A MODEL FOR SYSTEMATIC INNOVATION IN CONSTRUCTION COMPANIES

Eugenio Pellicer[1], Víctor Yepes[2], Christian L. Correa[3] and Luis F. Alarcón[4]

[1]*Associate Professor*, *School of Civil Engineering*, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain, tel.: +34.963.879.562, fax: +34.963.877.569, email: pellicer@upv.es

[2]*Associate Professor*, ICITECH, Universitat Politècnica de València, Camino de Vera s/n, 46022 Valencia, Spain, email: vyepesp@upv.es

[3]*Assistant Professor*, *Faculty of Engineering Sciences*, Universidad Católica del Maule, San Miguel 3605, Talca, Chile, email: clcorrea@ucm.cl

[4]*Professor*, GEPUC, Pontificia Universidad Católica de Chile, Vicuña Mackenna 4860, Santiago, Chile, email: *lalarcon@ing.puc.cl*

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 Manseau (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.

<TABLE 1 HERE>

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).

<FIGURE 1 HERE>

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.

<TABLE 2 HERE>

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 P_4 with a higher rating (medium). It is worth noting that this proposition P_4 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_{15} and P_{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_{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_{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_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 P_7 and P_{17}. 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 P_4, P_{15} and P_{16}, 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

This research was partially funded by Universidad Católica del Maule (project MECESUP-UCM0205), the Spanish Ministry of Infrastructure (project 2004-36) and Universidad Politécnica de Valencia (contract UPV-20050921). The authors would like to thank Ricardo Lacort, Francisco J. Vea, and Manuel Civera for their collaboration and support, and José C. Teixeira for his advice. Likewise, the authors thank the anonymous reviewers for their suggestions and constructive comments.

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 (P_1); (c) responding to client requirements (P_2); (d) increasing the quality of the infrastructure; (e) improving the ability of the company to compete (P_3); (f) Other.

2. Has your company done any of the following types of innovation? (indicate "high," "medium," or "low") (P_6): (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 (P_7); (b) Organizations that adopt an

innovation management system understand better their external environment (P_8); (c) Having a certified quality system in accordance with the UNE 9001 standard makes it easier to implement an innovation management system (P_{10}); (d) Innovation requires the participation of multidisciplinary teams (P_{13}); (e) The active involvement of the site manager in the innovation process has a significant impact on innovation results (P_{12}); (f) The certification of an innovation project improves the results at the construction site (P_{16}); (g) The control of internal processes (production, management, etc.) is fundamental for innovation (P_9); (h) Having a system for innovation management facilitates subcontracting specialized companies that add value to the innovation process (P_{11}); (i) Innovation systems are implemented in construction companies due to the need to create positive differentiation that clients will perceive (P_5); (j) Adopting a system of innovation management increases the construction company's ability to compete (P_{15}); (k) Adopting an innovation management system increases the technical capacity of a construction company (P_{14}); (l) A construction company requires an innovation management system to innovate as part of a predefined strategy (P_4).

4. What are the primary barriers to innovation? (indicate if "high," "medium" or "low"): (a) Prioritization of productive processes (P_{18}); (b) Lack of incentives; (c) Lack of an appropriate culture; (d) Underestimation of I+D+i as a competitive strategy (P_{17}); (e) Lack of leadership in I+D+i (P_{17}); (f) Lack of personnel trained in I+D+i; (g) Other.

REFERENCES

AENOR (2006) UNE 166002/2006. *R&D&i management: requirements for R&D&i management systems*. AENOR, Madrid.

Blayse, A.M., Manley, K. (2004) "Key influences on construction innovation". *Construction Innovation*, 4, 143-154.

Bossink, B.A.G. (2004) "Managing drivers of innovation in construction networks". *Journal of Construction Engineering and Management*, 130(3), 337-345

Casadesus, M., Karapetrovic, S., Heras, I. (2011) "Synergies in standardized management systems: some empirical evidence". *The TQM Journal*, 23(1), 73-86.

Coelho, D.A., Matias, J.C.O. (2010) "An empirical study on integration of the innovation management systems (MS) with other MSs within organizations". *Proceedings of ERIMA*, pp. 5-13.

Correa, C.L., Pellicer, E., Yepes, V. (2007) "Factores determinantes y propuestas para la gestión de la innovación en las empresas constructoras". *Revista Ingeniería de Construcción*, 22(1), 5-14.

