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Knowledge Management Systems in construction: a case study in the Portuguese industry

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Abstract: Knowledge Management Systems (KMS) are a structured framework for the retention and application of organisational knowledge. The costs of investment in KMS can be high and such systems need to be well planned to increase the likelihood of success. KMS in construction companies have been analysed in the last decade by both industry and academia to identify the best solutions for successful implementation. This research reports on a comparative case study in Portugal on the perception of KMS by construction professionals, architecture and engineering consultants and consultants in the business, information technology, and communication sectors. This comparison helped to identify the lessons learned in sectors where KMS are successfully developed and transpose this learning to the construction industry. Research data was obtained through semi-structured interviews encompassing professionals, Operational Managers, Project Managers and technical experts to ensure that a broad range of views was obtained. Findings demonstrate that for a KMS to be effective and successful in the construction industry, the system should be seen as integrated rather than external. This paper identifies the need to prepare a successful KMS in organisational culture with a strategy and identification of values of knowledge into an integrated organisational process.

Keywords: Knowledge Management, Knowledge Management Systems, Construction, Portugal.

1. Introduction

Business strategies are driven by the demands of new markets and new competitors. As such, companies have built new capabilities to learn quickly and change in order take advantage of and respond to the "knowledge economy". The need for companies to manage change to facilitate innovation in a systematic way is characteristic of how the nature of knowledge has evolved in contemporary organisations (Drucker, 1993; 2009). Knowledge Management Systems (KMS) are known as management models that have allowed organisations to identify, capture, share and reuse their knowledge. The attempt to manage organisational knowledge has seen the development of KMS, such as systems based on tacit and explicit knowledge, the *SECI Model* and recently the *phronesis model* (Nonaka *et al.*, 2014) which is a combination of both.

Since 1999, Davenport and Prusak (2000) have argued for the conceptualisation of a firm as a collection of its knowledge, history, and culture all of which need to be aligned with technology for effective and productive KMS. However, knowledge-management programs require organisational commitment and cannot solely be left to information technology systems to garner success (Hauschild *et al.*, 2001). KMS require an environment that allows workers to create, capture, share, and leverage knowledge to improve performance. Malhotra (2004) has argued that the main reasons behind the failure of such systems lay with a lack of robust application in defining, implementing and executing effective KMS. Also, Malhotra (Malhotra, 2004) identified that KMS need to deal with human and technology relations, lo-tech and hi-tech methodologies, and unconventional and conventional means of producing 'business performance'. The integration of business models as simultaneous and parallel sets of knowledge processes, as against isolated operational modes, facilitates ongoing innovation of business and customer value propositions.

Knowledge sharing and learning behaviours contribute to better performance, business process improvement and have a direct application in the construction industry (Chen and Fong, 2013; Forcada *et al.*, 2013; Serpella *et al.*, 2014; Tkachenko *et al.*, 2014; Lundberg and Lidelöw, 2015; Wibowo and Waluyo, 2015). Approaches to an integration model, such as the concept of the live capture of knowledge (Udeaja *et al.*, 2008) have been seen as applicable to the construction industry. For Sommerville and Craig (2006) good decisions are also the result of careful management and the analysis of project information and knowledge. What has been identified is that organisations encounter a vast range of knowledge zones; however, difficulties are encountered in differentiating between what is essential, important, or merely interesting. For Drucker (2013), making knowledge productive further requires that it be clearly focused, and highly concentrated. Whether done by an individual or by a team, the knowledge effort requires purpose and organisation. An initial lack of focus has been one of the reasons why some KMS fail. As a result, KMS processes are seen to be ineffective and a source of management frustration within organisational structures often leading to an abandonment of KMS at high financial cost. This paper analyses a case study in Portugal where the context of the economic crisis has called for the need of new solutions to reduce costs and improve KMS methodologies for the construction industry.

2. Knowledge management systems in construction

Construction organisations in a knowledge-based industry (Egbu and Robinson, 2005) willing to improve their business performance and achieve sustainable competitive advantage in global markets are looking to implement Knowledge Management (KM) tools that lead to an improvement in their 'learning capability' (Ribeiro, 2009). KM concepts and techniques are required to improve lessons learned from completed projects (Forcada *et al.*, 2013), employing ontologies and graph-based reasoning operations in eliciting and visualising knowledge concepts (Kamsu-Foguem and Abanda, 2015) are increasingly being adopted by construction-related firms. Several systems have been developed for the construction industry, such as *OSMOS* (Rezgui, 2007), *CAPRI.NET* (Udeaja *et al.*, 2008), *KFWFCO* (Yin *et al.*, 2008), *SPICEC* (Vaz-Serra, 2011), *CNIM* (Lin, 2013) and *MBKM* (Chih-Cheng *et al.*, 2014). Also, construction companies developing their internal systems include *Link.ME* (Curado and Ramos, 2010) and *Construknowledge* (Vaz-Serra *et al.*, 2012) in Portugal and '*i*Konnect' and 'EDMS KM' (Zou, 2012) in Australia.

