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Engineering Classification: The Key to Filing and Finding Construction Project Information

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1 Introduction

Electronic documentation systems have largely replaced paper-based systems in construction projects. Unfortunately, these systems have yet to provide the full functionality provided by the paper-based systems. A key deficiency is their inability to file and manage project information according to the rigorous principals expected by engineers and project management.

We present a solution to the electronic filing problem for construction projects: the use of *engineering classification* as the primary way of organizing project information. We will argue that engineering classification is the most appropriate and, for construction personnel, the most natural way of filing and finding construction project information.

This paper starts by stating the basic requirement for project filing and then continues to explain how current practice, as implemented in today's generation of electronic systems, is largely unable to fulfil it. Following that, we explain the principles of engineering classification and show them to be a more appropriate basis for a project's filing system. We conclude with a series of practical considerations.

Our recommendations are largely based on experience gained on the Kárahnjúkar Hydroelectric project, which is described in (Hodgkinson, 2007) and (Petursson, 2007).

2 Project Filing – Basic Requirement

Our experience, confirmed by numerous engineers and project managers, is that well-organized project documentation is a prerequisite for a successful construction project.

> ***On construction projects, the ability to efficiently and accurately locate all project documents associated with an engineering or managerial issue is mission critical.***

3 Project Filing – Current Practice

The practice for managing construction documentation is in the midst of a change from paper-based to electronic systems. While globalization has meant that paper-based systems are no longer feasible for document exchange, the newer electronic systems replacing them do not have the rigour and fitness for purpose of their paper-based predecessors. Yesterday's strict document management procedures evolved in parallel with project management procedures, which are still in use today (Hamilton, 2004). The procedures for managing the documents and managing the project worked well together. The newer electronic systems, in particular their filing and retrieval mechanisms, do not co-exist as well with today's management procedures. This is caused by the mismatch between the project's needs and the features typically offered by electronic filing systems. This section explains the problem.

3.1 General Purpose Document Management Systems

Most commercially available electronic document management systems were originally programmed for other industries. These systems have been created without adequate regard to the well-defined procedures normally used on construction projects (Some engineering companies have recognised this problem and have attempted, often at great expense, to implement their own custom electronic systems).

3.2 Document Trees and Keyword/Tag Searching

The primary mechanism for organizing documents in the current generation of electronic filing systems is the *document tree*, which consists of the nested set of file folders familiar to PC users. The most obvious example is the filing system used by Microsoft's file explorer.

The main limitation of document trees is that they can only present one organizational hierarchy. This makes it is difficult to find related documents if the relationship is not directly expressed by the document tree. For example: if the document tree stores civil and mechanical drawings in separate branches, how do you find which civil drawings need to be updated in the event of a specification change to a mechanical component? This type of query, which exposes potential problems at project interfaces (which cross organizational boundaries), occur frequently, and successful project management depends on having a reliable answer.

In an attempt to overcome these limitations, the ability to search by keywords or tags is frequently provided. This includes the ability for users to assign 'tags' to the documents. There is seldom any ability to limit the allowed tags, leading to a proliferation of tags caused by misspellings and non-standard terminology. Multi-language projects and non-native speakers further compound the problem. Keyword and tags lack the rigor required for construction projects.

3.3 Google-Like Searches

While Google is a breakthrough for finding information on the Internet, it is not the most appropriate model for searching for construction project information. Google searches are based on keywords and Google does not impose any structure on the search space beyond recognizing the popularity of the target pages. Note that Google searches the entire Internet, which is an infinite without any predefined structure. Luckily, when performing Google searches we are generally not interested in finding *all* the documents that match our keywords.

However, on a construction project we frequently require the ability locate every document related to the issue at hand. The ability to locate all the documents associated with an engineering or managerial issue is often critical for being able to resolve it. Unlike the Internet, a construction project has a finite set of documents, a well-defined structure and it is possible to fit the project's documents to its structure. We believe that organizing documents according to the project's structure leads to systems that better fit the working practices of the construction industry.

3.4 Classification Standards

In parallel with transition to electronic documentation systems, there has been increasing interest in promoting standards and increasing pressure to conform to them. The standards have been promoted, in part, as a way for construction projects to organize and manage their documentation.

In practice, standards do not provide enough detailed guidance on how to implement the processes being standardized. Standards normally mandate that you work to a well-defined process, that the process is documented and that you keep records in order to prove that you are following it. The details are up to you. Standards are simply not adequate for explaining how to identify the industry's best practices, or how to implement them in software systems. (Hodgkinson, 2008b, section 4.2) explains this problem in more detail.

