# Just-In-Time Documentation for Delivering and Managing Building Information Using Intranet

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## PROBLEMS AND NEW VISION

The building life cycle is very complex. Various disciplines are involved in creating large amounts of information throughout design, construction, and facility operation and maintenance. The number of participants and complexity of their activity has dramatically increased over time during a building project. With increasing fragmentation of the responsibilities in the building process, information created from design and construction is not properly transferred to the facility operations and maintenance phase. There is also a general tendency that design and construction teams are often unaware of importance of transferring necessary information for the facility operations. As a result, the information necessary for facility operations is often poorly structured, missing, inaccessible or incomplete (Liu, et al. 1994, Hitchcock, 1996 and Clayton, et al. 1997).

More and more architecture, engineering, construction and facility management (A/E/C/FM) disciplines are using computer-aided design (CAD) and computer-aided facility management (CAFM) systems for their building project. It has become natural and beneficial to get the design files (CAD and specifications) electronically to start planning and control of the building operations. CAD information is used in conjunction with CAFM systems for many facility management areas such as renovation, calculation of areas for internal chargebacks, tracking resources for asset management, space planning, and plans for maintenance applications (Teicholz, 1995). However, none of these CAD and CAFM products are specifically designed to provide and manage information to support facility operations. Electronic document management systems (EDMS) have been developed to manage large numbers of documents in a systematic way. They are becoming popular among A/E/C/FM organizations to organize building information. Current EDMS provide many excellent features such as CAD document browsing, work flow management, version controls, easy customized features, and Internet connectivity. (Smith, 1999). However, it is hard to organize information with EDMS by establishing proper relationships between building product information and process or task information that is required to support the facility operations.

Facility operations personnel use so called "as-built" documents delivered by A/E/C teams for their daily operations. The as-built documents are intended to show the actual location of building systems and components after completion of a project. These documents are not properly designed to support facility operations and maintenance. Previous research (Johnson et al., 1999) at CRS Center has identified the following major problems of current as-built documents:

- *Inappropriate design and construction formats for FM*: They may require translation or extensible reformatting.
- *Complicated drawings*: Drawings contain unnecessary information and they are complicated and difficult to read by a facility operator. Simplified drawings are needed in conjunction with simplified diagrams such as load flow diagrams.
- *Hard to update information*: Facility information is routinely lost. It may be incorrect. Current information management practices may lead to poor documentation.
- *Information integration*: Building equipment is often dependent upon other systems or equipment. Information needs to be integrated with related information.
- *Inaccessible information*: Information may be difficult to find, difficult to retrieve, inaccurate or simply missing.
- *Unavailable information at point of use*: Proper labels are needed at the point they are used.
- *Low percent of structured information*: As-built information is often difficult to retrieve from large, paper-based archives. Some historical information is in paper format and is stored in standard file cabinets or is in a format that cannot easily be integrated into useful information.
- *No standard for labels*: Architects, consultants, and facility operators rarely use one standard label convention for delivery and storage of information. Proper labels and standard naming conventions are required for managing information.

Previous research (Clayton, et al. 1998) has conducted a study of facility documentation to assist in planning new information systems for facility management. This research pointed out that current as-built documents provided from the design and construction phases are not appropriate for facility operation. It introduced the

concept of "operations documents" that are different from other kinds of facility documentation. Operations documents are intended to be dynamic, living documents of the evolving state of a facility as needed to support operations and maintenance, while as-built drawings or record drawings are intended to document the constructed state or designed state of a facility.

We have developed the concept of JIT to create a more efficient operations document production system. The origin of the JIT concept can be found in the manufacturing field. JIT manufacturing is used as a process to eliminate waste to improve productivity and product quality (Karmarkar, 1989). This management style has shown success in the areas of production and product quality of the automobile industry (Duncan, 1988). In the context of operations documents, the necessary information can be produced and used "just-in-time" when it is needed instead of storing all building information just in case it is needed for the next facility operations work. Emerging Web technologies have great potential to handle complex A/E/C/FM information. The Web technologies provide a potential solution to implement a JIT facility document system because of their ability to handle various different information formats in a dispersed work environment. We focused our search for solutions upon the emerging information technologies that enable the creation of JIT documents using an intranet.