Davenport, T.H. (2005) "The coming commoditization of processes". *Harvard Business Review*, 83(6), 101-108.

Dikmen, I., Birgonul, M.T., Artuk, S.U. (2005) "Integrated framework to investigate value innovations". *Journal of Management in Engineering*, 21(2), 81-89.

Dulaimi, M. (1995) "The challenge of innovation in construction". *Building Research and Information*, 23(2), 106-109.

Eaton, D. (2001) "A temporal typology for innovation within the construction industry". *Construction Innovation*, 1(3), 165-179.

Evangelista, R., Perani, G., Rapiti, F., Archibugi, D. (1997) "Nature and impact of innovation in manufacturing industry: some evidence from the Italian innovation survey". *Research Policy*, 26 (4-5), 521-536.

Gann, D.M. (1997) "Should governments fund construction research?". *Building Research & Information*, 25, 257- 267.

Gann, D.M. (2000) *Building innovation. Complex constructs in a changing world*. Thomas Telford Publishing, London.

Gann, D.M., Salter A. (2000) "Innovation in project-based, service-enhanced firms: the construction of complex products and systems". *Research Policy*, 29 (7-8), 955-972.

Hardie, M.P., Miller, G., Manley, K.J., McFallan, S. (2005) "Experience with the management of technological innovations within the Australian construction industry". *Proceedings of the International Conference on Management of Engineering and Technology*, 244-250.

Hartmann, A. (2006) "The context of innovation management in construction firms". *Construction Management and Economics*, 24(6), 567-578.

Harty, C. (2008) "Implementing innovation in construction: contexts, relative boundedness and actor-network theory". *Construction Management and Economics*, 26, 1029–1041.

Kangari, R., Miyatake, Y. (1997) "Developing and managing innovative construction technologies in Japan". *Journal of Construction Engineering and Management*, 123(1), 72-78.

Ko, R.K.L. (2009) "A computer scientist's introductory guide to business process management (BPM)". *Crossroads*, 15(4), 11-18.

Kornish, L.J., Ulrich, K.T. (2011) "Opportunity spaces in innovation: Empirical analysis of large sample of ideas". *Management Science*, 57(1), 107-128.

Lim, J.N., Schultmann, F., Ofori, G. (2010) “Tailoring competitive advantages derived from innovation to the needs of construction firms”. *Journal of Construction Engineering and Management*, 136(5), 568-580.

Manseau, A. (1998) “Who cares about overall industry innovativeness?”. *Building Research and Information*, 26(4), 241-245.

Marimon, F., Cristobal, E. (2005) “A study on ISO 9000 certification process: Consultant profiles and company behaviour”. *Managing Service Quality*, 15(3), 290–305.

Mir, M., Casadesus, M. (2011) “Normas para la gestión de la innovación: Un análisis comparativo”. DYNA, 86(1), 49-58.

Mitropoulos, P., Tatum, C.B. (2000) “Forces driving adaptation of new information technologies”. *Journal of Construction Engineering and Management*, 126(5), 340-348.

Nam, C.H., Tatum, C.B. (1992) “Strategies for technology push: Lessons from construction innovations”. *Journal of Construction Engineering and Management*, 118, 507-524.

Nam, C.H., Tatum, C.B. (1997) “Leaders and champions for construction innovation”. *Construction Management and Economics*, 15(3), 259-270.

Parikh, M. (2001) “Knowledge management framework for high-tech research and development”. *Engineering Management Journal*, 13(3), 27-33.

Park, M.S., Nepal, M.P., Dulaimi, M.F. (2004) “Dynamic modelling for construction innovation”. *Journal of Management in Engineering*, 20(4), 171-177.

Pellicer, E., Correa, C.L., Yepes, V., Alarcón, L.F. (2012) “Organizational improvement through standardization of the innovation process in construction firms”. *Engineering Management Journal*, 24(2), 40-53.

Pellicer, E., Yepes, V., Correa, C.L., Martinez, G. (2008) "Enhancing R&D&i through standardization and certification: The case of the Spanish construction industry". *Revista Ingeniería de Construcción*, 23(2), 112-119.

Pellicer, E., Yepes, V., Rojas, R.J. (2010) "Innovation and competitiveness in construction companies: A case study". *Journal of Management Research*, 10(2), 103-115.

