Collaborative Best Practices for Construction Projects

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Keywords: collaboration; project controls; document management; risk management; classification.

Abstract

Proactive development of collaborative *best practices* for the construction industry will lead to significant productivity gains.

While the technical issues associated with large infrastructure projects is well understood and largely standardized, the organization and management of such projects is not yet subject to the same rigor. Globalization has lead to project structures where project participants are located worldwide and tasks are outsourced to distant sub-contractors, increasing the need for effective long-distance collaboration.

Large projects typically deploy multiple systems for managing documentation, drawings, schedules, risk, correspondence, claims, etc. While these systems may be adequate for their stated tasks, little systematic effort has been put into unifying them or adapting them to the particular needs of the construction industry. Such systems are seldom effectively inter-linked, nor are they readily available to all project participants. Projects accept the costs associated with these inefficiencies because they have no clear idea of the productivity gains that could be achieved.

We believe that major efficiencies on large construction projects can be achieved by adopting a set of *collaborative best practices* developed specially for the industry. The practices we propose are intended to promote collaboration between the organizations taking part in the project.

The benefits of collaboration are twofold:

1. During the project: ***Collaboration improves efficiency*** – There is a synergistic affect from sharing information. More eyes promote better solutions, lower risk and lead to better-informed discussion of issues.
2. After the project: ***Complete and well-organized documentation*** – Preserves know-how, proves regulatory compliance, increases the asset's value and decreases the maintenance costs.

The need for effective inter-company collaboration clearly places the responsibility for managing

project documentation *above* the level of the individual project participants. This realization is the key to implementing document management systems for construction projects.

Our focus is therefore on defining practices for the entire *project*, rather than for the *individual* organizations. This causes a major shift in documentation responsibilities, which is critical for the successful adoption of the best practices. It also represents a departure from current attempts at automating project documentation management, which: usually focus on individual companies; and mandate the adoption of tools that fail to adequately consider the existing practices of the engineering and construction communities.

In order to succeed, the responsibility and authority for managing project documentation must be made early enough and at a level high enough to ensure sufficient resources are allocated and guarantee compliance across the entire project. Ideally, the project owner makes their requirements for collaborative practices known at the outset via contractual provisions.

The project focus also imposes limitations on the types of information sharing systems can be deployed. The collaborative best practices must be pragmatic and based upon concepts that engineers are already familiar with.

The fundamental requirements for our vision for collaborative best practices are:

1. Project information should be centralized at one location, regardless of its form.
2. The project information shall be accessible (given appropriate authorization) to all project participants, irrespective of their location.
3. The project's requirements for approvals and revision should be fully supported.
4. A single project-wide classification system should be applied to all information.
5. The classification system should be based on concepts already understood by engineers.
6. It should be possible to easily search for information using the classification system, without the need for formal training.
7. Budgets and responsibilities should be allocated to ensure that the system is satisfactorily implemented and useable.

The resulting best practices are a combination of procedures and software systems, which are Internet based and designed to work with normal web broswers.

The key recommendations distilled from our field experience are:

1. Productivity gains can be achieved from adoption of collaborative best practices.
2. Support from the project owner, and a few key line engineers and managers, is essential.
3. Improved efficiency is possible even with partial implementations.
4. Earlier adoption produces better results.
5. Classification systems are well received by engineering and construction personnel.
6. Ease of use, especially when searching for documents, is critical.
7. Quality management procedures and controls, including the responsibilities assigned to the project team, must be directly integrated into the document management system.

Our recommendations as based on our practical experience from the Kárahnjúkar Hydroelectric project, Iceland's largest construction project, where we have directly contributed to the development of collaborative procedures, and software to support them, for the past four years.

We are convinced that large changes in collaboration practices are going to take place within the construction industry. Companies and projects proactively implementing improved collaboration practices along the lines of our recommendations will realize a significant competitive advantage.

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Summary

Proactive development of *collaborative best practices* for the construction industry will lead to significant productivity gains. Currently, construction projects suffer inefficiencies due to the proliferation of disjointed and incompatible data management systems. The solution is to focus on inter-company collaboration, with the goal of creating a set of project-wide best practices based on the quality management processes and classification systems already familiar to the construction industry. We provide the detailed requirements for such a system, along with the practical consequences that result from them. Key factors that influence the implementation and adoption of our suggested best practices are identified, and we enumerate the lessons learned during our four years implementing collaborative best practices for the Kárahnjúkar Hydroelectric Project.