Investments in KMS can be considerable; Zou (2012) reported on two construction companies in Australia that expend an average of AUD $2.5 million per year in systems related to KM. Given the considerable financial and human resource investment required in the introduction of KMS, some issues have been identified which contribute to the failure of effective implementation. These failures encompass 'technical, human and business related factors' (Udeaja *et al.*, 2008) requiring a need to improve KM processes and create new knowledge to ensure that KMS application extends beyond project completion (Wiewiora *et al.*, 2013). Such systems need to respond to human resource issues, such as workload stress, time pressures and long working hours (Forcada *et al.*, 2013).

Drucker (2013) identified the *Post Capitalist Society* as *The Knowledge Economy* where specialisation in knowledge has given an enormous performance potential in each area. Drucker also emphasises that to turn potential into performance each organisation needs a process to identify their 'productive knowledge' clearly focused. The process to identification of each productive knowledge areas can be done by each organisation through the analysis of the answers of the questions: *what do I know? What have I learned?* and *What I will apply?*

Consequently, the definition of different 'knowledge areas' has been developed by several authors and organisations and is now a concept accepted worldwide. For construction companies, those different knowledge productive areas have to be identified and prioritised in the moment of developing a KMS.

Generally, construction companies in Portugal have a common organisational structure in several business areas: Financial, Market and Supply Chain, Planning and Scheduling, Production and Technical. For the purpose of this research, those business areas have been used to ask respondents to rate their needs according to their professional activities. The results of the business areas of main focus have been identified as their knowledge productive areas.

3. Research methodology

This research reports on a comparative case study on the perception of KMS in Portugal by construction professionals, architecture and engineering consultants and consultants in the business, information technology, and communication sectors. The focus of this pilot study was to identify sectoral characteristics and issues raised in the perception of KMS by differing communities of practice, determine where KMS value lie and the factors that may contribute to the improvement of KMS processes. A case method study approach was selected, using semi-structured interviews, in order to provide insights into the nature and characteristics of reusable project knowledge and end-user requirements for knowledge capture and reuse (uit Beijerse, 1999). A questionnaire was prepared to guide the interviews and the survey questions were targeted to identify: (1) The perception of firms of the importance of KM to their organisation; (2) methodologies for effective knowledge-creation and continuous improvement; and (3) KM in supporting decision-making and implementation.

Semi-structured face-to-face interviews were conducted with 44 senior staff from 34 companies, 22 participants from the Architecture and Engineering (AE) and construction (C) industries and 22 from other sectors: Business Consultants, Information, Technology and Communication and Training Consultants (BITT). Participants ranged from Operational Managers (commercial and human resources), Project and Construction Managers and Technical Experts (Engineers, Architects) and information technology experts (IT Experts) to ensure that a broad range of views was obtained. This approach

recognises that some of the successful examples of KMS come from other industries (Nonaka *et al.*, 2014), such as the automobile industry (Toyota), technology and telecommunication firms (Fuji Film and Apple). There may be advantages for the construction industry to understand these systems, further, such research also may assist in identifying the unique characteristics of the construction sector in the application of KMS.

Interviews encompassed five sections: Section 1 - Respondents' profile and awareness of internal communication; Section 2 - KMS and value adding; Section 3 - KMS and process improvement; Section 4 - KMS and assistance in decision making, where research results were statistically organised into data sets with a qualitative analysis undertaken to identify common themes arising from the extended responses of participants; and Section 5 - Assessment of different knowledge areas only for the construction companies to identified and assess different areas with a major focus to be used as a starting point for KMS implementation.

4. Research results and discussion

The structure of the interview to collect data was carried out in five sections.

4.1. Section 1 – respondents' profile and awareness of internal communication

Background information is presented in Table 1 which includes interviewees' profile by age, position and years in the company and company information identified by type and size. Table 2 summarises aspects related to internal communication awareness.

