

*La gestión del conocimiento
en el sector de la
construcción: estado del
arte y evolución de la
investigación*

Knowledge management in the construction industry: state of the art and trends in research



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Resumen

Esta investigación realiza una revisión sistemática de las contribuciones científicas realizadas hasta el momento en el campo de la gestión del conocimiento en la construcción y establecer la influencia que tiene la gestión del conocimiento en las empresas de este sector. Para alcanzar este objetivo, este artículo presenta los resultados obtenidos de un estudio bibliométrico que desarrolla un análisis cuantitativo y cualitativo del estado actual de la gestión del conocimiento en las empresas del sector de la construcción. El método de investigación se dividió en las siguientes etapas: aproximación preliminar a la bibliografía, establecimiento de las estrategias de búsqueda, selección y clasificación

de los artículos, análisis cuantitativo y discusión de los artículos relevantes. Se identificaron tres factores principales: generación de conocimiento, transferencia de conocimiento y uso y explotación del conocimiento; también se identificaron cinco aspectos complementarios: cultura, innovación, calidad, tecnologías de la información y factores humanos. Los resultados muestran que, en general, las empresas del sector no desarrollan una estrategia coordinada de gestión del conocimiento, por lo que debería llevarse a cabo un mayor esfuerzo con objeto de mejorar la competitividad empresarial, especialmente en el uso y explotación del conocimiento generado en las obras.

Palabras clave: Estudio bibliométrico; sector de la construcción; gestión del conocimiento; transferencia de conocimiento; aprendizaje organizativo.

Abstract

This research systematically reviews the scientific contributions published so far in the field of knowledge management in construction and to establish the influence of knowledge management in the companies of this sector. To this end, this paper describes the results obtained from a bibliometric study that involved a quantitative and a qualitative analysis of the current state of knowledge management of companies in the construction industry. The research method was divided into the following stages: preliminary literature approach, establishment of search strategies, selection and classification

of papers, quantitative analysis, and discussion of relevant papers. Three main factors were identified: generation of knowledge, knowledge transfer, and use and exploitation of knowledge; five complementary facets were also identified: culture, innovation, quality, information technology, and human factors. Results show that, overall, companies in this sector have no coordinated knowledge management strategy, and that they must still make a greater effort to improve business competitiveness, especially in the use and exploitation of knowledge generated at the worksite.

Key words: *Bibliometric analysis, construction industry; knowledge management; knowledge transfer; organizational learning.*

1. Introduction

There are several peculiarities that distinguish construction from other industries. Perhaps the most noteworthy of these is that construction firms produce and manage by projects, which are based on temporary coalitions of different organizations coming together to meet particular targets in a given timeframe (Pellicer et al., 2009). The temporary nature of projects makes it difficult to transfer knowledge from one to another as work teams are continuously reorganized. Further, their episodic nature makes it difficult to capture, store and later exploit this knowledge (Gann and Salter, 2000). If it is accepted that one of the primary objectives of any business is to survive, then business survival means obtaining competitive advantages. Thus, knowledge is an essential resource for organizations because it can provide competitive advantages, if effectively utilized (Alvarado et al., 2009). It may be stated that the construction sector is knowledge intensive as its activities require a high level of expert knowledge and know-how to solve the problems that professional encounter (Carrillo et al., 2004; Alvarado et al., 2009; Dave and Koskela, 2009).

The competitiveness of firms is highly dependent on individuals and organizations (Peña et al., 2006); organizations that form part of the construction industry need to develop their capacity to learn and create knowledge in order to survive, using the experience and intellectual capacity of the individuals who work for them (Ferrada and Serpell, 2009). For this reason, employees and collaborators must be considered the most valuable resource of a firm, and companies ought to provide the best possible environment for knowledge to be adequately developed (Camisón, 2002).