Keywords: collaboration; project controls; document management; risk management; classification.

1. Introduction

While the technical issues associated with large infrastructure projects are well understood and largely standardized, the organization and management of such projects is not yet subject to the same rigor. Globalization has lead to project structures with project participants located worldwide. Tasks are outsourced to distant sub-contractors, who may never appear at the job site. These trends have accelerated with the rise of the Internet and are likely to continue and create additional difficulties for project managers.

The fundamental management challenge in the heavy construction industry is coordinating the activities of all the project partners. This task is complicated by the requirement of completing the project to a specified quality within a given budget and schedule. Decisions must often be made quickly, balancing the overall project requirements against the realities present at the job site. All decision making requires input information, today generally in the form of digital documents, emails, etc. The effectiveness of project management is therefore limited by the timely availability of information. A project’s ability to share information within the project team is a critical success factor.

The requirements for managing the information on large construction projects have outstripped the techniques and tools currently being used. Large projects typically deploy multiple systems for managing documentation, drawings, schedules, risk, correspondence, claims, etc. While these systems may be adequate for their stated tasks, little systematic effort has been put into unifying them or adapting them to the particular needs of the construction industry. Such systems are seldom effectively inter-linked, nor are they readily available to all project participants. Unfortunately, projects accept the costs associated with these inefficiencies because they have no clear idea of the productivity gains that could be achieved.

We believe that major efficiencies on large construction projects can be achieved by adopting a set of *collaborative best practices*. Our recommendations are based on practical experience from the Kárahnjúkar Hydroelectric project, Iceland's largest construction project, where we have directly contributed to the development of collaborative procedures, and software to support them, for the past four years.

2. Collaborative Best Practices

In this context, *collaboration* (from the Latin *collaboratus*, meaning *to labor together*) is defined to be the activities associated with working together on a construction project, emphasizing the sharing of know-how, information, documentation and other project data between the organizations taking part in the project.

The benefits of collaboration are twofold:

1. During the project: ***Collaboration improves efficiency*** – There is a synergistic affect from sharing information. More eyes promote better solutions, lower risk and lead to better-informed discussion of issues.
2. After the project: ***Complete and well-organized documentation*** – Preserves know-how, proves regulatory compliance, increases the asset's value and decreases the maintenance costs.

2.1 Appropriate Incentives

The need for effective inter-company collaboration clearly places the responsibility for managing project documentation *above* the level of the individual project participants. This realization is the key to implementing document management systems for construction projects.

Our focus is therefore on defining practices for the entire *project*, rather than for the *individual* organizations. This causes a major shift in documentation responsibilities, which is critical for the successful adoption of the best practices. The responsibility and authority for managing project documentation must be made early enough and at a level high enough to ensure sufficient resources are allocated and guarantee compliance across the entire project. Ideally, the project owner makes their requirements for document management known at the outset of the design phase, but at the latest prior to tendering, via contractual provisions.

2.2 Classification System

The project focus also imposes limitations on what types of information sharing systems can be deployed. As many of the project members, for example distant equipment suppliers, will have limited contact with the project, it is unrealistic to expect all users to require training in order to be able to find project information. Thus, the collaborative best practices must be pragmatic and based upon concepts that engineers are already familiar with.

The fundamental system already used by engineers for organizing information is classification. This manifests itself on all construction drawings, which are identified by drawing codes composed of components that classify the drawing according to various criteria. All engineering companies have quality documents that explain their document numbering systems, and all engineers are familiar with the concept.

We propose:

1. Adaptation of a single project-wide classification system (which conceptually is merely an extension of a document numbering system).
2. The classification system is the link that joins all the types of project information.
3. The classification system should recognize the project's own structure, incorporating the organizational, work-breakdown, location, technical and other classification structures defined for the project and should be employed for all document types.

2.3 Approvals and Revision Control

The most fundamental workflow associated with construction project documentation management is the issuing of documents. This workflow makes use of the most basic quality management controls: identifying the appropriate version of the document; and ensuring that it has been checked and approved. The workflow can also be applied to other project management duties such as task assignment and tracking.

Any attempt to implement collaborative best practices must also implement revision control and document checking/approval procedures, including recognizing the responsibilities and authorities assigned to the project team.

