

Acknowledgement

In January 2006, the U.S. National Institute of Standards and Technology (NIST) published the *Capital Facilities Information Handover Guide, Part 1* (NISTIR 7259) in cooperation with FIATECH and Uitgebreid Samenwerkingsverband Procesindustrie, Nederland (USPI-NL). Project leaders for this publication were Mark Palmer of NIST and Kristine K. Fallon, FAIA. The following article, which also appeared in the print version of the *AIA Report on Integrated Practice* (2006), has been excerpted from NISTIR 7259 by Kristine K. Fallon, FAIA and Stephen R. Hagan, FAIA.

Report on integrated practice

10

Information
facility

for the
life cycle

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Information for the facility life cycle

Introduction

The AIA Technology in Architectural Practice (TAP) Knowledge Community has outlined three inevitable technologies: collaboration; building information modeling; and interoperability. Although the architectural and engineering professions and the building industry have focused on the visual, aesthetic, and functional aspects of the built environment, inevitably it is the flow of information that transports visions and ideas into constructed reality.

Information is a critical asset in the life cycle of capital facilities. Industry organizations, academic institutions, and professional practitioners are now beginning to grasp just how critical information really is.

Frameworks are emerging to describe this concept in the life cycle of capital facilities. Roadmaps, such as FIATECH's Capital Facilities Technology Roadmap, are one example of these frameworks. FIATECH is actively engaging industry partners in projects that flesh-out details, parse the components, discover governing principles, and implement components of their roadmap.

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CABA (Continental Automated Building Association) has its own Technology Roadmap and OSCRE (Open Standards Consortium for Real Estate) is at work on its Technology Framework.

Process change diagrams, such as the one popularized by the Construction Users Roundtable (CURT), also illustrate the current and possible future states of this life cycle concept.

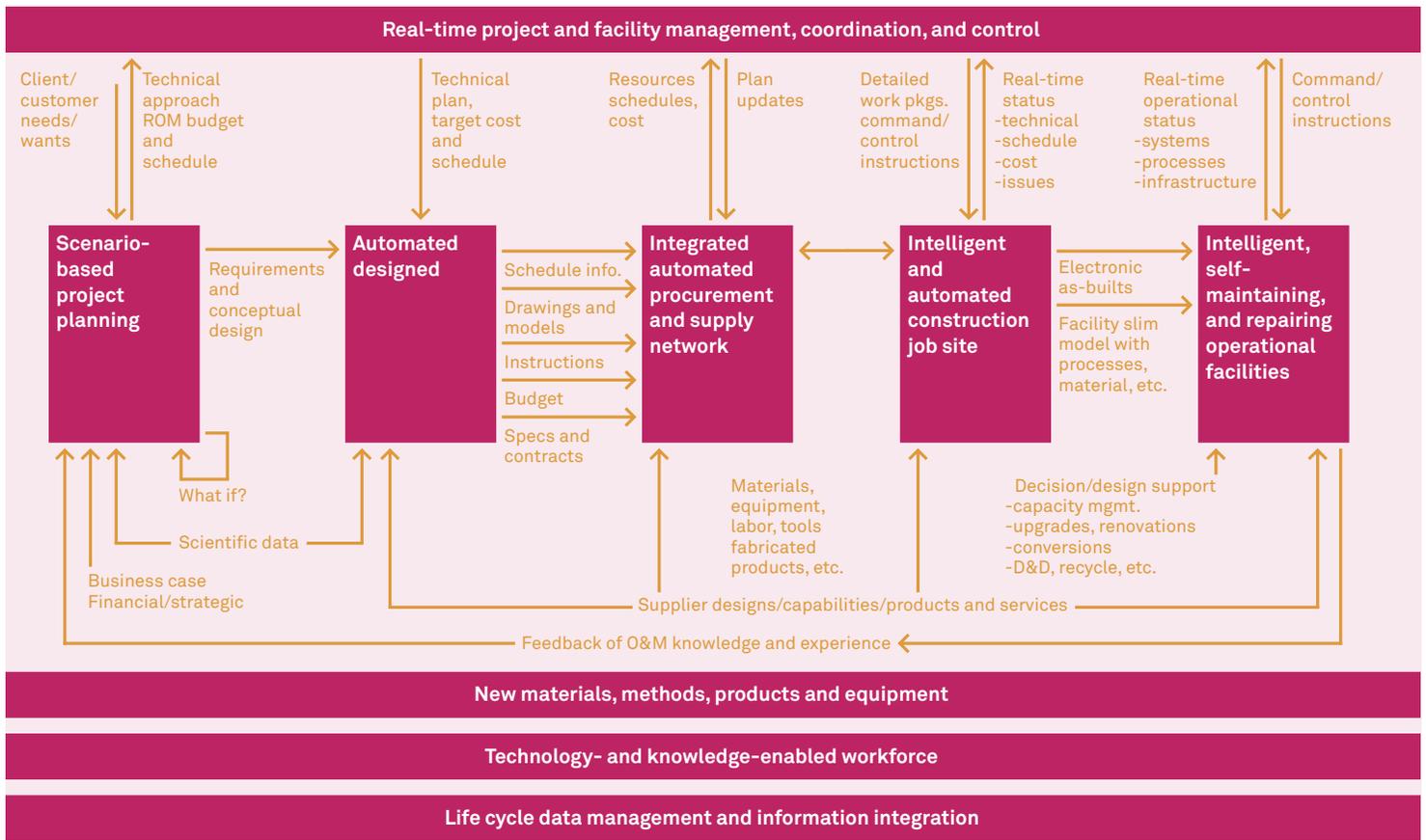


Figure 1
The FIATECH Capital Projects Technology Roadmap Vision Model.
 (Source: FIATECH, 2004b)

Much work on these frameworks and process change diagrams remains to be done; much is well underway. What is notable and crucial for progress in this area is described in the excerpts of the Capital Facilities Information Handover Guide, Part 1, which follows: taxonomies, definitions, and the characterization of information are critical building blocks in the foundation of the Information for the Facility Life Cycle.