Knowledge management is an unavoidable challenge for firms today since it is vital for competitiveness, intellectual capital and the intangible assets of the organization (Camisón, 2002). In the case of the construction sector, this affirmation is even more accurate (Pellicer et al., 2009). These businesses need to integrate the knowledge acquired by their team members in continuous processes, in such a way as to guarantee learning, the coherence of the knowledge and, as a result, the survival of the organization (Gann and Salter, 2000). The particular characteristics of the sector mean that work previously done must be repeated because of errors in communication and the absence of organizational learning (Carrillo et al., 2004). Construction professionals should consider their past experience as an asset, with an open perspective, which allows them to incorporate new ideas to improve the quality and productivity of their activities in addition to innovating faster (Anumba et

al., 2005). As indicated by Ferrada and Serpell (2009), this is not possible in the construction sector without appropriate knowledge management.

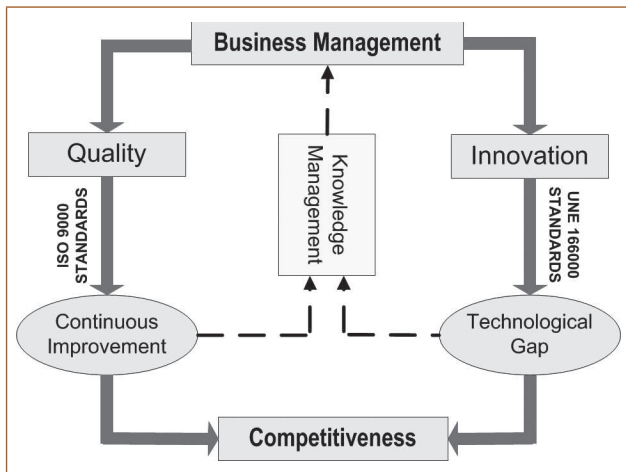
Having established the problem, this study systematically reviews the scientific contributions related to knowledge management in construction. The study is carried out through a bibliometric search of relevant scientific publications and a subsequent quantitative and qualitative analysis of the results produced. All of this analysis is based on a classification of the main factors that constitute knowledge management. This approach is distinct from that of traditional literature reviews, also called narratives, in which the difficulty of the review increases if the number of empirical studies grows exponentially.

2. Knowledge Management

A learning organization is not only one with the capacity to create, capture and transfer knowledge but it is one which modifies its behavior in order to reflect new knowledge and experiences (Garvin, 1993). This applies to knowledge creation at all levels and in all areas of the business and explicit policies should be integrated into the organization's operations so as to transform information and experience into knowledge which will be shared and reused by all employees and their collaborators (Huang et al., 2000). Pellicer et al. (2008) conceive knowledge management as fundamental for feedback processes of quality and innovation management in firms (see Figure 1). These authors also argue that unlike quality and innovation, knowledge management still is not open to standardization, and this prevents improvement in competitiveness, especially in firms that manage and produce by projects.

In addition, knowledge management is fundamentally the responsibility of the individuals who form the organization (Love et al., 2005). However, for the organization to function correctly, a basic level of information and communication technology must be adapted to the needs of the firm (Lee, 1997). Although this factor is crucial, it is the human factor that prevails as the principal protagonist (Carrillo et al., 2004). Furthermore, firms must find out the best ways to learn and the advantages that these bring with them, on the basis of knowledge created by the organization. Once eliminated the barriers to the creation of knowledge, its transfer and storage must be secured (Anumba et al., 2005).

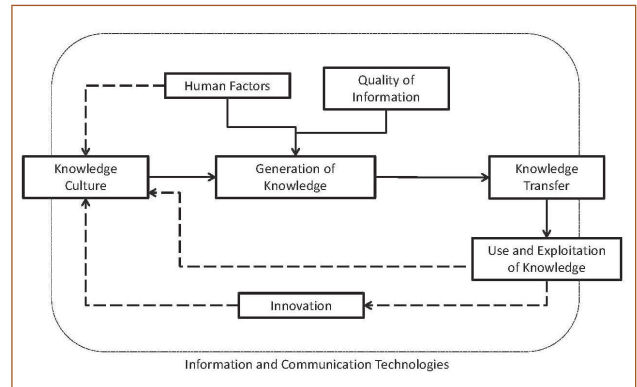
Figure 1. Quality, innovation, and knowledge relationships in firms (Pellicer et al., 2008)



