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Delivering Facility Documentation Using Intranet Technology

Intranet technologies present new opportunities for delivering facility documentation for use in facility management. After the design stage, building documentation is reused to support construction and then facility operation. However, a common perception is that construction documents and as-built drawings are less than optimal for reuse to support operations. We have conducted a study of facility management processes and the information content of facility documentation in the context of information technologies that are emerging into the marketplace. The study provides guidance for facility managers who are implementing and fielding new information technology systems. A better understanding of information needs during operations may also help designers to better structure their own documents for reuse.

An analysis of documents that are used throughout the life cycle of facilities has led us to a characterization of operations documents that are distinct from design drawings, record drawings or as-built drawings. From an analysis of facility management processes, we have identified different roles for facility documentation in those processes. Facility documentation may be used as a resource, as input, or as output. Furthermore, from interviews of facility management personnel, we identified facility information that was rated high in importance and low in satisfaction that might be targeted when implementing a facility information system. We prepared software demonstrations that show how the information may be extracted from drawings, entered into databases and then retrieved via Web and CAD interfaces. We suggest that operations documents consist of a variety of information types and require several kinds of information tools, including databases, CAD drawings and hypertext. Intranet technologies, databases and CAD software can be integrated to achieve facility management systems that address shortcomings in current facility management operations. In particular, intranet technologies provide improved accessibility to information for facility management customers and occasional users of the systems. Our study has produced recommendations based upon utility and ease-of-implementation for delivery of information from the design team to the owner, and among personnel during operation of the facility.

Livraison de la documentation sur les installations par technologie intranet

Les technologies intranet présentent de nouvelles opportunités pour la livraison de la documentation et la gestion d'une installation ('facility'). Après l'étape de conception, la documentation sur une installation est réutilisée lors de la construction et le maintien de l'installation. Néanmoins, une perception commune est que les documents de construction en tant que dessins ne sont pas convenables pour la réutilisation au niveau de la gestion de l'installation. Nous avons effectué une étude du processus de gestion d'une installation et du contenu de la documentation sur l'installation. Dans le contexte de la technologie de l'information qui apparaît sur le marché, cette étude donne des conseils aux gérants d'installations qui utilisent des technologies nouvelles comme les systèmes d'information. Une meilleure connaissance des besoins informatiques au cours de l'opération quotidienne de l'installation peut aider aux concepteurs à mieux structurer leurs documents pour la réutilisation.

Une analyse des documents employés au cours du cycle de vie d'un bâtiment a mené à une caractérisation de documents opérationnels, distinctes des documents de design, des dessins pour les archives, ou des dessins 'tels que construits'. Partant d'une analyse des processus de gestion d'une installation, nous avons identifié des rôles différents pour la documentation de l'installation au cours de ces processus. La documentation sur l'installation peut être utilisée comme ressource, comme données d'entrée ou de sortie('input' ou 'output'). De plus, au cours d'entretiens avec le personnel de gestion de l'installation, nous avons identifié des informations sur l'installation qui ont un grand niveau d'importance mais un niveau bas de satisfaction et qui pourraient être ciblées lors de l'implantation d'un système d'information pour l'installation. Nous avons préparé des démonstrations de logiciel pour montrer comment ces informations peuvent être extraites de dessins, placées dans des banques de données, et retrouvées à travers les interfaces Web et DAO. Nous suggérons que les documents opérationnels consistent en une variété de types d'informations et rquièrent plusieurs outils informatisés tels que les banques de données, les dessins DAO et le hypertexte. Les technologies intranet, les banques de données et les logiciels DAO peuvent être intégrés pour obtenir des systèmes de gestion d'installations qui comblent les lacunes existant à présent au niveau de ces opérations. En particulier, la technologie intranet rend l'information plus accessible pour les clients en gestion des installations et pour les utilisateurs occasionnels du système. Notre étude a produit des recommendations basées sur l'utilité et la facilité d'implantation afin de fournir des informations en partant de l'équipe de design jusqu'au propriétaire, et parmi le personnel durant la gestion de l'installation.

intranets and facility management

Although Internet technologies have rapidly emerged as commercial applications, there is not yet a full understanding of how they can be used effectively by architects and facility operators to support the life cycle of a building. In particular, the application of Internet technologies in a private local area network as an *intranet* appears to be a promising way of representing architecture and delivering it to facility management customers. To gain a better understanding of these opportunities, we have studied the current processes and information needs of facility management and explored how Internet technologies can satisfy those needs. This paper provides a snapshot of currently emerging technology and how it can assist in solving real problems in facility management.