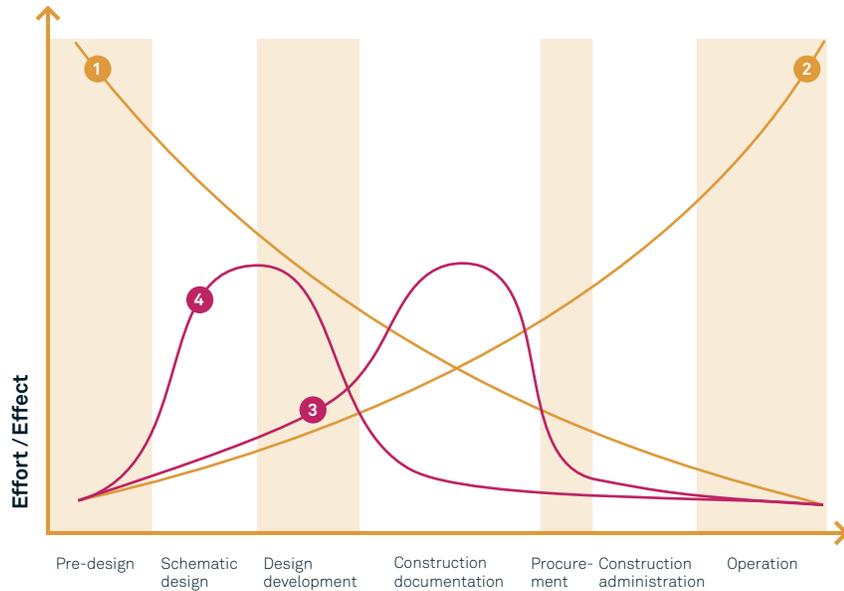


Figure 2
Collaboration, integrated information, and the life cycle in building design, construction and operation.
 (Source: CURT, August 2004)

- 1 Ability to impact cost and functional capabilities
- 2 Cost of design changes
- 3 Traditional design process
- 4 Preferred design process

Developed nations invest a substantial portion of their gross domestic product in capital facilities – their planning, design, construction, operation, maintenance, renovation, and decommissioning. According to the U.S. Census Bureau, more than \$370 billion was invested in new facilities, facility renovations, and additions in the United States in 2004. This figure excludes residential facilities, transportation infrastructure such as bridges and roads, and facility operation and maintenance costs.

The global capital facilities industry could perform more efficiently and it is under increasing pressure to do so. Recent studies that address this issue and provide analyses and recommendations include:

American Institute of Architects (AIA) Interim Report. *A Response to “Collaboration, Integrated Information and the Project Life Cycle in Building Design, Construction and Operation” (WP-1202): a Report of the Construction Users Roundtable (CURT). 2004.*

Construction Cost Effectiveness Task Force, *The Business Roundtable. The Business Stake in Effective Project Systems. 1997.*

Construction Users Roundtable Architectural/ Engineering Productivity Committee. *Collaboration, Integrated Information and the Project Life Cycle in Building Design, Construction and Operation (WP-1202). 2004.*

The Dutch Process and Power Industry Association (Uitgebreid Samenwerkingsverband Proces Industrie-Nederland - USPI-NL). *Reaching the Process Industry Vision: Roadmap to Competitive Advantage via Sharing and Storing Plant Life Cycle Data. 2002.*

FIATECH. *Element 9 Tactical Plan, Life Cycle Data Management and Information Integration. In Capital Projects Technology Roadmap. 2004.*

Gallaher, Michael P., Alan C. O'Connor, John L. Dettbarn Jr. and Linda T. Gilday. National Institute of Standards and Technology (NIST GCR 04-867). 2004.