Firms must also ensure that the correct information is provided to the right person at the right moment in order for him or her to make the best decision. Thus, firms manage knowledge efficiently when they are not only able to apply and use knowledge, exploit and explore its resources, adapt to and change its environment, but also ascertain and develop what has been learned so as to transform it into new knowledge (Petrash, 1996; Guilló and García, 2009). Finally, to innovate it is necessary to capture external knowledge (technological watch) and generate new knowledge by solving problems on-site and implement solutions to increase the competitiveness of the company (Pellicer et al., 2012).

Therefore, knowledge management consists of a set of eight factors (Lee, 1997; Guilló and García, 2009): knowledge culture, human factors, quality of information, generation of knowledge, knowledge transfer, use and exploitation of knowledge, innovation and, finally, information and communication technologies. All these factors must work in harmony for organizations to efficiently manage knowledge. Figure 2 shows the inter-relationships among the eight factors of knowledge management. A solid line indicates a direct relationship between two factors, so that one factor has a straight influence on the target factor. In contrast, a dotted line indicates an indirect relationship between two factors. In this case, however, the link is not direct; i.e., the source factor influences other factors which, in turn, have an impact on the target factor. These relationships are shown in Figure 2, resulting in a model which represents the influences among the knowledge management factors.

Figure 2. The knowledge management cycle in organizations (developed by the authors from Lee, 1997, and Guilló and García, 2009)



This model of knowledge management is developed this way because of its simplicity and clarity showing the different links among the eight factors. As it can be seen in Figure 2, these relationships create a cycle, which allows for a process of continuous improvement in knowledge management. This is considered as a key factor for developing this model.

3. Method

This study seeks to determine the current state of research in knowledge management in the construction sector. The research began with a first exploratory stage, a bibliometric study, followed by a quantitative and qualitative analysis of the scientific documents found. Based on this analysis, it was possible to draw conclusions regarding the state of the art in knowledge management in the construction sector. The research was carried out following these stages:

1. Preliminary approach and bibliometric search.
2. Initial selection of papers.
3. Classification of papers.
4. Data mining.
5. Discussion of relevant papers.

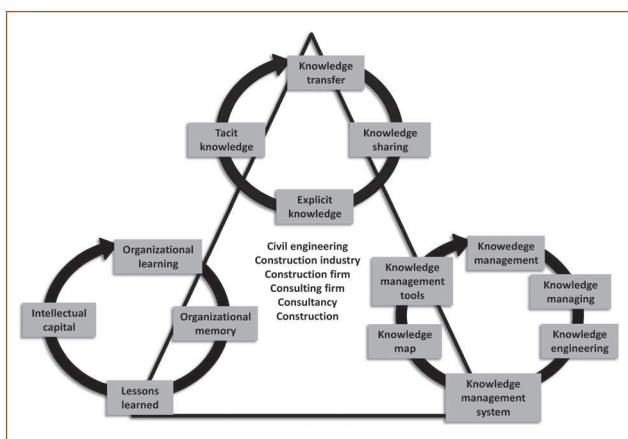
4. Analysis Of The Results

4.1. Preliminary approach and bibliometric search

This primary stage involved searching for, examining and reading theses and books related to the objective of the study so as to determine keywords and esta-

blish bibliometric search strategies. These strategies are shown in Figure 3. The search strategies combined four groups of keywords: (a) "knowledge transfer", "knowledge sharing", "explicit knowledge", or "tacit knowledge"; (b) "knowledge management", "knowledge managing", "knowledge engineering", "knowledge management system", "knowledge map", or "knowledge management tools"; (c) "organizational learning", "organizational memory", "lessons learned", or "intellectual capital"; (d) "civil engineering", "construction industry", "construction firm", "consulting firm", "consultancy", or "construction". The last group of keywords was used in every search strategy in order to contextualize the search in the construction sector. The research was carried out using specialized, scientific databases (ISI Web of Knowledge, Engineering Village and Science Direct) over the period from 1960 to 2012 (August 31st). On the basis of the aforementioned criteria, 3,594 articles were found.

