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THE CHALLENGE OF KNOWLEDGE MANAGEMENT FOR DESIGN, ENGINEERING AND MANAGEMENT COMPANIES

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ABSTRACT

The challenge of Knowledge Management (KM) can bring new innovative solutions, competitiveness advantages, reduced response times and increased control risks. For the Design, Engineering and Management (DEM) companies, identification, capture, dissemination and reuse of knowledge is a priority and, therefore, one their most valuable assets. However, there is little consensus on the ways this knowledge is managed and the true nature and challenges of knowledge creation and dissemination processes. Previous research has found that the knowledge created in each design is often lost due to the fast pace of the design process of a typical building project. This research identifies the challenge of KM implementation in twelve DEM companies in Portugal and with three international Business Consultants (BC) with successful Knowledge Management Systems (KMS). Data were collected through semi-structured interviews with closed and open-ended questions. The analysis of the data revealed that DEM companies in Portugal are aware of the importance of KM systems, but that only one-third has implemented them. Comparison with international BC companies with mature KMS clearly demonstrated that some management rules are essential to success. In conclusion, ten recommendations were identified to help DEM companies in their KMS implementation challenge.

Keywords: Knowledge Management, Risk, Design, Engineering, Portugal.

INTRODUCTION

In an increasingly global world, where the only certainty is uncertainty, companies must be constantly alert change to changes and be prepared to give quick responses. Companies must be aware of a permanent need for innovative solutions to be more competitive, limit their costs, reduce their response times and control their risks (Serpella, et al. 2014; Kamsu-Foguem and Abanda 2015). Knowledge Management (KM) has been identified as an essential tool to help organizations manage an important source of competitive advantage. It is specific knowledge that distinguishes each organization from others, creates value (King and Zeithaml 2003) and identifies their *DNA* (Kim, et al. 2014). Often people are not even aware that they hold this knowledge, which makes it all the more difficult to manage. Further, KM has more value the sooner it can be reused, and techniques of communication are necessary for the process could to be effective (Ribeiro and Bettiol 2006; Tan, et al. 2006). The

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understanding of a communication management system should, therefore, be the first step before preparing a knowledge management system inside of an organization (Vaz-Serra, et al. 2012). Information and communication must circulate inside and outside the organization through an efficient communication management system, involving the installation of an appropriate infrastructure to help the data-information-knowledge-wisdom hierarchy (Vaz-Serra 2006; Kirsch, et al. 2015).

For the Design, Engineering and Management (DEM) companies in the Architecture, Engineering and Construction (AEC) industry it was understood early on that the rapid advancement of information and communication technologies brought new concepts and acronyms for a new digital world. Within the AEC sector the approach of systems as Building Information Modelling (BIM) can be an example of innovation in the collaboration working environment (Grilo and Jardim-Goncalves 2010). Moreover, top management commitment, total employee involvement, performance assessment and the culture of knowledge-learning and sharing must also be considered when implementing KM (Lee, et al. 2016). Therefore, modeling systems, processes of semantic modeling, and user graph interaction systems can be important paths for the simplification of KMS with a view to facilitating access to users (Fruchter and Demian 2005; Kanapeckiene 2010; Kamsu-Foguem and Abanda 2015).

Within this context, Portuguese DEM companies, due to the political and economic situation, are accepting challenges in internationalization. The use of web-based KM tools is essential to reduce distances in order to have quick access to knowledge of people and past projects regardless of where people are, to improve competitiveness and reduce risks related to the internationalization challenge. This paper identifies the main issues in developing a KMS in DEM companies in the AEC industry in Portugal and proposes ten recommendations, making a comparison with three international Business Consultants (BC) with KM maturity, where applicable. The research analyses strategic, organizational and instrumental aspects of KM based on literature review and analysis of the answers collected through semi-structured interviews.

KNOWLEDGE MANAGEMENT AND THE AEC INDUSTRY

The prevailing theory for KM found can be summarized by application of the method *SECI generic Model* (Nonaka, et al. 2014) which was one of the most important theory concepts for KM. Subsequently, After that, there has been an explosion in the literature surrounding the developing concept of KM. Suresh and Egbu (Suresh and Egbu 2007) concluded that the fundamental issues of small and medium enterprises, regarding the implementation of initiatives of knowledge capture, were basically the following: (i) main concern only financial issues, leading to knowledge capture initiatives on a platform to be seen as a cost and as superfluous activities; and (ii) employees taking too much time gaining the ability to work and take advantage of systems, and thus, upon leaving a company, the organization loses not only their knowledge, but also all the investment in developing and training the employee.