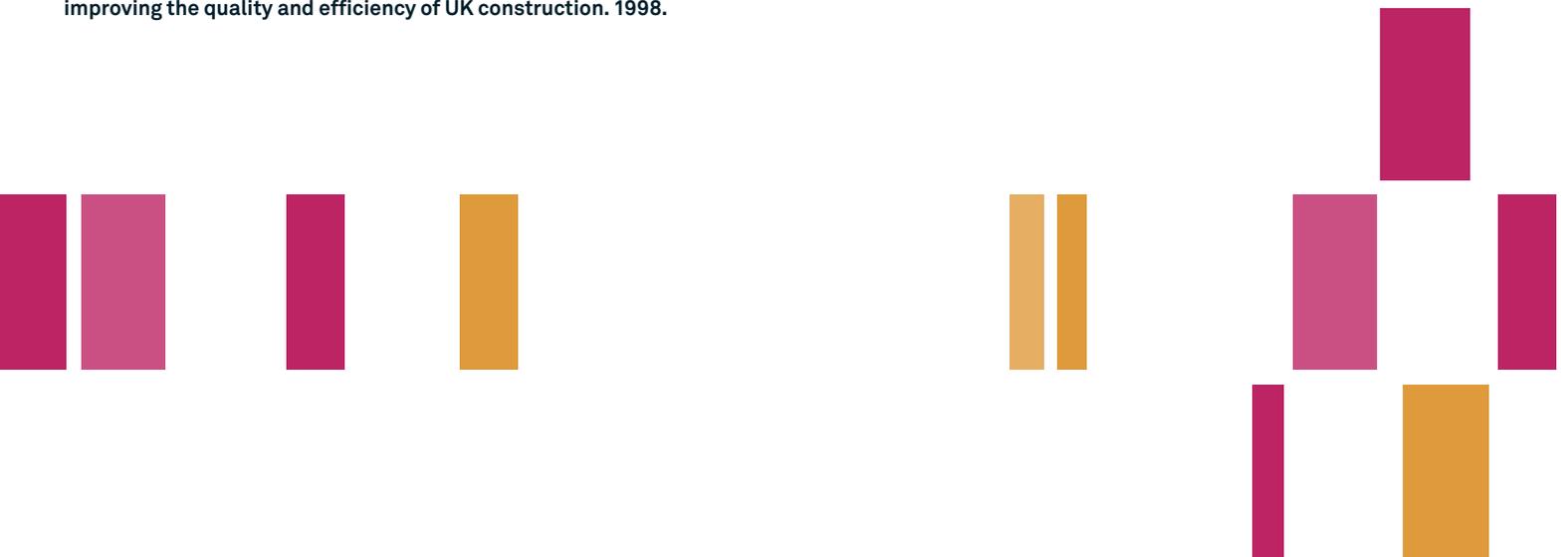
Rethinking Construction: report of the Construction Task Force to the Deputy Prime Minister, John Prescott, on the scope for improving the quality and efficiency of UK construction. 1998.

Based on the experience of other industries, particularly manufacturing, there is increasing conviction, evidenced by the reports cited here, that the capital facilities industry could improve performance by leveraging information technology to reduce the cost and execution speed of business processes that span multiple organizations along the entire supply chain.

The NIST publication cited above, *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry*, is of particular interest because it identifies and quantifies the efficiency losses in the U.S. capital facilities industry attributable to inadequate interoperability, defined as “the ability to manage and communicate electronic product and project data between collaborating firms and within individual companies’ design, construction, maintenance, and business process systems” (NIST GCR 04-867). The researchers very conservatively estimated those losses to be \$15.8 billion in 2002 in the United States, excluding the losses for residential facilities and transportation infrastructure.

The reports cited above identify the major obstacles to improving interoperability within the capital facilities industry:

1. There is a lack of understanding on the part of industry participants of how to achieve integrated information and workflows through the application of information technology.
2. There are gaps in the availability of information technology tools and data standards to support integrated information and workflows throughout the facility life cycle.
3. Current industry structure and business practices, including procurement practices and regulatory, insurance and contractual requirements, present obstacles to integrated work and information flows.



In *Cost Analysis of Inadequate Interoperability*, RTI International and the Logistics Management Institute calculated the costs of inadequate software interoperability by constructing a “hypothetical counterfactual scenario.” In this scenario, data exchange and access for all work processes related to design, construction, and facility management were unencumbered by data exchange issues. The cost difference between the hypothetical scenario and the real world scenario yielded the \$15.8 billion economic loss estimate.

Clearly quantifiable costs were categorized as: (1) “avoidance” – costs incurred to prevent or minimize the impact of technical interoperability problems; (2) mitigation – costs of activities responding to interoperability problems, including scrapped materials costs; and (3) delay – costs incurred when interoperability problems delay completion of a project or the length of time a facility is not in normal operation. The authors did not include other costs they considered too speculative, such as opportunity costs or costs to tenants. As a result, the \$15.8 billion estimate is very conservative. The cost data were gathered from 70 organizations: 19 architecture/ engineering firms; 9 general contractors; 5 specialty fabricators and suppliers; 28 owners and operators; 2 software companies and 7 research consortia. Data were gathered through focus groups, interviews, and surveys.

Costs were reported by stakeholder group, type of cost, and facility life cycle phase. The facility life cycle was divided into three major phases: design (project initiation, planning, design programming, site selection and acquisition, conceptual design, engineering analysis, contract documents); construction; operations and maintenance (O&M).

A fourth phase, decommissioning, was included in the surveys. However, insufficient data were received upon which to base cost estimates.

The highest costs were incurred by owners and operators (OOs), and 85 percent of those costs were incurred during operations and maintenance. The major cost was time spent finding and verifying facility and project information. Operations and maintenance personnel were estimated to have spent \$4.8 billion during 2002 verifying that documentation accurately represented existing conditions and another \$613 million transferring that information into a useful format.

Most stakeholders believed that OOs should take the lead in addressing interoperability issues because they set and drive business and system requirements, in addition to bearing the majority of the costs of lack of interoperability. They believed that top management leadership should identify the players and facilitate agreement among them. This was the approach taken by the U.S. semiconductor industry to establish interoperability standards.

