

# KEYNOTE PAPERS



# Information Management for Construction

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**ABSTRACT:** Changes brought about from advances in information technology for the architecture, engineering, and construction industries (construction IT) are not purely technical, but must be accompanied by significant changes to the management processes. This paper explores approaches to information management processes, and the role of a *project information officer*. The paper first presents the context for construction IT in the form of simple models representing the role of IT on construction projects. It then presents a framework for construction information management, organizing the wealth of issues around the dimensions of general management processes, breakdown of project elements, breakdown of information system elements, and information system objectives. It also discusses a breakdown of the areas of expertise required for construction IT. Finally, it suggests that from an organizational perspective, these information management practices should be consolidated around a high-level project management position dedicated to information management—the position of a project information officer.

## 1 INTRODUCTION

Current trends in information technology (IT) are yielding a wide range of new computer-based tools to support the architecture, engineering, construction and facilities management industries (collectively referred to simply as “construction” in this paper). These tools—everything from project collaboration web sites to virtual building environments—promise great increases in the effectiveness and efficiency of designing and managing construction projects. However, these improvements cannot be realized without corresponding changes in the work tasks and skill sets of the project participants. In particular, this paper explores the assertion that new advances in IT must be accompanied by corresponding changes in project management. This paper focuses on changes in the form of an enhanced information management process and the role of a Project Information Officer. Elsewhere, we examine changes to the overall process of project management in general (Froese & Staub-French 2003).

This paper addresses the early phases of research on this topic: clarifying the observations and research questions, discussing the context (e.g., emerging IT), and suggesting solution frameworks (this further develops work reported earlier in Froese 2004). Future work will include further development

of the proposed solutions, experimentation and validation.

## 2 THE CONTEXT FOR IT IN CONSTRUCTION

### 2.1 *A Model Depicting the Role of IT in Construction Projects*

As a first step in examining the relationship between IT and project management, we introduce a simple project processes model for exploring the role of IT in construction projects (Aouad et al. 1999 use a more elaborate project process model—the process protocol model—to analyze project IT). This model adopts a process perspective of construction projects, and views projects in terms of the following elements (illustrated in Figure 1):

- A collection of tasks carried out by project participants (all tasks required to design and construct the facility).
- A collection of transactions involving the exchange of goods or communication of information between tasks.
- A collection of integration issues—issues relating to the interactions between the tasks and transactions as a whole rather than as a set of individual elements. This also includes issues relating to in-

