Knowledge management in construction sites: a comparative case study

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Abstract

Construction firms all over the world are increasingly being challenged by high cost pressure, shortened project cycles and increasing competition. Within a business environment, where the fast and reliable access to knowledge is a key success factor, an efficient handling of the organisational knowledge is crucial. Construction firms need to be aware of the advantages of knowledge management initiatives and practices. Each project provides a unique experience regarding knowledge and expertise. Knowledge management (KM) requires an environment that allows workers to create, capture, share, and leverage knowledge to improve performance. Firms are increasingly utilizing interdisciplinary organizational structures in which employees share knowledge and expertise within and between groups in order to cope with complex tasks.

This paper presents a comparative analysis of the knowledge management effort set up in three cases studies of construction companies. It presents the findings from these case studies from the perspective of the construction firm.

Keywords: Construction, case study, firm, knowledge management

1. Introduction

In today's construction market, ensuring business margin is simply harder to achieve. Competition keeps margins thin and projects become more complex. As knowledge is taking on a key business role a growing number of firms are expecting their knowledge management to be performed in order to transform corporate knowledge into competitive advantage. Therefore, the core of the construction organisation is currently moving from capital intensive towards becoming knowledge intensive (Ribeiro, 2006). With the advent of knowledge economy, knowledge itself has become not only a strategic asset but also the main source of organisational competitive predominance (Adenfelt and Lagerstrom, 2006). However, effective knowledge management (KM) should be able to support the core tasks of project management, including decision making, planning, control, and production (Yim et al., 2004).

As knowledge is taking on an important strategic role numerous firms are expecting their project management tasks to be performed effectively in order to leverage and transform the knowledge into competitive advantages (Desouza, 2003). Liao (2002) stated that the knowledge derived from projects is the intangible resource for solving problems, creating core competitiveness, and initiating new situations for both individuals and organizations now and in the future. KM in construction is about managing organization's knowledge assets to fulfill its organizational objectives. Thus, KM should enhance individual, group and organizational learning; improve information circulation; and even support innovation. Therefore, a KM system in construction is seen as a means of identifying and exploiting corporate individual knowledge assets: individual experiences, lessons learned, and best practices (Whetherill et al., 2002; Mohamed and Anumba 2005). Knowledge associated with previous construction projects success and failure, services, customers and products are resources that can produce a long-term and sustained competitive advantage for construction organizations (Newcombe, 1999; Ribeiro, 2005). Each project provides a unique experience regarding knowledge management. While project organisations have become common, the KM of construction project organisations is still largely underdeveloped. Enabling sharing and reuse of project knowledge and experience and finding ways to make such knowledge useful to enhance project cost and schedule performance is a key challenge.

This paper points out the importance of managing project knowledge and experiences. It investigates the current problems that occur on the construction site and how project knowledge and experiences are managed based on two firms and three case studies. Finally, it presents the findings and lessons learned from two firms and these case studies based on the project cost and schedule performance indexes.

2. Construction project knowledge

Construction is a knowledge based industry. Each construction business is unique regarding the way specialist professionals manage, share and use knowledge. Construction projects generate a large body of knowledge available for sharing and reuse within the construction organization and across projects. In addition, projects provide opportunities for new knowledge to emerge in a cross functional, site management context (Senge, 1990; Mohamed and Anumba, 2005; Renzl, 2008). In the site management context, site managers and professionals alike take decisions and solve new technical and complex problems by using their expertise and judgment to find prompt solutions (e.g., selection of an alternative construction method or component, corrective action for a non conformity, complex formwork design).