Table 1: Companies and interviewees

a) Companies					b) Interviewees		C	AE	BITT
Measure	Items		%		Measure	Items	%	%	%
C (27%)	Contractors			27	Age	25 – 34			5
AE (23%)	Design			14		35 – 44	42	30	77
	Developers.			9		45 and above	58	70	18
BITT (50%)	Business Consultant			20					
(with KMS)	ITC and Telecom			23	Position	Oper. Manager	25	30	36
	Training Consultant			7		Proj. Manager	25	40	9
						Tech. Manager	8	30	36
		C	AE	BITT		IT experts	42		18
Size	Micro <10			14					
(number of	Small 10-24		30	18	Years working	< 5	8	10	9
employees)	Medium 25-250		60	27	in the	5-15	67	50	55
%	Large >250	100	10	41	company	16 +	25	40	36

The large majority of the interviewees (90%) have been working with the company for more than five years, ensuring that participants offered exposure to project experience, had an awareness of knowledge-based requirements, knowledge receipt, its application and retention, and needs of leadership related to knowledge sharing.

Table 2: Awareness of internal communication (%)

Question (responses in agreement)	C	AE	BITT
Your organisation gives value to internal communication	92	100	95
Documentation and communication are managed by an Intranet system	75	40	79
Workshops for knowledge sharing and/or socialization	58	100	89
Decisions in your organisation are based on past experiences	92	70	84

Internal communication was seen as being valued by respondents' organisations, with relative consistency between C and AE firms. A discrepancy was identified in the use of an intranet system in documentation and communication management by AE firms to those of the BITT group. Further research is required to identify the reasons behind such difference, but it is suggestive of communication methodologies in AE being geared towards non-server based systems. The difference is also reflected in the discrepancy between C and AE, where socialisation and workshops of knowledge sharing are central features of AE. However, only 58% respondents of construction identify this as features in their firm. This matter may be influenced by the company size, where AE firms were overwhelmingly small to medium-sized firms and where capital investment in sophisticated networked systems carry greater cost impost and where organisational size facilitates easier direct personal interaction.

The awareness of the value of past experiences in decision-making processes is held to have greater recognition in the C and BITT sectors as against those in AE which rated this question an average 11 percentage points below their industry sector counterparts. Although the AE sector values internal communication, communication strategies do not rely on formal digitally-based systems, while reflection on past experiences does not necessarily translate into informing future decision processes. This case study suggests that there may be cultural and structural differences inherent in communities of practice of industry players, which influence the introduction and form of KMS application.

4.2. Section 2 - KMS and value adding

The role of KMS as a value-adding tool in business performance was next reviewed and is summarised in Table 3. Participants were asked to reflect on client recognition of KMS investment and the risks and benefits such systems offer.

Table 3: KM and company value adding (%)

Question (responses in agreement)	C	AE	BITT
The investment on KMS is valued by clients	83	85	60
KM can bring risks of leakage of information external to the organisation	68	76	20
KM helps to improve competitive bids	88	92	100
Can reduce duplication of works and mistakes	93	96	100

The open-ended nature of the interview process elicited differences between the construction sector and other industry sectors. A point of difference was the value placed by the client on KMS. The

construction sector is characterised by being project-based as against the product-based nature of other sectors in that the project-based nature of the construction industry and client participation in project delivery processes garnered recognition of KMS investment by clients. However, it was observed that this did not necessarily transfer into financial compensation of KMS investment as the industry still operated under competitive fee bidding where clients were focussed on minimum fee strategies. The exception to this was on projects of a specialised nature where the open-market competition of fee bidding was not as prevalent and clients recognised the value of KMS to project outcomes.
The product-based nature of other sectors elicited a perception of the lower value of KMS by clients, being 60% as against an average of 84% in construction and AE. An example of this was provided in the telecommunications sector, where client value to KMS was conceived regarding the effective functioning of the final product at the lowest cost.

The risk of information and knowledge leakage outside the organisation were acknowledged as factors for construction (68%) and AE (76%). However, for BITT (20%) it was considered that information leakage was not a risk if organisations have robust systems. Respondents from BITT identified that it was not simply a factor of the KMS per se, but also the manner in which it is used that gives rise to system failure. All sectors affirmed the value of KMS in formulating well-considered bids and in reducing work duplication.

4.3. Section 3 - KMS and process improvement

In this section, Table 4 summarises perceptions of how KMS may assist in the improvement of future processes. Participants were asked to reflect on the use of the KMS and its 'usability' features within their respective firms, encompassing such aspects as time investment, ease, and applicability of access, participation rates and integration with organisational culture.