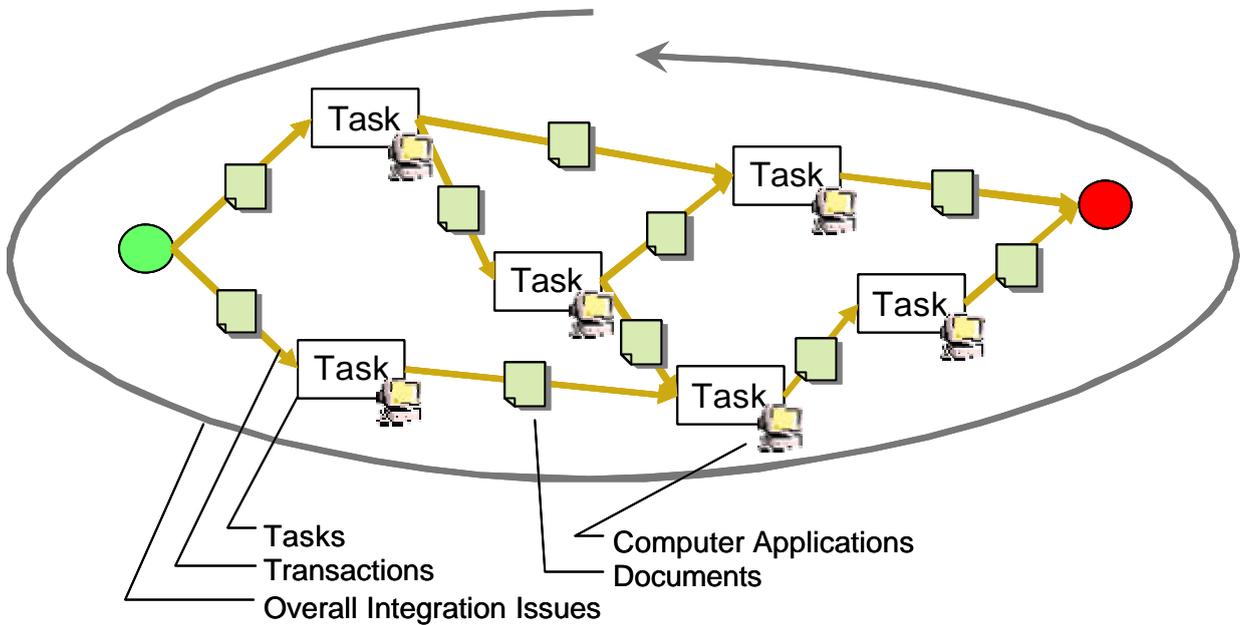


Figure 1: A model of project processes that considers projects in terms of tasks, transactions, and overall integration issues. From an information perspective, tasks are associated with computer applications and transactions are associated with documents.

tegration across organizational boundaries, integration over time (such as integration with legacy systems or future systems), and so on. The model considers these elements across all project participants.

Given this process view of a construction project, it can be seen that construction projects are heavily information-based. Design and management tasks involve the processing of information rather than physical goods and even the actual construction operations involve critical information-based aspects in addition to the physical processing of the building components. Similarly, many of the transactions involve the communication of information rather than (or in addition to) a physical exchange of goods. Finally, there are many overall integration issues that relate specifically to information, such as providing appropriate access to the total body of project information for any of the project participants.

From an IT perspective, the model provides a

categorization of the important IT elements of a project, and a basic understanding of the main roles of IT in supporting the construction process:

- The project tasks correspond to the individual tools or computer applications used to help carry out the task.
- The transactions correspond to the documents or communication technologies that are used to convey the information.
- The overall integration issues correspond to IT integration and interoperability issues.

## 2.2 A Model Depicting the Human and Computer Information Flows

In addition to this process view of the overall project, it is beneficial to look more closely at the information flows that exist between one participant, his or her computer applications, and other project

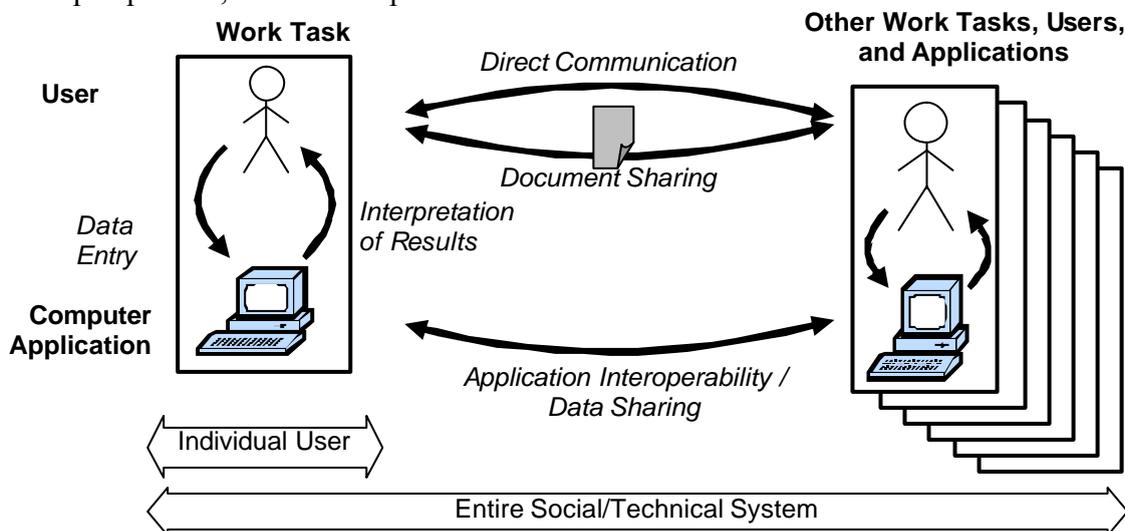


Figure 2: A model of human and computer information flows, showing elements and information interfaces for an individual participant and the overall system of a construction project.

participants. Figure 2 illustrates a model of human and computer information flows that shows key elements and information interfaces in an IT environment. Within the construction industry, most design and management tasks are fairly well-supported by computer tools. However, these are not isolated activities—rather they are highly collaborative, involving large numbers of project participants operating in a highly fragmented and dynamic environment. Correspondingly, IT solutions involve not only stand-alone computer applications, but must be viewed as elements in an overall technical and social system.

