A Knowledge Management Approach through Product Lifecycle Management Implementation: An Industrial Case Study

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Abstract. During new product development, knowledge must be exchanged across organizational, geographical, cultural, and language barriers [1]. Emerging technologies such as Product Lifecycle Management (PLM) combined with Business Process Modelling (BPM) tools provide means to enable collaboration among distributed participants specifically in the product design process. In this paper, an alternative approach for planning and development of projects that requires knowledge management and information integration in small and medium enterprises, is presented. A case study in the Architecture Engineering and Construction (AEC) industry is performed and, as a result, the methodology is applied to support the design and construction of waste treatment plants. Finally, the design of the proposed approach is presented including how engineering processes were identified, analyzed and improved through BPM and PLM.

Keywords: Product Lifecycle Management, Business Process Modelling, Knowledge Management, Industrial implementation.

1 Introduction

Increasing market demands has forced companies to take into account Knowledge Management (KM) during the complete product lifecycle [2] but they present issues such as disjointed processes and lacking in automation. In addition, organizations are trying to get their senior engineers to write more significant guidelines, best practices and design manuals [3] in order to preserve company´s knowledge and know-how, but as it should be exchanged, it creates high potential to failure [4]. On the other hand, there is a need to combine human-based and computer-based methods and tools for KM and Product Lifecycle Management (PLM) [5]. However, computer-based tools for KM only improve part of the knowledge exchange in a company, being necessary to implement methodologies that not only allows access to knowledge, but integrates PLM, Business Process Modelling (BPM) and Business Process Re-Engineering (BPR).

PLM aims to maximize the value of current and future products for both customers and stakeholders [6], but companies will fail to exploit PLM advantages, without a correct understanding of PLM. It is necessary to incorporate business process understanding, in order to fully implement a PLM strategy. With this purpose, an integrated approach is presented for project design and development applied in a Small and Medium Enterprise (SME) from the Architecture Engineering and Construction (AEC) sector, using a novel PLM implementation strategy and considering mechanisms that offer high potential for developing countries. The case study aims to impact knowledge capture and transfer and project efficiency in the company´s New Product Development (NPD) process [1].

2 Background

KM is an organizational strategy that seeks to structure, formalize and define the proper manner to capitalize, manage and exploit the intellectual assets of an organization [7][8]. The understanding of knowledge as a company resource has become of great interest in recent years [9][10]. The ability to constantly harness company knowledge creates competitive advantages for organizations due to the increase of high quality developments and efficient processes performance. In a project base, task oriented industry such as the AEC case, these benefits are achieved through the proper use of tools, methods and techniques to capture, re-use and produce knowledge as a result of constant project analysis and feedback.

The multidisciplinary groups involved in design, construction and assembly activities demand efficient planning, programming and execution under low margin profits and strict time constrains demanded by clients. Usually the knowledge captured is related to the consolidation of lessons learned after project conclusion and during post project evaluation [11]. Although this information may be stored, it is usually ruled out in new developments due to the lack of effective frameworks for knowledge re-use and communication. As a result corporative knowledge is not suitable for real use.

The engineering process planning can be restructured through the use of BPR. This method seeks to improve process efficiency, reduce project development cycles and include the extended enterprise into the company's perception. It is achieved through the definition of the initial AS-IS and TO-BE analysis of the company's process (step 1), the new solution is physically built (step 2) and then tested in a pilot environment before the final implementation (step 3) [12]. Allowing access to knowledge requires integration of BPM with methods and tools such as PLM that incorporate an understanding of business processes and facilitate knowledge transfer.

Product Lifecycle Management (PLM) is a strategy developed to manage the product life cycle, from generating an idea, concept description, business analyzes, product design, solution architecture and technical implementation, to the successful entrance to the market, service, maintenance and innovative product improvement, through the management of intellectual capital that is generated around it, in the extended enterprise, by integrating people, processes and resources supported by an organizational culture that can be supported on a technological platform [13][14][15][6].

PLM has been proposed to be used as a KM tool [16][17], as it offers the possibility of capturing domain specific knowledge, such as product development and fabrication knowledge [3].

3 PLM Implementation Methodology

The proposed methodology is an alternate approach for design and development of projects that requires KM and information integration in SME. The implementation team decides to use two different approaches towards knowledge capture, distribution and communication. (1) The use of IT tools may be an option to capture implicit knowledge manage it, communicate it and re-use it. (2) The use of people-centered techniques such as interviews and group sessions may contribute to the implicit knowledge capture and facilitate the communication of tacit knowledge.