The report also notes that information about capital facilities is much more comprehensive than the geometric model and surrounding technical specifications, and that interfaces are required with human resources, finances, purchasing, project management and accounting, and asset management information systems. This insight challenges the traditional approach to interoperability, which focuses on the ability to exchange data between similar systems, particularly computer-aided design/computer-aided engineering (CAD/CAE).

The 70 businesses participating in the study identified interoperability of procurement, project management, construction, and financial systems as a high priority. They wanted to see CAD interoperability extended so that the same data and software could serve both design and construction. They also identified challenges in moving beyond the status quo:

- Delivery models must motivate all participants to optimize value of the end result, realizing that motivation derives from financial gain. There is a need to articulate project goals, define metrics and experiment with contract alternatives that link participants' financial rewards with the project's goals.
- The industry must develop tools and work processes to integrate across multiple disciplines.
- Information must be shared on a real-time basis.

In 2004, the Construction Users Roundtable (CURT) released a white paper entitled *Collaboration, Integrated Information and the Project Life Cycle in Building Design, Construction and Operation*. This paper was produced by CURT's Architectural/Engineering (AE) Productivity Committee, which CURT convened to address the perception of inadequate, poorly coordinated AE drawings that result in difficulties in the field, cost overruns and lost time. The committee concluded "the goal of everyone in the industry should be better, faster, more capable project delivery created by fully integrated, collaborative teams. Owners must be the ones to drive this change, by leading the creation of collaborative, cross-functional teams comprised of design, construction, and facility management personnel" (CURT 2004).

In November 2004, the American Institute of Architects responded to CURT: "From the architect's perspective, CURT has defined a vision for an integrated and accessible decision-making process that is transparent to all contributors to the design, construction and operation of a facility throughout its life cycle...In order to achieve the vision described in [CURT's white paper], the performance of the project team cannot be based on traditional contract documents, but on mutually agreed upon goals, shared responsibilities, shared risk and liability, and compensation" (AIA Interim Report 2004). In responding to CURT's request to identify obstacles to moving forward, the AIA cited several issues:

- Adversarial relationships between AEs and constructors reinforced by traditional project delivery, compensation and risk allocation arrangements.
- Short-term thinking on the part of owners who frequently seek the lowest first cost for each phase of development.
- Standard contracts that reinforce compartmentalization of team members, rather than support integrated and collaborative effort.
- Current risk management strategies, driven by insurers, that run directly counter to open information sharing.
- Technological barriers, including the cost and rapid obsolescence of technology and the lack of interoperability of advanced building modeling software.

AIA's response concluded that owners must lead the transformation of the capital facilities industry by committing to an integrated project delivery approach; by committing to use new models for risk management, contractual and legal relationships, and compensation; and by supporting these new models when confronted with scepticism from lawyers, insurers and financial institutions. Owners must commit to a project process that optimizes the overall outcome over the long term.

All stakeholders must realize that more effective project delivery, supported by updated contractual, compensation, and insurance models, is in the best interest of the entire industry. Individual companies and industry organizations should combine efforts to affect the necessary structural changes as quickly as possible. Although all stakeholders have incentives to improve project process and performance, it is the owners who gain the most and who have the ability to establish the project process parameters and enforce compliance by all participants. Owners must actively support the necessary change initiatives.

Facility life cycle information strategy

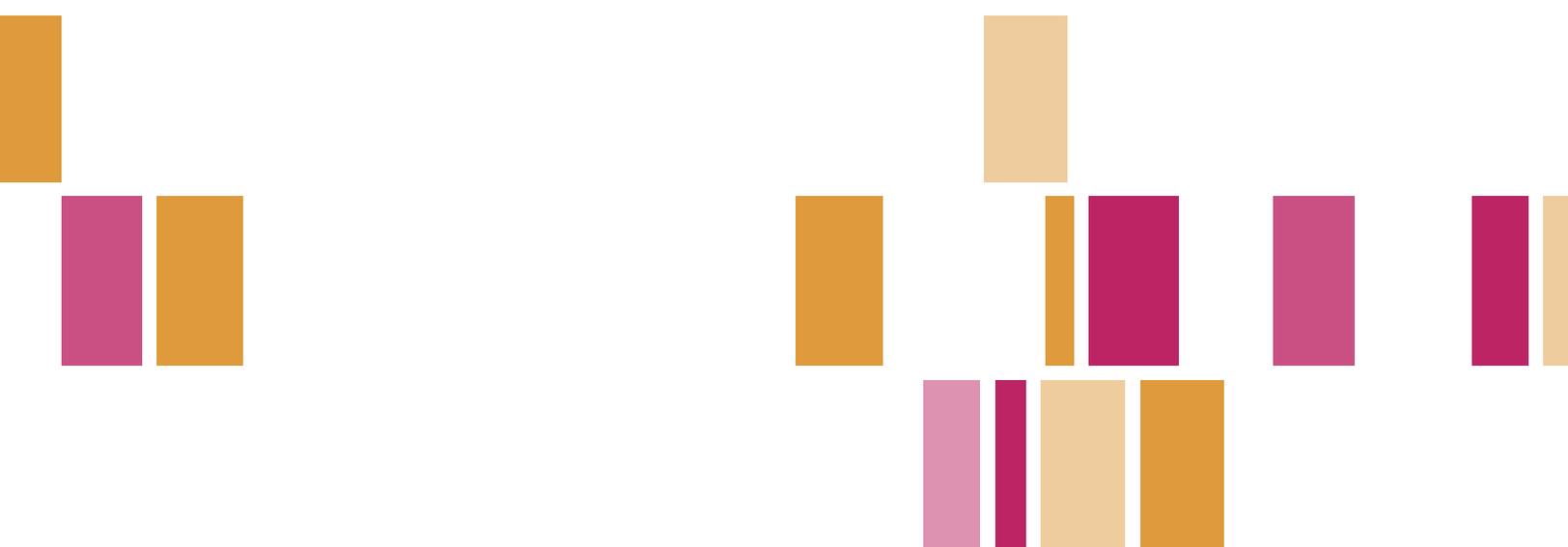
Some of the information created in a design or retrofit project informs facility operations for decades. Other information is useful only for the execution of the construction work. Still, other information is required for regulatory compliance regardless of functional value. In establishing a facility life cycle information strategy, the organization examines the business regulations, decisions, and processes that require facility information and defines the precise information required by each (this is known as an “information package”). It prioritizes information packages based on business value. If a certain information package is used in many business processes, its value increases. Another way to identify high-priority information packages is by looking at businesses processes that are inefficient and/or costly due to lack of information.