Within this system, information flows between individual users and their computer-based tools (data entry from the user to the computer, and data interpretation from the computer to the user). Information also flows between users (as direction communication—i.e. face-to-face or telephone conversations—or via exchanged documents), and between different computer applications (as shared computer data).

At present, information sharing typically involves a project participant entering project data into a computer application to produce useful project information, creating a paper or electronic document containing the information, and distributing the document to others (via mail, fax, courier, or e-mail), after which other participants interpret the document and re-enter relevant information into their own computer applications. Thus, there is little systems-integration and interoperability, and the data exchange that does occur is inefficient, time-consuming, error-prone, and a barrier to greater computer functionality.

The inefficiency of this approach to exchanging information between computer systems (from computer application to human-interpreted documents and back into a second computer application) is improved by using direct computer-to-computer data sharing. However, it is not sufficient to rely on computer-based data sharing alone, since this creates the opposite effect. A user working with one application may interpret some project information as having certain significance for the project (e.g., the design doesn't meet certain user requirements, the costs are over budget, or the work method is infeasible). If the same project information is successfully communicated to different computer application used by another project participant, there is no assurance that the second user will interpret the same information in the same way. That is, they may have the same data available to them, but they may not recognize the design, cost, or work method problems.

Efficient project communication, then, must take place along all of the communication channels: human-to-human, human-to-computer, and computer-to-computer.

### 2.3 Trends in IT for Construction

The previous discussion of the role of IT relative to construction projects can be used in assessing the overall trends in IT for construction. We describe these trends in terms of three major focus areas that have been pursued over different time periods: i.e., three main eras in construction IT:

- The first era of construction IT: most construction IT has historically focused on developing stand-alone tools to assist specific work tasks. Examples include CAD, structural analysis tools, estimating, scheduling, and general business applications. This era of construction IT has been underway for more than four decades, and still continues. Most of the main computer tools used throughout the construction process are relatively mature: they have existed for many software generations and their basic feature sets have largely stabilized. This era corresponds to the processes in the project processes model and to the computer-human information flows in information flows model.
- The second era of construction IT: more recently, a separate trend in construction IT has focused on computer-supported communications. For example, E-mail, the web, document management systems, etc. This era began largely with the advent of the world-wide web and the popular uptake of e-mail in the mid 1990s. This is a less mature field, with new tools and core features still emerging, and correspondingly, business processes are still adapting. The focus of this era corresponds to the transactions in the project processes model and to the human-to-human information flows in the information flows model.
- The third era of construction IT: Much of the research and development relating to IT in construction carried out over the past decade has focused not on individual applications or transactions, but on the potential for uniting all of these as a cohesive overall system. This work has focused on the overall integration issues defined in the model of project processes, and the computer-to-computer data sharing communications shown in the model of information flows. It has addressed the integration and interoperability of intelligent data between applications. This era is discussed in the following section.

(This notion of evolving IT eras is reminiscent of Hinks et al., 1999, which presents a maturity model for construction IT that shows evolving levels of IT use including “application”, followed by “integration”, and then “managed”. They also suggest that the maturity of construction IT and project management must evolve together).

#### 2.4 The Third Era of Construction IT

While most construction IT resulting from the first two eras describes various aspects of the same construction projects, there is little direct exchange of data between these different systems. Construction IT provides “point solutions with no real data and workflow integration between them. Data is still being recreated multiple times and transferred manually within and across enterprises.” (Vaidyanathan & O’Brien 2003). This lack of interoperability in construction is a major source of inefficiency and a barrier to innovations. The US National Institute of Standards and Technology finds that, “Unfortunately, the construction industry has not yet used information technologies as effectively to integrate its design, construction, and operational processes. There is still widespread use of paper as a medium to capture and exchange information and data among project participants.” (Gallaher et al. 2004). The report estimates “the cost of inadequate interoperability in the U.S. capital facilities industry to be \$15.8 billion per year.”

