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Knowledge Sharing and Reuse for Improving Construction Project Earned Value

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ABSTRACT

Construction is an information and knowledge driven industry. Each construction project is unique regarding the way specialist professionals manage and use information and knowledge. A building project generates a large body of knowledge for sharing and reuse within the construction organisation. Each project provides a unique experience regarding knowledge management. The real issue for building researchers and professionals is how to reap the advantages out of these knowledge and experiences to improve project cost and time performance. Enabling sharing and reuse of project knowledge and finding ways to make such knowledge useful to enhance efficiency and effectiveness of construction processes is a key challenge.
Within a business environment, where the fast and reliable access to knowledge is a key success factor, an efficient handling of the project knowledge and experiences is crucial. This paper points out the importance of managing project knowledge. It looks at ways project knowledge and experiences are managed in the construction projects sites based on three case studies. Finally, it presents the findings and lessons learned from these case studies based on the project performance indices.

Keywords: **Construction, Earned Value, Knowledge Management**

1. INTRODUCTION

During recent decades, the core of the construction organisation is currently moving from capital intensive towards becoming knowledge intensive. With the advent of knowledge economy, knowledge itself has become not only a strategic asset but also the main source of organisational competitive predominance. 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 companies are expecting their KM 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 (Mohamed and Anumba 2005; Whetherill et al., 2002).

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 (Ribeiro, 2005; Newcombe 1999). Each project provides a unique experience regarding knowledge management. While project organisations have become common, KM of construction project organisation 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 looks at ways project knowledge and experiences are managed in the construction projects sites based on three case studies. Finally, it presents the findings and lessons learned from these case studies based on the project cost and schedule performance.

2. CONSTRUCTION PROJECT KNOWLEDGE

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 and guidelines (Lin et al., 2006; Liebowitz and Wright, 1999). Knowledge is also stored within the project organisations in the form of common organisational practices and routines.

A construction project generates a lot of information and knowledge available for reuse. Identification of critical 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).

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).

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 needed for future projects (Adenfelt and Lagerstrom, 2006). 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 (Schindler and Eppler, 2003; Lundin and Midler, 1998). The end of the project is consequently 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 product, its production, use and management.
- Lessons learned during project implementation

The systematic retention of project knowledge and experiences enables a project organisation to save considerable costs (which result from redundant work and the repetition of mistakes), reduce project risks, improve project cost and schedule performance. However, knowledge and lessons gathered in different construction projects are not systematically integrated into the organisational memory (Ribeiro, 2006). Moreover, engineers and experts normally take domain knowledge with them, leaving little or nothing that will benefit subsequent projects or the company when they finish projects or leave the company.

Construction organisations must learn to gather, share and reuse project knowledge and lesson learned from previous projects. Savings are considerable if lessons learned from prior projects can be transferred and reused efficiently within the organisation. The construction phase of any project creates experience, problem-solving, know-how, know-what and innovation. Therefore, one of main goals of project management is managing knowledge and knowledge competences in projects sites and project organisations.

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.

3. PROJECT EARNED VALUE MANAGEMENT

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).

The earned value system incorporates scope and integrates it with cost and schedule. 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).

Prior to the latest edition of the Project Management Institute's A Guide to the Project Management Body of Knowledge (PMBOK) (PMI;

2000), the abbreviations used for these three essential earned value quantities were taken directly from the initials of the defining nomenclature:

- BCWP: the budgeted cost of work performed
- ACWP: the actual cost of work performed
- BCWS: the budgeted cost of work scheduled

In an attempt at improving this terminology, the latest edition of the PMBOK reduces the number of words to two per cost term:

- EV: Earned value (BCWP)
- AC: Actual cost (ACWP)
- PV: Planned value (BCWS)

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. 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 indices are:

$$\text{Schedule performance index (SPI)} = EV/PV$$
$$\text{Cost performance index (CPI)} = EV/AC$$

Current performance is the best indicator of future performance and therefore using trend data it is possible to forecast cost or schedule overruns at quite an early stage in a project. EVM indicates how much of the budget and time should have been spent, with regard to the amount of work done to date. EVM differs from the usual budget verses actual costs incurred model, in that it requires the cost of work in progress to be quantified. This allows the project manager to compare how much work has been completed against how much he/she expected to be completed at a given point (PMI, 2000).

EVM provides the project manager with an objective way of measuring performance and predicting future outcomes. This can enable him/her to report progress with greater confidence and highlight any overrun earlier. This in turn enables the management team to make cost and time allocation decisions earlier than would otherwise be the case and as such EVM is a very useful tool for predicting the outcome of projects in terms of time to completion, cost to completion and expected final costs.

4. CASES AND DATA

In this paper, knowledge management in a construction project is considered to consist of four groups of activities:

a) Knowledge creation, for example collection, combination and refinement.

b) Knowledge administration, for example storage, organisation, representation and retrieval.
c) Knowledge sharing within and outside the project.
d) Knowledge utilisation and productisation, for example integration into products and decisions, and application in other projects.

The cases involved three construction projects sites and organisations. They were:

a) Case A: Adducer of the Lisbon Water Supply Scheme
b) Case B: Viaducts of Lisbon - Sintra
c) Case C: Hotel Praia

Case A: This case comprises the duplication of the adducer of a water supply scheme with 3,000 meters long. This project is connected to the water supply scheme of the city of Lisbon. The duration and cost are respectively 24 months and 11.801.534€. The level of subcontracting is high, around 90%.

Case B: This case comprises the construction of two viaducts including their access roads in major highway connecting Lisbon to Sintra. 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 C: This case comprises the enlargement and renovation of a hotel. The construction cost is around 6.000.000€ and the expected duration is 20 months. The building comprises 6 upper floors and 3 underground floors.