## WEB TECHNOLOGIES AVAILABLE FOR JIT DOCUMENTS

Web technologies are widely available, relatively low in cost and platform independent. The intranet is a network built using Internet technologies for internal use to provide information and distribute applications to employees within an organization. While the Internet is global and universal in accessibility, an intranet is restricted to an organization. We have explored several basic technologies (Clayton et al., 1999) that can contribute to an intranet-based facility document system. The basic technologies include:

- ***Web browsers and HTML***: Web browsers and HTML are the fundamental technology in our explorations to implement an intranet. Information on the Web is delivered to a client Web browser using the Hypertext Markup Language (HTML) format and the Hypertext Transfer Protocol (HTTP). By calling a Uniform Resource Locator (URL) the browser can locate and retrieve a specific document from any server on the Web.
- ***Active Server Pages (ASP)***: Active Server Pages is a Microsoft web application tool that allows one to combine HTML, scripts, and reusable ActiveX server components to create dynamic and powerful Webbased applications. ASP in conjunction with Internet Information Server (IIS), makes it easy to access data and put it on a Web page from an database. With ASP, one can insert HTML fragments, perform database queries, and process the values in user input fields to generate HTML code on-the-fly.
- ***Database Management Systems***: Relational Database Management Systems (RDBMS), such as Microsoft SQL Server and Oracle, are a fundamental repository for information that is structured into tables. Open Database Connectivity (ODBC) is a widely accepted application programming interface (API) for database access. The ODBC allows performing queries on many brands of Structured Query Language (SQL) based RDBMS.
- ***DWF***: Drawing Web Format is a file format established by Autodesk to support distribution of vector drawing information on the Web. Like CAD drawings, drawings in DWF can be zoomed and panned while maintaining visual integrity and dimensional accuracy. DWF files can have embedded links, multiple named views, and layers that can be toggled on and off. The settings can be controlled via JavaScript and parameters in a URL.
- *XML*: Extensible Markup Language (XML) is a subset of an international standard, Standard Generalized Markup language (SGML) which is widely used in certain high-end areas of information management and publishing (Leventhal et al., 1998). XML provides enriched structure that enables machine processing of documents to support multiple uses. It provides content-based markup that allows Document Type Definitions (DTD) to define new and custom tags that enable machine parsing and manipulation; inclusion of sub-documents that can be made of many files; and externally stored style sheets so that a common format can easily be applied to many documents.
- ***DOM***: The Document Object Model (DOM) provides a standard set of objects for representing HTML and XML documents, a standard model of how these objects can be combined, and a standard interface for accessing and manipulating them. Anything found in an HTML or XML document can be accessed, changed, deleted, or added using the DOM. With DOM, authors can write to the standard DOM interfaces that allow increasing interoperability on the Web (W3C, 1998).
- ***Dynamic HTML***: Dynamic HTML (DHTML) is not really a technology, but is a loose collection of technologies (Goodman 1998). It includes Java, Scripts, DOM, Cascading Style Sheets (CSS) and other accepted or proposed formats that enable the appearance of HTML files to be adjusted on the fly. Data binding features of DHTML allow users to connect embedded data sources or databases that are connected remotely in a Web page. The DHTML can use multimedia components in any Web site that needs specific multimedia elements (Microsoft, 1999).
- ***Redlining***: A number of tools are becoming available that allow simplified editing of a CAD file to support mark-ups, note errors, and indicate changes. The edited information is kept in a separate file from the original CAD drawing to establish authorship of suggested changes. Redlining is a key step in keeping drawings up-to-date, coordinated with other drawings or field surveys, and in collaborative design efforts.
- *VRML*: The Virtual Reality Modeling Language (VRML) is a standard language for describing interactive 3-D objects and worlds delivered across the Internet. With VRML, a user can navigate through a 3D space that has been delivered to the userís computer using the Web. The 3D objects can be links to text, audio, or video files, HTML pages, or links to other VRML objects. However, VRML is still not widely supported and it makes large demands upon computing resources.

## JIT DOCUMENT GENERATION PROCESS

In our prototype system, a document generator automatically generates JIT documents. Conventional as-built documents are usually created without considering the facility operations and maintenance processes. In contrast, JIT operations documents are designed for organizing information based on specific tasks or process needs. The task centric document generator uses a task template that allows collecting, filtering, customizing and retrieving concise information on the fly based on the specific operations tasks. The following steps explain the JIT document generating process.