Now, the third era in construction IT is emerging that focuses on the integration of project information among the various IT tools used by all project participants throughout the entire project lifecycle. The US National Science Foundation has defined the need for a new cyberinfrastructure to revolutionize science and engineering: “a national, reliable and dynamic, interoperable and integrated system of hardware, software, and data resources and services.” (NSF 2003). Garrett (2004) argues that cyberinfrastructure defines a necessary vision for civil engineering: an extensive set of functionalities, data models and data flows, and interoperability standards. Elements of a construction cyberinfrastructure have been the focus of research and development over the past decade, and results are beginning

to reach industry. Figure 3 illustrates the main elements of a technology roadmap in which FIATECH (2004)—a North American industry organization dedicated to advancing technology for capital projects—has positioned these emerging technologies into an overall vision for the construction industry. This roadmap (the largest, industry-driven effort of its kind) defines potential technologies for each of the major lifecycle phases of construction projects, with an over-arching management and control element, and elements addressing new materials and the workforce underlying them. A foundation layer supporting all of these objectives is an element providing integrated data and information management technology.

In other industries (e.g., banking or automotive), integration has been achieved through large-scale computing systems established collaboratively among organizational partners. In construction, the fragmentation and short duration partnering of many small companies (Turner & Muller 2003) inhibits this type of solution. Systems must interoperate across all project participants with little customized configuration. This calls for a solution based on industry-wide data interoperability standards. In construction, the Industry Foundation Classes (IFCs), established by the International Alliance for Interoperability (IAI 2003) is the most significant data standards effort. The IFCs have been under development since 1995 and they now form a mature data exchange standard supported by many commercial software systems (Kam et al. 2003). The U.S. General Services Administration, the world’s largest building owner, has set a goal of providing IFC-based building information models for all projects starting in 2006 (GSA 2003). The near-term potential for this level of interoperability increases the efficiency of information flows throughout the industry; the longer term potential involves re-structuring the entire design and construction process around comprehensive computer-based models of the building—a virtual design and construction process. These comprehensive building information models (BIM’s) can play the same role in construction that prototypes play in manufacturing, revolutionizing the civil engineering design and construction processes.

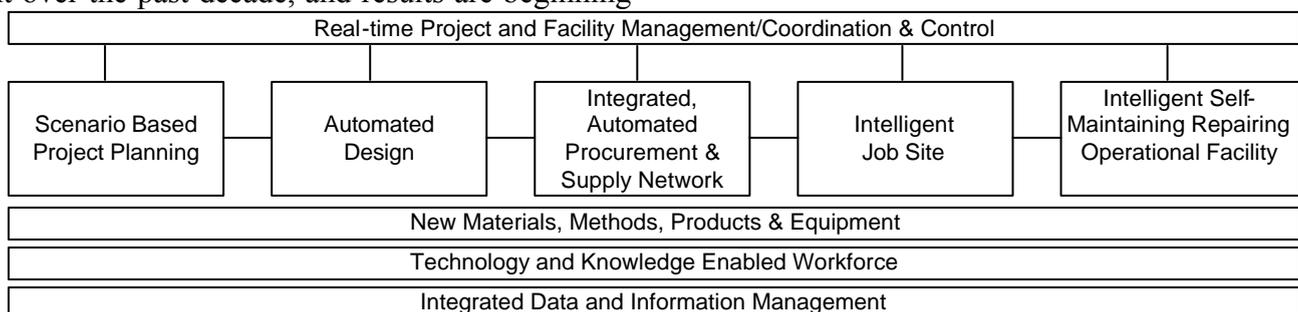


Figure 3: Primary elements of the FIATECH capital projects technology roadmap.

This construction IT era is quite young. It has reached a stage where there is general alignment among researchers and industry leaders as to the general vision for the future and the key elements required (e.g., as depicted by the FIATECH roadmap). For many of these elements, much basic research has been completed and related technologies are now emerging as commercially viable solutions (Froese 2003). A full set of practical tools and changes to industrial practice are only beginning to appear.