3.5 Mismatch between Features and Construction Requirements

In the construction domain there are often limitations with electronic document systems when you implement strict revision control or when searching for documents related to a particular project component. These are specific requirements of the construction industry, which are poorly met by most electronic systems. In spite of the extensive 'enterprise' features found in many electronic systems, the basic needs of a construction project are seldom satisfactorily fulfilled. Text and tag based searches are unable to accurately answer basic construction queries, for example the list of 'all as-built concrete outline drawings for gate shaft number two'.

The current state of art of electronic filing systems is a disappointment. There is a tendency by software vendors to distract their customers with impressive but unnecessary features. Often the actual system capabilities are quite limited with respect to the needs of the construction industry. In many systems your documentation is forced into an organizational scheme constrained by the software's capabilities, rather than being determined by your engineering and construction requirements. The result is a sub-optimal filing system that becomes a productivity hindrance rather than a gain. (The importance of choosing an electronic document management system that actually meets your specific needs is discussed in (Hodgkinson, 2006)). The consequence is increasing difficulty in managing project information, which increases project risk and cost. Projects currently accept these inefficiencies because they have no clear idea of the productivity gains that could be achieved. (The collaborative benefits that could be achieved are discussed in (Hodgkinson, 2008b)).

4 Engineering Classification

We believe that the best solution to the documentation filing and retrieval problem for construction projects is to use *engineering classification* as the primary organizational method, and that engineering classifications should be applied to all project documents.

4.1 Attribute-Based Classification Tags

In this paper engineering classification is defined to be the assignment of codes to documents for the purpose of identification. The codes represent one or more engineering criteria (attributes) that help identify a document's 'place within the project' and its relationship to other documents. The most familiar example of such a system is a drawing code. An example drawing code, with the description of its individual components is shown in table 1. It has been taken from a real project.

Like a drawing code, an engineering classification is ultimately a filing code, which can also be used as a search key. The code is composed of individual components (attributes), each of which has a specific meaning. The permissible values for each component are selected from pre-defined lists, called attribute lists. Attribute lists are recommended because they avoid the problems associated with tags and text searches, described earlier. The attribute lists should be defined by the project and documented in the project's quality standards.

Table 1: Components of the Drawing Code: ***14-C-2.17.101-A3***

Component	Value	Meaning
Contract	14	Headrace Tunnel
Engineering Discipline	C	Civil
Location	2	Gate Shaft 2
Work Type	17	Concrete Outline
Sequence Number	101	101
Revision Type	A	As-Built Drawing
Revision Number	3	3

4.2 Use Accepted Practice

Engineering classifications are already being used on construction projects. Since our proposed system is simply an extension of the drawing code system, all construction professionals are familiar with the concept and have experience using such systems. Other examples of familiar engineering classification systems include the organizational and work-breakdown structures found on all projects. While the specific details vary, these classification systems are understood and accepted by project teams. Engineering classification *is* the de-facto standard for organizing information.

4.3 Searching Using Engineering Classifications

Searching is easier when using a well-defined coding system. Let us return to our previous example of finding 'all as-built concrete outline drawings for gate shaft number two'.

Assuming we are using the drawing code system defined in table 1, an engineer would search for drawings with drawing code components matching particular search keys, as shown in table 2.

Table 2: Searching for *'all as-built concrete outline drawings for gate shaft number two'*

Component	Search Key	Meaning
Contract	*any*	
Engineering discipline	*any*	
Location	2	Gate Shaft 2
Work Type	17	Concrete Outline
Sequence Number	*any*	
Revision Type	A	As-Built
Revision Number	*'most recent and approved'*	See below

Clearly the search keys, since they are selected from attribute lists, avoid any problems that might be caused by inconsistent terminology and spelling. In fact, since the attribute lists are defined by the project, the project team will naturally adopt the correct project terminology.

This example also exposes an additional complication: workflows states. In our search we are not interested in the actual version number, but only in the most recent *approved* revision. The document archive will contain superseded revisions, which have to be clearly marked as such, when a new revision is approved. Obviously, we must include additional information in our engineering classifications besides that which is already encoded directly in the drawing code. In this case, we have to manage workflow state and the concept of a 'most recent revision'. As your search queries get more complex, they will identify additional components that must be included in your classification codes.

Consider another, more complex, example: you need to decide whether you accept or decline a turbine specification change. The issues are:

1. Avoid claims from the civil contractor.
2. Identify ongoing work that must be delayed pending the decision.
3. Quantify the drawing updates required by the change.

4. Make sure the turbine can be delivered though the access tunnel.

In order to find the documents necessary to make the decision, you will have to perform multiple searches, as shown in table 3.

Table 3: Searching for documents associated with a turbine specification change.