2.4 Tool Building Approach

What we are proposing is a departure from current attempts at automating project documentation management, which often mandate the adoption of tools that fail to adequately consider the existing practices of the engineering and construction communities.

We realize that currently there is no software that fully implements our vision [1]. Nevertheless, we are convinced that the all attempts to automate construction project information management will not succeed unless the systems fully support existing construction practices.

3. Collaboration in the Past

3.1 Paper Based Information Management

Before the age of digital computers, all project documentation was produced on paper and filing systems depended on the physical presence of the items being filed. All documentation was stored in a central location and there were well-defined procedures for indexing and filing. The project archive contained physical copies of all construction drawings, technical reports, bills of quantities, correspondence and any other material that had bearing on the project.

In order to master the considerable effort of managing all the paper companies employed clerks and specialist librarians to perform the filing. All locally produced and incoming documentation was routed to project teams, where copies were made ‘for the file’. If engineers or project managers needed a document they could to go to the files to get it. The corporate libraries that resulted were valuable assets. Engineers were expected to know their way around the corporate archives and be able to refer to previous projects when solving technical problems.

3.2 Quality Management

Documentation management procedures evolved in parallel with project management processes, many of which survive to this day [2]. The drawing blocks found on construction drawings indicating design responsibilities and approvals, the coded drawing and correspondence numbering systems and the procedures for assigning them are all products of this era.

The procedures were strict and were developed to support the quality control procedures necessary to ensure the safety and correctness of the design and construction processes. All technical proposals were subject to review and a culture of peer review prevailed. Calculations had to be documented and repeatable. Documents had physical approval signatures to guarantee that they had been reviewed.

The overhead of managing a centralized, paper based project archive was acceptable because projects were technically less complex and the partner companies were local. Companies often worked together on multiple projects and the long-term relationships that developed helped streamline the processes.

The documentation and project management practices were appropriate given the size of typical projects. Unfortunately the procedures from this era have mostly not been appropriately adapted and re-scaled to the current technology and globalized projects of today.

4. Current State of the Art

4.1 Focus on Corporate Collaboration

The current state of the art for collaboration on construction projects focuses on implementing digital document production and computerized filing systems for use within a single organization. At the lowest level, the production of construction drawings and documents, the current generation of CAD (computer aided design) systems and word processors are suitable for the tasks they are asked to perform.

The difficulties begin with the management of the documents these systems produce. Since there is no generally accepted standard for filing and exchanging the digital documents associated with a construction project, companies are free to choose or build any system they want. Often documents are simply stored on corporate file servers. Other companies use CMS (content management systems) designed primarily for other industries. While these systems can integrate well with the Internet for file sharing, they do not support the rigorous quality control and classification systems used by the construction industry [3].

The situation is further complicated by the prevalent use of corporate e-mail and individual shared drives for communicating and filing critical project information. While convenient, e-mail systems and shared drives impose no filing structures or quality control procedures, nor are they easy to integrate with Internet based CMS systems.

The result is a myriad of disjointed and incompatible systems, often usable only by members of the company that implemented them. This mismatch, between the needs of project management and the limited capabilities of available computer software, has seriously eroded many of the traditional engineering quality controls. Many young engineers, who have no direct experience with traditional engineering management and documentation procedures, actually believe that the current generation of computerized tools and Internet filing systems are adequate (though not necessarily convenient) for managing large construction projects. There is a real danger that an 'Office' mentality is replacing engineering methodologies.

4.2 Standards and Collaboration

Parallel to the rise of globalization, there has been an increasing interest in international standards and increasing pressure to conform to them. Companies go to great expense to become certified as conformant to various ISO standards, notably the 9000 series. One goal of standardization to improve the abilities of companies to work together. In theory, standards should make it easier to adopt common project management and information exchange processes, and build unified archives of construction project data.

In practice, most standards do not provide enough detailed guidance on how to implement the process being standardized. *ISO 9001*, for example, merely states that you must document your processes, that your processes must follow your documentation and that you keep detailed records to prove it. The standard provides no advice on how the records should be kept, organized or shared within or outside the organization.

