

# Development of a conceptual model for Knowledge Management for Improving Construction Management.

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**Abstract:** The free market economy encourages the emergence and growth of competition between organizations working in the same sector. When compared to other markets, the Construction Industry appears to be extremely competitive due to reduced schedules for each project, tight profit margins, complex construction methods, diverse and non-standard working procedures, in addition to a large number of stakeholders during the project. To increase productivity with efficiency and effectiveness, both in the construction sector as for other business sectors, it has been noticed the emergence of new project management concepts including the one presented in this work: Knowledge Management. After consulting scientific studies about Knowledge Management and Construction Management, the utmost importance of knowledge in the development of an organization was noticed.

The purpose of this paper is to propose the development of a conceptual model for Knowledge Management in support of Construction Management. Thus a methodology using different tools to allow the acquisition, extraction, storage, sharing and ultimately the creation of new knowledge, is suggested.

This model is presented as an asset for organizations resulting in major improvements to the database accessibility, increasing efficiency and effectiveness, knowledge gains and ultimately Integration of company employees.

**Keywords:** Knowledge, Construction Management, Knowledge Management, Knowledge Management System

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## Extended Abstract

### 1 Introduction

The free market economy encourages the emergence and growth of competition between organizations working in the same sector. Their differentiation is seen in the form of their assets, tangible and intangible goods. The organization's management must be effective and efficient. This objective only becomes reachable when there is an optimization of the organization's activities. When compared to other markets, construction Industry appears to be extremely competitive due to the reduced schedules for each project, tight profit margins, and complex construction methods, diverse and non-standard working procedures, in addition to a large number of stakeholders during the project. To increase productivity with efficiency and effectiveness, both in the construction sector as for other business sectors, it has been noticed the emergence of new project management concepts including the one presented in this work: Knowledge Management.

In this context, this paper presents the development of a model for Knowledge Management for supporting Construction Management.

### 2 The Construction Industry

The increasing competitiveness in the construction industry requires increasing care in the development and implementation of projects. Aspects such as quality of construction, implementation deadlines and budgeting are factors to be in focus to achieve success. Since this is vital for the implementation of an enterprise, their optimization becomes the subject of study in order to secure gains.

#### 2.1 From Project to Construction Project Management

It has come to notice a large number of associations focused on the theme "project" and "Project Management": Association for Project Management (APM) and Project Management Institute (PMI).

A project is made of a group of interrelated work activities constrained by a specific scope, budget, and schedule to deliver capital assets needed to achieve the strategic goals of an Agency. All projects must have a beginning and an end. [1,2]. According to PMI, Project Management is the application of knowledge, skills, tools, and techniques to project activities in order to meet or exceed stakeholder needs and expectations from a project [3]. Construction Project Management (CPM) is defined as: "the planning, controlling and coordinating of a project, from conception to completion on behalf of a client,

requiring the identification of the client's objective in terms of utility, function, quality, time and cost, and the establishment of relationships between resources, integrating, monitoring and controlling the contributors to the project and their output, and evaluating and selecting alternatives in pursuit of client's satisfaction with the project outcome" [4].

CPM comprises three distinct phases: design, implementation and exploitation [5]. If the design phase is extremely important to outline the objectives and the different phases of the project, the implementation phase appears to be of great importance to insure the success of the venture. Construction Management objectives are to maximize the capabilities of the development and the implementation of enterprise at all levels: manpower, equipment, materials, construction site, contractors, contracts, legal aspects, security of the participants, costs and deadlines. Construction Management will consider the following: cost control, deadlines control, quality control and safety.

## **2.2 Construction Preparation**

Before the construction phase, preparation must be made in order to perform it well. Many processes are executed in this phase in order to plan the future construction work [7]. This phase proves to be of great importance because decisions taken here will influence the entire implementation phase. Any unexpected event occurred during implementation phase that has not been adequately considered during preparations, will result generally in cost overruns and delays. At this time, you define the templates of the project: budget, planning, resources and worksite safety.