An intranet approach employs key technologies of TCP/IP, HTML and Web browsers that are proven to be robust, practical and easy to use. Widely available Web technology can support a variety of graphic and text information, can act as a front end to databases, and can be integrated with traditional facility management systems (Al-Qawasmi et al. 1997). An intranet can consequently be adapted to the richness of information and presentations of information that are needed in facility management. The technologies of Web browsers, plug-ins and database access present a familiar, consistent and easy-to-use interface to complex information. The information is accessible to both technical and non-technical staff.

In this paper we will first present a description of the life cycle of facilities and the many documents used throughout that life cycle. We will then outline the processes that must be supported by facility documentation. Then, we will describe the results of discussions with facilities personnel at USAA, Inc., the sponsor for this research. Our intention in these sections is to establish a better understanding of the content of facility documentation and the problems that are extent in contemporary facility documentation practices. After establishing what the problems are, we will describe some of the intranet technologies and applications that are most attractive as solutions to these problems. Our conclusions are presented as a list of potential solutions prioritized by a sense of ease of implementation and utility. In our judgement, these potential solutions are the best opportunities for improving facility documentation for use in building operations.

a customer-centered approach to FM

Our study builds from a customer-centered view of facility management. A customer-centered view helps to focus efforts upon identifying very real needs and implementing policies and procedures that directly respond to those needs. The customers in facility management vary widely. They may be personnel with missions in facility support, interior design, engineering, construction management, maintenance or operations. Customers may also be personnel who are involved in strategic planning for the company to identify trends in facility use and needs for expansion or contraction. Customers may be any employees in the company who generate a work order or request for maintenance or improvements. Finally, customers may be engineers, architects, consultants and regulatory personnel who participate in design and construction of facilities. This wide range of customers is likely to require many different tools for accessing facility information.

guidelines for facility documentation

Many guidelines for organizing digital drawings have been suggested. However, most approaches focus upon a single technology, such as CAD, or a single view of the facility in its life cycle, such as design. Research efforts are also underway that purport to address the entire life cycle of a facility. Little work has yet been performed to take advantage of Web technologies.

CAD-oriented standards. The AIA has recently released the second edition of their CAD layer guidelines (AIA 1997). In addition to providing a master list for layer names, it suggests techniques for naming digital files, organizing drawings into sheet files and model files, and some advice regarding organization of 3D models. The organization of drawings into layers employs a primary classification by discipline, such as architectural, structural, civil, and interior design.

The Construction Specifications Institute has suggested an approach to organizing drawings in

