IMPLEMENTATION OF CONSTRUCTION INDUSTRY BEST PRACTICES INTO WORKFLOW MANAGEMENT SYSTEMS

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Abstract: Several research studies have confirmed that identification and adoption of industry best practices drive performance improvements in terms of cost, schedule, and productivity. Best practices specifications facilitate the reuse of experience within a domain. However, they typically offer abstract suggestions and recommendations that include not only explicit, but also tacit knowledge. Key approaches of adopting and promoting best practices include socialization and face to face interactions, such as meetings, workshops, and training. These approaches, however, are not easily scalable to large capital projects, to provide systematic and consistent adoption of best practices throughout different phases of a project or among different projects. An alternative solution is to transform best practices into processes implementable into workflow management systems. In this paper, well-known best practices in the domain of the construction industry and their common characteristics are investigated. A framework is then established for transforming best practices into structured processes implementable into workflow management systems. Only parts of a best practice can be transformed into a structured process. The proposed framework describes which components of a best practice are more suitable for this transformation. The result is a process with the essence of a best practice that can be embedded into and automated through workflow management systems. This approach of integrating construction industry best practices into workflow management systems, not only facilitates consistent implementation of best practices throughout the project lifecycle and within projects, but also improves conformance to those practices, with the end result of improved capital project performance.

1 INTRODUCTION

It is well established from statistical analysis of several projects that effective implementation of best practices and integration of information technologies are correlated with substantial improvements in project performance (Figure 1 & Figure 2). Research studies state that systematic implementation of best practices is one of the most important contributing factors to mega projects’ success (Chanmeka et al. 2012). A best practice might be a single procedure or method, but most usually it is a combination of several policies, rules, procedures, and methods, in a particular domain.
Well-known organizations, such as the Construction Industry Institute (CII), the Construction Owners Association of Alberta (COAA), and the Project Management Institute (PMI), develop and promote best practices pertaining to various aspects of capital project management and delivery. Table 1 presents a list of organizations that develop and promote such practices and the term they use for best practices. However, the systematic and consistent implementation of such practices throughout the lifecycle of a construction project and from project to project remains a significant challenge.

<table>
<thead>
<tr>
<th>Organization</th>
<th>Guidelines referred as</th>
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</thead>
<tbody>
<tr>
<td>Construction Industry Institute (CII)</td>
<td>Best Practices</td>
</tr>
<tr>
<td>Construction Owners Association of Alberta (COAA)</td>
<td>Best Practices</td>
</tr>
<tr>
<td>Independent Project Analysis (IPA)</td>
<td>Value Improving Practices (VIPs)</td>
</tr>
<tr>
<td>Project Management Institute (PMI)</td>
<td>Foundational and Practice Standards</td>
</tr>
<tr>
<td>Construction Management Association of America (CMAA)</td>
<td>Standards of Practice</td>
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<tr>
<td>The Association for the Advancement of Cost Engineering (AACE) International</td>
<td>Professional Practice Guides (PPGs)</td>
</tr>
<tr>
<td>The American Institute of Architects (AIA)</td>
<td>AIA Best Practices</td>
</tr>
<tr>
<td>The American Institute of Architects (AIA)</td>
<td>AIA Contract Documents</td>
</tr>
<tr>
<td>Process Industry Practices</td>
<td>Practices</td>
</tr>
</tbody>
</table>

According to CII, best practices are processes or methods that provide improved results when implemented effectively, and thus, can lead to enhanced project performance. Companies implementing best practices consistently, report higher profits, increased customer satisfaction, and improved safety and productivity. Traditional approaches of adopting best practices include socialization and face-to-face interactions, such as meetings, workshops, and training, which are not easily scalable to large-scale
capital projects. An alternative solution is to transform best practices into workflow processes implementable into Electronic Product and Process Management (EPPM) systems – a type of workflow management system particularly being used for managing mega capital projects. This approach utilizes business process models and workflow engines to facilitate more consistent implementation of best practices throughout different phases of a project or among different projects.