When discussing project knowledge, one confronts the characteristics of knowledge. Knowledge that resides within individuals is often referred to as tacit knowledge. Being inferred from the action of individuals, and being hard to verbalise and codify, tacit knowledge is acquired through sharing and practices. In contrast, explicit knowledge can be expressed in codified form and can, therefore, be diffused throughout the corporation in the form of rules, procedures, specifications and guidelines (Liebowitz and Wright, 1999; Lin et al., 2006). Knowledge is also stored within the project organisations in the form of common organisational practices and routines. Explicit knowledge can be transferred and communicated relatively easily in an organisational context, as opposed to tacit knowledge, which is highly personal in nature and difficult to organise, represent, store, transfer and share (Bhagat et al. 2002; Jewell and Walker, 2005). However, challenges involved in successfully transferring and utilising knowledge across organisational units create a crucial problem for firm's top management. The challenge confronted by firms seeking to stimulate innovation in project management through knowledge transfer is captured in the concept of knowledge "stickiness" (Szulanski, 1996). Knowledge is "sticky," or difficult to codify and transfer, the more it is embedded in individuals, contexts, or locations, causing transfer to be, costly and uncertain (Kogut and Zander, 1993).

A construction project generates a lot of information and knowledge available for reuse. Identification of key knowledge and the ability to utilize it is a challenge for any construction organization. Successful project management is based, on the one hand on accumulated project knowledge, and, on the other hand, on individual and collective competences (Kaski et al., 2003). There is growing evidence that firms are increasingly investing in KM initiatives and establishing KM practices in order to acquire and better exploit lessons learned, best practices and experience in project based environments (Choi et al. 2008). However, A relatively small number of studies have addressed the relationship between KM practices and project performance because of the difficulty in measuring and quantifying the value of knowledge (Choi and Lee, 2003; Keskin, 2005).

The construction project is a temporary organisational unit composed of individuals of different backgrounds, thereby possessing specialised knowledge for solving a common knowledge intensive task. Construction companies have people working on different construction projects. People involved in construction projects are not only organisationally but also geographically dispersed. But projects are temporally limited, and the people involved, and the lessons learned are dispersed or even lost when the project ends. Combined with employee empowerment and information decentralisation typical to project organisations, these result in organisational knowledge fragmentation and loss of organisational learning (Jarvenpaa and Ives, 1994).

According to Adenfelt and Lagerstrom (2006), the construction project is founded upon the principle of leveraging knowledge of dispersed teams to a temporary organisation to enable project development and implementation, and creation of new knowledge and expertise needed for future projects. Due to the special nature of project organisation form (e.g.

limited time and resources, great complexity, scope and cost constraints, new teams), projects are suitable for learning and sharing knowledge across the project team members (Lundin and Midler, 1998; Schindler and Eppler, 2003). The end of the construction project is the end of collective learning. The risk of a knowledge loss at a project's end is a problem for organisations, especially in knowledge intensive industries such as construction industry. Every construction project has several potential outputs, not all of which are necessarily intentional:

- A product (building, road, bridge) delivered for an internal or external client.
- Project knowledge related to the final product, its production, performance, use and management.
- Project history and lessons learned during project implementation and use.

Kaski et al. (2003) introduced the concepts of Project Memory (PM) to describe knowledge from project's history that can be used now, and Project Memory System (PMS) to describe the means by which the PM is realised. The PMS should be able to capture and handle the project knowledge and experience, and therefore enhance project learning. Most project-related problems, solution, experience and know-how are in the heads of individual engineers and experts during the construction phase. Implicit knowledge is normally not documented or stored in a system database. Capturing the implicit knowledge in the PM and providing it in form of explicit knowledge is important for executing knowledge management to preserve implicit knowledge as corporate property.

According to Schindler, M. and Eppler M. (2003) the learning from project experiences can be classified into two groups:

a) Process-based methods of gathering lessons learned from concluded projects

b) Documentation-based methods to learn from project experiences

Process-based methods stress the relevant actions and their sequence in the project life cycle while documentation-based methods focus on aspects of the organization and representation of the experiences and the storage of contents within the project management structure. Maqsood et al. (2005) demonstrated that various kinds of knowledge can elicited and documented, including tacit knowledge, by applying soft systems methodology (SSM) as a tool for KM in project-based environments. Maqsood et al. (2005) suggest that SSM can be applied to KM problems, in the construction management context, that are challenging to understand and act upon.

3. Assessing project performance with earned value management

Knowledge management plays a key role in project-based environments. The use of lessons learned, capturing and sharing relevant experience and implementing mechanisms to enhancing the reuse and sharing of knowledge are important elements that can improve project management (Love et al. 2005).