## **2.3 Actors**

An added difficulty in the construction sector is the extensive list of actors during execution. As a project evolves, many stakeholders appear during construction process such as contractors, auditors and designers [6]. Due to a big number of participants in each activity, there is a great importance in defining every stakeholders' function in order to get better results.

## **2.4 Production Control**

During implementation, Production Control consists of very importance since it can define the success or failure of a construction project. The production control focuses mainly on deadlines, costs, quality, environment and security. As the program is defined previously, a follow-up work should be performed in order to verify the work evolution, and identify, prevent and/or easily solve possible complications [6]. The earlier you know that you have a problem on your project, the better chance you will have to mitigate that problem [8]. In order to perform different controls, many systems have been developed.

### **2.4.1 Cost and term**

The definition of control cost and time is of great importance in its implementation. Cost overruns during execution may turn it an economically unattractive project, while delays in the execution involve unanticipated cost increases (payment of fines, delays in sales, validity of building permits ...). To assure a correct control over costs and terms, a recent tool known as Earned Value Management, (EVM), has been developed and applied to different areas. Based on three dimensions of Earned Value (Planned Value, Earned Value and Actual Cost), EVM is announced as a simple adaptable method with great results in construction Industry [8, 9, 10].

### **2.4.2 Quality, Environment and Security**

In the construction industry, quality can be defined as meeting the requirements of the designer, constructor and regulatory agencies as well as the owner. [11] Quality control consists of checking the quality of work and its components (mainly materials) by comparing it with the desired quality, usually defined in terms of technical specifications [6]. The increasing concern and regulatory environment, coupled with the increasing importance and public pressure, gradually put the issue of energy and environmental performance increasingly on the agenda of building construction and in its relationship with its surroundings, understood in the enterprise [12]. The high level of accidents at work in the Construction Sector and Public Works is of concern to the general population and for all those involved in the act of building which, directly or indirectly, have responsibilities in this area [13]. It is important to note that there are solutions to Integrated Management Systems certification covering directly on three factors presented previously.

### **3 Knowledge Management**

#### **3.1 Data, information, knowledge and wisdom**

It is important that the concepts of data, information, knowledge and wisdom are properly defined here for one to clarify the fine line that differentiates them. Data can be defined as "a sequence of quantified or quantifiable symbols" [14]. For data, we can consider numbers, letters, pictures or sounds, among others. Information is usually defined as data endowed with relevance and purpose [15]. The purpose of information flows by changing the way the receiver perceives a certain theme, creating an impact on his wits and his behaviour [16]. Knowledge can be interpreted, in a simplistic way, as information that has been lived, experienced or studied. More importantly knowledge enables more efficient performance, developing a better ability to forecast future events. Finally, wisdom rises over knowledge. Wisdom is associated with a maturity of knowledge. Wisdom is associated with the capacity/competence to carry out a critical or practical appraisal in a given situation.

Recently, Ryle and Polanyi exposed an innovative concept of knowledge. Ryle demonstrates the difference between the types of knowledge: "knowing how" and "knowing that" [17]. For Ryle, the intelligence ("knowing how") cannot be defined through knowledge ("knowing that"). Polanyi provides a similar theory, but he develops the concepts of "tacit knowledge" and "explicit knowledge" [18]. The first reflects the personal knowledge, difficult to explain, the result of life experiences, while the second refers to the knowledge acquired in formal, systematic, easy explanation. Polanyi suggest that both types of knowledge are always present, creating a sense of continuity of tacit and explicit knowledge. Alavi & Leidner define tacit knowledge as knowledge rooted in actions, experience and involvement in the specific context, while explicit knowledge is knowledge articulated and widespread [19]. Based on Polanyi's theory, and on a Japanese economic study, Nonaka and Takeuchi (1995) stated that the interaction between these two types of knowledge allow the creation of new knowledge. The combination of these two categories allows the development of four types of knowledge conversion, called "The SECI Method": Socialization, Externalization, Combination and Internalization [19]. Knowledge becomes a circular and endless cycle, generating new knowledge.