Perdomo-Ortiz, J., Gonzalez-Benito, J., Galende, J. (2006) "Total quality management as a forerunner of business innovation capability". *Technovation*, 26, 1170–1185.

Perdomo-Ortiz, J., Gonzalez-Benito, J., Galende, J. (2009) "The intervening effect of business innovation capability on the relationship between total quality management and technological innovation". *International Journal of Production Research*, 47(18), 5087-5107.

Prajogo, D.I., Sohal, A.S. (2006) "The integration of TQM and technology/R&D management in determining quality and innovation performance". *Omega*, 34(3), 296-312.

Pries, F., Janszen, F. (1995) "Innovation in the construction industry: The dominant role of the environment". *Construction Management and Economics*, 13(1), 43-51.

Santos-Vijande, M.L., Alvarez-Gonzalez, L.I. (2007) "Innovativeness and organizational innovation in total quality oriented firms: The moderating role of market turbulence". *Technovation*, 27(9), 514-532.

Seaden, G., Guolla, M., Doutriaux, J., Nash, J. (2003) "Strategic decisions and innovation in construction firms". *Construction Management and Economics*, 21(6), 603-612.

Seaden, G., Manseau, A. (2001) "Public policy and construction innovation". *Building Research and Information*, 29(3), 182-196.

Serpell, A. (2001) "Innovation in the Chilean construction industry: Public policy instruments". In: *Innovation in Construction: An international Review of Public Policy* (Eds. A. Manseau and G. Seaden), Spon Press, London, 111-128.

Sexton, M., Barrett, P. (2003) "A literature synthesis of innovation in small construction firms: insights, ambiguities and questions". *Construction Management and Economics*, 21(6), 613-622.

Slaughter, S. (1993) "Innovation and learning during implementation: A comparison of user and manufacturer innovations". *Research Policy*, 22 (1), 81-95.

Slaughter, S. (2000) "Implementation of construction innovations". *Building Research and Information*, 28(1), 2–17.

Stewart, I., Fenn, P. (2006) "Strategy: the motivation for innovation". *Construction Innovation*, 6, 173-185.

Tatum, C.B. (1987) "Process of innovation in construction firms". *Journal of Construction Engineering and Management*, 113(4), 648-663.

Taylor, J.E., Levitt, R.E. (2004) "Understanding and managing innovations in project-based industries". *Innovations – Project Management Research 2004*. Project Management Institute, New York.

Teixeira, J.C, Pellicer, E., Pedro, P., Yepes, V. (2009) "Fostering research, development and innovation in construction companies". *CIB Joint International Symposium 2009 – Construction Facing Worldwide Challenges*, Dubrovnik, 27 September-1 October.

Tidd, J., Bessant, J., Pavitt, K. (1997) *Managing innovation: integrating technological, market and organizational change*. John Wiley & Sons, Chichester, UK.

Trkman, P. (2010) "The critical success factors of business process management". *International Journal of Information Management*, 30, pp.125-134.

Van de Ven, A.H., Poole, M.S. (2005) “Alternative approaches for studying organizational change”. *Organization Studies*, 26(9), 1377-1404.

Vanhaverbeke, W., Torremans, H. (1999) “Organizational structure in process-based organizations”. *Knowledge and Process Management*, 6(1), 41–52.

Veugelers, R., Cassiman, B. (1999) “Make and buy in innovation strategies: evidence from Belgian manufacturing firms”. *Research Policy*, 28 (1), 63-80.

Wagner, S.M. (2003) “Intensity and managerial scope of supplier integration”. *Journal of Supply Chain Management*, 39(4), 4-15.

Winch, G.M. (1998) “Zephyrs of creative destruction: understanding the management of innovation in construction”. *Building Research and Information*, 26(5), 268-279.

Yepes, V., Pellicer, E., Correa, C.L., Alarcon, L.F. (2010) “Implementing a system for achieving innovation opportunities in a construction company”. *Proceedings of the CIB World Congress 2010 – Building a Better World*, 319-330.

Yin, R. (2003) *Case study research: Design and methods*, 3rd Ed. Sage Publications, London.