- ***Analyze operations task***: Analyzing an operations task is the key to identify necessary information to perform the task. An operations task might need a project schedule, building drawings, operations procedures or current system performance documents. An analyst or administrator can create and document needs through a task analysis. The task analysis document can be used to create document templates that will generate a JIT document based on the specific task.
- ***Create documents templates***: A document template provides a predefined format and content for a JIT document. The template collects, filters, customizes and retrieves necessary information for a specific operations task from the files and data in the generic repositories. We created the task-centric templates with ASP in conjunction with Java Script, VB Script and DOM.

- ***Create JIT documents***: The predefined templates generate HTML documents on the fly by querying the related document links from a link farm. The scripts retrieve data from a database, drawing files, images, text and many other kinds of data formats and dynamically generate a concise document in a predefined format (Figure 1).

## IMPROVEMENT OPPORTUNITIES WITH JIT DOCUMENT SYSTEM

Our prototype JIT operations document system has employed the JIT document concept. The vision embodied in our concept of developing the prototype system is that information technologies can actively and automatically collect, filter, and retrieve relevant information from data repositories in response to task oriented requests by operations personnel. This system will deliver necessary, concise and complete information that is focused on specific operations tasks instead of an entire operational manual or ill-structured archives of information. The following describes what are the requirements for operations documents and how JIT document system can improve the information requirements to support facility operations.

### 1. Storage of diverse information from A/E/C team

The information used by operations personnel is complex and has diverse origins. Current formats of documents delivered by A/E/C teams are usually different from each other. Although there are many standard formats available such as CAD Layer guide line from AIA (AIA., 1997) and Uniformat (CSI, 1997) etc., there are no widely accepted and dominated standards throughout A/E/C/FM industry. This is an obstacle for efficient facility operation. JIT documentation process can be optimized by using structured standard formats such as templates; symbol library; naming and classification system for labeling; drawings and diagrams; predefined digital formats of tabular data; and text format for design rationale etc. Previous research (Clayton, et al., 1999) has identified some recommendations for preparing information formats to store in a generic repository. Table 1 presents some of the examples.

We have developed a "link farm" as a means of delivering and managing document links. A link farm is a link management database. The purpose of a link farm is to store and manage information links with a relational database that allows users to access one or more related documents through hyper-links (Figure.2). The link farm allows Web browsers to be able to traverse between simple and extended links. We employed a Microsoft Access relational database to change, update, delete and save the link information.

### 2. Incorporation of diverse formats of information delivery

The AEC team delivers a variety of formats of information such as drawings, graphics, text, tables and spreadsheets. Operations need to incorporate the variety of information formats and be able to access any combinations of these formats. With a proliferation of "plugin" software, a variety of information formats is available on the Web browsers. Web browsers incorporate the information formats such as drawings, graphics, text, tables, and spreadsheets as well as multimedia (e.g., sound, audio and video) formats. Our prototype system uses the Web browsers such as Microsoft Explorer and Netscape Communicator as a front-end user interface.

### 3. Navigation of information

A systematic searching mechanism is necessary for navigating information during operations. In our prototype, we employed three different information access routes for systematic navigation. Users can access same information through the access routes based on their preference and needs.

We have developed functional systems, task centric, and project specific information views to access information. The following describes each of these views.

- ***Functional systems view***: In this view, information is organized by functional systems of a building such as spatial, structural, mechanical, and electrical systems etc. In our prototype, we organized information in Uniformat from the Construction Standard Institute (CSI). We linked each drawing object with linkfarm database, so users can navigate information through the building systems in a drawing.
- ***Task centric view***: In this view, information is organized by operational tasks. Example operational tasks are installation of new HVAC equipment, replace a fan or emergency shut down. A user can navigate necessary information to perform a specific task on the list.
- ***Project specific view***: The information is organized by each individual person who is responsible to perform a specific task in a project. In this view, we listed project related information such as project schedule, resource availability, and contact list, as well as individual to-do list.