#### **3.2 Knowledge Management**

Although this is a fairly recent discipline, projected especially since the 90's, it can be assumed that Knowledge Management has always existed. However, the concept of Knowledge Management (KM) at enterprise level is much more recent, having its origin in the mid-20<sup>th</sup>-century. "The most valuable assets of a 20<sup>th</sup>-century company were its production equipment. "The most valuable asset of a 21<sup>st</sup> - century institution, whether business or non business, will be its knowledge workers and their productivity" [15]. Bollinger and Smith (2001) define the organizational knowledge as a strategic asset because it is a valuable asset, rare, inimitable and non-replaceable. [20]

There have been several definitions of KM developed by different authors [21, 22, 23, 24, 25]. In the present study, the Lin and Tserng's suggestion is considered: KM consists in acquisition, extraction, storage, sharing and update [26]. According to Zhang et al. (2009), knowledge will not bring value unless it is actively used [27].

Knowledge transfer is one of the most important aspects of KM: to gain competitive advantage, organizations should facilitate the effective transfer of knowledge among employees. The interaction between the continuous transfers of knowledge and the conversion of tacit knowledge into explicit and vice versa, according to the SECI method, within an organization allows the creation of knowledge [19]. Chu and Fong determined some key aspects for a better understanding of knowledge sharing such as the main barriers and possible benefits [28].

#### **3.3 Knowledge Management in Construction Industry**

The construction sector is considered as a high risk industry, with reduced profit margins, fragmented processes involving partnerships between different stakeholders applied in several places, making every project unique [29,30]. Construction is a project based industry where each project is unique and involves a big number of stakeholders who collaborate with each other at various stages during the project lifecycle [31]. Workers are project loyal, rather than company loyal, and more likely to change their job and company at the end of the project [29]. Thus, construction industry can be defined as a competitive industry, with a tight schedule, reduced profit margins, diversity of processes and not standardization of production, where there are several actors temporarily assigned to the completion of a project. However, there are also great knowledge flows during lifecycle project which is considered an asset for companies that should not be wasted.

To obtain capital gains, the knowledge used during a construction project, tacit or explicit, should always be managed, in order to be stored for later use. In the construction industry, explicit knowledge

refers to documented information being collected, stored and archived in paper or in electronic format. Tacit knowledge is the experience and expertise kept in mind of construction professionals, the company's culture, lessons learned and other valuable information [27]. Many analysts have recognized the limitations of current approaches to managing information and knowledge related to the construction sector [30]. Problems such as lack of motivation to share knowledge or fear of sharing are real in construction industry.

While it has long maintained a sceptical view about the benefits of information technology in the last decade, the construction industry has made significant efforts to adopt these solutions, developing many KMS.

## **4 Knowledge Management Systems**

The evolution of IT has enabled considerable improvements in the storage of documents and in the development of databases. Since Knowledge Management Systems (KMS) have been created, new methodologies allowing to share, acquire, extract/collect, store or update existing knowledge in the company were developed. KMS refer to a class of IT applied to organizational KM [32]. Alavi & Leidner have defined three key applications in the development of systems for KM: codification and sharing of best practices, creation of corporate knowledge directories, and networking of knowledge [32].

### **4.1 Requirements**

To develop a KMS, some features are necessary to enable an easy application of the instruments. Carillo et al (2000) define the main requirements for the development of a KMS [33]. To improve performance, it must be adjusted to the needs of each organization. Nevo and Chan (2007) defined the key success factors as well as the main flaws of a KMS [34]. A KMS will only succeed if the direction outlined by the company is followed. [35]

### **4.2 KMS Generations**

In order to allow the application to different business areas, KMS have undergone various changes with the purpose of better adapting to each specific organization. In 2002, McElroy determined two generations of KMS. The first generation was based on the exchange of ideas and knowledge between people. The second generation focused on the creation of knowledge from collaborative work [36]. Based on McElroy's work, Rezgui et al. (2010) enumerated three generations of KMS: the first generation emphasizes sharing and access to information. The second generation is characterized by an increasing awareness about human and organizational factors, including adoption of technology. The third generation of knowledge adopts a capability perspective with a view of creating value, with a strong total lifecycle orientation [37].