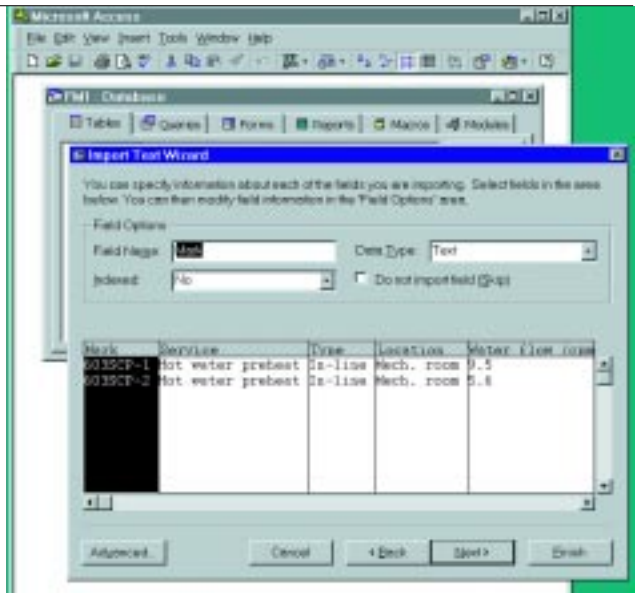
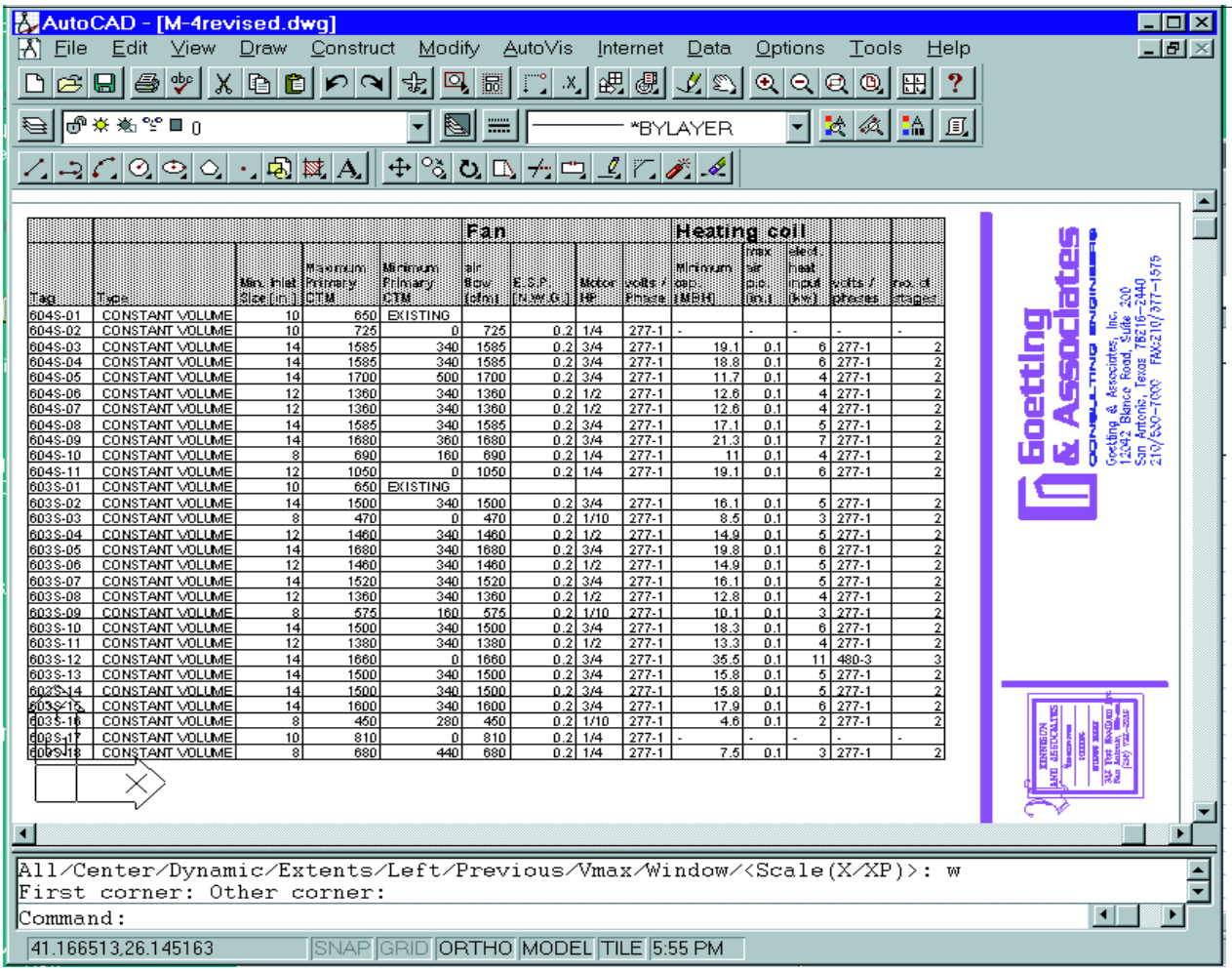


Figure 1. Importing schedule data from a CAAD drawing to a Microsoft Excel spreadsheet.