### 3 THE DISCIPLINE OF INFORMATION MANAGEMENT

The third era of construction IT, with its focus on the integration of all computer-based resources into interoperable systems, may be poised to make significant impacts on the construction industry. These impacts may lead to far-reaching changes to industry practices. A consequence of this is that the management of information and IT will need to be greatly enhanced over current information management practices. This section discusses different aspects of an information management process to be carried out as a major sub-discipline within the overall practice of project management: a general framework for information management, a representative description of an information management scope, and an organizational role for information management.

#### 3.1 *Current approaches to Information Management*

Information and communications have long been recognized as important elements of project management and formal information and communication management processes currently exist. An example of a current communications management approach is described in the Project Management Body of Knowledge (PMI 2000), which defines a communications planning framework (defining requirements and technologies, analyzing stakeholder issues, and producing a communications plan) and then three sub-issues of information distribution, performance reporting, and administrative closure. Information management, then, can be seen as very analogous to safety, quality, or risk—which have always been essential issues in construction, but which have increasingly become the focus of more formal project management processes over time. Nevertheless, it is likely that information management is less frequently and less formally included in typical project management practices than safety, quality, or risk

management, and certainly much less than cost, schedule, or scope management practices.

A number of efforts have been carried out within construction IT research related to information management practices. For example, Björk (2002) defines a formal model for information handling in construction processes. Turk (2000a) explored the relationships between information flows and construction process workflows, and makes a distinction between base processes (the main value adding activities) and glue processes (that make sure that the materials and information can flow between the base processes) (Turk 2000b). Mak (2001) describes a paradigm shift in information management that focuses mainly in Internet-based information technologies. Betts (1999) includes much work on the role of information technologies in the management for construction, with an emphasis on strategic management of the firm.

These and other works have much to offer in the area of information management practices. This paper, however, takes a fairly specific perspective that has not been widely addressed: that is, the development of specific information management practices as they relate to the management of individual construction projects in the context of emerging (third era) IT.

#### 3.2 *A Framework for Information Management*

A comprehensive list of all of the issues involved in the management of information systems for construction can grow very long indeed. To provide some structure to these issues, we propose that construction information management be defined as the management of information systems to meet project objectives. Though simple, this definition suggests a breakdown of construction information management into four main topic dimensions: a management process, project elements, information system elements, and objectives. The following sections will examine each of these topic areas. (In the following sections, we have revised our earlier approach with issues suggested by Mourshed 2005).

#### 3.3 *A Management Process for Information Management*

The management of information systems should follow general management processes:

- Plan all aspects of information system. This includes analyzing the requirements and alternatives, designing a suitable solution taking into account all objectives and constraints, and adequately documenting the plan so that it can be communicated to all. Some of the analytical

tools that can be used include cost/benefit analysis (though this may not be a straight-forward process since the costs involved in improving information management elements may be incurred by parties that are different from those receiving the resulting benefits), and a consideration of life-cycle issues in assessing costs and benefits (e.g., future information compatibility or hardware obsolescence issues).

- Implementation of the plan, including issues such as security the necessary authority and resources for the plan, implementing communication and training, etc.
- Monitoring the results, including appropriate data collection relative to established performance measures and taking necessary corrective action.

### 3.4 Project Elements

The information management actions of planning, implementing and monitoring an information system should be applied to all of the parts of a project. This can involve the same project work breakdown structures used for other aspects of project management (e.g., breaking the project down by discipline, work package, etc.). However, there are perspectives on decomposing the work that are of particular relevance to information systems. We adopt the project processes model (shown in Figure 1) as a basis for structuring an information management approach. Information management should address the three primary elements in the model: project tasks, information transactions, and overall integration issues.

First, the process should define each task, transaction, or integration issue, including identifying participants, project phase, etc. This should correspond largely to an overall project plan and schedule, and thus it may not need to be done as a distinct activity.