Once the organization has identified its high-priority information packages, it then determines when in the facility life cycle those information packages are created and by whom. Some information packages may be created across multiple life cycle phases and by several different organizations. This is typically the case with commissioning information.

Information handover should be based on the information packages required *throughout* the life cycle of the asset. Thus, information requirements at each handover point should be determined based on which information will be needed at any point downstream, and not just by the next-phase participants. Identify the next user of each information package as well as the party responsible for receiving each information package, ensuring its completeness and maintaining its integrity until its next use.

Handover requirements

The way in which information is to be used determines its properties, appropriate form, and format. Issues that need to be considered include which version(s) of the information package is required; whether the information will be kept up to date or frozen at the point of handover; what the legal requirements are for the retention of the information (these vary by jurisdiction and facility types); how long the information will be retained; how frequently the information will be accessed and updated; and the access requirements – who or what system(s) will use the information and where it will need to be accessed (office, field, production floor, etc.), for view only or for update.



There are three major properties of each information package to be defined. Status defines the exact version(s) of the information package required for handover; type defines whether or not the information package should be modified after handover; retention defines how long the information package must be maintained. Type and retention are the primary determinants of preferred form and format.

Status

As information moves through a project, its status is changed, normally under configuration control. For example, a drawing may start as “issued for comment.” After review, an authorized person might change it to “issued for construction,” and finally at the end of the project it will be updated to “as built.” An initial standardization step is to define the status terms to be used.

For each information package, it will be necessary to identify which status is to be handed over. Much important information will be required in “as built” status. It should also be determined whether the information is needed in more than one status, such as “issued for construction” and “as built.”

Type

Information is either static or dynamic. Static information represents a certain moment in time. Dynamic information should be updated to reflect any changes in the facility. When the creation of static information has been completed, it is never updated. Examples include certificates, standard drawings, technical specifications and inspection reports. Although there may be subsequent inspection reports, these are not “revisions” or “versions” of previous ones.

Dynamic information requires more formal information management than static information and generally has a greater frequency of access. Industry regulations and quality systems require that the latest version of the information be made clear to the end user. It may also be necessary to maintain the revision history of the information. Examples of dynamic information include facility layouts, process flow diagrams, equipment data sheets, loop diagrams and lists of safety-critical equipment. All information that is still part of the design cycle is, by definition, dynamic information.

It is important to determine whether each information package is static; dynamic with past revisions discarded; dynamic with revision history maintained; whether all versions are required; and whether a specific number of previous versions need to be maintained.

Retention

All information designated for handover should have a purpose. When the information is not available, there are consequences to the business. The severity of the consequences and the rapidity with which they are incurred are good measures of the importance of the information and dictate the appropriate level of effort and expense that should be put forward to ensure its availability.

The following retention codes are a minimum set for categorizing information packages:

Essential Information required for the operation of the facility. Without this information, an unacceptable risk would be created with regard to reliable operations and safety. This information must be retained for the full life cycle of the facility. It may be preferable to define degrees of business criticality rather than a single “essential” category.

Legally mandatory Data that are not expected to be referenced on a regular basis in the operations phase but for which there is a legal or contractual obligation to archive the information for a specific retention period. The retention period must be explicitly defined.

Phase specific Data developed in one facility life cycle phase that are deemed useful for a subsequent phase but not for long-term operations. The use phase must be specified.

Transitory Data that are not required to be referenced in any subsequent life cycle stage. These data need not be included in the information handover plan.

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Increasingly, facility information is produced and managed electronically. However, much electronic information is still held in documents that do not have a formal structure. Most correspondence, including project reports and drawings, fall into this category. For these documents, the only way to interpret the contents or to check their quality is for someone to actually read them.

Advanced systems can now provide facility information in a structured form that is immediately machine-interpretable. This development advances productivity and reduces errors. It permits the use of computer tools to assist in managing, using and checking the data. A common example is a database. Even graphics and drawings can now be managed in a structured form.

There are four major categories of information forms and formats. Figure 3 identifies their comparative longevity and reusability. A discussion of the forms and formats follows.

