

The AEC Workflow

You won't find anything new in the first part of this chapter if you are a gray-haired AEC professional, as you have gained experience working with a paper-based workflow the hard way. If you are a student, carefully read about paper-based workflows in the first part of this chapter.

Regardless of your level of expertise, the second part of the chapter describes a new way of working – without paper. Acrobat offers an electronic workflow that effectively replaces the transport and processing of multiple iterations of files and documents.

In this Chapter

The AEC workflow is based on a series of coordinated and interconnected events. In this chapter you will learn about the components of an AEC workflow, first by examining a paper-based workflow, and then an equivalent digital workflow

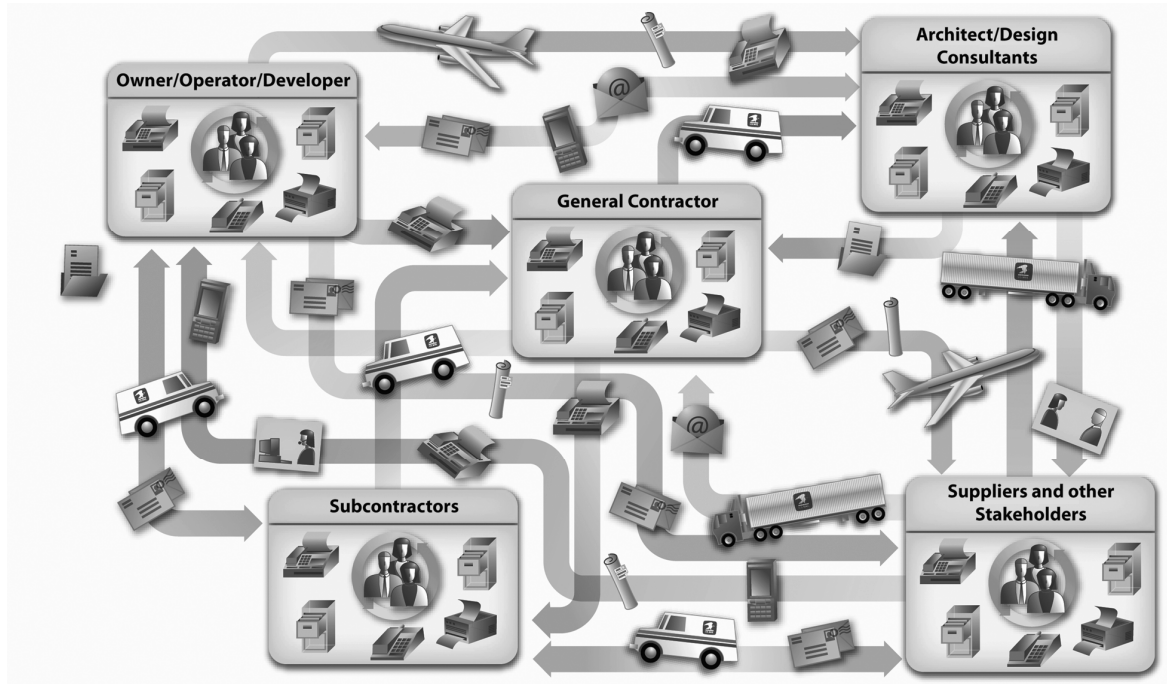
You will learn that:

- All projects start with a definition of scope, a document on which the design is formulated.
- The design process defines the structure of a project, and the contributions made by various specialties and disciplines.
- The bid is developed using a methodical, systematic formatting system, and submitted.
- The bid opening announces the winner of the bid, as well as qualifying the winner.
- The submittal process defined in the contract requires that documents identifying materials used in the project be submitted to the owner for review.
- According to the contract's requirements, payments are generated based on specified milestones; change orders are processed on an *ad hoc* basis and subject to review and approval.
- Project wrap-up includes provision of sets of redlined drawings, as well as manual sets for all equipment.

A Paper-based AEC Workflow

For purposes of discussion, we are presenting two different workflow diagrams in this chapter, both developed by Adobe Systems.

Adobe has developed a highly simplified, but very true diagram of a paper-based AEC workflow (Figure 2.1). Everywhere you see an airplane, mail truck, or fax machine in the figure, you can also add a dollar (\$) sign. The cost is not only in the actual costs of producing the printed pages and moving the paper – much of the cost is in the time invested in the distribution of the paper.



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Figure 2.1 A complex, paper-based workflow

Project Scoping

Let us take a look at the workflow in detail. A project starts with an idea from the Owner/Operator/Developer. Either the project initiator prepares a scoping document identifying their needs, or the task is assigned to the Architect/Design Consultant (A/DC). The needs and constraints of the owner must be detailed in a format that the A/DC can use for generating design parameters. Producing a working document may require multiple iterations, and a lot of paper is moved during project scoping.