Earned Value Management (EVM) methodology is commonly defined as a management technique that relates resource planning and usage to schedules and to technical performance requirement (Abba, 1997). EVM provides value by enabling project teams to easily control progress and evaluate performance against initial baselines. Early analysis of the performance of projects immediately communicates the current health of projects and can be used as a measurement of early performance to predict final cost and delivery schedules (Kuehn, 2006). Earned value analysis not only helps the project management manager identify project issues, but it can also provide deep insights of how to resolve each issue based on cost and schedule performance history. Having a project management tool that indicates the impact that any slip in the work packages of our baseline plan will have on all future work is a big help for any project manager.

The earned value system incorporates scope and integrates it with cost and schedule (Figure 1). It is used to measure and communicate the real physical progress of a project and to integrate the three critical elements of project management (scope, time and cost management). It takes into account the work completed, the time taken and the costs incurred to complete the project and it helps to evaluate and control project risk by measuring project progress in monetary terms. The basic principles and the use in practice have been comprehensively described in many sources (Fleming and Koppelman, 2000; 2003).

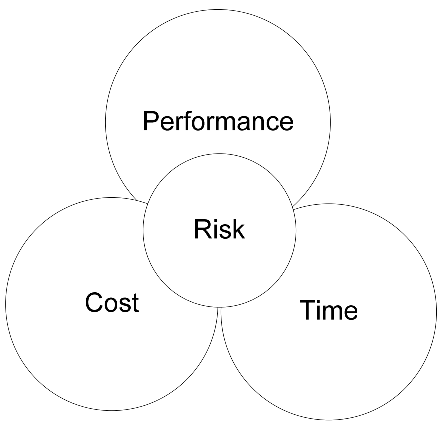

Figure 1- The EVM elements

The goal of the EVM is to control costs and schedule performance during the project. In the EVM, the schedule and cost performance indices (CPI/SPI) are used for constant monitoring of the project’s cost and schedule based on a baseline schedule (Kuehn, 2006). EVM indicates how much of the budget and time should have been spent, with regard to the amount of work done to date (PMI, 2000). Therefore, EVM is a common technique for cost and schedule control through sampling CPI and SPI during the construction phase. The general expressions for the cost and schedule performance indexes are:

- Schedule performance index (SPI) = EV/PV
- Cost performance index (CPI) = EV/AC

Earned value analysis information can be used to predict future performance by integrating project’s scope with costs and schedules. It enables the project manager to be able to forecast the (probable) final cost and schedule results on the project from as early as the 20 percent completion point (Fleming and Koppelman, 2003). It also enables the project manager to identify cost and schedule overruns, what might happen on the project in the future if things do not change and promote efficient use of the resources for the remaining work of the project. However, EVM need to be linked to other knowledge resources (such as lessons learned, best practices and project manager’s expertise) to quickly adapt to making changes to counter adverse trends and resolve project issues.

4. The knowledge management life cycle in construction projects

Project performance can be improved, when people communicate and share best practices, lessons learned, experiences, insights, as well as common and uncommon sense (von Krogh, 2002). Firms are increasingly utilizing interdisciplinary organizational structures in which employees share knowledge and expertise within and between groups in order to cope with complex tasks (Cummings, 2004). However, as pointed out by Renzl (2008) reusing and sharing knowledge and expertise have proven a rather difficult challenge in project-based environment.

Life cycle models can be used to organise one’s thinking about KM in an organizational environment (Lee et al., 2005). There are several KM life cycle model available that outline the key aspects and processes of KM (Davenport and Prusak, 2000; Ward and Aurum, 2004; Lee et al., 2005; King et al., 2008). The model proposed by King et al. (2008) describes the key aspects of KM in the organisational context and relate them to the organisational performance. We have used the KM life cycle model introduced by King et al. (2008) to analyse the KM practices in project based environments. Therefore, in this paper knowledge management in a construction project environment is considered to consist of five groups of activities:

a) Knowledge creation, for example socialization, collection, externalization, internalisation and combination.

b) Knowledge refinement for example explication, drawing inferences, evaluation and encoding.

c) Knowledge storage for example organisation, mapping, structuring, representation and retrieval.

d) Knowledge sharing across and outside the project.

e) Knowledge utilisation and productisation, for example integration into products and decisions, innovation, learning (individual and collective), collaborative problem solving, reuse, story telling, and application in other projects.