Table 4: KM to improve processes (%)

Question (responses in agreement)	C	AE	BITT
Time commitment in KMS will be recovered in future	90	84	89
Anyone can record knowledge regardless of experience level	77	88	71
People prefer to record well-executed processes rather than those not as well executed	73	76	69
Participation is high where the company recognises KM as being important	97	94	90
Knowledge is power, but sharing knowledge results in loss of power	87	86	85

Although it was considered by all sectors that time commitment in KMS had benefit recovery in the future, the AE sector rated this lower than their counterparts. This result was linked to a lack of developed performance measurement reporting that demonstrated explicit value back to team members, which in turn serviced improvement iterations. Contribution in recording knowledge regardless of experience was considered favourably by the AE sector, while C and BIIT, comparatively, felt that experience was a necessarily prerequisite in KM.

The type of information recorded favours those processes where it is perceived that they have been well executed, rather than those less successful. This issue was the case particularly in the AE sector, while BITT recognised the benefits arising from KM in learning from mistakes. This difference may reflect the product focus and product improvement imperative under which this sector operates. This is set

against the often bespoke and multifarious nature of projects and the dynamic structure of project teams in the construction sector where value is given to those things that generally worked well as against project specifics of those which did not. Respondents also commented on the need for people within the organisation to recognise the relevance of the knowledge that was recorded in the system. Management recognition of the value of KM was viewed as paramount in the promotion and support of participation in KM processes, ranking highly across all sectors.

A factor identified by interview respondents as being significant from the BITT category was that recording knowledge is mandatory for their companies, where internal systems record levels of individual knowledge sharing. This integrated and obligatory approach (Figure 1) was seen as a feature in the perceived success of KMS in the sector.

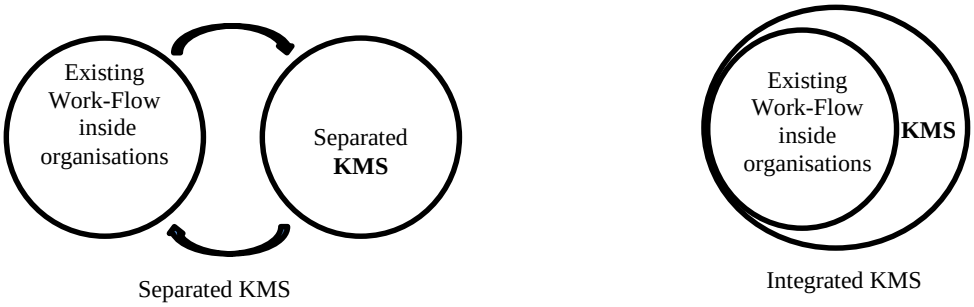

Figure 1 – Separated KMS versus Integrated KMS

Organisational Sociology related to power dynamics as a barrier to KMS (Soenen and Moingeon, 2001) comes into play where respondents acknowledged reluctance to share knowledge. This giving over of knowledge was seen as undermining individual capital, potentially placing at personal risk leverage within the employment setting. Respondents across all sectors had high levels of agreement that there was a risk affiliated with sharing knowledge, not only in the personal loss of power but also at an organisational and market level.

4.4. Section 4 - KMS and assistance in decision-making

The primary objective of KMS is to provide a platform for effective decision making through the utilisation of organisational, individual and project knowledge. This section, therefore, addressed the perception of practitioners of how an effective KMS can aid in informing decision-making (Table 5).

Table 5: KM to support decision-making (%)

Question (responses in agreement)	C	AE	BITT
Complex accessibility to KMS can create obstacles	82	96	93
No new solutions developed because it is easy to look only at past solutions in KM	63	72	78
KM reduces the risk of less optimal solutions in urgent decision-making	78	84	93
KM access to past examples allows better decision-making	93	96	92

There was a cross-sector acknowledgement, via consistent high affirmative values, that the complexity of KMS ran the risk of generating obstacles in the usefulness of the system in informing

decision making. Some argued that their organisations already had given up on some systems because they were overly complex or slow leading to people refusing to use the system. The need for an integrated and transparent system that was embedded into the particularities of the organisation environment was, therefore, an important aspect for final users.

The perception that reliance on a KMS ran the risk of preventing innovation and de novo solutions was more acutely felt in the AE and BITT companies, where there was a ten percentile point minimum difference with the construction sector. KMS was seen as having significant benefit by BITT respondents (93%) in optimising solutions where urgent decision making comes to the fore. Comments from this sector revolved around the aspect of KMS value in avoiding disputes. This benefit was not as highly valued by construction respondents (78%).

4.5. Section 5 - Assessment of different knowledge areas

This section was only answered by construction companies and addressed the perception of practitioners in different knowledge areas as a major focus. Respondents were asked to identify the areas that are important to them and the knowledge of the areas that they need, have, retain and share their professional activity (Figure 2).