All cases were under construction at the time that this study was carried out. Cases A and B share the same contractor, which is different from case C.

This study was based principally on semi-structured interviews with one project manager of each construction project case, and on the review of projects related documents, best practices and project management tools. Therefore, the KM sources and practices were identified and analysed within each construction project.

5. RESULTS

5.1 Knowledge management sources and practices

Paper documents (project related documents, project management tools, project management procedures, monthly site report and best practices), monthly meetings and interaction with colleagues were identified as the most important sources of knowledge in cases A and B.

Project related documents in cases A and B include: contract documents, budget, CPM based schedule, specifications and site monthly

report. Figure 1 presents the project management workflow used in both cases A and B.

All knowledge generated during construction phase is captured and stored in the monthly site report (RMO). The RMO registers all data, information related to the progress of the schedule, budget, quality and safety. The RMO also includes the lessons learned during the execution of the construction activities.

The main management tools in case A and B are as follows: (a) Microsoft Project; (b) CCS Candy database, (c) Microsoft Access database.

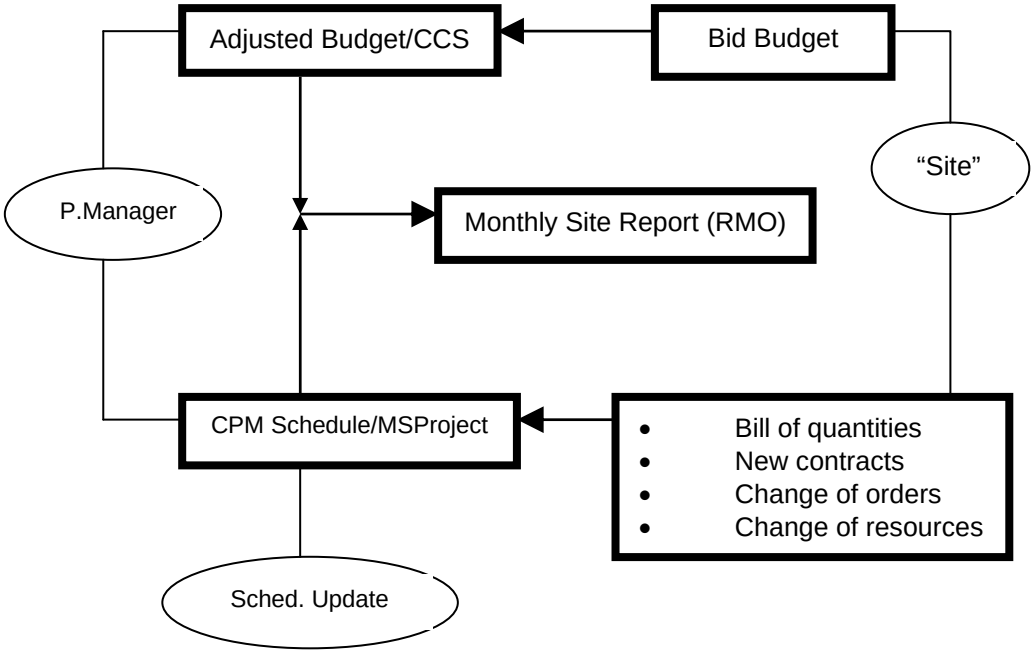

Figure 1 Project management workflow of cases A and B

The main sources of knowledge in case C were limited to the project related documents. Project related documents in case C include: contract documents, budget, Excel sheet Gantt chart and specifications.

The role of social interaction was underlined in case A by several references to seminars and benchmarking visits, but the interviewee from case B had had problems participating in these occasions.

Intra-organisational work practices and the RMO were considered to be the main areas of new knowledge created in case A. This was partly due to the fact that one of the main goals of case A was to develop new logistical practices for a distributed supply network.

No particular document management or groupware systems were identified in the three cases.

Storage of new knowledge relied on monthly reports that the project organisation required in cases A and B. No other written material exists or is needed. Nothing has been used to store new knowledge in project C.

Almost all the interviewees mentioned reports as a way to accumulate and store project experiences. Reporting was often found to be a competence and resource problem. Documenting the work done required skills that were not necessarily available in case C.

Web documents were available to the personnel of cases A and B. The Web documents include company best practices, corrective and preventive actions. Even in case B, the Web-pages were not used by all the parties involved, even though the pages contained a comprehensive collection of project documents.

The interviewees found the questions concerning the utilisation of knowledge created in the projects difficult, even puzzling, due to the absence of a KM culture within their organisations.

5.1 EARNED VALUE RESULTS

Schedule and cost data needed for EVM calculations were not available in case C because of the absence of project management formal practices in place. Therefore, cost and schedule performance indices are calculated from cases A and B for each of the 4 months of 2006 and presented, respectively, in tables 1 and 2.

Table 1 Data set from Case A

Month	CPI	SPI
April	0,97	0,66
May	1,33	0,82
June	1,18	0,71
July	1,11	0,69

Table 1 Data set from Case B

Month	CPI	SPI
April	1,01	0,73
May	0,99	0,35
June	0,97	0,43
July	0,89	0,57

6. DISCUSSION AND 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 A and B,

who mentioned various knowledge management problems, such as the absence of formal KM procedures. Nevertheless, the observed knowledge management practices were weak and unsystematic in cases A and B, except for the retrospective reporting process. It does not benefit immediately the projects.

Paper documents and interaction with colleagues were identified as the most important sources of knowledge.

The observed knowledge management practices were absent in case C.

The observed cost and schedule performance indices from case A are better than those observed from case B. This is explained by more effective project management practices observed in case A which benefited from better KM procedures.

Construction management can be improved by sharing experiences among engineers, helping to avoid mistakes from previous projects. Problems that have already been solved do not need to be solved again. 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 organisation 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 collective learning.

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