For each of these elements, the information management process must analyze information requirements, design information management solutions, and produce specific information management deliverables. The level of detail required for the breakdown of project tasks and transactions described below should reflect the detail needed to achieve an effective overall project information management system. In general, this will be at a level where distinct work packages interact with each other, not a finer level at which work is carried out within the work packages themselves (for example, it will address the type and form of design information that must be sent to the general contractor, but not the way that individual designers must carry out their design tasks).

The model considers these elements across all project participants (spanning all participating companies, not just internal to one company), and the information management tasks should be carried out for each of these project elements.

Also, the project should be considered to be made up of not only the physical elements of the facility to be constructed, but certain information artifacts should be considered to be project elements in their own right, with their own value distinct from the physical facility. For example, a building information model resulting from the design and construction, which may be used as the basis for a facilities management system, is a significant project element.

### 3.5 Information System Elements

For each of the project elements to which we are applying our information management processes, here are a number of different elements of an information system that must be considered:

- Information: Foremost, we must consider the information involved in each of the project elements. First, the process should assess the significant information input requirements for each element, determining the type of information required for carrying out the tasks, the information communicated in the transactions, or the requirements for integration issues. With traditional information technologies, information requirements generally correspond to specific paper or electronic documents. With newer information technologies, however, information requirements can involve access to specific data sources (such as specific application data files or shared databases) that do not correspond to traditional documents. Second, we must assess tool requirements by determining the key software applications used in carrying out tasks, communication technologies used for transactions, or standards used to support integration. Third, we must assess the significant information outputs produced by each task. This typically corresponds to information required as inputs to other tasks. After analysis, these results should be formalized in the information systems plan as the information required as inputs for each task, and the information that each task must commit to producing.
- Resources: the information management process should analyze the requirements, investigate alternatives, and design specific solutions for all related resources. These include hardware, software, networking and other infrastructure, human resources, authority, and third party (contracted)

resources.

- Work methods and roles: the solution must focus not only on technical solutions, but equally on the corresponding work processes, roles and responsibilities to put the information system to proper use.
- Performance metrics, specified objectives, and quality of service standards: the information systems plan should include the specification of specific performance metrics that can be assessed during the project and used to specify and monitor information systems objectives and standards of service quality.
- Knowledge and training: The information systems solution will require certain levels of expertise and know how of people within the project organization. This may well require training of project personnel.
- Communications: implementing the information systems plan will require various communications relating to the information system itself, such as making people aware of the plan, training opportunities, procedures, etc.
- Support: information system solutions often have high support requirements, which should be incorporated as part of the information management plan.
- Change: the information management plan should include explicit consideration of change—how to minimize its impact, how to address unauthorized changes by individual parties, etc.

### 3.6 Information Systems Objectives

The previous sections outline a number of information system elements to be developed for all of the project elements as part of the information management process. Solutions for these should be sought that meet the general project objectives of cost, time, scope, etc. However, there are a number of objectives that are more specific to the information system that should be taken into account:

- System performance is of primary concern, including issues such as efficiency, capacity, functionality, scalability, etc.
- Reliability, security, and risks form critical objectives for information systems.
- Satisfaction of external constraints: here, we have here placed the emphasis on the project perspective, but the information management must also be responsive to a number of external influences. Of particular significance in alignment with organization strategies and information management solutions, including appropriate degrees of centralized vs. decentralized information management. Other external influence include

client or regulatory requirements, industry standards

- Life-cycle issues should be considered. These include both the life cycle of the information (how to ensure adequate longevity to the project data), and of the information system (e.g., life-cycle cost analysis of hardware and software solutions).
- Interoperability is key objective for many aspects of the information system.

### 3.7 Maturity Models

The permutations of all of the issues listed under the previous four dimensions leaves a monumental range of issues to be addressed in a project information management program. Not all projects will be able to do a thorough job of addressing all of these. Indeed, an organization could be assessed in terms of the degree to which it addresses each issue. For example, Mourshed (2005) uses the following maturity model scale for assessing organizations' performance on information management tasks:

- Non-existent: Not recognized/present,
- Initial/Ad-Hoc: General awareness of the topic. process is informal and reactive,
- Repeatable: Agreed-upon but informal and not usually revisited,
- Defined: Formal and defined,
- Managed: Increasingly defined, measurable, and
- Optimized: Continuously revisited to measure performance against goals, best examples are applied.