### 4. Filtering and customizing information

Some of the delivered information is too specific and too voluminous for operations. The operations document must filter the information for specific operations tasks. Facility operators also need information customized for their specific work tasks. The

| Types of documents | Data format recommendations |
|---|---|
| *Drawings* | • Deliver documents in CAD format and web-enabled format (e.g., DWG or DWF format ).<br>• Use sheet organization standards such as Uniformat.<br>• Provide consistent label names and tag-names.<br>• Use a layer standard such as CAD Layer guide line from AIA.<br>• Define and Link all necessary information. |
| *Text documents (design intents, product manual)* | • Provide style sheets for text documents.<br>• Use Form Function Behavior ( as a format to describe design intention in engineering format.<br>• Apply HTML/ XML documents. |

Table 1. Examples of data format recommendations

Table 2. Summary of JIT document system

| Improvement opportunity | Development strategy | Prototype JIT system solution |
|---|---|---|
| *Storage of diverse information sources* | Identify structures and contents | Stored in a generic repository, database and link farm |
| *Incorporation of diverse formats of information delivery* | Develop user interface for diverse information formats include multimedia | Used web browser as an user interface |
| *Navigation of information* | Develop data access route for navigating information | Provided various data access routes |
| *Filtering and customizing information* | Simplify drawings<br>Provide opportunity to select contents of information | Created simplified drawings and diagrams<br>Used DWF and VRML for drawings and diagrams<br>Used ASP and DHTML to produce alternatives of contents |
| *Inclusion of design intentions* | Document design intentions and link with drawings | Created HTML and Text documents<br>Used link farm for links<br>Planning potential use of XML |
| *Integrated views across functional systems* | Identify interdisciplinary documents to perform a specific task and link documents | Linked related documents<br>Used DWF for layer controls |
| *Support for training* | Identify training requirements and reuse of information | Created and reused task templates<br>Planning potential use of XML |
| *Feedback for document maintenance* | Update information<br>Provide automatic process to the responsible person | Used redlining tools for drawings<br>Used EDMS for updating documents<br>Used ASP, DHTML and e-mail for automatic workflow |

Table 2. Summary of JIT document system

operations document system must provide an opportunity to customize information. We used DWF to filter drawing information. A user can toggle layers on and off to get rid of unwanted information on a drawing. We also created simplified drawings and diagrams to understand the systems and components easily. We used VRML for 3D information, so a user can navigate through a 3D space on the Web to understand building systems and components. In order to provide alternatives of information contents to the users, we made selection forms with ASP, DHTML and VB Script. A user can select customized information contents on the Web based on their knowledge, skills and purpose.

## 5. Inclusion of design rationale

In current practice, design intention documentation is often missing. Information about design rationale is also an important component of the training experience. In order to understand the design or construction objectives that may impact the buildingís operation and maintenance performance, it is necessary to link design intentions with drawing object. Our prototype system shows integration between drawings and design intentions. To capture and document design rationale information, we are investigating use of XML technology. This part of the research is in the planning stage. Convincing designers to employ a standard format for recording design rationale is likely to be difficult or impossible. One solution could be to employ an expert internal to the operations organization to undertake "harvesting" of design rationale from a design team. Equipped with custom XML editors and inventories of facility components, the design rationale expert can interview members of the design team and record their responses in an XML document instance, embedding appropriate tags. The tags can then be used by the information system to extract particular pieces of information for composition into just-in-time operations documents.

## 6. Integrated views across functional systems

Many operations tasks involve views across mechanical, electrical, controls and architectural systems. While designers and constructors divide responsibilities to focus upon single systems, the building operators must understand how all systems contribute to an interrelated whole. Rarely does the structure of facility documents support easy retrieval of information across discipline or system boundaries. In order to implement the integrated views in our system, we linked information so users can traverse different func-