CODE	PROPOSITION	REFERENCES
P_1	Innovation comes from technical problems that arise in project execution at the construction site	Slaughter (1993), Nam and Tatum (1997), Winch (1998)
P_2	Construction companies innovate to meet client requirements	Nam and Tatum (1997), Mitropoulus and Tatum (2000), Blayse and Manley (2004)
P_3	Senior management propels innovation projects to improve the competitiveness of the company	Tatum (1987), Winch (1998), Slaughter (2000)
P_4	By adopting an innovation management system, innovation follows a previously defined strategy	Gann and Salter (2000), Seaden et al. (2003), Stewart and Fenn (2006)
P_5	By implementing an innovation management system, the company responds to the need to generate positive differentiation that is valued by clients	Slaughter (2000), Sexton and Barrett (2003), Van den Ven and Poole (2005)
P_6	Construction companies generally innovate in processes	Gann and Salter (2000), Sexton and Barrett (2003)
P_7	The implementation of an innovation management system improves knowledge management	Winch (1998), Parikh (2001), Hardie et al. (2005)
P_8	Construction companies that adopt an innovation management system understand their environment better	Tatum (1987), Pries and Janszen (1995), Seaden et al. (2003)
P_9	The control of internal processes (mainly production and management) constitutes a basic source for generating innovative ideas	Dulaimi (1995), Stewart and Fenn (2006), Kornish and Ulrich (2011)
P_{10}	The existence of a quality system certified by the ISO 9001 standard facilitates the implementation of an innovation management system	Prajodo and Sohal (2006), Santos-Vijande and Alvarez-Gonzalez (2007), Casadesus et al. (2011)
P_{11}	The existence of an innovation management system stimulates subcontracting to specialized companies and adds value to the innovation process	Blayse and Manley (2004), Wagner (2006)
P_{12}	The active involvement of the site manager in the innovation process has a significant impact on the results of innovation	Park et al. (2004), Dulaimi et al. (2005)
P_{13}	Innovation in construction requires the participation of multidisciplinary teams	Gann and Salter (2000), Bossink (2004)
P_{14}	The adoption of an innovation management system improves the company's technological capabilities	Tatum (1987), Nam and Tatum (1992), Slaughter (2000)
P_{15}	The adoption of an innovation management system improves the company's competitiveness	Tatum (1987), Nam and Tatum (1992), Mitropoulus and Tatum (2000)
P_{16}	The certification of an innovation project improves the results of construction projects	Marimon and Cristobal (2005), Coelho and Matias (2010), Vea et al. (2010)
P_{17}	Innovation in construction is delayed when senior management does not perceive it as a competitive strategy	Nam and Tatum (1997), Slaughter (2000), Blayse and Manley (2004)
P_{18}	The prioritization of production processes hinders the identification of innovation opportunities	Tatum (1986), Pries and Janszen (1995), Gann and Salter (2000)

Table 1. Propositions of the case study and main supportive references (Pellicer et al. 2012)