In the AEC industry engineering, knowledge is mainly generated from: (1) technical specifications that define and constraint the work subject, (2) technological knowledge, (3) knowledge that is generated during the project's development, and (4) re-use of engineering performed on similar projects already completed.

To capture both implicit and tacit knowledge a close understanding of the processes and the operational information is necessary. An integration of a loosely coupled PLM environment is proposed to support the design and construction processes. PLM includes processes, organization (people), information, tools and software [18]. Each of these elements is approached in different ways:

- Processes are modelled through workflows or Work-Breakdown-Structure (WBS). Workflows define a sequence of activities that must be performed in a specific order. Here we aim to model internal knowledge representation of the operational processes that conforms the core business.
- Organization is approached involving the entire organizational structure from technical engineers to CEO and managers.
- Information is captured in documents, which are digitally stored allowing speeding up the search and retrieval processes.
- Tools and software are considered, especially, open source tools that minimize costs, licenses fees and deployment time. It is important to clarify that the software in this project is a decision-making supporting tool.

PLM is used to communicate knowledge throughout the organization and during all the stages where a product is involved. The status of each document is reflected during its entire lifecycle. This means that each document, and thus, the information and knowledge gathered, is accessible at any time, allowing not only knowledge generation through document creation, but also knowledge transmission. As a result, data, information, and knowledge are integrated within the PLM. One important aspect is that information is centralized, thus, having an overview of the whole process and facilitating the access to knowledge.

Finally, PLM is used in knowledge communication integrating information storage/retrieving, decision-making support and organization involvement during the core business processes. The previously exposed elements may be integrated through four stages: 1) *Discerning knowledge*: In order to capture the existent knowledge, people centered methodologies such as interviews and works sessions must be executed. These methods allow the proper understanding of the aspects involved in the knowledge usage to achieve a successful project development. 2) *Consolidation*: Involves the understanding and analysis of AS-IS processes and the creation of an improved TO-BE process through BPR methodology. In addition, the use of BPM tools implies the integration of the process captured information in a graphic model that facilitates the understanding of engineering processes; such representation improves the visualization and logical analysis of all concepts and factors involved in the process providing suggestions and improvements to the AS-IS processes. 3) *Transformation*: The BPM models were implemented in the PLM software using workflows and WBS, along with the related working methods applied in the company. This open source technology results the perfect means to store and manage the integrated Knowledge Information and Data (KID) regarding product design, manufacturing process and production capabilities, specifically for collaborative process planning tasks[19]. 4) *Use*: Although the software provides the means to communicate information, it only becomes knowledge through usage. The creation of forms and instructive documents to store the information should carry a common standard so they can be found and retrieved.

PLM is used as the main mechanism for knowledge transfer, i.e. project members can share common representations (e.g. CAD drawings and 3D visualizations) facilitating cohesion and tight coupling [20].

4 Case study

The presented methodology has been applied within an ACE SME to support the design and construction of waste treatment plants. Identified difficulties regarding the low profit margins of the project developments seem to focus attention on improving project profitability. Also, constant difficulties regarding delivery time constrains demanded by customers were reported. Moreover, the company did not have standardized processes or better practices implementation. The increased need for KM methods came from the constant re-work done by engineers, the repetitive mistakes unsolved by the absent historical information and the willingness to gather all the exclusive implicit knowledge that provide them with competitive advantages.

Considering the company's investment constrains, ARAS PLM Open source software [21][22] was chosen to promote the distribution and communication of knowledge between project members. Also to determine a KM approach, the necessity of understanding the working methods and the engineering activity sequences involved in the company's processes was a priority. The implementation of a BPR method and Aris express BPM tool [23] were chosen to create the process models.

The knowledge capture resulted in the complete definition of the AS-IS model. It comprises the core engineering process of the organization and the identification of the complete operational information regarding approvals, interactions, role profiles and current documents. The findings were presented in a process model generated with ARIS Express using Event-driven Process Chain (EPC) diagrams. Each stage was detailed and analyzed in order to (1) ensure activity sequences coherency, with their associated subsequent events (2) fill the gaps with possible best practices and (3) eliminate those activities that had no value in the process. In addition, the complete operational information regarding approvals, interactions, role profiles and current documents was identified (see Fig 1).