Tag	Type	Min. Inlet Size (in.)	Maximum Primary CFM	Minimum Primary CFM	Air flow (cfm)	E.S.P. (in.w.g.)	Motor HP	Volts / Phase	Minimum cap. (MBH)	Max. air p.d. (in.)	Heat input (kw)	Volts / phase	No. of stages
604S-01	CONSTANT VOLUME	10	650	EXISTING									
604S-02	CONSTANT VOLUME	10	725	0	725	0.2	1/4	277-1	-	-	-	-	-
604S-03	CONSTANT VOLUME	14	1585	340	1585	0.2	3/4	277-1	19.1	0.1	6	277-1	2
604S-04	CONSTANT VOLUME	14	1585	340	1585	0.2	3/4	277-1	18.8	0.1	6	277-1	2
604S-05	CONSTANT VOLUME	14	1700	500	1700	0.2	3/4	277-1	11.7	0.1	4	277-1	2
604S-06	CONSTANT VOLUME	12	1360	340	1360	0.2	1/2	277-1	12.6	0.1	4	277-1	2
604S-07	CONSTANT VOLUME	12	1360	340	1360	0.2	1/2	277-1	12.6	0.1	4	277-1	2
604S-08	CONSTANT VOLUME	14	1585	340	1585	0.2	3/4	277-1	17.1	0.1	5	277-1	2
604S-09	CONSTANT VOLUME	14	1680	360	1680	0.2	3/4	277-1	21.3	0.1	7	277-1	2
604S-10	CONSTANT VOLUME	8	690	160	690	0.2	1/4	277-1	11	0.1	4	277-1	2
604S-11	CONSTANT VOLUME	12	1050	0	1050	0.2	1/4	277-1	19.1	0.1	6	277-1	2
603S-01	CONSTANT VOLUME	10	650	EXISTING									
603S-02	CONSTANT VOLUME	14	1500	340	1500	0.2	3/4	277-1	16.1	0.1	5	277-1	2
603S-03	CONSTANT VOLUME	8	470	0	470	0.2	1/10	277-1	8.5	0.1	3	277-1	2
603S-04	CONSTANT VOLUME	12	1460	340	1460	0.2	1/2	277-1	14.9	0.1	5	277-1	2
603S-05	CONSTANT VOLUME	14	1680	340	1680	0.2	3/4	277-1	19.8	0.1	6	277-1	2
603S-06	CONSTANT VOLUME	12	1460	340	1460	0.2	1/2	277-1	14.9	0.1	5	277-1	2
603S-07	CONSTANT VOLUME	14	1520	340	1520	0.2	3/4	277-1	16.1	0.1	5	277-1	2
603S-08	CONSTANT VOLUME	12	1360	340	1360	0.2	1/2	277-1	12.8	0.1	4	277-1	2
603S-09	CONSTANT VOLUME	8	575	160	575	0.2	1/10	277-1	10.1	0.1	3	277-1	2
603S-10	CONSTANT VOLUME	14	1500	340	1500	0.2	3/4	277-1	18.3	0.1	6	277-1	2
603S-11	CONSTANT VOLUME	12	1380	340	1380	0.2	1/2	277-1	13.3	0.1	4	277-1	2
603S-12	CONSTANT VOLUME	14	1660	0	1660	0.2	3/4	277-1	35.5	0.1	11	480-3	3
603S-13	CONSTANT VOLUME	14	1500	340	1500	0.2	3/4	277-1	15.8	0.1	5	277-1	2
603S-14	CONSTANT VOLUME	14	1500	340	1500	0.2	3/4	277-1	15.8	0.1	5	277-1	2
603S-15	CONSTANT VOLUME	14	1600	340	1600	0.2	3/4	277-1	17.9	0.1	6	277-1	2
603S-16	CONSTANT VOLUME	8	450	280	450	0.2	1/10	277-1	4.6	0.1	2	277-1	2
603S-17	CONSTANT VOLUME	10	810	0	810	0.2	1/4	277-1	-	-	-	-	-
603S-18	CONSTANT VOLUME	8	680	440	680	0.2	1/4	277-1	7.5	0.1	3	277-1	2

Figure 2. Using OLE to integrate spreadsheets and CAD drawings.

their Uniform Drawing System. This approach attempts to define the internal structure and layout of construction documents. It focuses upon sheet sequence, title block layout, dimensioning conventions, notation methods and other aspects of form and presentation of the information (Sanders 1996). It attends much less to the content of the drawings in terms of systems and components that correspond to the actual building.

Another system provides layer guidelines and a practical approach to separating building design information into drawings in AutoCAD and spreadsheets in Microsoft Excel (Jules 1997). It includes templates for drawings, symbol libraries, layering standards, spreadsheet templates for schedules, and office standards.