Fundamental improvements in communication and collaboration technologies and the increased use of EPPM systems – that are process-based and workflow-driven – in managing mega capital projects provided the required infrastructure, and facilitate putting this approach into practice. Utilization of EPPM systems and workflow engines offer the advantages of consistency, accuracy, and scalability, and thus can be considered a key tool for adopting best practices in mega capital projects.

2 BACKGROUND

Mega construction projects typically involve many stakeholders from different parts of the world, with diverse organizational structures and cultures, and with distinct specialized expertise. A typical oil and gas project is comprised of a few owners, tens of general contractors, and hundreds of sub-contractors from different firms and disciplines, such as engineering, consulting, construction, and facility management; nevertheless, all striving towards the common goal of completing the project.

This level of cooperation is made possible in part by advancements in communication and collaboration systems in the domain of information technology. This includes essential communication infrastructure provided by the World Wide Web, database management systems, and real-time data exchange services. Furthermore, such multilateral accomplishments have been aided by substantial improvements in systems tailored to projects and corporations. Examples include advanced project management tools, enterprise resource planning (ERP) (Chung, Skibniewski, and Kwak 2009; Ghosh et al. 2011; O’Connor and Dodd 2000), workflow engines (Tang and Akinci 2012; Cardoso, Bostrom, and Sheth 2004), electronic document management systems (Al Qady and Kandil 2013), knowledge-based information systems (El-Gohary and El-Diraby 2010; Kang, O’Brien, and O’Connor 2012), and more specifically electronic product and process management (EPPM) systems (Shahi et al. 2014).

Electronic Product and Process Management (EPPM) Systems are the new technology trend for management of mega capital projects. Their core components are typically a combination of a workflow management system (WfMS), a document management system (DMS), and a collaboration management system. A workflow engine at the heart of the workflow management system facilitates enactment of workflow processes; a document management system supports several types of files and enables sharing and modifying various types of documents. The collaboration management system enables project delivery by collaboration among several stakeholders.

The services that EPPM systems offer encompasses planning, coordination, and management activities within the product and project lifecycle. EPPM systems store and retrieve various types of information regarding the lifecycle of a project, and can be used to mine repositories to capture hidden knowledge, and analyze the acquired knowledge for more informed decision making. This knowledge is typically represented in the form of status and progress reports, lessons learned, cost and performance analysis, etc. through dashboards. Implementation of best practices into EPPM systems involves transforming practices into workflow processes. Thus, distinguishing the differences between practice, process, and workflow is vital. Before establishing a framework for practice to process transformation, this paper discusses these differences.

2.1 Process vs. Practice

A process is a series of well-defined inter-related steps which delivers repeatable, predictable results. Key features of a process include 1) predictable and definable inputs, 2) linear, logical sequence, 3) clearly definable set of activities, and 4) predictable, desired outcome (Lee 2005). An activity is typically considered as a major unit of work comprising more detailed steps called sub-activities. Whenever an activity is considered as the smallest unit of work, it is called a task. A process is typically used in routine
circumstances in which repeatable, predictable results are required. Each necessary step is codified in detail and there is no spontaneous decision making involved.

A process can be performed manually or can be automated through an information system. For an automated process, the inputs, outputs, and steps involved should be clearly defined; and to implement a process in a workflow management system it should be defined in a standard process modeling language. Typically, automated processes include both automated and manual activities. Request for Information (RFI) and Change Request (CR) processes are examples of such processes. Processes in which all of their activities are automated are called fully automated processes, such as the buying processes in Amazon or eBay.

A practice, on the other hand, is a frequently repeated act, habit, or custom that needs a recognized level of skill to be performed. It is an un-codified knowledge that results from human experience and improvisation (Lee 2005). While a practice is still a series of steps, the steps are loosely defined, and the details of how to perform each step is left to the experts who perform them based on their knowledge, experience, skill, and judgment. Practices, thus, are more suitable for dealing with uncertain situations with uncommon or unique results (“IT Catalysts” 2013). Table 2 summarizes key differentiators of processes and practices.