Management Objective	Document Search	Classification Components
Check contract and specifications to avoid claim from civil contractor.	All contractual documents and specifications from design phase associated with civil contractor.	project phase document type company
Delay any work orders that might need to be changed.	All site instructions to civil contractor building the turbine foundations.	document type company location
Quantify drawing updates.	All structural, concrete and electrical drawings associated with turbine units 1, 2 and 3.	document type engineering discipline location unit number
Make sure that new turbines will fit through the bend in the access tunnel.	All tunnel profiles of Adit-2 from 1,200m to 1,400m.	document type alignment chainage

This example exposes a number of new classification components and demonstrates that our simple drawing code does not contain sufficient information for locating all the documentation required for solving the problem.

The key point is to think in terms of classification components, which based on attribute lists derived from construction management principles. Different sets of the components can then be used to create different document coding systems for different types of documents. For example: design documents might be identified using engineering discipline, location and work type, while for cost control documents you will prefer accounting, procurement package and material codes.

The intent is not to change a project's document coding systems, but to illustrate that additional classification components are required to have a complete engineering classification system. While it is beneficial to have your document coding systems match your engineering classification system, you must also realize that not all classification components make sense for all document types.

4.4 Classification Hierarchies

The question naturally arises: What is the complete set of classification criteria? A suggested list of classification criteria is shown in table 4.

The classification hierarchies shown in table 4 are not strictly hierarchical trees, but in some cases represent sets of related classification components. Work-breakdown and organizational-breakdown structures are discussed in (Moavevanzadeh, 2007). Classifications associated with workflow steps can be problematic, and are described in (Hodgkinson, 2008b).

Table 4: Classification Hierarchies

Classification Hierarchies	Classification Criteria
Work-Breakdown	project phase engineering package engineering discipline work type
Organization	company unit working group

	individual team member
Location	location code unit number alignment/chainage elevation geographical coordinates
Cost-Breakdown	contract accounting codes procurement package material codes
Workflow	scheduled dates completed dates production/receipt signoff approval distribution
Document	document/data type revision number sequence number

The best practice is to assign classification attributes to all project information, and that enough classification attributes are assigned to make it possible to resolve typical queries. Not all attributes make sense for all documents, but more comprehensive classification makes retrieval easier and more accurate.

The classification codes are not necessarily the same as the document codes, although in the ideal case they are related.

5 Practical Considerations

This section provides a series of practical considerations that can be used to reduce the effort and improve the benefit of engineering classifications.

5.1 Automatic Classification

Many classification attributes can be set automatically based on context or other information. For example:

1. Document codes can be used to automatically infer classification attributes.
2. Document type, supplier or other information can be used to set classification attributes.
3. Sets of documents have similar classifications, which are frequently known in advance.
4. Text searches on titles can be used to select items that will have similar classifications.

5.2 Stepwise and Optional Classification

Assignment of classification codes can be done in stages. Assign the vital information first and fill the rest in later. This can also be done in multiple stages. Be sure you have the ability to flag classifications that are incomplete or incorrect.

Classification attributes can be optional or required. Whether a classification attributed is required is a policy decision. It normally depends on the type of document.

5.3 Use Codes, Not Titles for File Names

When naming the document file, use codes wherever possible. Codes are shorter, more exact and less subject to mistakes caused by language and terminology mistakes. With a well-designed coding system you may even be able to generate parts of the title directly from the document code. This does require that your document coding system is built from attributes that are relevant to the documents contents. *Always* put the revision number at the end of the filename.

5.4 Separate Naming from Classification

The document coding system is not required to have a one-to-one match to the engineering classification system. Since some classification attributes have no meaning for certain classes of documents, it makes no sense to include them in their document codes. Strive for a one-to-one mapping between you document code components and their associated classification attributes.

5.5 Be Able to Handle Naming Errors

Occasionally a drawing will be assigned an inappropriate drawing code, and it will be administratively difficult to change it. Make sure your coding system allows the flexibility to re-classify the drawing without having to change its code.

5.6 Consider Multiple Classifications

Multiple classifications may be needed for certain documents. For example drawings that contain multiple units, or tunnel reports that cover a from-to range of chainage or elevation. For power plants, the KKS system is widely used and operators like to know which drawings contain specific components.

5.7 Consider Classifying Individual Parts of Certain Documents

Certain documents, such as contracts and specifications, can be broken down into component parts and classified individually. This allows you to search for individual contractual clauses and requirements that can be matched against design drawings.

5.8 Partial Implementation is Better than None

Many of our recommendations pre-suppose a single universal project archive and a unified database of classification information. For a variety of reasons, this is not always possible. That said, implementing engineering classification for a subset of your documents provides immediate benefits. A good place to start is with drawings, which generally already have a well-defined classification system.

6 Conclusions

We believe that the current generation of electronic document management systems is unsuited to the requirements of the construction industry, and that systems based on engineering classification are a better alternative.

Engineering classification is well understood by the construction professionals, and our experience indicates that systems incorporating it have been well received.

We believe that document management systems incorporating engineering classification systems will increasingly contribute to project efficiencies.

7 References

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8 Authors

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