These guidelines are oriented toward design and construction rather than facility management and operation. Organization of a drawing by disciplines makes much sense from the point of view of several cooperating design professionals, but may be less useful from an operations perspective that emphasizes particular building systems and life cycle concerns. A particular building system may span across several realms of responsibility from the design discipline point of view. In comparison to design and construction documents, operations documents may need to place greater emphasis upon processes and performance. It has been suggested that hypertext and hypermedia systems can serve as effective manuals that document how to maintain and operate waste treatment plants (Tidwell and Leckington 1994).

Research Initiatives. Research initiatives are addressing the comprehensive classification of facility information for use throughout the life cycle. Research and development efforts in product modeling for the AEC industry are more ambitious than the CAD layer guidelines but perhaps less practical in the short term. The Standards for Exchange of Product Data (STEP) is an international effort to establish standard representations of manufacturing data to allow producers and users of components to share data and expedite work processes (Watson 1995). Most progress has been made in manufacturing and heavy industry, but there is an active building and construction group. Because of its endorsement by the ISO, the STEP initiatives are likely to be on-going and to lead to some accepted standards. The International Alliance for Interoperability (IAI) is an organization of industry groups that was founded on the initiative of Autodesk's AEC group (IAI 1996). By using an object-oriented approach, it is attempting to set standards for software interfaces to allow software products from multiple vendors to share data and execution processes. Due to its origin in the AEC industry and backing by major CAD vendors, the IAI is likely to lead to widespread and practical representations of facility information. However, these international standardization efforts are moving very slowly and may not address facility operations issues strongly enough for the needs of the building owners.

Other efforts more directly address operations. INFO is a classification system for facility information for use in operations (Beckett and Sanvido 1992). It provides codes that distinguish functional system, level of space (building, floor, room or component), graphic projection, Uniform Construction Index narrow scope index, and kind of information. It may serve as a comprehensive accessing system for facility information that can be adapted to object-oriented or hypertext implementations. At the Tri-Service CADD / GIS Technology Center, efforts are underway to develop standards that coordinate and integrate information used by the US Armed Forces in building and operating facilities. A recent study compared existing standards for AEC drawing representations (the A / E / C CADD Standards) and GIS information (the Spatial Data Standards, or TSSDS) (Hanson et al. 1996). The A / E / C CADD Standards are similar to the AIA CAD Layer Guidelines in that they specify naming conventions for layers. They also establish symbol libraries, color conventions, sheet names and file names. The TSSDS is a more complex and sophisticated approach that is predicated upon linking database systems to the graphic or CAD representation. The report suggests that a FM standard can evolve out of the A / E / C CADD Standards by incorporating an approach similar to that of the TSSDS of linking database records to the CAD drawings. The report outlines the process of migrating data from one standard to another as a preliminary necessity before full integration is

Type of Documentation	Stage in Lifecyle	Purpose	Author	Customer
Design drawings	Design	Record and communicate design to assist in decisionmaking	Design team	Owner, design team
Bid Documents	Building and construction	Communicate scope of construction	Design team	Constructor
Construction documents	Construction	Communicate materials, methods of construction and finishes	Design team	Design team
Record drawings	End of construction	Record final design that incorporates changes made during construction	Design team	Design team
As-built drawings	End of construction	Record the state of the facility at delivery	Constructor	Owner
Operations documents	Occupancy	Record and disseminate information needed to operate, maintain, and renovate the facility	Owner, operator	Owner, operator
Demolition drawings	Demolition and renovation	Describe scope of demolition	Design team	Owner, design team, contractor

Table 1. Facility documentation at different stages.

achieved.

Among these research efforts, there has yet been little study of how intranet technology may be applied in facility management and operations. Consequently, we have looked specifically at intranet technology within contexts of the building life cycle, the facility management processes, and the content of facility documentation.

distinguishing types of FM documentation

Although the documentation of facilities is often colloquially called "as-built" drawings, that term is misleading in regards to purpose and participants. Several types of documentation of a facility can be distinguished in the facility life cycle. Many different participants produce documents and many different "customers" may make use of them. Collectively, one may group all of these kinds of documents as "facility documentation."

Table 1 summarizes the kinds of facility documentation, when they are used, what their purposes are, who creates the documents and who uses the documents. For our study, several points are important. Design drawings, bid documents, and construction documents, while they certainly are of interest to the owner, are directed mostly toward the members of the design team and the constructors. Furthermore, both record drawings and as-built drawings are relatively static descriptions of the facility. They are produced by the design team (record drawings) or the constructor (as-built drawings) and help to define the completion of the project. They are not intended to support operations or to be updated by facility management personnel. Indeed, it is arguable that the customers for record drawings and as-builts are the design team and constructors who use them to establish limits of liability. Their use by owners to support operations may be incidental and expedient.