The main barriers to implementing KM in DEM companies are concerns about sharing best practices and an unwillingness to share knowledge (Ankrah and Langford 2005). The ability to manage the knowledge generated from the projects not only can help to prevent the ‘reinvention of the wheel’ and the repetition of similar mistakes, but also serves as the basis for innovation, overall improvement and sustaining of competitive

advantage (Egbu 2004; Gray and Meister 2004; Tan, et al. 2006). Approaches have been taken to help the AEC industry to effectively manage their knowledge, identifying best practices and KM tools (Forcada, et al. 2010; Zou 2012; Kamsu-Foguem and Abanda 2015). One of the aims of this research, therefore, was to help close the gap between the models suggested in the literature and an accepted methodology for guiding practitioners in implementing and assessing KM in the DEM industry (Obaide and Alshawhi 2005; Javernick-Will and Scott 2010).

RESEARCH METHODOLOGY

The method chosen for the collection of data was through semi structured interviews, in DEM and BC companies in Portugal, using a questionnaire for the guidance of the interview. The interviews were typically two hours long and asked a range of closed and open-ended questions.

The research collected data through interviews in twelve DEM companies in Portugal and with three international BC with KMS maturity. The questionnaire was based on questions devised by Uit Beijerse (1999) for KM identification and in line with recommendations for the AEC industry (Zou 2012; Forcada, et al. 2013) for the strategic, organizational and instrumental aspects of KM. It was structured in three parts: (1) The importance of communication and KM to the organization; (2) KM adding value and improving future processes; and (3) KM supporting decision-making and implementation. Companies were selected from among the most significant in the industry that had agreed to collaborate and were among contacts of the author. They were DEM companies in the AEC industry, with or without a systematic, explicit and deliberate KMS; and in the BC industry as international business consultant companies with activity in Portugal and with extensive experience in KMS. For those companies, knowledge sharing is their "core business", thus, their experiences were analyzed as lessons learned by other industries and targets to be achieved in the future for the AEC industry.

The questionnaire was designed for the following positions: Central Manager, Project Managers and technical and/or experts (engineers, architects, etc.). It was divided into five sections: Section 1 - Interviewees' details (age, position, and years in the company) and company background (size, type, years in activity); Section 2 - Awareness of communication and KM in the organization (documentation, communication, training, and knowledge management); Section 3 - Retention of knowledge and value-adding to the company to the company (knowledge as a value asset, customers giving value to KM, reducing costs and time losses, obstacles to KM, etc.); Section 4 - Recording and sharing of knowledge to improve future processes (time-consuming, record errors, internal recognition, culture (habits) of employees hindering KM, etc.); and Section 5 - KM in supporting decision-making (quick access to past experiences, experts and projects, reducing waste, etc.).

RESEARCH RESULTS AND DISCUSSION

The quantitative data was analyzed using the means score of Likert scale responses, and comparisons were made between DEM and BC companies. Qualitative data was analyzed using the final comments of the interviewees at the end of each section of questions. The results and discussion of answers were presented by sections.

Interviewees' details and company background

The interviewees' details and company are presented in Table 1. The majority of the interviewees have more than five years in the company (71%) and positions with management responsibilities (60%).

Table 1

Interviewees' details and company background.

a) Companies				b) Interviewees			
Measure	Items	DEM	BC	Measure	Items	DEM	BC
Size (n. employees)	Micro Fewer than 10	1		Age	36-45	4	3
	Small 11-25	3			46-55	7	
	Medium 26-250	6		Position	Central Manager	3	2
	Large 251 and above	1	3		Project Manager	3	1
Years in the activity	Fewer than 10	1	1		Engineer/Expert	5	
	10-20	3		Years in the compa- ny	Fewer than 5	2	
	21 and above	7	2		5- fewer than 15	6	1
					15 and above	4	2

DEM companies were in the majority medium and large size (64%) and over ten years in the activity (91%).

Awareness of communication and knowledge management

The assumption was that it was necessary to have a notion of how prior communication was seen by the interviewees and the organizations where they work. The awareness of communication and knowledge management within communication management systems is summarized in Table 2.

Table 2

Awareness of communication and KM (%)

Question		DEM	BC
Documentation management system	Within an Intranet system	36	100
	Mostly by documents in hard copy	45	0
Communication with employees	Email	100	100
	Phone/Mobile phone	74	100
	Memos	26	33
	Newsletter	63	100
Forms of training or knowledge sharing	Visits and/or monitoring of projects	84	67
	Training with internal or external trainers	89	100
	Meetings for sharing and/or socializing	89	100
Your organization has a KMS	Yes	27	100

The results confirmed the literature review that companies in the DEM industry in Portugal are still far from the full utilization of an intranet for internal communication. However, 100% of the respondents said that their organizations are aware of the importance of communication, and in comparison with BC communication, is one of the most important activities in their day to day activity. The surprising 67% of positive answers in BC against the 84% in DEM, for visiting or monitoring other projects was because of the high level of performance of their KMS that made visiting other projects unnecessary, and also due to confidentiality issues on client sites. Further, 73% of respondents in DEM answered that they do not have KMS, but that their organizations are aware of the importance of developing such systems in the future. At the end of the interview in the open-ended questions, BC respondents suggested that the values of communication and knowledge sharing need to be included in the vision and mission of the organization, and should not only be based on information and communication technology. They also added that it is important to avoid information overload; alerts and warnings need to be creative, and KMS must promote self-consultation and be present only when needed in day to day activities.