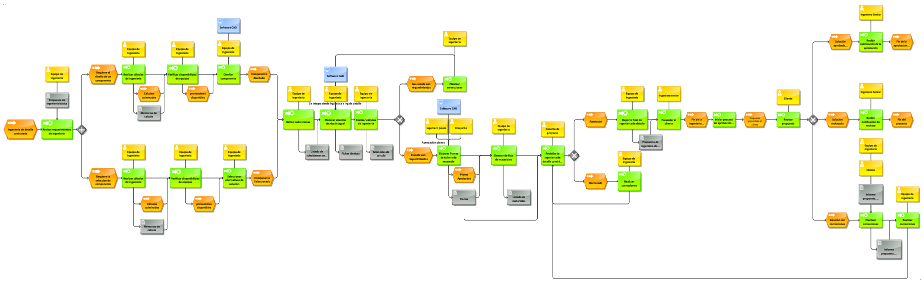

Fig. 1 EPC diagram

The application of BPR methodology has foreseen five core AS-IS processes in waste treatment plant design. Two of them are related to design activities and three of them are related to the execution of construction an assembly. Learning occurs in every day operations or in specific critical events of these stages. The results gathered from the BPM modelling were submitted for analysis in order to find weaknesses and mistakes in the sequence of activities generated for each process and create a new model (TO-BE). This analysis was done through the evaluation of activity value, criticality, cost, time and complexity. The results show that:

- Although the process was suitable, some of the identified activities were not correctly performed or done at all, interrupting the proper performance of the projects. There was not existing information to ensure how many times were done and how many times were neglected due to the lack of historical performance indicators.
- Out of the 92 identified activities only 34 had consistent records, meaning that 64% of the process occurred without keeping any associated documents. Moreover, the small amount of resulting records, lack of information standards and conventions, and the company had no instructive documents or manuals indicating the proper execution of complex tasks to ensure successful outcomes of the activities.

The revisions were often made by engineers, the participation of other roles such as lawyers, accountants and commercial agents was absent from the decision making process even when the legal and cost related decisions were crucial to ensure delivery within requirements, hence the planning process may be inconsistent and the construction an assembly stages may present multiple corrective actions.

The PLM implementation identified six core TO-BE engineer processes for Project development in the AEC industry. Three processes belong to the design stage; two belong to the construction stage, a delivery process occur at the end of each process as well. The use of EPC diagrams allowed the business unit members to define the activity sequences, the responsible roles; the events and the inputs and outputs necessary to develop the activities. The diagrams prove to be efficient in providing visualization and understanding on processes regardless of the participant's knowledge area. The BPR methods proved to be particularly compatible with the needs of the PLM software. Most of the methods outcomes supported the PLM software modules. The identification of roles, participants, events, items and, state of those items within the core processes were suitable to customize the PLM modules.

The deployment of the PLM software involved the following steps: (1) selection of the tool, in this case, Aras Innovator was selected due to its free availability as an open source software that is based on a service-oriented architecture. (2) Process modelling: For each process identified with BPM, a workflow was defined and modelled in Aras innovator including the activities, assignees and tasks. For each workflow, the lifecycle and permissions of each item were defined. (3) Modules implementation: Different modules were used in the implementation such as project scheduling and document management. The result is a data structure represented in PLM that let users associate members with activities, components and documents. Additionally, a structure expressed through variety of relationships such as project structure, activity structure and data structure was created (see Fig 2). (4) KM: mechanisms to assist in searches were defined, adding value to existing knowledge and data collected. Also, mechanisms for finding, collecting, aggregating and displaying information were defined (e.g. forms).