Another standard, *ISO 15926 Industrial Automation Systems and Integration*, appears to be a standard for process data integration, sharing and exchange between computer systems. It was developed for oil and gas production facilities, and the potential exists to extend it for large civil engineering projects. It turns out that *ISO 15926* is merely a definition of a *lingua franca* for modeling terminology, and to get any practical benefit you have to instantiate it with your own domain specific vocabulary (e.g. classification system). Smith [4] has identified further technical limitations to *ISO 15926*.

4.3 Inter-Company Collaboration

As the organization comprising a large construction project is ultimately a temporary entity and the participating companies are permanent, it is logical that the individual companies prefer to focus their efforts on improving their own internal collaboration, at the expense of the project.

True project collaboration between companies currently occurs on an ad-hoc basis, with little prior planning or thought given to the development of integrated procedures and unified information systems suitable for all. This is accentuated by a lack of contractual incentives.

Given the lack of standards for integrating construction information, the inappropriateness of the current generation of software systems and the sheer difficulty of the task, it is hardly surprising that project partners are unwilling to do this for free. Stated bluntly: in today's project environments collaboration does not pay.

5. Vision for Collaboration

5.1 Requirements

The fundamental requirements for our vision for collaborative best practices are:

1. Project information should be centralized at one location, regardless of its form.
2. The project information shall be accessible (given appropriate authorization) to all project participants, irrespective of their location.
3. The project's requirements for approvals and revision control should be fully supported.
4. A single project-wide classification system should be applied to all information.
5. The classification system should be based on concepts already understood by engineers.
6. It should be possible to easily search for information using the classification system, without the need for formal training.
7. Budgets and responsibilities should be allocated to ensure that the system is satisfactorily implemented and useable.

These requirements are intentionally imprecise because we do not intend to dictate a particular implementation. Our goal is to convey *what* should be done, not the details of *how* it should be done. In fact, our experience has shown that considerable amount of trial and error is required in order to converge on the best solution.

5.2 Practical Consequences of the Requirements

The requirements, together with our experience, lead directly to a number of conclusions:

1. The best practices are a combination of procedures and software system(s), and the procedures should dictate the software (and not the other way round).
2. The system(s) should be Internet based and work with a normal web browser. This makes it easy for end users who already have browsers installed on their computers and are experienced in using them.
3. Considerable effort must be made into translating the project's structures into a suitable classification system.
4. In order to keep the implementation effort at an acceptable level, the system should merely store and retrieve electronic files and documents. E.g. the system need not have any inherent understanding of the documents' contents. Classification data associated with documents should be stored externally as metadata.
5. It is unlikely that off-the-shelf software can be found to satisfactorily implement the entire system, meaning that personnel with programming, Internet and database skills will be needed.

5.3 Management Issues

The project must commit to the collaborative best practices, meaning:

1. All project participants are expected to register all their project documentation in the system.
2. The versions of the documents on the system are defined to be the authoritative copies.

The first point means that the responsibility for ensuring that all documents are, in fact, in the system must be delegated to someone that has the authority to enforce compliance. This implies that a *documentation manager* role, directly under the project manager, should be created.

The second point means that the system must support the revision (version) control and workflow associated with the project's requirements for document checking and approval.

6. Practical Experience from the Kárahnjúkar Project

The Kárahnjúkar Hydroelectric Project is building a 700 MW power plant in a remote area in northeastern Iceland. Landsvirkjun, Iceland's national power company, initiated the project five years ago and the project went on line towards the end of 2007. The completed works have two main reservoirs, five dams, a six-turbine powerhouse and over 70 km of tunnels. There are more than twenty major supplier companies, from all over the world, taking part. At the height of the construction phase there were over one thousand people on-site.

6.1 Kárahnjúkar Document Management System

At Kárahnjúkar we created a web-based construction drawing management system [5], which initially handled the approvals workflow associated with the creation and distribution of drawing submittals. Over time we expanded the system to manage other document types and the tasks associated with revising and updating them. To date the system manages more than 20,000 documents. The system currently has more than 300 users who make approximately 5000 mouse clicks per week.

From the outset we allowed all documents (and in later versions, tasks) to be classified using standard engineering criteria. At the time this was thought to be a minor feature, and it was only later that we realized that we had stumbled upon the key to document management for construction.

One important factor influencing the wide acceptance to our system has been our willingness to adapt and change our system as new requirements arose. Indeed, we have overcome our inability to predict what users really want by making smaller enhancements and waiting for the subsequent feedback.