Figure 3. Search strategies (developed by the authors)



4.2. Initial selection of papers

Once the papers were identified, the initial selection took into account the topic addressed and type of document, with duplicates being eliminated. Later, standards for judging the relevance of the paper per subject were created: (1) closely related, (2) moderately related, and (3) slightly related. The articles that fell into category (3) were excluded. Finally the importance of the contribution was assessed at 3 levels: (1) very important, (2) moderately important, and (3) of little importance. In this case, papers falling into class (3) were also excluded. The selection by relevance and importance was carried out jointly by the whole research team. Table 2 presents the successive stages

of selection carried out in order to establish the final set of papers to be analyzed.

Table 1. Stages for the selection of papers

Stage	Number Of Papers
Bibliometric search	3,594
First selection: type of document and topic	819
Second selection: elimination of duplicates	552
Third selection: level of relevance	333
Fourth selection: level of importance	230
Total number of papers analyzed	230

4.3. Classification of papers

In order to adequately classify these 230 papers, it was necessary to establish a logical categorization of knowledge management in the construction sector. Thus the articles were classified in accordance with the factors previously established (Figure 2). Table 2 presents the results of this classification. The research on knowledge management has mainly focused on three factors (Table 2): use and exploitation of the knowledge (27%), generation of knowledge (17%), and knowledge transfer (15%). Regarding the other five factors, the least studied factor was quality of information (less than 3%), as displayed in Table 2.

Table 2. Classification of papers

Factor	Percentage
Quality of Information	2.6
Knowledge Culture	10.4
Human Factors	10.0
Generation of Knowledge	17.0
Innovation	7.4
Information and Communication Technology	10.4
Knowledge Transfer	15.2
Use and Exploitation of Knowledge	27.0
TOTAL	100.0

4.4. Data mining

The data mining phase involved the quantitative analysis of the 230 papers and included information regarding:

- Research trends.
- Authors with the largest number of publications.
- Journals with the largest number of publications.
- Countries of origin of the research.
- Types of firms dealt with.
- Method employed by the authors.
- Focus of the articles in terms of the classification.

Although the search through the different databases spanned between 1960 until today, the first result

was published in 1981; it was not until the year 2000 that a significant number of papers dealing with this matter began to be published. Production thereafter increased with slight variations. Between 2001 and 2010, more than 80% of the work was published, with 2009 being the year with the largest number of contributions. The number of published papers declined thereafter. Table 3 shows the trends in those items that have served as the basis for the classification of the papers. Interest in this area of study began with the application of information and communication technologies, though it was not until 1995 that the first article appeared on the use and exploitation of knowledge. From 1998 on, research began to appear on general aspects of knowledge management in the construction sector.

Table 3. Research trends per category*

Year	Generation of Knowledge	Quality of Information	Knowledge Transfer	Use and Exploitation of Knowledge	Innovation	Information Technologies	Culture of Knowledge	Human Factors	Total
1981						1			1
1990						1			1
1992								1	1
1993						1	1		2
1995				1					1
1996				2					2
1997								1	1
1998	3		2		2				7
1999	1		1	6		1	2		11
2000	2	1		1		1	2		7
2001				1			1		2
2002	1		3		1		1		6
2003	3			3	2	1	1	2	12
2004	4	2	1	6	1		2	1	17
2005			1	5	2	1	2	3	14
2006	5	2	4	5	2	2	2	3	25
2007	3		3	5		3	2	3	19
2008	8		5	4	1	2	2	1	23
2009	3		5	10	3	2	5	5	33
2010	4	1	6	10	2	4	1	3	31
2011	2		3	2	1	2			10
2012*			1	1		2			4
Total	39	6	35	62	17	24	24	23	230

* Until August 31st

The results show that there was no single researcher in a predominant position. There is a group of authors with three articles each: Carrillo, Chinowsky, Kale, Kululanga, Love, Ribeiro, Robinson, and Tserng. With regard to journals, those with more than six publications are listed in Table 4, along with their impact factors for 2011 according to the *Journal Citation Reports*. Worthy of note is the Journal of Construction Engineering and Management published by the *American Society of Civil Engineers* (ASCE) with 28 articles (13% of the total).