Design Process

The design process begins once the project scope is approved. The workflow diagram shows a single box for the A/DC, although the vast majority of projects are not done via a single entity.

Some very large architecture and engineering firms have all disciplines in house, but are the exception rather than the rule. Even the large A&E firms grow by acquisition and may have the disciplines needed at different locations, using incompatible design programs. Coordinating design efforts among disciplines requires considerable paper shuffling and distribution using various mediums. There are a lot of invisible \$ signs in the design process.

The Bid Process

The specifications on a project are designed using MasterFormat™ Numbers and Titles, a system developed jointly by the Construction Specifications Institute and Construction Specifications Canada that has been in use since the early 1960s. The basic divisions, groups, and subgroups are listed in Table 2.1.

MasterFormat™ is the specifications-writing standard for most North American commercial building design and construction projects. The standard lists titles and division numbers to organize data about products, construction requirements, and activities [1]. The system is used to standardize filing and retrieval schemes, and is appropriate for many types of communication, such as project manuals, cost and technical data, reference notes on drawings, and product information.

The MasterFormat™ standard also contains up to 999 subdivisions, as well as cross-references, which are important when an item could logically be placed in multiple locations. *See* and *See Also* references direct the user to other divisions or subdivisions.

Plans and specifications are prepared and, since paper has been the only common format, they are printed. The cost to produce a set of plans and specifications can easily reach or exceed \$100. In the past, the cost of producing the plans and specifications was covered by the owner, but no-cost plans often resulted in too many people requesting plans that did not submit bids. Some owners started requiring a deposit on the plans and specifications, while others pre-qualified the bidders. Pre-qualification of bidders adds time to the process, and commands higher fees to the designers to qualify the bidders. Many owners opt for requesting a set fee for a copy of the plans and specifications to offset the printing costs.

Plans Based on Discipline

Plans are often arranged around discipline and may change based on the discipline in charge. Let us look at an example using site work. If an engineer is in charge, the pages may be numbered starting at C-01 (for Civil). If an architect is in charge, the pages may be numbered starting at AS-01 (for Architectural Site).

For the most part, the page number prefixes follow this pattern: “A” for Architecture, “C” for Civil, “E” for Electrical, “M” for Mechanical, “S” for Structural, and “P” for Plumbing. Other work may be prefaced with “MP” for Mechanical Process and “NC” for Controls and Instrumentation.

Developing the Bid

The general contractor rarely has all the specialties in house, and sends plans and specifications to subcontractors and vendors for price quotations. The contractor often spends the time and money to make a complete subset of the plans and specifications for each of the mechanical, plumbing, electrical, civil, or specialty contractors providing a bid.

Creating subsets of plans and specifications can save money on reproduction, but may cost the contractor if a key piece of information is hidden in part of the specifications not furnished to the

subcontractor. A contractor may need a dozen copies of a project's plans and specifications to distribute to the various subcontractors.

Table 2.1 MasterFormat™ specification divisions

Group	Division		Number
Procuring and Contracting Requirements	Procurement and Contracting requirements		00
Specifications Group	General Requirements		01
Facility Construction Subgroup			
Division	Number	Division	Number
Existing Conditions	02	Finishes	09
Concrete	03	Specialties	10
Masonry	04	Equipment	11
Metals	05	Furnishings	12
Wood, Plastics, and Composites	06	Special Construction	13
Thermal and Moisture Protection	07	Conveying Equipment	14
Openings	08		
Facility Services Subgroup			
Division	Number	Division	Number
Fire Suppression	21	Electrical	26
Plumbing	22	Communications	27
HVAC	23	Electronic Safety and Security	28
Integrated Automation	25		
Site and Infrastructure Subgroup			
Division	Number	Division	Number
Earthwork	31	Transportation	34
Exterior Improvements	32	Waterway and Marine Construction	35
Utilities	33		
Process Equipment Subgroup			
Division	Number	Division	Number
Process Integration	40	Pollution Control Equipment	44
Material Processing and Handling Equipment	41	Industry-specific Manufacturing Equipment	45
Process Heating, Cooling, and Drying Equipment	42	Electrical Power Generation	48
Process Gas and Liquid Handling, Purification, and Storage Equipment	43		

The Bid Opening

The bid is developed and delivered or faxed to the bid opening. The apparent winner is often announced at the opening. However, the winning bid is not official until the engineer reviews the bids and determines that the apparent winner is in the owner's best interests.