### 3.8 Project Systems and Areas of Expertise

The previous section outlines a very generic framework for information management. Here, we look at the specific types of systems and technologies that might come into play on projects that take full advantage of both traditional and emerging IT. The systems range of systems that should be considered within the overall information management is as follows:

- Project document management and collaboration web site: a web site should be established for the project to act as the central document management and collaboration vehicle for the project. This will include user accounts for all project participants, access control for project information, online forms and workflows, messaging, contact lists, etc. A commercial service would generally be used to create and host the site.
- Classification systems, project breakdowns structures and codes, and folder structures: much of the project information will be organized according to various forms of classification systems.

These range from the use of industry-standard numbering schemes for specification documents, to the use of a project work breakdowns structure, to the creation of a hierarchical folder structure for documents placed on the project web site. The information management process must consider relevant industry classification systems such as OCCS (OCCS Development Committee 2004), and establish appropriate project classification systems.

- Model-based interoperability: many of the systems described below work with model-based project data, and have the potential to exchange this data with other types of systems. The project should adopt a model-based interoperability approach for data exchange for the lifecycle of the project. The information management process must consider relevant data exchange standards, in particular the IFCs (IAI 2003), and must establish specific requirements and policies for project data interoperability. It must also establish a central repository for the project model-based data (a model server).
- Requirements management system: a requirements management tool may be used to capture significant project requirements through all phases of the project and to assure that these requirements are satisfied during the design in execution of the work.
- Model-based architectural design: The architectural design for the building should be carried out using model based design tools (e.g., object-based CAD). Although this improves the effectiveness of the architectural design process, the primary motivation here is the use of the resulting building information model as input to many of the downstream activities and systems.
- Visualization: using the building information model, which includes full 3-D geometry, there can be extensive use of visualization to capture requirements and identify issues with the users, designers, and builders. This may include high-end virtual reality environments (e.g., immersive 3-D visualization), on-site visualization facilities, etc.
- Model-based engineering analysis and design: the building information model is used as a preliminary input for a number of specialized engineering analysis and design tools for structural, building systems, sustainability, etc.
- Project costs and value engineering: the building information model can also be used as input to cost estimating and value engineering systems. These will be used at numerous points through the lifecycle of the project (with varying degrees of accuracy).

- Construction planning and control: the project should use systems for effective schedule planning and control, short interval planning and production engineering, operation simulation, resource planning, etc. Again, the systems will make use of the building information model and will link into other project information for purposes such as 4-D simulation.
- E-procurement: project participants will make use of on-line electronic systems to support all aspects of procurement, including E-bidding/tendering, project plans rooms, etc.
- E-transactions: on-line systems should be available for most common project transactions, such as requests for information, progress payments claims, etc. These will be available through the project web site.
- E-legal strategy: project policies and agreements will be in place to address legal issues relating to the electronic project transactions.
- Handoff of project information to facilities management and project archives: systems and procedures will be in place to ensure that complete and efficient package of project information is handed off from design and construction to ongoing facilities operation and management, as well as maintained as archives of the project.

The above provides a breakdown of IT areas of expertise from the perspective of the major systems that might be used on a construction projects. This is a useful approach in considering the required areas of expertise for IT. However, it does not provide the best way of organizing a comprehensive “body of knowledge” for construction IT. For example, the European Masters program in Construction IT (Rebolj & Menzel 2004) gives a good example of a curriculum for construction IT. Even here, however, there is a strong emphasis on the technology of construction IT and less on the overall information systems and management perspective.