### **4.3 KMS in Construction Industry**

While one might argue that the concept of KM exists in the construction industry for a long time (through the company's manuals and procedures), strictly speaking it has only gained importance since the development of KMS.

Many systems applied to the construction sector have been presented by researchers, among which: Clever [24], e-Cognos [30], C-Sand [38], TRIZ and BIM.

### **4.4 KM Software**

Countless software tools have been created in the development of KM. This software tools were designed to allow the development of KM in different application areas.

In addition to database tools allowing storage and sharing, KM software also enables the creation of new knowledge as well as its extraction and updating. In the early 90's, the emergence of KM software was limited to a simple groupware technology that facilitated group work. With the evolution of IT and Internet, we have witnessed the proliferation of KM solutions increasingly tailored to the needs of each organization.

In 2009, Dave & Koskela determined different tools that enable the exchange of knowledge within groups of people [31] (for example: Wiki, Blog, Internet Forum, Instant Messaging and Enterprise Portal).

After exposing the applicability of KM in several areas, and particularly in the construction sector, we can now present the model proposed by this article.

## 5 The Model

The general advantages of KM, associated with the need to make available the information's organization for improving construction management, led to the creation of a KM model aimed at creating new knowledge in the construction industry, especially during the implementation phase.

### 5.1 Description

In order to allow the knowledge to flow through different channels, the creation of two distinct work areas is suggested. The first area has the objective of supporting the production control process during implementation whereas the second area is aimed towards the development of KM supporting the construction supervision. This model also envisages the integration of employees in the company's KMS: all users will have access to the company's database and operating system.

#### 5.1.1 Components

##### 5.1.1.1 Stakeholders:

The stakeholders are entities who are involved in the implementation phase, who possess knowledge and who are able to share it with the company. There are two different types of stakeholders: internal stakeholders and external stakeholders. It should be noted that each internal user, called common user, has its own profile in the company's social network, personal blog and email account. It is important to separate the common user from the allocated user who is posted to a particular construction project. Next, it is presented a summary of the functions of each stakeholder in the proposed model:

**Table 1 - Stakeholders' Function**

<b>Internal stakeholders</b>	<b>Common User</b>	<ul style="list-style-type: none"> <li>• Communicate with others through social networking;</li> <li>• See and comment on the articles published on other users' blogs;</li> <li>• Create, view and fix/update entries in the Wiki of the company;</li> <li>• See reports of earlier works and exceptionally blogs tracking earlier works;</li> <li>• Insert and reply to threads in the discussion forum;</li> <li>• Consult the manual of the company.</li> </ul>
	<b>Allocated User</b>	<ul style="list-style-type: none"> <li>• Preparation of the Closing Work Report (Project Manager);</li> <li>• Control and maintenance of the blog-tracking site (Project Manager);</li> <li>• Support for the Closing Work Report (director of construction);</li> <li>• Elaboration of the concluding comments about the work execution (foremen and pointers);</li> <li>• Entering information in the project-tracking blog (all).</li> </ul>
	<b>Knowledge Management Support Team</b>	<ul style="list-style-type: none"> <li>• Control the activities of allocated users;</li> <li>• Analyse the personal blogs and social networks;</li> <li>• Wiki Update;</li> <li>• Database Maintenance;</li> <li>• Company's Manual Update.</li> </ul>
<b>External stakeholders</b>	<b>Suppliers, Contractors, Designers</b>	<ul style="list-style-type: none"> <li>• Fill out surveys.</li> </ul>

##### 5.1.1.2 Tools:

As announced by Dave & Koskela, the tools proposed in this model are characteristic of KM [38]. Thus, the model uses tools such as Wikis, Blogs, Social Networks and Internet Forums, among others. The tools' functions on the model's development will be explained next.

## 5.1.2 Model Presentation

AS announced previously, the model's operational development is divided into two distinct work areas.