The determination process usually involves manually developing a spreadsheet, adding data from competing bids, and then comparing the bids. Often, a contractor can detect a bad assumption on the engineer's part and load the bid to make a certain line item and the total bid low. The contractor is then in a position for a change order and renegotiation of the line item. The engineer can catch the assumption during the determination process, and decide the bid is not in the best interests of the owner.

The Submittal Process

Once the project is awarded, the contractor is responsible for submittals required by the contract. The submittals assure the owner's representative that the material used is the same or equal to the specified materials, and that choices of materials and methods will not cause problems with other parts of the project.

The submittal process is highly resource intensive. Up to six copies of each submittal are required, including a form. The submittal form tells the engineer where the submittals originate in the project's specification.

Once received, the copies are logged and distributed to the reviewers by the document manager, who is usually a junior engineer. The reviewers mark up the documents and return comments to the document manager. The document manager then forwards them to the engineer-in-charge, who reviews the comments and approves, conditionally approves, or rejects the submittal. The submittal is returned to the document manager again, who sends the results back to the contractor.

The Payment and Change Order Processes

Each project's documentation includes forms for payment and for change orders. Paper forms are commonly used, and of course it is simple to make calculation errors on the forms.

The contractor fills out the forms after calculating the math, and the project engineer double-checks the figures. According to the contract's requirements, payments are generated based on specified milestones; change orders are processed on an *ad hoc* basis and subject to review and approval.

Project Wrap-up

One of the last things that is done on a project is to generate a set of redlined drawings and manuals for all the equipment. *Redlined* drawings are project drawings on which the contractor identifies the changes with a red pencil. Often, a contract requires two sets of redlines for both the owner and the engineer; the contractor is remiss in not making a third set of redlined drawings for himself. Until recently, large-scale color scanners were prohibitively expensive and redlining on all sets was added by hand.

In addition to redlined drawings, most contracts usually require two sets of equipment manuals. Some contracts require that the manuals be organized in binders, while other contracts do not require that level of organization.

Future Considerations

Suppose it is one year later, and the contractor is called back to the site to work on the equipment. He may or may not be able to find the drawings or manuals, and even if he does, it is not necessarily the case that the drawings will be updated based on the contractor's work, thus establishing a scenario that can lead to

future unnecessary expenditures of time, money, and manpower. Drilling through an electric conduit or cutting a water pipe are common mishaps that may be attributed to lost, missing, or out-of-date drawings and manuals.

Using PDF in the Bidding Process

The earlier part of this chapter identified the mountains of paper generated and moved about on a design and construction project. In this part of the chapter you see how an equivalent process can be managed digitally.

Electronic bidsets have seen some success in recent years. The US Army Corps of Engineers Engineering Research and Development Center runs an electronic plans and specifications service for the Corps and other agencies. The Corps has used PDF for the specifications for some time, but use CALS for the drawings. The Corps have been experimenting with PDF drawings and may eventually go to an exclusively PDF-based system.

Electronic Specifications

Specifications are composed of a series of word processing, spreadsheets, and scheduling files. The design firm develops a set of the various sections and divisions for projects. Each section or division is an individual file; the appropriate section and division files are collected and modified for a specific project. A typical project often contains 50 – 100 word processing files. In addition, specifications usually have at least one spreadsheet and/or a schedule, and may also include scanned maps.

Both Acrobat 6 and 7 have the ability to combine all the electronic formats into one file in one step using the Create PDF from Multiple Files command. The files are selected and ordered, and then converted to PDF and combined into a single file.

About the CALS Format

CALS is a proprietary raster format similar to TIFF. Like other raster formats, enlarging a CALS drawing results in pixelation. As they are in a raster format, CALS drawings do not contain fonts, and consequently lack the ability to be searched. On the other hand, PDF is a vector format like CAD drawings, which can be zoomed without any distortion of the drawings, as vector drawings are based on equations.

Bid Sheets

Word and Excel have both been used to make electronic forms, although neither program was intended for forms development. Form users had to have access to the same programs to complete the forms. Word forms change appearance as they are filled out; Excel forms, although they are visually more stable, may also have problems in their use.

PDF forms are becoming the industry standard. Since the free Adobe Reader is one of the most widely distributed programs in the world, the problem of the user not having access to the proper program for completing the form is eliminated. Acrobat 7 has added the ability for the form to be e-mailed back to the originator automatically by clicking a button on the form that is preconfigured to send the FDF (form data format) file containing the form data back to the originator. The person completing the form cannot electronically save the completed form with Adobe Reader, although the form can be printed.

Viewing PDF Plans

There are numerous CAD programs available, and numerous viewers have been developed to make the CAD drawings available. It is not uncommon for one project to require three viewers to display drawings.