## 4 ORGANIZATIONAL ROLES: THE PROJECT INFORMATION OFFICER

### 4.1 *Organizational Issues for Information Management*

The previous sections have argued that emerging IT could significantly impact construction project processes. The magnitude of this potential for IT to improve project processes depends upon the degree to which these processes evolve to fully embrace and exploit the IT. With IT playing a critical central role in the work processes, the information management becomes correspondingly critical to the overall pro-

ject management processes—managing the project will be just as much about managing the information and IT as it is about managing people, managing costs, managing risks, etc. With information management becoming an increasingly important element of overall project management, the following challenging criteria must be considered in defining the organizational responsibility for information management:

- **Project focus:** information management should be project-focused and organized as a project management function, as opposed to centralized within a corporate IT department. The information management process, as described above, is tightly coupled to the project processes and, inversely, the project processes should be strongly influenced by the IT perspective. Furthermore, the information management must be responsive to project objectives and the needs of all project participants, rather than being driven by the corporate objectives and the needs of one company alone. This does not imply that a centralized IT group is not needed: the depth of IT expertise and resources required may be well-served through some centralized resources. Thus, a matrix organizational structure may be suitable, with primary organizational responsibility for information management residing in a project position supported by a centralized information management group (although matrix organizational structures are generally not ideal, their use here would be similar to other common applications in the construction industry such as estimating or field engineering services).
- **High level:** since information management is central to the overall project management, it should not be relegated to a low level within the project organizational structure (e.g., as might be found with typical IT support personnel), but should be the primary responsibility of someone within the senior project management team.
- **Separate function:** Although the responsibility for information management should lie within the senior project management team, it would often be a poor fit with current senior project management staff. It requires a depth of specialized knowledge in areas of technology that are rapidly evolving. It may also be overshadowed by traditional practices if it is added as a new, additional responsibility to someone that already handles other aspects of the project management, such as a contracts manager, a project controls engineer, or the overall project manager.

The above criteria suggest that, where possible, information management requires a new, senior-level position with the project management team. We call

such a position the Project Information Officer (PIO). The overall responsibility of the PIO is to implement the information management as described previously. The follow sections outline additional issues relating to the PIO position.

#### 4.2 *Organizational ROLE*

The PIO may be an employee of the project owner, lead designer, or lead contractor organizations, or may work as an independent consultant/contractor. Regardless of employer, the PIO should be considered to be a resource to the project as a whole, not to an individual project participant organization. The PIO should be a senior management-level position within the project organization (i.e., not a junior technology support position). The PIO should report to the owner's project representative and work with an information management committee consisting of project managers and information specialists from key project participants. Depending upon the size of the project, the PIO may have an independent staff. In addition to the information management committee, liaison positions should be assigned within each project participant organization.

#### 4.3 *Skills and Qualifications*

Candidates for the position of PIO must have a thorough understanding of the AEC/FM industry, information management and organizational issues, data interoperability issues, and best practices for software tools and procedures for all of the major project systems described previously. Preference would be for candidates with a master's degree relating to construction IT and experience with information management on at least one similar project.

#### 4.4 *Compensation and Evaluation*

Advanced construction IT offers great promise for improving the project effectiveness and efficiency while reducing risk. Not all of these benefits directly reduce costs, yet the overall assumption is that the costs of the PIO position will be fully realized through project cost savings. This will not be a direct measure, but will be assessed on an overall qualitative basis through an information management review processes that examines the following questions of the information management and technology for the project:

- To what degree was waste (any non-value-adding activity) reduced?
- What new functionality was available?
- How efficient and problem-free was the information management and technology relative to pro-

- jects with similar levels of IT in the past?
- What was the level of service and management effectiveness offered by the PIO?
  - What is the potential for future improvements gained by the information management practices on this project (i.e., recognizing the long learning curve that may be associated with new IT)?

## 5 CONCLUSIONS AND FUTURE WORK

This paper has argued that emerging IT will significantly alter the work practices of construction projects, and that corresponding changes to the construction project management practices are required. The paper has focused on enhanced information management processes, presenting an overall framework for information management, listing the types of IT systems and issues that could make up the IT environment of future construction projects, and outlining a corresponding organizational role in the form of a project information officer. In other work, we present a second aspect of this required change, an evolution to the way that overall project management itself is carried out. This evolution promotes the use of integrated IT to allow project participants to share a more common vision of the project as it progresses through planning, design, construction, and operation: we call this a Unified Approach to Project Management. These proposed changes to information and project management represent a conceptual solution to the defined problem. In future work, we hope to further develop these solutions and to apply them as pilot studies on full scale projects for testing and validation.

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