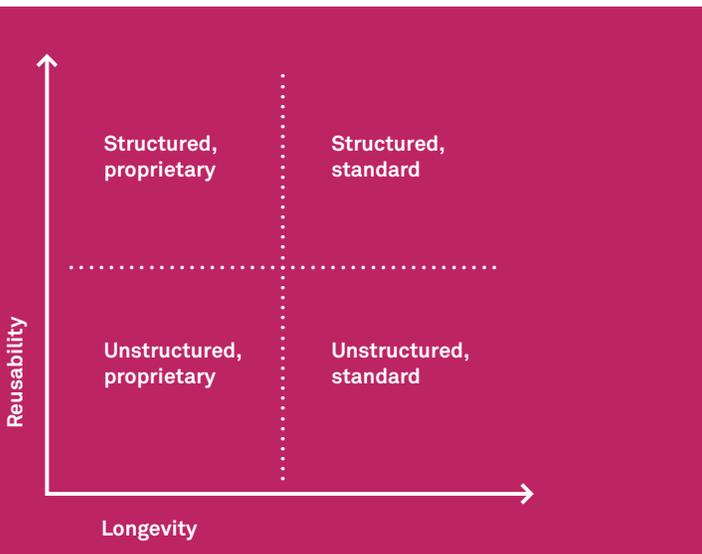


Figure 3
Longevity and reusability of information forms and formats.

Proprietary format

This is the format created by specific software applications such as CAD or word processing programs. It is also sometimes referred to as “native” format. Proprietary is the more significant term, however, because it means that the format is the property of a single software vendor. At any time, the vendor can modify the format. If this happens, archived data maintained in the format may no longer be usable in current versions of the application. Also, a vendor may cease doing business or discontinue the products that output the format. Either of these circumstances threatens to render the proprietary data unusable.

Standard format

There are two types of standard formats:

“Ad hoc standards” refer to formats that may have originated with a single vendor, but have been made publicly available and are supported by multiple vendors and products. Relevant examples of *ad hoc* standard formats include DXF and PDF. Since the format specification is published, anyone can write an application to access data stored in that format. This assures data longevity.

Formal standards are those maintained by an official standards development organization, such as ISO or ITU. In addition to the advantages of data longevity described above, these standards are typically developed through a consensus process that considers the information requirements of multiple organizations. Thus, formal standard formats may be more flexible and useful.

Standard formats are preferred for any data that will be archived for an extended period.

Structured data

“Structured data” means that the data can be accessed and manipulated directly by computer programs without human intervention. In this form, information adheres to a well-defined model. Structured information may be quantitative (such as structural analysis data), descriptive (such as finishes or coatings) or graphical (such as schematic diagrams, scaled drawings or 3DCAD models). This information form allows for automated—and therefore cost effective—search, retrieval and update, while maintaining the intelligent information content.

There are a number of proprietary structured data models. While useful in achieving the benefits of structured data for a limited number of collaborators during specific life cycle phases, no proprietary models support the full range of facility life cycle activities and their participants. Although proprietary models demonstrate to a limited extent the benefits of a structured approach, common models that adhere to international information standards are preferred. Use of such standards also avoids data being locked into a format controlled by a single vendor.

Examples of structured and standard data formats include ISO 15926 and the International Alliance for Interoperability’s (IAI) Industry Foundation Classes (IFCs). Structured standard formats are preferred for information that will be used in downstream automated processes or updated regularly throughout the life cycle of the capital facility.

Unstructured data

Any data that cannot be machine-interpreted are “unstructured.”

Electronic images are a type of unstructured data. This format is simply a dot pattern that can be interpreted by a viewer. Often, paper documents are brought into the electronic environment by scanning them into image format. Although these electronic images are suitable for read only access, updating information in this format is difficult. There are a number of both *ad hoc* and formal standards for image data: ITU Group 4, TIFF and JPEG are widely used.

The electronic image is the simplest format that allows controlled multiple access of information from one master source. By selecting an electronic image format standard, the cost of information upgrading for future innovations in file formats can be minimized. With information in electronic image format, filing, retrieval, tracking and monitoring can easily be supported with the proper application of metadata, but machine interpretation is difficult or even impossible.

Considerations in selecting preferred form and format

The use of the data through the life cycle of the asset should be the prime consideration in selecting the preferred form and format of the information to be handed over. This should be offset against the cost and difficulty of delivering the information in that way. Identify the preferred form and format of the information, taking into account:

- Information priority
- Information type – static or dynamic
- Retention period
- Software application(s) to be used downstream and which formats they support
- Need to share the information with external organizations
- Frequency of update
- Costs and difficulties in getting the information into the preferred form and format
- Capability of the creator of the information to deliver the information in the preferred form and format.

Structured vs. unstructured

Priority for structured form should be given to information that is frequently updated, particularly if that information is shown in multiple drawings or other documents. If this priority information is provided in structured form, the other documents will be derivative and therefore automatically generated. By identifying these derivatives, the list of documents required for handover can be reduced. This reduces information management costs and downstream efforts of retrieving, updating and coordinating multiple documents, providing substantial business benefits throughout the facility life cycle.

Although there are benefits to maintaining any information in structured form, there is less value for information that will never be updated. An example would be the installation instructions for a piece of equipment. This type of information can be accepted in an unstructured form.

