivers of innovation; however, the influence of the outputs is not as clear, not only for the construction company, but also for its projects; the only exception is the increase in the technological capabilities presented in proposition P_{14}. Proposition P_4, indicates that “by adopting an innovation management system, innovation follows a previously defined strategy”; it showed a weak acceptance level in spite of its importance in the literature (Nam and Tatum 1992, Eaton 2001, Seaden et al. 2003, Sexton & Barrett 2003, Taylor & Levitt 2004, Hartmann 2006, Lim et al. 2010). It is difficult to draw a cause-effect explanation between adopting strategies focused on innovation through a management system, and achieving innovative results. Companies do not acknowledge the existence of a previous and specific strategy for innovation. However, this has not been a barrier to innovation, coming from companies that have certified their innovation management system. Therefore, there are informal business strategies of innovation that exist in non-mature stages of innovation management processes.
A second level of discrepancy is reflected in propositions P\textsubscript{15} and P\textsubscript{16}. Both the companies interviewed, as well as the Lamda managers and the experts consulted, do not clearly perceive a relationship between the adoption of an innovation management system and the increase in the construction company’s ability to compete (P\textsubscript{15}). This perception is also evident in other areas of business management where the simple certification of a quality management system with the ISO 9001 standard does not guarantee an increase in the company's ability to compete. While the adoption of an innovation management system helps to improve competitiveness of a construction company, this measure seems insufficient, on its own to reach this final objective. Proposition P\textsubscript{16}, which states that “the certification of an innovation project improves the results of construction projects,” was not overwhelming confirmed. There was a weak relationship expressed by the experts, versus the average of the other groups. One possible interpretation comes from the financial results demanded in the short term from projects. Innovation generates benefits, which are not just profit; this benefit can expand to the entire organization with an adequate knowledge management system. There are taxes, organizational and competitive benefits which are sometimes difficult to express as profit for a given construction project. While it is clear that innovation contributes to achieving the goals of a construction company and its construction projects, the short run may distort the visibility of the cause-effect relationship between innovation and financial results. This distortion is accentuated when the success of a construction project is subjected to other factors than innovation.

The third level of disagreement is where experts differ regarding the internal motivation of the innovation management process. In this sense, proposition P\textsubscript{2} says that “construction companies innovate to meet client requirements.” This may be due to the close relationship which construction companies have with their clients; a relationship which the experts do not
have. Even though there are other sources of innovation, it is clear that client requirements are one of the most important reasons to innovate. This small discrepancy between the experts and the rest of the groups is also seen in propositions P7 and P17. The first states that “the implementation of an innovation management system improves knowledge management.” Experts are not as strongly in agreement with this proposition, possibly because they do not have the experience of the certified construction companies, where simply standardizing innovation has allowed them to open vertical and horizontal communication channels in the company, greatly influencing the flow of information and knowledge. Also, the experts did not consider managers’ support of innovation to be decisive. This vision that competitive strategy based on innovation should receive the support of upper management is a fact clearly viewed differently by the construction companies. This may be somewhat minimized in the experts’ opinion, since they are more likely to emphasize the influence of technical personnel on topics related to innovation.

Therefore, the strong support of the propositions that outline the model allows clarifying the process and reasons which drive innovation management in construction companies. The discrepancies exist mainly for propositions P4, P15 and P16, and they may be explained by the lack of cumulative experience in innovation processes of these companies within the outline of standardized management. Moreover, the lack of visibility of long term competitive advantages is diminished within the organization when innovation processes are based on informal strategies.
CONCLUSIONS

This paper presents the validation of an innovation management model for construction companies; it is based on research conducted using a case study of a medium-sized company, with the additional collaboration of other companies and professionals working in the Spanish construction sector. This entailed having 18 propositions reviewed by managers of companies, which are externally certified in innovation management, managers of company under study, and independent experts. The result was a broad consensus between the different groups interviewed, and a strong support for 15 of the propositions presented. As a result of this research, it was possible to conclude that:

• Technical problems in construction projects, client requirements and upper management are the strongest drivers of innovation in construction companies.
• Construction companies mainly innovate through processes and their related products.
• Innovation opportunities are identified as a result of examination of the internal processes of the company, as well as the construction projects and the environment.
• Identifying, developing and transferring an innovative solution requires the integration of multiple disciplines:
  ✓ Environment observation, including technological watch, in order to look for opportunities to innovate, feasible solutions and technological partners who add value to the innovation process.
  ✓ Knowledge management in the organization can transfer findings to other projects, whether they are related to construction or innovation.
  ✓ The ability to detect requirements from the demanding clients.
• Collaboration with technological partners and management of multidisciplinary teams are necessary conditions to have innovation in construction companies.
The main benefit of innovation management is an increase in technical capability. The implementation of an innovation management system can benefit from a quality management system already in place.

The proposition with the least support states that “by adopting an innovation management system, innovation follows a previously defined strategy”; this can happen because of the existence of informal innovation strategies at times when innovation management is not mature yet. Besides, it is not clearly perceived that there is a connection between the adoption of an innovation management system and an increase in the competitiveness of the construction company. This situation may be due to the fact that, when the research was conducted, these processes were in their earlier stages of implementation. Also, while companies clearly agree, the experts do not show the same appreciation of the importance of client demands, the influence of management personnel on innovation, or the positive impact of innovation on knowledge management.