Although record drawings or as-built drawings may serve as a starting point toward operations documents, they do not effectively express the information that is needed to operate a facility. A survey of US Army facility managers reached a conclusion that "Most information established during construction is usually not structured in a way to support the tasks needed by facility operators / maintainers" (Liu et al. 1994). The Army survey also revealed that, sometimes, important information is not collected or stored for use by facility managers. The researchers recommended more attention to design standards and criteria, warranty information, maintenance records, condition of equipment and facilities, and utility information.

The documents that are commonly produced by designers and constructors are poorly structured for supporting the wealth of non-graphic data, ready accessibility and ease of change that are

needed in maintenance and operations. They may lack information that is important in facility management and operations. They differ very much in purpose, authorship and customer from other types of facility documentation. We suggest that it is important to distinguish operations documents as a distinct category of facility documentation. However, the needed content of operations documents remains poorly defined in comparison to the content of construction documents.

processes, participants and information

An understanding of the information content of operations documents must begin with an understanding of the processes that are supported by that information and the participants in those processes. The facility documentation contributes to several processes that are generally included under the umbrella of facility management, including day-to-day operations, renovations, cable management, strategic planning and budget projections (Rondeau, Brown and Lapides 1995).

The role of the information in the processes can also lead to a deeper understanding and to clues regarding how to use information technology. Information may serve in three roles: *inputs* to a process, *outputs*, or *resources* that inform the process but are generally unchanged by the process. In Table 2, we have characterized the role of facility information for various processes. While facility documentation serves as input and output of churn projects and major renovations, it often plays a role of a resource that is unchanged. The difference between the role of input and output as opposed to resource is a key indicator for what kind of information technology can be applied to representing the information. In particular, when information is primarily a resource, intranet technologies may be very effective at publishing that information.

content of operations documents

To identify issues in content, we conducted interviews and surveys of personnel at the enterprise that sponsored our research. Personnel from each of the four departments within Facility Management assessed importance and satisfaction with facility information. The survey provided an extensive list of 64 information categories that are commonly included in facility documents. The participants rated each type of information for importance and for satisfaction. The complete list of information and rankings have been reported (Clayton et al. 1998). Only a few categories (5, or 8%) received a very low satisfaction rating of 1, while 58% received either a 3 or 4 satisfaction rating.

When a category of information has both a high importance rating and a low satisfaction rating, that category of information is clearly a strong candidate for further examination. From the survey, the following categories of information appear to be particularly strong candidates for improved documentation:

- electrical breaker panel schedules,
- valve tag schedules,
- door hardware schedules,
- lock set schedules and
- mechanical design rationale.

It may be significant that the categories of information with low satisfaction ratings are not easily represented with conventional or CAD drafting. There may be a bias toward representing and storing information that can easily be drawn. Computer technologies such as databases and hypertext may expand the set of information technology tools to better accommodate a wider range of information categories. For example, electrical breaker panel schedules, valve tag schedules, door hardware schedules, lock set schedules, valve descriptions and electrical circuit information may easily be represented with database tables. Mechanical design rationale may be represented effectively as hypertext.

The survey also collected perceptions of the use of information across departments. Participants indicated which departments originated categories of information, accessed the information, modified it and maintained it. The survey results suggest that information must cross many departmental boundaries. However, there was not a clear awareness of the importance of information to people in other departments. Nearly all (88%) of the information content categories that were included in the survey were very important to someone. Over 30% of the information categories received both a ranking of least important and a

Process	Participants	Input, Output or Source	Key Context
Space planning and churn projects	Customers, interior designers, engineers, architects, operations personnel	Input and output	Wall locations, door locations, room identification, furniture layout, light fixtures, finishes
Major renovations and construction	Customers, interior designers, engineers, architects, operations personnel	Input and output	Wall locations, door locations, furniture layout, light fixtures, finishes, mechanical systems, electrical systems
Maintenance and operations planning	Operations personnel	Resource, occasionally output	Equipment identification, cut-off locations, distribution capacity, design rationale
Equipment and cable management	Operations personnel	Resource, occasionally output	Equipment identification, cut-off locations, distribution capacity
Operations training	Operations personnel	Resource	Design rationale, equipment identification and location
Wayfinding	Customers	Resource	Wall location, door location, room identification