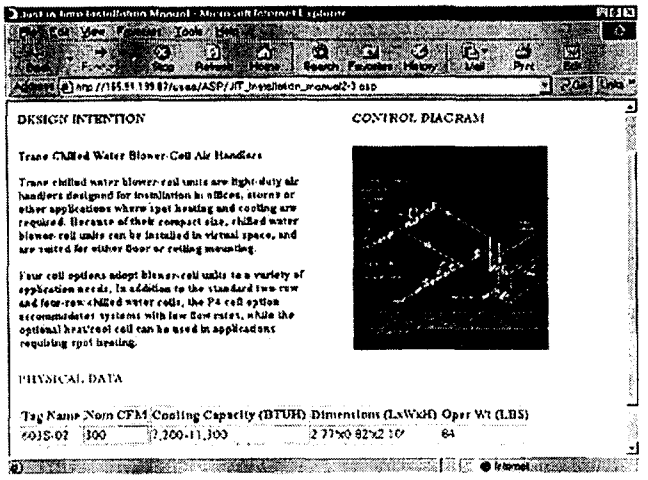


Figure 1. Example of Just-In-Time document

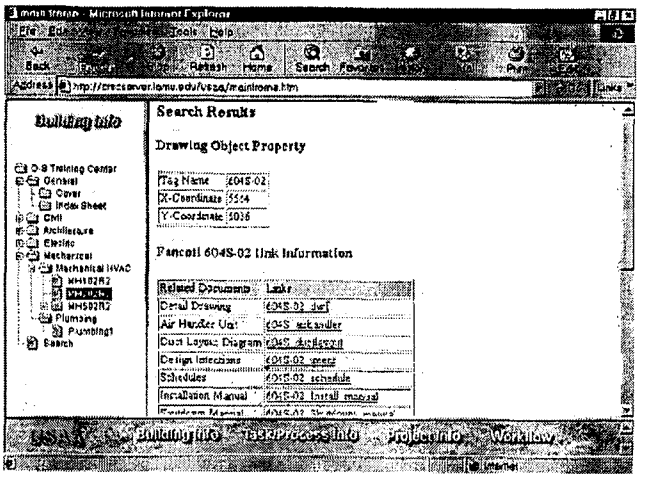


Figure 2. Example of query results from link farm

tional system information. We provided DWF drawings to manipulate layer controls so users can easily select any layers of functional system they want.

## 7. Support for training

A particular problem area has been the lack of useful documents for training. Conceptual overviews, usage scenarios, and emergency procedures must be presented to new or transferred employees to facilitate their learning about the building. JIT document is ideal to provide training information on site. We can create a new task template for JIT training document or reuse a previous task template from JIT document. The task templates will generate all the necessary information for training. We are also planning to investigate XML technology for the use of training documents.

## 8. Feedback for document maintenance

As-built drawings often become out of date or incorrect. Specialization has led to dissociation between personnel responsible for operations and personnel responsible for facility documentation. Assuring automatic and reliable up-date procedures as operators change the facility is crucial to long-term success of an information system for facility operations. Our prototype system generates work reports, notices, and feedback to report, notice or update information to the responsible person. The work reports are usually sent to facility managers for operational or strategic planning purposes. The notices are sent to the affected people due to activities such as shutdown, or emergency. The feedback to the information system is crucial to keep the portrait of the facility up to date. Forms to send and collect information for a project can be automated with ASP and DHTML with e-mail. The workflow incorporates predefined forms and e-mail. In particular, feedback must include graphic information to direct modification of drawings to reflect field conditions. We used CADViewer by ArNoNa Internet Software Inc (ArNoNa 1998) for redlining drawings on the Web. Mark-ups can be made to a DWF file and then saved as a separate file. The mark-up files, updated databases, and messages to the document maintenance staff serves as feedback by which documents are kept up to date.

## CONCLUSION

Our initial experiment of the JIT facility document system led us to envision that this system might be a practical and economic way of delivering and managing building information for daily operations work. Our prototype system provides a proper search mechanism, related information links, and automated mechanism for information feedback. Proper documentation of design rationale, setting up its relationship to building information and interdisciplinary view of building systems are important actions prior to fielding a system. Our prototype system successfully produced JIT documents that include design intent and related building information that is helpful to perform a specific task. All the links are systematically managed in a link farm database. The prototype system enables efficient management of building information by providing automatic feedback for updating information. This system also keeps track of information for strategic information planning. An empirical test of the prototype system will provide us further in-depth guidelines to implement the system in an organization. Monitoring of information in a link farm, cost benefit analysis and subjective evaluation by operations personnel will guide us in the further development of the system. The following table 2 is the summary of our JIT document system solution.

Information technologies are constantly changing and emerging. In particular, common objects and XML technologies are still developing and promise many potentials uses for facility operations. The strategies of A/E/C/FM data exchange and interoperability can be found in various research organizations such as International Standard Organization (ISO), International Alliance for Interoperability (IAI) and The Tri-Services CADD/GIS Center. Most of their research related to facility management is now in the development and planning stages. With interoperable common objects, building information will be shared and exchanged across applications more efficiently in the future. We are planning to investigate the use of the common objects for facility documentation. XML technologies can be used to document the design rationale for use in operations manuals, maintenance manuals, training manuals, troubleshooting and redesign. We are also planning to implement XML solutions to our prototype system in the near future.

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