The country of origin of the studies was assigned on the basis of the institution where the main author of the article was based. The study shows that Europe (43%) was the primary producer of scientific articles dealing with this matter, followed by America (23%) and Asia (23%). The United Kingdom had the largest scientific production with 20%, followed by the USA (17%).

Furthermore, 53% of the research focused on companies in general, while 31% focused on construction firms and 16% on consulting firms. As for the research method or technique employed, 22% used case studies, 11% surveys, and 5% interviews; 62% of the papers did not specify the method used.

With regard to the foci of the articles in accordance with their classification, this study established that knowledge exchange was the most attractive focus for the classification items knowledge generation and human factors. Strategies was the most often mentioned focus for work on knowledge transfer and innovation, while lessons learned was a noteworthy focus in research on the use and exploitation of knowledge. With regard to the cultural aspect, the most analyzed focus was human factors.

Table 4. Journals with most publications

Journals	Impact according to JCR (2011)	Number of articles	Percentage
Journal of Construction Engineering and Management	0.818	29	12.6
Automation in Construction	1.500	20	8.7
Journal of Knowledge Management	1.248	11	4.8
Journal of Management in Engineering	0.787	10	4.4
Construction Innovation	Not indexed	8	3.5
International Journal of Project Management	1.532	7	3.0
Building Research and Information	1.476	6	2.6
Others	Various	139	60.4

5. The Current State Of Knowledge Management

Once analyzed the papers from a quantitative point of view, the articles that contribute the most were examined from a qualitative perspective as well. The knowledge management cycle in the organization explained in Figure 2 was used as the framework of reference, as previously explained in the classification of papers. Therefore, the state of the art was summarized for each of the facets of the model, taking into consideration the importance of the papers. The main contributions made by the researchers are presented in the following section, ordered by each of the eight facets of the cycle.

5.1. Culture

Culture influences the commercial activities of firms and so knowledge management practices may be affected by cultural differences (Kivrak et al., 2009). Kull (2005) holds that there is an increasing recognition of culture as a source of innovation and competitive advantage. There is a growing interest in research into the culture of the construction industry and its projects, as well as the effects of culture and cultural differences on construction (Kivrak et al., 2009). "Good" knowledge management is hindered by the lack of an appropriate organizational culture that encourages members of a project team to create and share knowledge as well as of a suitable definition of what knowledge is valuable for the firm. Previous studies and experience in the sector show that cultural differences have a daily impact on construction firms, either negatively or positively. Furthermore, trust is one of the fundamental values for knowledge management along with open communication and conducting work properly (Fong and Kwok, 2009).

5.2. Human factors

Construction industry businesses depend on the knowledge of their workers (Esmi and Ennals, 2009). Carrillo et al. (2004) hold that individuals are a firm's biggest asset, as they play a crucial role in the transfer of knowledge (Love et al., 2005). One of the problems experienced by most businesses that manage and produce by projects is that the workers are more loyal to the project than to the firm, and are more inclined to change jobs at the end of the project. As projects are temporary in nature, the knowledge and lessons learned are dispersed when the project ends, fragmenting and deleting the organization's knowledge (Gann and Salter, 2000; Esmi and Ennals, 2009). Additionally, one of the

most difficult challenges regarding human factors is the employees' resistance to change (Sheriff et al., 2012).

Staff participation and motivation in projects can be evaluated to establish the effectiveness of knowledge management. Knowledge transfer depends directly on the participation of staff and the capacity to consolidate what has been learned once the project is finished. The problem becomes evident when employees have no time to share and evaluate experiences before moving on to the next project. In fact the pressure on employees as they work on a project prevents them from making the necessary effort to meet, share and reflect on the knowledge produced by previous projects, which would produce a greater exchange of experiences (Love et al., 2005).