6.2 Lessons Learned

The following are some of lessons we learned along the way:

Usability is Critical – *You cannot guarantee the use of the system by mandate alone*. Engineers are incredibly resourceful (especially when sequestered on a job site), and if using the system is difficult, or merely awkward, they will invent their own. The only way to guarantee that the best practices will be used is to implement them in such a way that they are the easiest and most efficient way of getting the immediate job done. Be on the lookout for engineers using private spreadsheets and databases, which is generally a sign that the system is not fulfilling their needs.

System Advocates – A small number of opinion leaders who promote, often informally, the use of the system makes a huge difference in user acceptance. Opinion leaders can be encouraged to become system advocates by implementing their requests for system enhancements.

Document Librarians – You should appoint one or more document librarians, who are responsible for ensuring that all documents are placed into the system and classified correctly. The librarians should be the first points of contact for people having difficulty finding documents.

Computer and Database Experts – You will need help from computer and database experts, particularly when migrating large amounts of data into and out of the system. Ensure that your staffing requirements and budget are adequate.

Changing Requirements – The requirements for the system will change over time as the project progresses, and it is impossible to predict in advance the direction it will take. Likewise, users will suggest seemingly minor changes to the system, which will result in major usability improvements.

Critical Mass – In order to entice people to contribute documents to the system, they must believe that others will use it. Thus, in order to bootstrap the process you must put a critical mass of documents into the system as early as possible.

Document Searches – Searching should be as simple, yet as comprehensive as possible. Ideally you can enter a document number or a part of a document number into a search screen and then be presented with the document you are looking for. You also need to be able to enter complex search criteria based on the classification schema. Google's basic and advanced search screens are good models to follow.

Linking Documents and Activities –This seemingly simple feature, intended for tracking requests for updating documents, took an unexpected direction and ended up being used by tunnel inspectors for managing the tasks to be performed during walk-through inspections. Inspectors responded to requests for conditions in the tunnels (activities) by making links to the inspection reports and photographs (documents) created during inspections. The resulting data was then classified by the alignment and chainage, allowing engineers to locate all issues associated with particular tunnel segments. This highlights the importance of being flexible and sensitive to changing requirements.

Automatic Classification – Entering classification data is a chore that engineers would rather avoid. It is desirable to automate the settings of some of the classification information by making use of the context in which the data is being entered. For example, by noting the user's work group and the type of document being created, it is often possible to automatically determine values for many of the classification fields.

Classification System – The classification system should be based on the common drawing systems used on the project. Project partners should provide the quality documents describing their document numbering systems. These should be registered in the system and as used the basis for implementing automatic classification.

Metadata Export – Once a critical mass of documents and files have been stored in the system, the classification data (i.e. metadata) assigned to the documents starts to have value in its own right. Providing the ability to export the metadata into other programs, such as Excel, allows users to perform further analysis of the metadata and create complex reports.

Bulk Import/Export – It must be possible to efficiently enter large amounts of data into the system without having to type it all into web forms. Likewise, it must be possible to export all documents for delivery to project partners who must have their own copies due to archival and regulatory requirements.

External Keys – It should be possible to assign an external key value to every file in the information repository. The external key is typically used to assign a supplier's document number and makes it easier for members of external companies to search for their documents.

Monitor the System – In particular, monitor the number of users and number and types of transactions they perform. This is a good measure of the acceptance of the system by its users.

7. Conclusion

Implementing collaborative best practices for the Kárahnjúkar Hydroelectric Project has contributed to a productive project environment. Though it is difficult to calculate the indirect savings due to improved collaboration, we have anecdotal evidence from a wide range of project participants, all of whom indicate that the system has saved considerable effort. Two years into the project the direct savings were calculated, which exceeded the development costs up to that point.

Our strongest evidence of success has been the request, by one of the participating companies, to implement similar systems for two other construction projects. In addition, the project owner indicates willingness to consider using our techniques on further projects.

The key recommendations distilled from our field experience are:

1. Productivity gains can be achieved from adoption of collaborative best practices.
2. Support from the project owner, and a few key line engineers and managers, is essential.
3. Improved efficiency is possible even with partial implementations.
4. Earlier adoption produces better results.
5. Classification systems are well received by engineering and construction personnel.

6. Ease of use, especially when searching for documents, is critical.
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