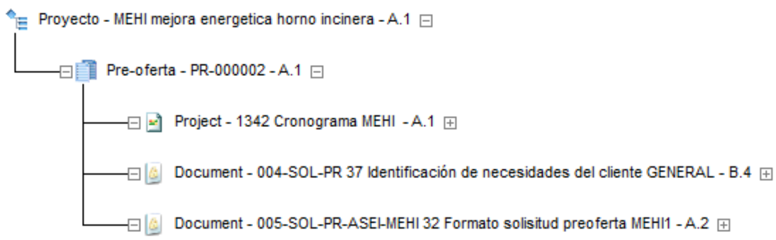

Fig. 2 Structure of a project

The autoclaving project (AYSA) began in February first 2013 with a Pre-Offer process. The objective of this process is to respond to a project request. This particular process included the participation of a project manager responsible of supervising a senior engineer and a junior engineer. It also involved some other roles of the company such as environmental engineer and a lawyer intervention due to the contractual responsibilities in which the customer and the company were involved. The workflow was initiated as soon as the project manager received an official request, accordingly, a set of automated activities were set in motion in the explained order (1) request reception (2) request evaluation, i.e. rejection or approval of request (3) request development (4) request final evaluation (5) request delivery to customer as shown in Fig 3.

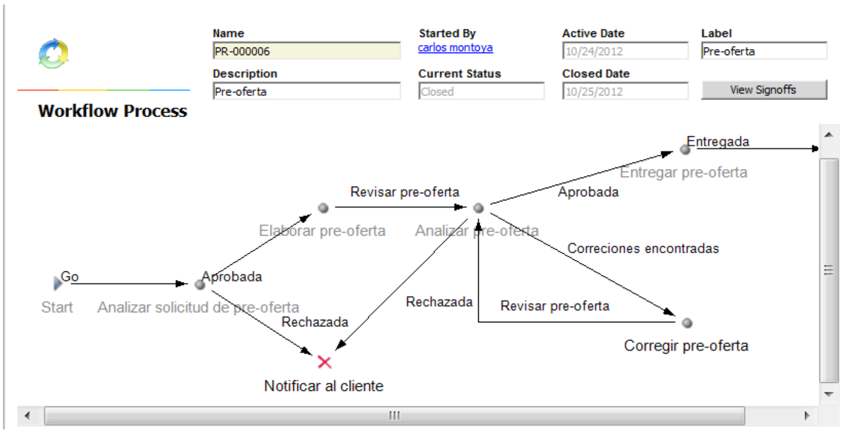

Fig. 3 Process implementation in PLM

The request was approved by an internal committee meeting and the project manager sent the approved decision through the software automatically enabling the activity of "request development", the senior engineer created the project schedule with its assignments as shown in Fig 4. The project schedule module was set with 35 activities, a notification alert was immediately sent to each project member with its corresponding assigned activity and the time range given to notify the activity completion.

The completion is mandatory, if a project member fails to fulfill the activity in the system the project will fall behind and so will the activities linked to it. Thus, the project schedule shows a real time execution of the project activities. Soon the engineers started to focus on the deadlines of the automated activities and the visualization of the project advance, making their own initiatives to ensure the activity completion.

N	Project Tree	Predecessors	Status	Leader [...]	Lead Role	Plan Start
	Pre-oferta		100			17/01/2013
	Visita ASEO Y SALUD		100			17/01/2013
1	Viaje a Riohacha		100	cesar dario c...		17/01/2013
2	Evaluación estado planta cliente	1	100	cesar dario c...		18/01/2013
3	identificar necesidades y definir requerimiento del cliente	1	100	cesar dario c...		18/01/2013
4	Informe asesoria	2	100	cesar dario c...		21/01/2013
	Generar listado equipos		100			22/01/2013
5	Definir plantilla equipos	4	100	cesar dario c...		22/01/2013
6	Definir autoclave requerida	5	100	cesar dario c...		24/01/2013
7	Definir proveedores	5	100	cesar dario c		24/01/2013

Fig. 4 AYSA project completion

The project manager changed his working methods to include daily check-outs on the project advance. A total of 33 documents were created 100% of them were properly named. The solution was delivered to the customer after being approved by consensus. The Pre-Offer was successfully closed after 46 days Fig 5, all process records remain in the PLM software accessible to all business unit members but restricted for modification due to the closed state of the process. The familiarization with the software took at list 3 month of usage, 40 training hours and 180 follow up hours were spend during 6 months to ensure optimal usage of the software.

Workflow History Report

Item: PR-000005 AYSA — Pre-oferta — Current Status is: Closed

Started By: cesar dario cock lara — Started On: 01/02/2013 11:54:53 a.m. — Completed On: 20/03/2013 11:46:53 a.m.