Finally, the impact of the time variable on the results and the local determining factors are aspects that should be analyzed more in depth in future research, which is already underway. On the one hand, there is research going on regarding multiple cases of Chilean construction companies to contrast the level of maturity of innovation management in an environment which is different than the one already analyzed. On the other hand, there is a broader reaching survey of Spanish construction companies which have already certified their innovation management processes. This will help to corroborate or improve the proposed model.
ACKNOWLEDGMENTS

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APPENDIX: QUESTIONNAIRE

1. Construction companies develop innovation projects with the goal of (indicate if it is “high,” “medium,” or “low”): (a) accessing new markets or obtaining a higher market share; (b) resolving technical problems in the construction project (P1); (c) responding to client requirements (P2); (d) increasing the quality of the infrastructure; (e) improving the ability of the company to compete (P3); (f) Other.

2. Has your company done any of the following types of innovation? (indicate “high,” “medium,” or “low”) (P6): (a) Product; (b) Process; (c) Organizational; (d) Marketing.

3. The following propositions refer to aspects of an innovation management system (indicate your level of agreement as “strongly agree,” “agree,” “disagree,” or “strongly disagree”): (a) The implementation of an innovation management system improves knowledge management in a construction company (P7); (b) Organizations that adopt an
innovation management system understand better their external environment (P8); (c) Having a certified quality system in accordance with the UNE 9001 standard makes it easier to implement an innovation management system (P10); (d) Innovation requires the participation of multidisciplinary teams (P13); (e) The active involvement of the site manager in the innovation process has a significant impact on innovation results (P12); (f) The certification of an innovation project improves the results at the construction site (P16); (g) The control of internal processes (production, management, etc.) is fundamental for innovation (P9); (h) Having a system for innovation management facilitates subcontracting specialized companies that add value to the innovation process (P11); (i) Innovation systems are implemented in construction companies due to the need to create positive differentiation that clients will perceive (P5); (j) Adopting a system of innovation management increases the construction company’s ability to compete (P15); (k) Adopting an innovation management system increases the technical capacity of a construction company (P14); (l) A construction company requires an innovation management system to innovate as part of a predefined strategy (P4).

4. What are the primary barriers to innovation? (indicate if “high,” “medium” or “low”): (a) Prioritization of productive processes (P18); (b) Lack of incentives; (c) Lack of an appropriate culture; (d) Underestimation of I+D+i as a competitive strategy (P17); (e) Lack of leadership in I+D+i (P17); (f) Lack of personnel trained in I+D+i; (g) Other.
REFERENCES


<table>
<thead>
<tr>
<th>CODE</th>
<th>PROPOSITION</th>
<th>REFERENCES</th>
</tr>
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<tbody>
<tr>
<td>P₁</td>
<td>Innovation comes from technical problems that arise in project execution at the construction site</td>
<td>Slaughter (1993), Nam and Tatum (1997), Winch (1998)</td>
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<td>P₂</td>
<td>Construction companies innovate to meet client requirements</td>
<td>Nam and Tatum (1997), Mitropoulos and Tatum (2000), Blayse and Manley (2004)</td>
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<td>P₃</td>
<td>Senior management propels innovation projects to improve the competitiveness of the company</td>
<td>Tatum (1987), Winch (1998), Slaughter (2000)</td>
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<td>P₄</td>
<td>By adopting an innovation management system, innovation follows a previously defined strategy</td>
<td>Gann and Salter (2000), Seaden et al. (2003), Stewart and Fenn (2006)</td>
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<tr>
<td>P₅</td>
<td>By implementing an innovation management system, the company responds to the need to generate positive differentiation that is valued by clients</td>
<td>Slaughter (2000), Sexton and Barrett (2003), Van den Ven and Poole (2005)</td>
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<td>P₇</td>
<td>The implementation of an innovation management system improves knowledge management</td>
<td>Winch (1998), Parikh (2001), Hardie et al. (2005)</td>
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<td>P₈</td>
<td>Construction companies that adopt an innovation management system understand their environment better</td>
<td>Tatum (1987), Pries and Janszen (1995), Seaden et al. (2003)</td>
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<td>P₉</td>
<td>The control of internal processes (mainly production and management) constitutes a basic source for generating innovative ideas</td>
<td>Dulaimi (1995), Stewart and Fenn (2006), Kornish and Ulrich (2011)</td>
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<td>The existence of a quality system certified by the ISO 9001 standard facilitates the implementation of an innovation management system</td>
<td>Prajodo and Sohal (2006), Santos-Vijande and Alvarez-Gonzalez (2007), Casadesus et al. (2011)</td>
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<td>P₁₁</td>
<td>The existence of an innovation management system stimulates subcontracting to specialized companies and adds value to the innovation process</td>
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<td>The active involvement of the site manager in the innovation process has a significant impact on the results of innovation</td>
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<td>Innovation in construction requires the participation of multidisciplinary teams</td>
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<td>P₁₆</td>
<td>The certification of an innovation project improves the results of construction projects</td>
<td>Marimon and Cristobal (2005), Coelho and Matias (2010), Vea et al. (2010)</td>
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<td>P₁₇</td>
<td>Innovation in construction is delayed when senior management does not perceive it as a competitive strategy</td>
<td>Nam and Tatum (1997), Slaughter (2000), Blayse and Manley (2004)</td>
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Table 1. Propositions of the case study and main supportive references (Pellicer et al. 2012)
## Table 2. Basic characteristics of the companies

<table>
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<tr>
<th>Company</th>
<th>No. Employees</th>
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<th>No. Projects with External Certification</th>
<th>No. Projects under Execution</th>
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Table 3. Discrepancies among the level of validation of the propositions