Table 2: Process vs. Practice

<table>
<thead>
<tr>
<th>Process</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Series of well-defined steps</td>
<td>Series of steps, but loosely defined</td>
</tr>
<tr>
<td>Deliver repeatable, predictable results</td>
<td>The specifics are left to the experts performing them</td>
</tr>
<tr>
<td>Well-suited to mass production</td>
<td>Appropriate for dealing with uncertain situations with unique results</td>
</tr>
<tr>
<td>Includes clear steps and details for tasks</td>
<td>Not necessarily have a clear sequence and details for tasks</td>
</tr>
</tbody>
</table>

2.2 Process Modeling Tools and Standards

To implement a process in a workflow management system, it should be defined as a process model using a standard process modeling notation. Several process modeling languages and standards have been developed for modeling business processes. Process modeling can be performed either by representing a process using graphical notations or by representing the semantics of the process using modeling languages. Using graphical notations is more convenient for communication, reengineering, and improvement of processes. Recent modeling tools such as XPDL and BPMN support both a graphical notation and a modeling language. A classification of the most popular modeling tools and standards is presented in Table 3.

Table 3: Process Modeling Tools and Standards

<table>
<thead>
<tr>
<th>Classical</th>
<th>More Formal</th>
<th>Most Recent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowchart 1920s</td>
<td>Petri nets 1960s</td>
<td>UML 1997</td>
</tr>
<tr>
<td>Functional Flow Block Diagram (FFBD) 1950s</td>
<td>Workflow patterns</td>
<td>XPDL 2002</td>
</tr>
<tr>
<td>Data Flow Diagram (DFD) 1970s</td>
<td>YAWL</td>
<td>BPEL 2004</td>
</tr>
<tr>
<td>ICAM Definition (IDEF0) 1970s</td>
<td>Graph-Based Workflow</td>
<td>BPMN 2004</td>
</tr>
</tbody>
</table>

Business Process Modeling and Notation (BPMN) is the most promising process modeling standard. It has been designed by the Object Management Group (OMG) with the aim of identifying best practices of existing modeling tools and combining them into a widely accepted, easy to use language. The same process model in BPMN may encompass different levels of details, each useful for a particular group of
stakeholders, from business administration people to business analysts and software developers. BPMN defines three levels of process modeling conformance. ‘Descriptive level’, useful in high-level modeling, only includes visible elements and attributes; ‘analytic level’ includes descriptive and a minimal subset of supporting process attributes; and ‘common executable’ offers the elements required for execution of process models. In this paper we use BPMN 2.0 notation for representing sample process models.

2.3 Workflow vs. Process

Workflow and process are similar terms and, in certain situations, might be used interchangeably. However, workflow implies a more specific concept than process. While any group of well-defined interconnected steps with an expected result can be called a process, in a workflow the focus is on the piece of work or information that is being passed through initiation to completion. Therefore, a workflow associated with a particular process might not be involved with all the details that are important for completion of the process, such as recording to a database or calling a web-service, but is more dedicated to the flow of work through all the steps. A workflow thus can be defined as an outline or blueprint of a process. A summary of process and workflow differences are presented in Table 4.

<table>
<thead>
<tr>
<th>Process</th>
<th>Workflow</th>
</tr>
</thead>
<tbody>
<tr>
<td>A process is a series of well-defined inter-related steps</td>
<td>A workflow is considered as an outline of a process</td>
</tr>
<tr>
<td>A process is modeled using modeling tools and implemented by coding the steps</td>
<td>The flow of work in a workflow can be updated without changing underlying code</td>
</tr>
<tr>
<td>A process can be modeled with different abstraction levels: organizational, operational, and implementation levels</td>
<td>The focus is on organizational details, but can include operational and implementation-level details</td>
</tr>
<tr>
<td>The focus is on steps of work</td>
<td>The focus is on the flow of work</td>
</tr>
<tr>
<td>A programmer typically implements a process</td>
<td>A analyst typically can modify the steps and update the flow of a workflow</td>
</tr>
</tbody>
</table>