Proprietary vs. standard

The next question is whether proprietary format files, rather than standard format, are acceptable. The first consideration is whether a standard format exists for the information required and if the standard is implemented in the relevant software applications. In the absence of a standard format, proprietary formats must be used. There are a number of standard formats at various stages of development, validation and commercial deployment in software products. ISO 15926 is designed to provide a comprehensive standard for the description of process plant facilities. The International Alliance for Interoperability's (IAI) Industry Foundation Classes (IFCs)—the IFC2x Platform Specification to be precise—has achieved international specification status as ISO/PAS (Publicly Available Specification) 16739. This standard covers the general building type.

A second consideration in deciding between proprietary and standard formats is the intended life or retention of the information. If the life exceeds 5 to 10 years, a proprietary format is risky, due to the rapid pace of technological obsolescence, and a standard format is highly preferable. In the absence of a comprehensive standard, a preservation strategy must be articulated for the proprietary format. This would involve ongoing monitoring of the format and updating of the data as new versions were released, as well as translation of the data if the format were threatened with obsolescence. Consideration of these data preservation costs reveals the life cycle cost benefit of standard formats. However, if the information package has a very short life cycle (less than 5 years), a proprietary format may be an acceptable and less costly option.

In deciding on a standard format one must assess the level of adoption, the availability of reliable implementations and the cost of using the standard. Also, who will be the downstream users of the data? Will these users have access at a reasonable cost to software that supports the standard? It is also critical to consider the level of technological expertise of the potential information providers. Assuming that a comprehensive standard format is available and well supported by commercial application software, are the potential consultants, contractors and suppliers capable of creating a complete and accurate model? If it is unlikely that the level of technological expertise in the marketplace will support the optimal information handover approach, the facility owner must either provide training or modify the information strategy.

Metadata

Information is organized and classified differently in life cycle stages by different participants and in various industry sectors. In order for information handed over to be useful, end users must be able to organize, extract and present it flexibly. A good metadata schema is critical to managing and providing access to the information.

Metadata are defined as data about other data. Metadata are used to organize the information system and to search for particular items. A comprehensive metadata approach is necessary for long-term data access and preservation through the facility life cycle phases. Metadata requirements should be included in the handover requirements.

The source of the metadata can be internal to the information resource—defined automatically at the time the resource was created—or it can be external and added manually. In addition to other benefits, structured data typically creates and manages a good deal of the metadata required.

There are three basic types of metadata:

Descriptive metadata identify and describe the information with fields such as creator, title, subject matter, responsible organization and so forth. ISO 12006-2 provides a framework for the classification of information about construction works.

Administrative metadata are used to manage the information and include such fields as intellectual property status, file format, file size, creating system, archiving date, archiving expiration date and archiving refresh interval. This type of metadata is critical to implementation of a long-term facility life cycle information strategy. The Open Archival Information System (OAIS) Reference Model, ISO 14721:2003, defines an archival system dedicated to preserving and maintaining access to digital information over a long term.

Structural metadata describe the internal structure of the information and relationships between its components. They can be used to track the relationship between a single drawing and the set to which it belongs, multiple revisions of the same document or the relationships among files in a compound electronic document (e.g., reference files making up a CAD drawing, or a spreadsheet linked to a document). They can also be used to describe the documents that derive from a particular information package in structured form.

For document metadata, there is an ISO draft standard: *ISO/DIS 82045.5 Document management – Part 5: Application of metadata for the construction and facility management sector (2004-03-11)*. It specifies elements and methods for sharing and exchanging metadata for documents in the architecture, engineering and construction, and facility management domains. It is designed for use with both electronic and paper-based document management systems and includes all three types of metadata described above.

When to begin

Handover requirements—content, format and metadata—should be defined in the contract between parties. Unless the information is originally created in the desired form, it may be difficult and expensive to convert. Also, a structured form created after the fact fails to provide the same benefits. A study conducted by the Construction Industry Institute (CII) in the United States in the early 1990s (RS106-1: 3DCAD) suggested that the effort to convert facility drawings developed manually or in an unstructured CAD format to a structured model was ineffective in controlling construction costs or schedule, while the use of information-rich models during design did yield such benefits.

Therefore, it is essential that the facility life cycle information strategy and the handover requirements be established before project initiation so that contractual requirements for information hand-over can be defined.



References

American Institute of Architects (AIA) Interim Report.
A Response to "Collaboration, Integrated Information and the Project Life Cycle in Building Design, Construction and Operation" (WP-1202): A Report of the Construction Users Roundtable (CURT). 2004.

American Institute of Architects (AIA) Technology in Architectural Practice Knowledge Community. *Building Connections*. Internet.
<http://www.building-connections.info>
Accessed 20 April 2005.

Champy, James.
X-Engineering the Corporation: Reinventing Your Business in the Digital Age. New York: Warner Business Books, 2002.

Construction Cost Effectiveness Task Force, The Business Roundtable.
The Business Stake in Effective Project Systems. 1997.
<http://www.curt.org/pdf/104.pdf>

Construction Industry Council (CIC).
A Guide to Project Team Partnering. 2002.

Construction Industry Institute.
Alignment during Pre-Project Planning – A Key to Project Success. 1997.
Implementation Resource 113-3.

Construction Industry Institute.
Best Practices Guide for improving Project Performance. 2002.
Implementation Resource 166-3.