Activity	State	Assigned To	Completed By	How Voted	When	Comments
Recibir solicitud	Closed	cesar dario cock lara	cesar dario cock lara	Analizar	01/02/2013 12:27:49 p.m.	Se programa comité para enterarlos de la visita a la empresa Aseo y Salud
Analizar solicitud	Closed	Gerentes de Proyectos	carlos montoya	Delegate	01/02/2013 12:34:00 p.m.	
Analizar solicitud	Closed	cesar dario cock lara	cesar dario cock lara	Aprobada	01/02/2013 03:29:03 p.m.	
Elaborar pre-oferta	Closed	cesar dario cock lara	cesar dario cock lara	Revisar pre-oferta	19/03/2013 02:48:52 p.m.	
Analizar pre-oferta	Closed	Gerentes de Proyectos	carlos montoya	Delegate	19/03/2013 05:17:42 p.m.	
Analizar pre-oferta	Closed	cesar dario cock lara	cesar dario cock lara	Aprobada	20/03/2013 11:46:26 a.m.	
Entregar pre-oferta	Closed	cesar dario cock lara	cesar dario cock lara	Entregada	20/03/2013 11:46:53 a.m.	

Fig. 5 Workflow history report

The workflow and project activities are linked to the capture, transfer and use of knowledge. A great deal of information must be managed in the business process. Before the implementation the business unit members had addressed a number of issues regarding information management. The methodology and objectives suggested for the implementation solve the pending issues; BPR methods provide a clear understanding of the information flow and the interactions between participants. The findings were customized in the PLM software as follows:

Support information: The engineering activities often required regulatory proceeds; there was also interest on (1) ensuring the outcomes of the activities through the use of pre-established forms (2) capturing the business unit knowledge in instructive documents. The recompilation of information proved to be a long term task. 11 libraries were suggested for creation, 64% of those were created during the 11 months agreed for the implementation. The business unit members created 16 instructive documents, 39 forms, 3 Check list. Ensuring 100% supportive documents a 100% of knowledge capture for autoclaving plant design and construction, and providing a 64% improvement in project records compared to previous developed project within PLM strategy on place.

Information standards: During AEC projects different types of information are shared in different bodies of known how. From customer needs information, to protocols for equipment assembly and testing, information consistency is necessary to ensure the interactions between project stages and the quality and compliance of engineering developments. In order to control information the implementation team selected (1) naming conventions (2) version control and (3) approval permissions. The software kept a few versions of each development and recorded the evolution through a change history, in which each responsible person is also pointed out improving change management and document traceability. Information search went from hours to minutes. The projects developed previously in the business unit had no control over developments, the scenario in which the project manager was completely blind of project advance and information resulted in delays, overwork and non-compliance with customer requirements, issues that usually end in contractual difficulties and non profitable projects. The new scenario supported with PLM customized software provides real time information and demands deliverable revisions before presenting a solution to a client. The participants have at hand all the information of the evolution of the project for consulting and validation.

The information however is more efficiently used if classified in an autonomous way as an indicator. Direct information may be extracted from it percentage of detected failures and project metrics are still unavailable for measurement due to the long term developments of the industry.

5 Conclusions

PLM strategy and BPR methodology were successfully integrated inside the engineering unit of an AEC industry. The corporative knowledge was captured and the engineering processes were identified, analyzed and improved through BPR methodology, also the use of BPM tools allowed the visual understanding of process components and interactions and provides an organized way to properly introduce the combine elements into the PLM software modules.

The standardization of working methods and document management procedures and conventions allowed the creation of a common language for the multi-project team. In addition, proper distribution and communication of knowledge were executed through the PLM collaborative configuration. The integration resulted in proper capture, storage, distribution and communication of knowledge throughout the organization. Although the PLM Software prove to be an asserted IT tool to store, distribute and communicate explicit knowledge, it is also evident that the tacit knowledge shared between interviews and work sessions performed to discern engineering process in this case study, enhanced the personal knowledge of each company member. Strategies to share this tacit knowledge must be also implemented in the company to capitalize the experience of the employees in their combine working areas.

In this paper, an implementation methodology for new product development was shown. This approach uses emerging technologies such as PLM and BPM combined with KM that help reduce communication glitches among project members. BPR was used to identify best practices and processes that would enable companies to increase their control over product development and defining key project milestones and deliverables. PLM systems can contribute in different ways, such as retention of the knowledge, enhancement of project and process reuse and quality improvement through standardization [3].

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