5. Cases and data

The cases presented in this paper come from two construction firms here designated by firm A and firm B. The firm A is a large global construction organisation. The firm B is a medium size contractor organisation. The cases involved three construction projects sites. They were:

a) Case 1: Pipeline for a major water supply scheme

b) Case 2: Construction of two Viaducts in a major motorway

c) Case 3: Industrial building

Cases 1 and 2 come from firm A. Case 3 comes from firm B.

Case 1: This case comprises the duplication of the adducer of a water supply scheme with a tunnel 3,000 meters long. This project is connected to the water supply scheme of a large city. The duration and cost are respectively 24 months and 11.801.534€. The level of subcontracting is high, around 90%. Case 2: This case comprises the construction of two viaducts including their access roads in major highway. The first viaduct is 156 meters long and comprises 4 sections with the following spans: 24 meters; 45 meters; 54 meters; 33

meters. The second viaduct is 187.2 meters long and comprises 7 sections with the following spans: 25.75 meters; 30 meters; 4 of 27.5 meters; 21.5 meters. Expected project duration is 26 months. The level of subcontracting is high, around 80%. Case 3: This case comprises the construction of an industrial building with a total construction area of 6.898 m2. The expected duration for this project is 18 months. The building comprises four blocks with 2 upper floors and 1 ground floor. The level of subcontracting is below 80%.

All cases were under construction at the time that this study was carried out. This study was based principally on semi-structured interviews with two members of the project management team of each construction project case, and on the review of projects related documents, best practices and project management tools. Therefore, the KM models, sources and practices were identified and analysed within each construction project.

6. Analysis and discussion

Knowledge management practices and sources and practices

Firm A: Firm A was established as a global group in 2003 and has become the biggest Portuguese enterprise in the construction industry. The core business is shared by four distinct and autonomous business areas: engineering and construction; environment and services; property and tourism; and transport and concessions. According to the interviews, knowledge in firm A is viewed as an object to be stored and transferred. Its KM effort focuses on gathering, storing and transferring knowledge. Knowledge, is dealt with information access from a central repository. Firm A has developed and implemented since 2004 a KMS based on an information and communication platform aimed at enhancing transfer of best practices and lessons learned across projects teams and to promote sharing of experiences throughout the organisation. Knowledge is predominantly explicit and independent and is strongly centralized and customized by the technology and innovation department (TID) in the firms' head quarter (HQ). KM effort primary focus is on knowledge harvesting, refinement, storing, and transferring. There is neither collaborative teamwork nor network system to allow vertical communication in the organization. Most of the lessons learned from project implementation are not fully integrated into the firm's KM effort. Paper documents (project related documents, project management tools, project management procedures, monthly site report and best practices), monthly control meetings and interaction with colleagues were identified by interviewees as the most important sources of knowledge in cases 1 and 2. Project related documents in cases 1 and 2 include: contract documents, budget, critical path method (CPM) based schedule, specifications and site monthly report. All knowledge generated during construction phase is captured and stored in the monthly site report (RMO).

The role of social interaction was underlined in case 1 by several references to seminars and benchmarking visits, but the interviewees from case 2 had had problems participating in these occasions. Intra-organisational work practices, monthly control meetings and the RMO were considered to be the main areas of new knowledge created in case 1. This was partly due to the fact that one of the main goals of case 1 was to develop new logistical practices for a distributed supply network. Storage of new knowledge relied on monthly reports that the project organisation required in cases 1 and 2. No other written material exists or is needed.

Firm B: Firm B is made up of businesses in construction and property development. The construction contracts were the most significant contributors to the consolidated turnover. While top management formally recognised the importance of the knowledge assets in the firm, no resources are so far committed. Thus, firm B has no formal KM model implemented over its organisation. The main sources of knowledge in case 3 were limited to the project related documents. Project related documents in case 3 include: contract documents, budget, CPM based schedules, specifications and RMO. Nothing has been used to store new knowledge in case 3.