### 5.1.2.1 Production Control Support

The proposed model pretends to develop a tool to support the implementation phase of a project. In its development, the following tools were chosen: "project-tracking blog ", the external stakeholder's survey and the Closing Work Report. Other documents used usually during production control aren't presented here.

**Project-tracking blog (PTB):** tool used in the implementation phase of a project. It should be used as a diary of the implementation phase. It is expected that each user transmits information and assessments of the work either by itself or by the entities that are under its responsibility. Thus we obtain a general understanding of the evolution of project work at all levels.

**External Stakeholders Survey:** external entities are expected to fill out a survey to help the company to better understand how the partnership procedures are working in order to obtain gains in efficiency. It is not intended for the outside entities to reveal their business plans, but an orientation in order to improve future projects. The content of the surveys should be transferred to the Closing Work Report so that this information can be properly managed.

**Closing Work Report:** a reflective analysis about the implementation and solutions adopted. It is intended for sharing with other users so they can study the work occurrences. The contents of the Closing Work Report should cover the implementation of the work as a whole, but also distinguish the different phases by describing them in detail, taking into account the main activities undertaken, equipment used, difficulties encountered, the innovations adopted and teams of contractors, among others.

### 5.1.2.2 Knowledge Management in Construction Project Management

**Wiki:** This tool is an important way of sharing knowledge within the company. By applying it, a user can access the information in the Wiki and has also the ability to create new entries or correct previous ones. Proper maintenance of Wiki data by KM Support Team becomes of utmost importance to keep it a fast and reliable source allowing the user to access the company's knowledge. The data contained in the Wiki should be clear and precise, and represent the organization's good practices. The creation/correction of a topic will be reviewed by the KM Support Team, after confirmation on a trustworthy source thus maintaining the authenticity of the system.

**Social Network:** The implementation of a social network within the organization supports the integration of staff and high speed knowledge dissemination. This tool allows a direct and rapid communication between different users, providing an efficient information sharing. Being a personal application, each user can turn directly to other users in order to clarify precisely the questions or opinions.

**Personal Blog:** This tool enables idea sharing and maturation as well as the integration of different users. Each user, through his personal blog, can convey any idea that he deems interesting. The possibility of feedback from other users allows an exchange of ideas and possibly a development of new problems and solutions. Assigning a set theme to each blog is advisable. Thus, a user search for information about a particular subject may become easier.

**Internet Forum:** This tool allows an exchange of ideas where different users share formed opinions and ideas, rising problems and creating new solutions. Properly applied, this tool could be an important basis for the creation of new knowledge. This tool must be organized by topics and dates, allowing easy identification for users.

**Company's Manual:** Here are transcribed the company's standards when implementing its activities, namely in terms of business practices, methodologies and safety rules. The concepts discussed on the various tools of the present model, after verification of their compliance, should be integrated in the Company's Manual. The maintenance of the Manual is a responsibility of the KM Support Team. The Company's Manual is a consultation document available to all users. Its structure is divided into different topics that address important aspects in the development of business activity. The Company's Manual requires constant updating, ensuring it as a reliable source of knowledge.

### 5.1.2.3 Model Support Tools

In order for the model to function properly, the utilization of certain tools is required.

**Database:** All files relating to the proposed model are stored in the database which functions as a digital library; files are stored here and can easily be found using search tools. The database is divided into two zones: a public zone available to any internal stakeholder and a private zone for not yet finalized and non-properly stored documents or private documents (e-mails...).

**Search Tool:** Being a digital library, there is a concern to properly store the different files in order to facilitate research by users. In order to allow an easier organization, each file must be associated with a code, this way facilitating the identification of documents. Through its use, the user can organize his search according to different topics: document type, author, date of execution, subject of the document, among others.

**Intranet:** Organization's internal network, an integration system between the various members of an organization with different systems and applications developed in it, accessible everywhere. With limited access to authorized users, the intranet appears to be a quick and reliable source of information sharing within an organization.