Retention of knowledge and value-adding to the company

The answers received in this section are shown in Table 3, and confirmed the findings in the literature that practitioners in DEM recognize knowledge as an important asset that adds value to the company. The interviewees recognized that customers value a company that demonstrates good management of its knowledge. However, despite valuing knowledge, they argue that clients nevertheless still put a strong emphasis on price when making their decision.

Table 3

Retention of knowledge and value-adding to the company

(Likert scale: 1 strongly disagree to 5 strongly agree)

Question	DEM	BC
Knowledge is value asset that represents value-adding to the company	5.0	5.0
Customers value a company with a KMS	4.3	4.7
KMS can reduce duplication of work and reduce waste, improve business results	4.8	5.0
Access to previous processes avoids "reinventing the wheel", reducing costs and time losses	5.0	5.0
KMS can propose more competitive bids and better grounded, based on internal data	4.6	5.0
Retain knowledge can bring risk of leakage of knowledge to outside the company	3.8	4.0

The results indicate that a culture of knowledge management add value because it reduces waste and the duplication of work. Also, it was strongly agree by all respondents that KMS can eliminate the incidence of '*reinventing the wheel*', as the use of knowledge gained from past projects avoids lost time rethinking the process in similar cases. Moreover, it was strongly agree that KMS help to make bids more competitive by using cost analyses and smart solutions adopted on past projects. Issues arising from the open-ended questions were that the value of knowledge, being intangible and in motion, can sometimes be difficult to measure. And that, the risk of leakage of knowledge outside the company was considered to be lower than the risk of not having a system of knowledge management. At the end of the interview in the open questions, interviewees argue that one of the values of knowledge is the way it is used rather than the value of the knowledge itself. The lessons learned by BCs were that a KMS needs to link internal knowledge with external sources of knowledge and, as emphasised in the literature, that the knowledge must constantly be updated and refreshed, ready to be reused immediately. Furthermore, they argue that some companies started overenthusiastically developing KMS and committed some mistakes. Implementing new systems involving significant changes to the organization as a whole were in general unsuccessful. KMS needs to start its focus in the most important areas of knowledge within the organization and grow in line with the speed and needs of the organization. The use of exclusive and separate KMS fed only by dedicated experts has been identified as time and cost consuming, and transferred the gains for those who effectively do not create and use the knowledge, reducing the success of this implementation.

Recording and sharing of knowledge to improve future processes

Barriers were identified in the literature on how recording and sharing knowledge can be an obstacle or an opportunity for KMS. Some questions were prepared and the results regarding how these activities can be useful to improve future processes are shown in Table 4.

Table 4

Recording and sharing of knowledge to improve future processes

(Likert: 1 strongly disagree to 5 strongly agree)

Question	DEM	BC
Time consumed in KMS is a time that is recovered in the future	4.3	4.7

There are great advantages to record errors and processes less well executed	4.8	4.3
Anyone should register their knowledge regardless of their experience	4.5	3.3
The way knowledge is recorded and how is made available may condition its success	4.6	5.0
Employees register knowledge if the organization recognizes this activity as important	4.7	4.3
The culture (habits) can hinder KM in that share knowledge can be seen as loss of power	4.4	3.7
Communities of practice encourage the emergence of new ideas and stimulate innovation	4.6	3.7

Respondents in DEM agree that the time consumed in these activities can be recovered in the future. However, at the end of the interviews, they argued that this can be one of the main obstacles, that they are afraid that KMS could be very complex and that the value recovered will be less than the cost. Nevertheless, companies in the BC industry that are more experienced in KMS must be aware that criticism can inhibit participation. In the question, if anyone should register knowledge in the system regardless of their experience, DEM companies, where the majority of employees are very qualified, the answers showed either agreement or strong agreement. In contrast, for the BC business, the results are not so evident, as they argue only people inside their area of expertise should register knowledge. Respondents strongly agree that the way that knowledge is registered is essential for KMS success. For the question concerning whether the organization considers the activity important, the lesson learned from the BC industry is that it is not only important, but participation must be compulsory and included in the Key Performance Indicators (KPI) of each employee. Habits of employees can be an obstacle to sharing, as they have the internal power of being the ones that have the know-how to register the knowledge. Some employees are not only reluctant to accept new ideas, but also resistant in abandoning old ones. DEM interviewees strongly agree that a new era of communities of practice and places for sharing past experiences will help innovation. However, for the BC respondents, this is not enough, and these initiatives need to be very well organized to produce effective results. They can be important for socialization, but not as an exclusive tool for new ideas and innovation. BC respondents argue that innovation needs systematization and a focus on goals. They can be important for socialization, but not as an exclusive tool for new ideas and innovation. BC respondents argue that innovation needs systematization and a focus on goals. At the end of the interview in the open-ended questions, respondents argued that knowledge needs to be captured and reused in its “live” phase, and that an efficient system needs to be incorporated into the normal activity of the organization as a “big brother” and smart system, learning and being fed directly and immediately by those who create or share knowledge.