Table 2. Processes, participants and information that involve facility documentation.

ranking of most important. In particular, mechanical and electrical information categories were reported as both most important and least important. A lack of awareness of importance of some categories of facility information may lead to loss of information or a failure to record information that is needed by someone else. The use of an intranet could allow a higher degree of accessibility for all departments with an interest in a particular category of information.

technologies that may be solutions

Emerging information technologies provide new mechanisms for delivering operational facility documentation that could improve processes and increase satisfaction ratings for various categories of information. Both intranet and mainstream information systems such as CAD and Database Management Systems (DBMS) are likely to play a role. In this section, we will introduce some important emerging or under-utilized information technologies.

Hypermedia. One strength of intranet technology is simply its foundation as a multimedia hypertext environment. A proliferation of tools for integrating text, graphics, sound, animation, live video and other media allows solutions based on intranet technology to be very rich and appealing. The provision of links that allow a user to quickly move to related information further increases the richness and utility of the intranet. Intranet technology provides a relatively homogeneous interface to information that may be stored in many different applications and even on different hardware platforms. The homogeneous interface contributes to a perception of ease-of-use and approachability on the part of users. Because the standards behind the Web are relatively open, Web formats may be especially good for archiving facility documentation (Mays 1997).

As can be seen in the description of processes, much of the use of facility documentation is as a resource. When information is used as a resource, the notion of publishing the information is appropriate. Publishing distinguishes between authors and users (consumers). The HTML format that lies at the heart of intranet technologies is well suited to publishing.

Network Accessible Drawings. An inability to publish vector format CAD drawings has been a limitation of the Web. The DWF (Drawing Web Format) is an emerging standard for vector graph-

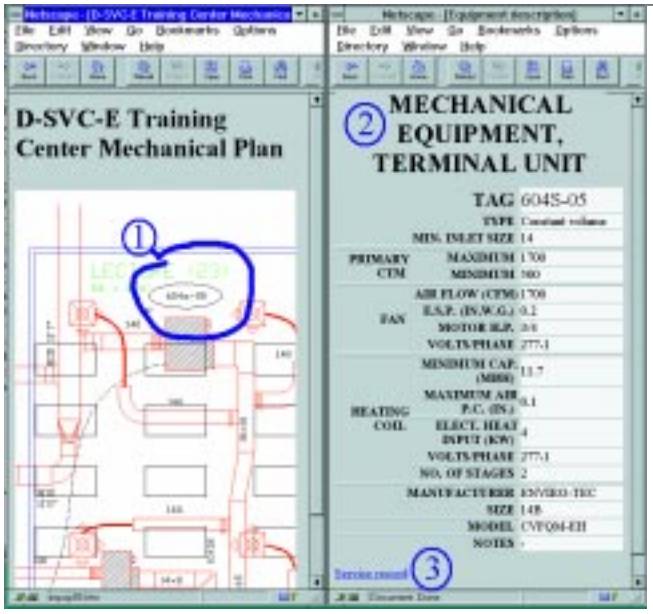


Figure 3. Retrieving operations information using Web technology.