Discussion

Firm A is well aware of the capital importance of KM in their businesses. KM is new for firm B and no plans have been made to implement KM in the future. Almost all the interviewees in cases 1, 2 and 3 mentioned reports and control meetings proceedings as formal ways to record and store project experiences. However, reporting was often found to be a competence and resource problem for case 3. Documenting the work done required skills that were not necessarily available in case 3. Almost all the interviewees in cases 1 and 2 highlighted the importance of monthly site control meetings as way not only for assessing the project status but also as a means for exchanging views and experiences based in earned value analysis information. The interviewees found the questions concerning the utilisation of knowledge created in the projects difficult, even puzzling, due to the knowledge stickiness within their organisations. As pointed out by Jewell and Walker (2005) knowledge stickiness is a problematic issue for the conversion of tacit knowledge in people's head into documented explicit knowledge.

7. Earned value results

It was found in all three cases that earned value analysis information recorded in the RMO is an integral part of project history. It represents the performance of the project and the results of management decisions taken by project managers during project implementation. The implementation of EVM as a project management tool in cases 1 and 2 provided a stimulus for the exchanging of views and experience within the project management organisation. To study the impact of KM practices on project performance, schedule and cost data needed for earned value analysis were obtained for the three case studies. Therefore, cost and schedule performance indexes are calculated from cases 1, 2 and 3 for each of the 10 months of 2006/2007 and presented in tables 1.

Table 1: Cost performance and schedule performance indexes

Month	Case 1		Case 2		Case 3	
	CPI	SPI	CPI	SPI	CPI	SPI
1	1,09	0,62	1,02	0,85	0,75	0,71
2	1,06	0,62	1,04	0,89	0,73	0,69
3	0,97	0,58	1,01	0,95	0,76	0,70
4	0,99	0,69	1,02	0,91	0,67	0,71
5	1,19	0,70	1,03	0,96	0,69	0,75
6	1,29	0,77	0,99	0,93	0,72	0,78
7	1,27	0,76	0,97	0,96	0,56	0,76
8	0,78	0,61	0,99	0,92	0,60	0,81
9	0,80	0,61	0,82	0,94	0,64	0,84
10	0,80	0,61	0,99	0,98	0,71	0,77
Mean	1,02	0,66	0,99	0,92	0,68	0,75
Standard deviation	0,19	0,07	0,06	0,04	0,07	0,05

As shown in table, cost and schedule performance indexes from cases 1 and 2 are much better than those from case 3. Case 1 has a higher CPI than case 2. Case 2 has a higher SPI than case 1.

8. Conclusions

Construction projects and project organisations require exceptionally efficient knowledge management, if they are to learn from their experiences. This was pointed out by the interviewees for cases 1 and 2, who mentioned various knowledge management problems, such as the difficulty for recording, storing are sharing project knowledge. Nevertheless, the observed knowledge management practices were weak and unsystematic in cases 1 and 2, except for the retrospective reporting process and control meetings. Paper documents (RMO), monthly control meetings and interaction with colleagues were identified as the most important sources of knowledge. The observed knowledge management practices were fragmented in case 3. The observed cost performance index from case 1 are better than those observed from case 2. This is explained by more effective project management practices observed in case 1 which benefited from better KM effort. The observed cost and schedule performance indexes from cases 1 and 2 are better than those observed from case 3. We may say that cases 1 and 2 benefited from KM effort.

Construction management can be improved by sharing experiences among engineers, helping to avoid mistakes from previous projects (Jewell and Walker, 2005*)*. From the perspective of knowledge management, the know-how and experience of construction engineers and experts are the most valuable because their accumulation depends not only on manpower but also on money and time. However, to succeed in a project organization, KM must be an integral part of the project management daily practices. It should be included in the project value creation chain. The essence of organizational culture is to encourage individuals to create, store and share knowledge as well as to define what knowledge is valuable and how to use it. We conclude that in a construction project, as a temporary unit, the individuals and the knowledge they create are the most critical issues for improving project performance and ultimately for collective learning.

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