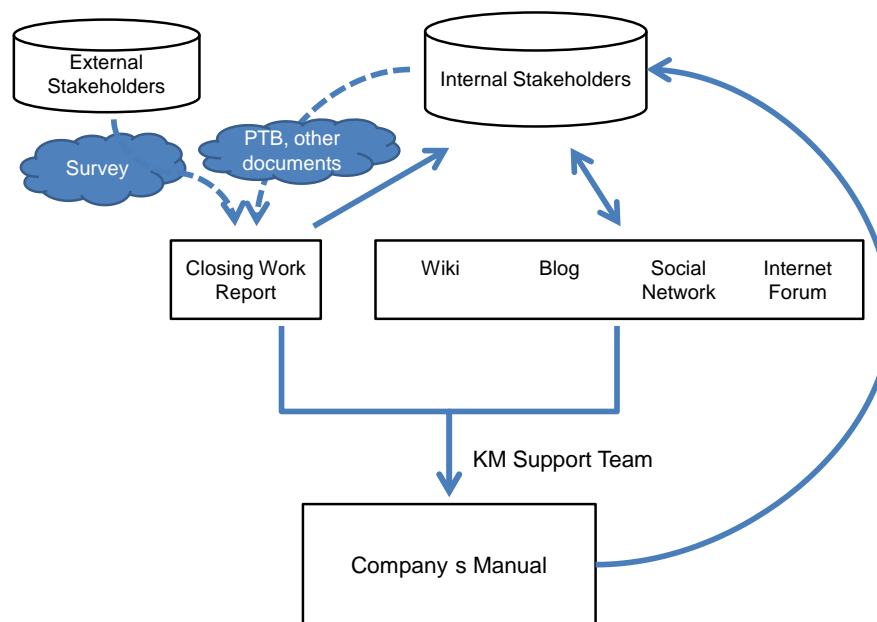
**Enterprise Portal:** It is the link between users and the KMS. Directly connected to the intranet, this tool allows users to easily and quickly exploit all the applications previously proposed.

## 5.2 Synthesis

Using the KM definition developed by Tserng and Lin (2004) presented earlier, this model meets the proposed five phases:

- Acquisition: the knowledge is translated into the network;
- Extraction/Collection: users extract/collect the stored knowledge;
- Storage: the use of the database allows the storage of knowledge;
- Share: with the use of the proposed tools (wiki, blog, forum, social network), Knowledge is disseminated within users of the company;
- Update: the proposed model allows the creation/update of content in the database.

In the next illustration it is shown the flow of knowledge in the company through the implementation of this model.



**Fig. 1 - Knowledge Flows in the Company**

## 6 Conclusion

One of the main assets of any organization is its Knowledge, therefore it is essential that companies develop and invest in the way it is applied, stored and re-used. The use of KM is an asset that differentiates enterprises as it allows them to store knowledge and to substantially improve the performance of the different phases of construction. Given the great diversity of activities performed during a construction project and the different possibilities to develop them, there is a huge flow of knowledge between the players involved in the construction process.

The main motivation behind the development of this study is related to the fact that the application of a KMS, supporting the implementation phase, permits optimization of the processes and the development of new techniques of procedures related to construction.

The implementation of the proposed model contributes to several improvements within an organization, among which the following should be highlighted:

- **Database accessibility:** The implementation of the proposed model of KM involves the development of a database where the various organizations' files are stored. The storage of knowledge and the selection/classification of information are undoubtedly key factors for the success of an organization and can be considered today a priority investment.
- **Efficiency and effectiveness:** The most important aspect in the implementation of a model of KM is the improvement of the company's organizational efficiency, as this would result in the promotion and re-usage of previously acquired knowledge, therefore preventing its loss.
- **Knowledge gain:** The development of a KMS brings new answers to various problems, thus developing new methodologies to be applied in the organization.
- **Integration of company employees:** All employees of an organization are called to contribute to the "collective knowledge". Each participant is asked to share his knowledge but also to use the information stored therefore keeping the "information bank" active.

The paper argues the importance of KM during construction phase and develops a model for its implementation. However, it is important to notice that a construction project consist not only in its implementation, but in previous conception and posterior usage. Therefore it would be of great interest to develop a KMS that encompasses the entire construction project in all its stages.

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