PDF is a logical solution to the problem of inappropriate viewers, by converting all drawing types to PDF and then viewing with either Acrobat or Adobe Reader. Although some CAD viewers have a few specialized advantages over PDF, Adobe is rapidly advancing Acrobat to meet the challenge. Bentley, the creator of MicroStation, has realized the advantages of one format and now users can make PDF files directly from MicroStation V-8 2004.

With the development of an ISO Standard PDF/E (PDF/Engineering), eventually all CAD programs will require PDF file-generating capabilities.

An Electronic Bidding Process

Figure 2.2 illustrates the electronic bidding process with one bidder. This is more like a design/build project. In this particular figure the Facilities Manager is the owner's representative or designer. An electronic PDF package is prepared from the various design programs. Security and digital signatures are added to the package to protect the content.

The Builder's Project Manager (PM) determines the various disciplines that need to work on the estimate and enables Adobe Reader's commenting capabilities for their review. Figure 2.2 does not include the process of receiving bids from subcontractors.

Once the estimate is finished, the PM completes the bid, digitally signs the document, and then electronically returns the information to the Facilities Manager for review by the project team. The Facilities Manager digitally signs the documents, and electronic copies are archived and forwarded to the Project Manager.

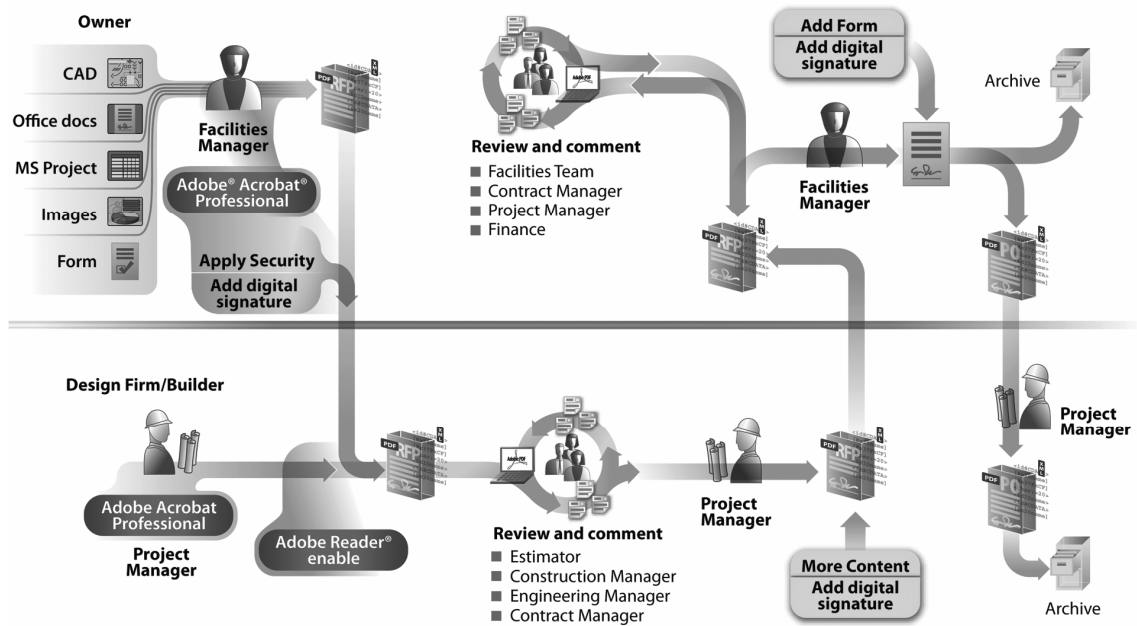
The electronic process saves a great deal of time, as well as the expense of printing, shipping, duplicating, collating, and reshipping the plans, specifications and contracts.

Summary

In this chapter we looked at two different processes for developing and administering a project workflow. In the first example, you saw how a traditional AEC project is developed and administered using a paper-based method. In the second example, a design/build workflow is illustrated, using an electronic PDF-based workflow.

Exercises

1. Using Figure 2.1, and the information outlined in this chapter, identify the processes in a traditional paper-based workflow.
2. Using Figure 2.1, determine areas in which savings could be realized by using an electronic workflow rather than a paper-based workflow.
3. Using Figure 2.2, examine a workflow that has been traditionally paper based, and determine ways to convert the workflow to an electronic format.



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Figure 2.2 An Acrobat-based AEC workflow

References

- [1] CSINet, *MasterFormat™ 2004 Edition Numbers and Titles*, 7 July 2005. http://www.csinet.org/s_csi/pdf.asp?TP=/s_csi/docs/9400/9361.pdf

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