2.4 Workflow Management Systems (WfMS)

Workflow management and workflow specification are concepts tightly related to business process management and process modelling; however, their approach is rather different. Workflow management involves the automation of processes which are comprised of human and machine-based activities (Hollingsworth 1995) and focuses on the flow of information or work among participants. A workflow specification is an abstraction of a process that might not be concerned with all the details of a task, but in any case it is concerned with the inter-relationship, the inputs and outputs, and the externally visible behavior of tasks (Krishnakumar and Sheth 1995).

Automation of business processes partly relies on the coding of software developers for embedding business processes into information systems. Originally, any modification to the process logic, the sequence of activities, and the execution constraints of a process was affecting the programming code and required software developer’s attention. The introduction of object-oriented programming concepts facilitated the separation of process logic modifications from the programming code, and led to the emergence of workflow driven systems. In a workflow management system, features of an application, or tasks of a process, are defined as steps in a workflow, and therefore, the behavior of the system can be modified through changing the steps without any modification to the programming code. Workflow technology, thus, provides separation of business process logic from IT operational support (Hollingsworth 1995).
A workflow engine is responsible for managing and enacting tasks within workflow specifications according to their execution constraints and organizational predefined rules. The execution constraints of a process are typically defined as properties or attributes of tasks in the workflow specification. The Workflow Reference Model (Hollingsworth 1995), developed by the Workflow Management Coalition (WFMC) is a key reference for workflow management systems and their interfaces. Workflow management systems facilitate more convenient design and implementation of processes with less involvement in programming details.

3 PROPOSED FRAMEWORKS

A best practice is a guideline to an improved way of organizing and performing a work. The steps offered in a best practice does not necessarily include well-defined sequence and details, and thus it typically relies on the skills and experience of the actor to fill the gaps, whereas in a structured process the sequence of activities and their execution constraints are completely defined. This paper proposes two frameworks for transformation of best practices into structured processes suitable for implementation via workflow management systems. The frameworks explain how the inherent knowledge of a best practice can be combined with the key characteristics of a structured process, such as well-defined steps, sequence, and execution constraints. In addition, the frameworks clarify how the components of a best practice can be associated with elements of a structured process.

3.1 A Conceptual Framework

A practice as a form of knowledge includes explicit, tacit, and implicit types of knowledge (Anand and Singh 2011; Faust 2007). The explicit is the category of knowledge that can easily be identified, codified, stored, and retrieved, and thus, its implementation and automation is relatively straightforward. Interrelated components of a best practice comprising explicit knowledge can be defined as a high level organizational process. Tacit knowledge is inherent with the skills and experience of people, and is hard to capture and codify, and thus, cannot easily be automated. Tacit knowledge or judgmental steps in a practice can be embedded into manual human-tasks of a process. A fraction of tacit knowledge, that is hard but possible to capture and make explicit, is called implicit knowledge. Implicit knowledge is associated with how a process is defined and how it is implemented. It affects the way a process behaves.

Table 5: Types of Knowledge in a Practice and their Association with a Process

<table>
<thead>
<tr>
<th>Practice Components</th>
<th>Association with …</th>
<th>Process Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit Knowledge</td>
<td>… What is done …</td>
<td>Structure of the Process</td>
</tr>
<tr>
<td>Tacit Knowledge</td>
<td>… Who accomplish …</td>
<td>Human-tasks of the Process</td>
</tr>
<tr>
<td>Implicit Knowledge</td>
<td>… How is defined …</td>
<td>Behavior of the Process</td>
</tr>
</tbody>
</table>

Accordingly, we can associate elements of a process with components of a practice. The structure of the process – which defines what is performed – can be defined based on the explicit knowledge present in the practice. The human-tasks of the process – which is related to who has the capability of performing the task – are associated with the tacit knowledge of the practice. The behavior of the process – which is consistent with how the process is defined – signifies the implicit knowledge of the practice (Table 5).