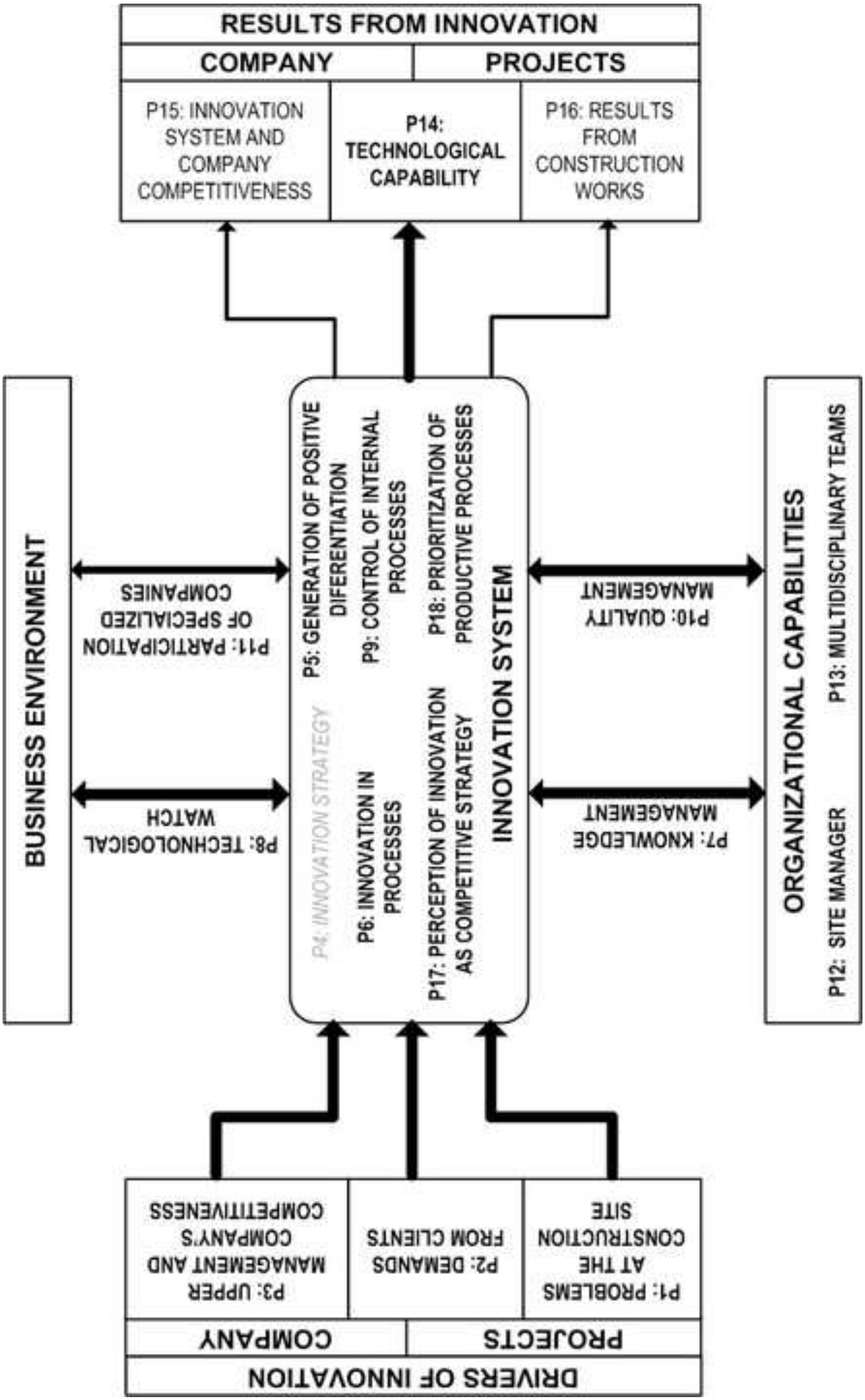
Company	Average Values (data from 2007)				
	No. Employees	Turnover (millions of Euros)	Investment in R&D (thousands of Euros)	No. Projects with External Certification	No. Projects under Execution
Lambda	430	488	200	1	3
A	3,100	2,600	18,000	20	28
B	2,200	900	4,000	12	12
C	7,000	2,700	18,500	25	62
D	15,000	3,500	1,500	1	6
E	80	60	5	0	4
F	500	190	300	3	5
G	500	150	2,000	0	8

Table 2. Basic characteristics of the companies

	P_2	P_4	P_7	P_{15}	P_{16}	P_{17}
Companies	**S**	*W*	**S**	M	M	**S**
Lambda	**S**	*W*	**S**	M	M	**S**
Experts	M	M	M	M	*W*	M
AVERAGE	**S**	*W*	**S**	M	M	**S**

Table 3. Discrepancies among the level of validation of the propositions

Figure 1


RESULTS FROM INNOVATION
COMPANY
PROJECTS
P15: INNOVATION SYSTEM AND COMPANY COMPETITIVENESS
P14: TECHNOLOGICAL CAPABILITY
P16: RESULTS FROM CONSTRUCTION WORKS
BUSINESS ENVIRONMENT
P11: PARTICIPATION OF SPECIALIZED COMPANIES
P8: TECHNOLOGICAL WATCH
P5: GENERATION OF POSITIVE DIFERENTIATION
P4: INNOVATION STRATEGY
P9: CONTROL OF INTERNAL PROCESSES
P6: INNOVATION IN PROCESSES
P18: PRIORITIZATION OF PRODUCTIVE PROCESSES
P17: PERCEPTION OF INNOVATION AS COMPETITIVE STRATEGY
INNOVATION SYSTEM
P10: QUALITY MANAGEMENT
P7: KNOWLEDGE MANAGEMENT
ORGANIZATIONAL CAPABILITIES
P13: MULTIDISCIPLINARY TEAMS
P12: SITE MANAGER
P3: UPPER MANAGEMENT AND COMPANY'S COMPETITIVENESS
P2: DEMANDS FROM CLIENTS
P1: PROBLEMS AT THE CONSTRUCTION SITE
COMPANY
PROJECTS
DRIVERS OF INNOVATION