Construction Industry Institute.
Constructability Implementation Guide. Bureau of Engineering Research. Austin: The University of Texas, 2002. Publication 34-2.

Construction Industry Institute.
RS106-1: 3D CAD Link. 1995.

Construction Industry Institute.
Pre-Project Planning Handbook. 1995. Special Publication 39-2.

Construction Industry Institute.
Project Definition Rating Index Industrial Projects. 1996.
Implementation Resource 113-2.

Construction Industry Institute.
Planning for Start Up. 1998. Implementation Resource 121-2.

Construction Users Roundtable (CURT) Architectural/ Engineering
Productivity Committee.
*Collaboration, Integrated Information and the Project Life Cycle
in Building Design, Construction and Operation (WP-1202)*. 2004.

Construction Task Force, Department of the Environment,
Transport and the Regions.
Rethinking Construction. London: DETR Publications, 1998.

Department of the Navy. Naval Facilities Engineering Command
(NAVFAC). 2000.
*Operations and Maintenance Support Information (OMSI)
for Facility Projects*. Internet.
http://www.navfac.navy.mil/doclib/files/11013_39.pdf
Accessed 24 May 2005.

Dutch Process and Power Industry Association.
*Reaching the Process Industry Vision: Roadmap to Competitive
Advantage Via Sharing and Storing Plant Life Cycle Data*.
Netherlands: Amersfoort, 2002.

FIATECH.

Element 9: Life cycle Data Management & Information Integration.
In *Capital Projects Technology Roadmap*. 2004.
<http://www.fiatech.org/projects/roadmap/workforce.html>

Gallagher, Michael P., Alan C. O'Connor, John L. Dettbarn Jr. and
Linda T. Gilday. National Institute of Standards and Technology (NIST).
*Cost Analysis of Inadequate Interoperability in the U.S. Capital
Facilities in the U.S. Capital Facilities Industry (GCR 04-867)*. 2004.
<http://www.bfrl.nist.gov/oe/publications/gcrs/04867.pdf>

InfoWeb. *Façade Example*. Internet.
http://www.infoweb.ws/cfihg_mapper
Accessed on 20 April 2005.

International Alliance for Interoperability.
Industry Foundation Classes, IFC-2X Platform Specifications. 2002.

International Organization for Standardization.
Open Archival Information System. Reference Model, ISO 14721:2003.

Open Standards Consortium for Real Estate. Internet.
<http://www.oscre.org>
Accessed on 20 April 05.

RTI International and the Logistics Management Institute.
NIST GCR 04-867. 2004.
<http://www.bfrl.nist.gov/oe/publications/gcrs/04867.pdf>

U.S. Census Bureau 2004b.
Annual Value of Construction Set in Place. Washington D.C.

U.S. Department of Energy. Federal Energy Management Program.
Model Commissioning Plan and Guide Specifications Version 2.05. 1998.

U.S. General Services Administration (GSA).
Whole Building Design Guide. Internet. Available from
<http://www.wbdg.org/project/buildingcomm.php>
Accessed on 20 April 2005.

U.S. National Institute of Building Sciences.
Total Building Commissioning Project. 1999. Internet.
[http://sustainable.state.fl.us/fdi/edesign/resource/totalbcx/
guidemod/docs/01nov98.html](http://sustainable.state.fl.us/fdi/edesign/resource/totalbcx/guidemod/docs/01nov98.html)
Accessed on 31 January 2005.

Report on integrated practice

- 0 Preface
Michael Broshar FAIA
In\Vision Architecture, Waterloo, IA
- Introduction
Norman Strong FAIA
Miller-Hull Partnership, Seattle, WA
- Architectural education and practice on the verge
Daniel S. Friedman FAIA
School of Architecture, University of Illinois
at Chicago
- 1 Change or perish
Thom Mayne FAIA
Morphosis, Santa Monica, CA
- 2 University and industry research in support of BIM
Chuck Eastman
Georgia Institute of Technology
- 3 Changing business models
James O. Jonassen FAIA MRAIC
NBBJ, Seattle, WA
- 4 Roadmap for integration
Laura Lesniewski AIA and Eddy Krygiel AIA
with Bob Berkebile FAIA
BNIM Architects, Kansas City, MO
- 5 Suggestions for an integrative education
Renée Cheng AIA
University of Minnesota
- 6 The Twenty-first century practitioner
Kimon G. Onuma AIA
Onuma & Associates, Tokyo and Pasadena, CA
- 7 Applications in engineering
Joseph Burns PE SE FAIA
Thornton-Tomasetti Group, Chicago, IL
- 8 Technology, process, improvement, and culture change
Jim Bedrick FAIA
Webcor Builders, San Mateo, CA
Tony Rinella, Associate AIA
Anshen+Allen Architects, San Francisco, CA
- 9 International developments
Ian Howell
Newforma, Inc., Manchester, NH
- 10 Information for the facility life cycle**
Kristine K. Fallon FAIA
Kristine Fallon Associates, Inc., Chicago IL
Steven R. Hagan FAIA
U.S. General Services Administration, Washington, D.C.
- 11 Construction industry perspectives: a conversation (DVD)
Norman Strong FAIA
Miller-Hull Partnership, Seattle, WA
David Mortenson and Greg Knutson,
M.A. Mortenson Co., Seattle, WA