KM in supporting decision-making

The results of this section are shown in Table 5. According to the data collected in the interviews, having alternative solutions can give support to decision-making. If they are well organised and simple, systems can help to recall previous solutions and allow future decisions to be taken with access to previously acquired knowledge.

Table 5

KM in supporting decision-making (Likert scale: 1 strongly disagree to 5 strongly agree)

Question	DEM	BC
Records of previous project are critical for future decisions	4.4	3.7
Access to past and real experiences allows better adapt future decisions to each new situation	4.6	5.0
Level of complexity to access KMS may create obstacles at the time of decision-making	4.8	4.3
Access to previous solutions can reduce demand for new solutions for convenience	3.7	4.3
Registration and dissemination of lessons learned can help to reduce errors	4.8	5.0
Access to past projects can reduce the risk of less optimal choices in urgent decisions	4.5	5.0

The DEM respondents strongly agree that having access to records of processes used previously is critical. However, due to the confidentiality of their business activity, BC

companies agree that it is important, but not critical. Respondents strongly agree that having records with alternative solutions allows for more adaptable decision-making in each new situation. All respondents strongly agree that complex KMS systems are an obstacle to supporting decision-making. KMS must be simple, must avoid additional effort and costs, must be transparent to users and must not introduce excessive changes. DEM respondents agree that the availability of prior solutions can decrease the incentive to create new solutions, and while BC companies strongly agree that the use of past examples reduces the risk that innovation sometimes brings. Their options can risk being overly conservative and systems need to be prepared to avoid this. Both, DEM and BC strongly agree that dissemination of knowledge reduces errors in decision-making, and can reduce the risk of less optimized choices in urgent decisions. The ability to see examples and to show these examples to others is helpful; since an image is often a powerful teaching tool. The systems have to be simple; as a rule, all responses must involve a KMS of no more than three or four steps. Some systems were abandoned due to an excess of information and complexity of solutions applied.

CONCLUSIONS AND RECOMMENDATIONS

This paper identified ten recommendations for guiding practitioners in implementing and assessing KMS in their organizations. These recommendations were based on the findings in the literature and the questionnaire data collected in five sections by interviews for the comparison of KMS in the DEM and BC industries. In section 2: (1) Communication is essential and values of communication and knowledge sharing need to be included in the vision and mission of the organization, not only based on software and technology. (2) Avoid information overload; alerts and warnings need to be creative; KMS must promote self-consultation and be present only when needed in day to day activities. In section 3: (3) Promote external access to link internal knowledge with external knowledge; KMS needs to be connected and also refreshed with ideas from outside. (4) Understanding knowledge as an intangible and in motion asset, to be shared not transferred, the KMS needs to promote and value those who share knowledge. (5) Organizations need to implement KMS in the area or areas of main focus, and must grow according to the organization's needs, speed and requirements. KMS implemented in all areas at the same time increases the likelihood of failure. People, techniques and planning have been identified as a good example starting point for a KMS in DEM companies. (6) The use of exclusive and separate KMS fed only by dedicated experts has been identified as time and cost consuming, and transferred the gains for those who effectively do not create and use the knowledge, reducing the success of this implementation. In section 4: (7) Time consumed in KMS needs to be recovered in the future and organizations must be aware that criticism can inhibit participation; and with a KMS people need to see advantages for themselves and not only for the organization, a win-win process. (8) Sharing knowledge in a new era of communities of practice with places for sharing past experiences will also help innovation. Participation must be compulsory and included as an annual Key Performance Indicator (KPI). (9) Knowledge needs to be captured and reused in its "live" phase. The system needs to be incorporated into the normal activity of the organization as a "big brother" smart system, learning and being fed directly and immediately by those who create or share knowledge. In section 5: (10) KMS need to be simple and avoid additional effort and costs, need to be transparent to the user and not introduce excessive changes increasing individual users' energy consumption. A recommendation for future research is increasing the

number of case studies and developing internal systems based on their procedures and requirements. One of the future goals is to find a common structure that could serve large numbers of DEM systems in the AEC industry. These systems could be adapted not only for the internal use of each organization but also for developing platforms of knowledge between different organizations.

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