3.2 A Practical Framework

The practical framework for transformation of a best practice into a process involves two main steps: (1) identify the related components of a best practice and define them as one or more high-level organizational processes, and (2) transform the organizational processes into well-defined structured processes suitable for implementation via workflow management systems. These steps are presented in Figure 3 and are discussed with examples in the following sections.
3.2.1 Practice to Organizational Process

Studying the contents of several known construction industry best practices, such as materials management, lessons learned, zero accidents techniques, and change management, confirms that construction industry best practices either include organizational processes or the related components can be defined as organizational processes. For instance, CII best practice for change management offers five principles, each of which has been defined as an organizational process. Figure 4 illustrates the five principles for change management offered by CII change management best practice (Project Change Management - Special Publication 43-1 1994).

![Figure 4: CII Change Management Principles, each offered as an organizational process](image)

An organizational process is a high level process that includes the conceptual steps of performing work, but does not include all the details of the steps, and the execution constraints that are necessary for implementation of the process. For instance, Table 6 presents an organizational process offered by CII change management best practice for the Evaluate Change principle.
3.1 Determine the time frame for change decision.
   3.1.1 Immediate or high priority decision required? If not, process through routine measures.
   3.1.2 Determine funding source for handling interim approval of a high priority change decision.

3.2 Collect data needed.
   3.2.1 Conduct a thorough analysis on cost, schedule, quality, safety, resources, and other items.
   Evaluate on both direct and associated indirect costs.
   3.2.2 Propose and evaluate alternate solutions and options.

3.3 Identify impacts.
   3.3.1 Finalize impact on cost and schedule.
   3.3.1.1 Primary impacts.
   3.3.1.2 Secondary (indirect/ripple/cumulative) impacts.
   3.3.2 Route to all involved disciplines/functions/organizations for impact.

3.4 Determine final funding source or “who pays” (cost reimbursable, design development, lump sum, and others). If applicable, confirm the interim funding source decision.

3.5 Re-evaluate project feasibility with proposed change included.
   3.5.1 If change makes project unfeasible, determine whether it is a required or an elective change.

3.6 Authorize change and send out notice to all affected organizations/disciplines.

Organizational processes, however, cannot directly be implemented into workflow management systems. They lack the required structure and details. As such, they should be transformed into structured workflow processes.

3.2.2 Organizational to Structured Process

In workflow management systems the flow of work or information among participants is a key characteristic. Thus, to transform a best practice to a structured process, implementable into workflow management systems, the steps of the associated process need to be defined as the flow of work or information among participants. Thus, the roles and responsibilities of participants should first be determined. The Responsibility Assignment Matrix (RACI chart) is a useful tool for this purpose. Then, the flow of work among participants should be identified. Finally steps of the high level process should be defined as activities that are performed by participants along with the flow of work.

In addition, the workflow should be defined as a structured process. A process in which the sequence of activities and their execution constraints are completely defined is called as structured process. To clarify, Figure 5 represents the main activities of a change request (CR) workflow and their sequence. A CR workflow is a formal process for authorizing any change in the scope, cost, or schedule of the project. Figure 6 is a more structured representation of the same workflow.

![Figure 5: Main Steps of a Change Request (CR) Process](image-url)
3.3 Summary

In this paper well-known best practices in the domain of the construction industry are explored, and their common characteristics and components are examined. Further, the differences between practices, processes, and workflows are investigated. Then two frameworks – a conceptual and a practical – are proposed for transformation of best practices into structured processes implementable into workflow management systems. The proposed frameworks suggest that specific components of best practices can more easily be transformed into structured processes. The result is a structured process with the essence of a best practice that can be automated through workflow management systems. Implementation of best practices via EPPM systems offers the advantages of consistency, accuracy, and scalability, and thus can be considered a key approach of adopting best practices in large scale construction projects.
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References