5.3. Quality of information

It is well known that construction projects are largely based on quality (Love et al., 2000), and quality monitoring is one of the great challenges for knowledge management systems (Ambos and Schelegelmilch, 2009). Love et al. (2000) indicate that total quality management has not been well received by the construction industry as it is perceived as the equivalent of a guarantee of quality. In consequence, construction firms have not made sufficient progress in this area; thus, their potential for learning is limited.

5.4. Information and communication technologies

Technology plays a fundamental role in facilitating the processes of knowledge management in a multicultural environment (Lee, 1997). Although technology cannot by itself solve the problems related to the exchange of knowledge, it can significantly improve its managerial processes (Kivrak et al., 2009). The use of information technology allows for the capture, accessibility, and re-utilization of information and knowledge. Many knowledge management systems focus on the use of a strategy of codification of information, with a heavy emphasis on the use of information technologies (Pathirage et al., 2006), which allows for knowledge to be worked on explicitly. It is important to clarify that knowledge management does not only depend on the use of information technologies (Carrillo and Chinowsky, 2006); these are simply tools which allow the firm to monitor information efficiently (Train and Egbu, 2006). In fact, information and communication technologies favor the creation, search for, and diffusion of knowledge because they allow for high speed transmission and response, as well as the easy storage

and sharing of information (Wakefield, 2005). The application of instant messaging is also a growing practice for the exchange of information (Sheriff et al., 2012).

5.5. Generation of knowledge

The generation of knowledge begins when an employee has an idea and transmits it to other members of the organization through a cycle which feeds back on itself and allows for learning. Software systems such as wikis, forums, bulletin boards, or blogs, support themselves on the basis of this factor. Fong and Choi (2009) highlight the fact that this exchange of knowledge is the first step towards its management. Spontaneous meetings in the corridor or at the coffee machine make for experience to be acquired by individuals in their daily practice, sharing information with their colleagues about specific cases. This knowledge is, to a large degree, tacit. The exchange of informal knowledge is thus defined as all the forms of exchange that exist, along with all the institutionalized forms of exchange of knowledge that exist (Fong and Choi, 2009).

Furthermore, Lu and Tsai (2004) hold that organizations ought to focus on the creation of knowledge in order to prevent their existing knowledge from becoming rapidly obsolete. Tserng and Lin (2004) affirm that the exchange of experiences and re-utilization of knowledge brings other benefits with it, such as a reduced need to consult previous projects, an improvement in the quality of solutions and a minimization of the time and costs involved in finding solutions to problems, as there is no need to constantly find answers for the same questions.

5.6. Knowledge transfer

Businesses in the construction sector tend to repeat all too often the same errors because they fail to effectively transfer the knowledge obtained through other projects (Landaeta, 2008). The exchange of knowledge between projects is equally important because transference from a current to a future project allows staff to use existing, already tested, knowledge to solve problems, instead of having to generate new knowledge which generally requires more time. This exchange improves overall performance and reduces the costs of the project (Love et al., 2005).

In spite of this, businesses in the construction sector have not managed to effectively achieve the transfer of knowledge between projects, nor have they developed a system of learning management which would take both technology and people into account. Knowledge

transfer in the construction industry has been shown to be difficult to achieve in practice (Argote et al., 2000). This could be explained by the temporary and unique nature of each project. As the time available for each project is limited, those involved focus on having the product or service ready on time, instead of devoting themselves to activities related to knowledge transfer. This lack of time is one of the most frequent barriers to knowledge transfer (Gann and Salter, 2000). Likewise, according to Fong and Kwok (2009), the lack of resources devoted to knowledge transfer by organizations is one of the main difficulties involved in the application of knowledge.

Finally, Javernick-Will (2012) states that there are four main factors that affect knowledge sharing: resources, intrinsic motivation, incentives, and overall social motivations. Among them, social motivations generate the greatest impact on knowledge sharing. Thus, strategies to promote the motivation of employees and increase knowledge sharing are vital within organizations.