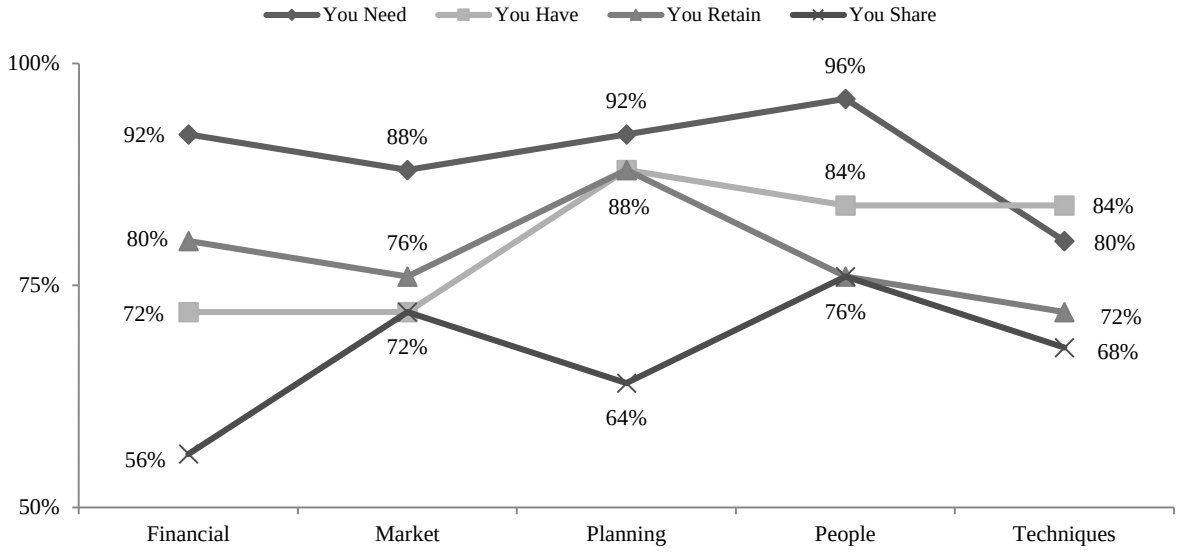

Figure 2: Knowledge areas in a construction company.

At the start of this section the respondents commented that all areas were important, however, at the time of the ranking they agreed that for their professional activity, in the day-to-day, some areas can be more important than others. The answers were that, currently, they have on average 80% of the knowledge that they need for their role, retain 78% and share only 67%. Respondents argued that one of the reasons to share less was due to lack of opportunities to share because sharing knowledge in their organisation is only between small groups and if requested. For the last question, interviewees were asked to classify between the five main different areas of importance for them and their activity. The results on average for each area were: Planning (71%), People (68%), Techniques (61%), Market (55%)

and Financial (45%). Therefore, for construction companies, the information about Planning and Techniques (Projects) and People (Human Resources) are the areas suggested to be used as a focus and starting points for KMS. Nevertheless, all the interviewees argued that all the areas are important and that it was a significant problem to choose the most important one. One of the possible reasons for selecting the financial knowledge at the end was because interviewees in the companies of this research already have sophisticated systems to control costs. Therefore, they may take that knowledge for granted, and might not realise the importance of not having it.

5. Conclusions

Ample literature exists to support a growing awareness of the advantages of using and implementing KMS in the construction sector. Research based on industry practice in the use of such systems can assist in reducing the risk of failure of KMS. This research confirmed an awareness of KMS in the Portuguese construction sector, however, it also identified that there are sectoral characteristics and organisational dynamics that may contribute to the undermining of effective KMS. The findings suggest that communities of practice within the construction sector differ, organisation size influences the nature of KMS, and recognition and commitment to KMS that are both intramural and extramural are necessary. Also, feedback loops that inform iterative improvement underpin user buy-in, and an understanding of organisational sociology dynamics are all necessary prerequisites that require consideration in KMS implementation.

To conclude, this study highlighted that KMS in construction companies to be successful need to start small, in one or two different areas, before spreading to the rest of the company. The steps must be small and incremental to the ambitious KMS global goal. Accordingly, given the results of the survey, and the nature of the people-based and project-based industry, construction companies need to start their KMS to focus in two main areas: managing knowledge of their people and their projects.
Further case study research is required to delve into the rationale that lies behind these findings in other regions. In the construction industry there barriers for knowledge management seem to exist and the sector tends to be very conservative, therefore, if KMS introduced high costs can be an additional obstacle. In this scenario research initiatives between academia and industry in KMS can be essential to help construction industry to implement their KMS efficiently and with minimum costs. KMS will help companies to be more competitive to address the economic crisis and to be better prepared to adapt to changes.

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