5.7. Use and exploitation of knowledge

Watkins and Marsick (1996) highlighted five key ideas regarding the efficient use of knowledge in organizations:

- Knowledge is more than a collection of learning individuals.
- The organization shows itself to have the capacity for change.
- Not only does it accelerate the individual's capacity for learning, but it also redefines the organizational structure, culture, design of work and assumptions regarding how things are.
- There exists broad participation on the part of the employees, and often by clients too, in the exchange of information and taking of decisions.
- Systemic thinking and the growth of the organization's memory are promoted.

It can thus be said that knowledge gained from and lessons learned from different construction projects are not systematically integrated into the firm's memory, and this means that work that has already been done must be repeated, solutions to problems must be reinvented, and time is wasted (Maqsood, 2006).

5.8. Innovation

Innovation is a key issue in knowledge management practices (Kivrak et al., 2009). However, in the con-

struction industry, little effort is made to implement new ideas or to innovate. Fong and Kwok (2009) clearly indicate that innovation is now considered to be a key factor in the success of organizations and creative ideas are seen as a secure parameter for the competitiveness of a firm. The organizations that effectively leverage their knowledge assets are more competitive (Sheriff et al., 2012).

To ensure that innovation occurs, a positive climate must be created which encourages a culture in which workers are competent and that they make use of the most up-to-date knowledge. They must also have the opportunity to develop new ideas. Management should make sure that organizational culture stimulates and encourages innovation and diversity in the work team (Kivrak et al., 2009). Financial consulting firms have been pioneers in the development of innovative systems in knowledge management, in the vanguard of the application of a culture of knowledge management and have recognized the productive potential of knowledge workers (Ambos and Schelegmilch, 2009).

6. Discussion And Concluding Remarks

As well as being based on projects, the construction industry is based on people and for this reason the companies that work in it need a change in mentality and culture. Since organizational culture is a prerequisite for the success of knowledge management, a culture of innovation should be promoted in which the exchange of knowledge and room for creativity are fundamental. Those cultural and social barriers that make knowledge difficult to manage in the construction industry must be broken down. One of the biggest problems faced by businesses in the sector is that much of their knowledge is held by the professional and technical staff that works on each of its projects. High staff turnover means that good practices are lost and that there is no clear culture that values their capture and management. Face-to-face and group meetings are the principal means utilized in the construction sector for the transfer of knowledge. Ways of acquiring knowledge through job rotation and the capture of knowledge by experienced personnel must be promoted. In order to ensure its quality, information should be selected and organized prior to being stored.

Companies have come to understand that knowledge is a resource and a vital asset for the carrying out of their activities, and they have come up with various ways of capturing, storing, transferring and reusing it. However, due to the fragmented nature of the

construction industry, it lacks a coordinated strategy for knowledge management. Many authors agree that knowledge management in the construction industry is more of an aspiration than a reality. The efficient management of knowledge would allow construction companies to transfer knowledge across their various projects, create synergies inside the organization, learn from the mistakes and successes of others, and receive benefits in terms of productivity and performance.

In this study, a bibliometric search produced 230 articles published between 1981 and 2012. The three more analyzed factors were: generation of knowledge, knowledge transfer, and use and exploitation of knowledge; these were the focus of most of the papers. Five complementary facets were also identified: culture, innovation, quality, information technology, and human factors. Considering the results of the bibliometric analysis, it seems that knowledge management in the construction industry is still a relatively new topic; the first paper was published at the beginning of the 1980s, and until 1998 there was no significant contribution to the subject.

This analysis shed light on several gaps in the literature that could be pursued by researchers in the future. For example, it is necessary to analyze the effectiveness of current technologies and techniques implemented in companies in order to capture, share, transfer, and store knowledge; a survey aimed to companies in the construction sector could enlighten this issue. An exploration of the quality of the information exploited may be an interesting subject as well. A more ambitious approach implies investigating the tangible benefits of knowledge management in the construction industry. Future research could assess, using comparative studies with other productive sectors, the opportunity costs of not addressing knowledge management properly. Examples include benchmarking studies regarding process improvements in manufacturing from a quality point of view, or quantification of long-term cost savings in the construction sector due to transfer of solutions already implemented at the worksite.

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