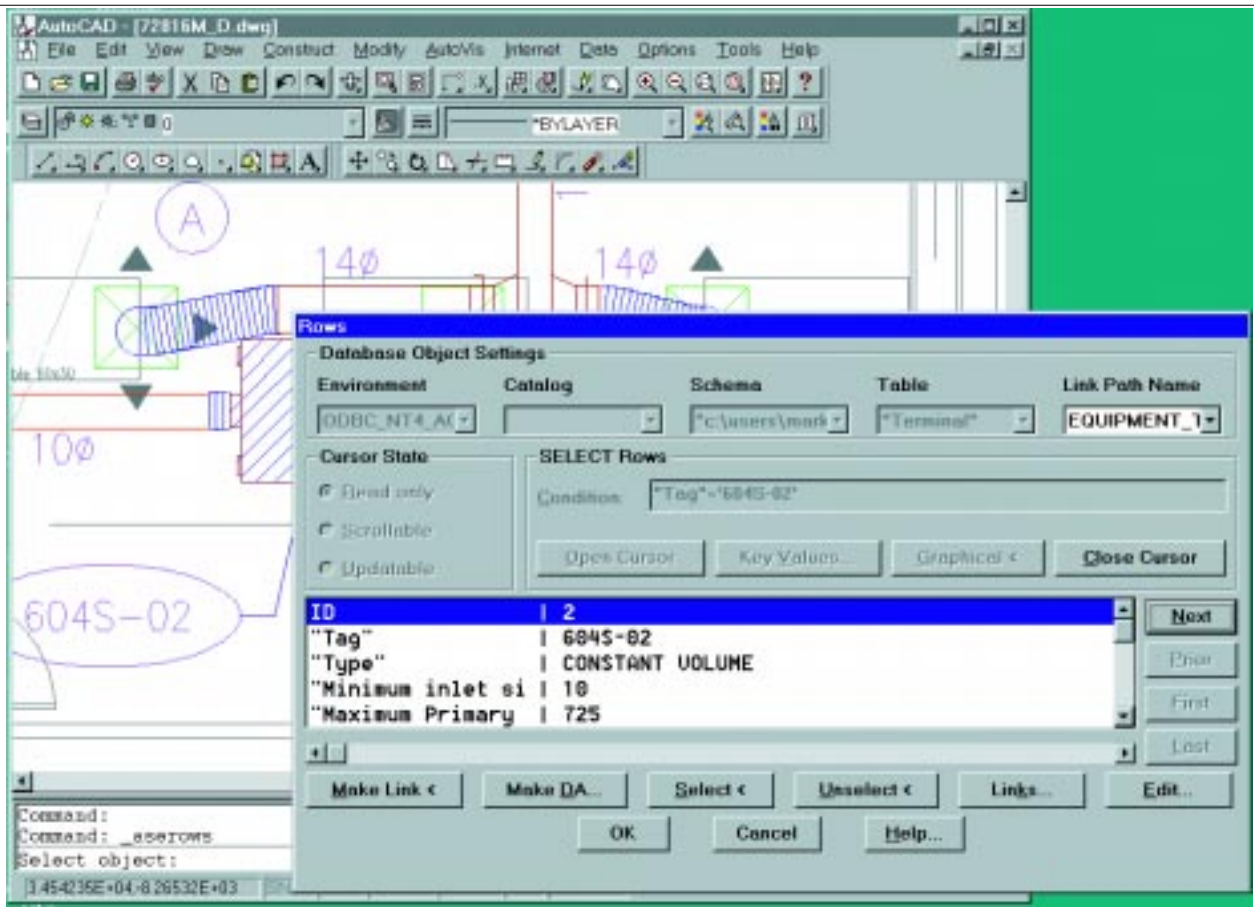


Figure 4. Retrieving operations information from within CAD software.

ics that are generated by CAD software for incorporation into Web pages. A user may pan and zoom them much like CAD drawings. Links to other Web pages may be embedded in the DWF file to associate vector entities or regions with other information. The links may also be queries to a database and the query results may be displayed as Web pages.

Technical Document Management Systems. When users in collaborative processes actively edit information, a publishing approach is less successful. With electronic publishing, the turn-around time for producing a document and distributing it can be reduced to merely minutes or seconds and thus electronic publishing can support collaborative processes. However, other capabilities are also useful, even crucial to using information as input and output. Managing revisions and versions, and routing information for approval or as a task assignment may be significant challenges. A company can implement solutions to these problems either through manual tracking or employing databases, perhaps in conjunction with intranet technologies to provide an interface. A commercial Technical Document Management system (TDM) is one way to automate these activities. Users may record changes in a quick and instructive way using electronic redlining. The redline changes can then be incorporated into the CAD drawings by technical drafting specialists. Version management capabilities help to assure that all process participants are using the latest version of the documents, while preserving a paper trail documenting the decision actions. Some experiments with tracking changes and routing information have been described in the earlier report on intranets for facility management (Al-Qawasmi et al. 1997).

OLE. Although not an intranet technology, Microsoft's Object Linking and Embedding (OLE), provides considerable utility in structuring complex documents. For example, a mechanical schedule could be prepared in a spreadsheet and then, using OLE, linked into an AutoCAD drawing. Because CAD drawings that are provided by consultants often end up as the basis for operations documents , the structure of consultants' drawings is important to the facility owner. The organization and formatting of information in documents delivered to the owner can aid in conversion of that information to internal formats that are of increased usefulness. Both internal standards for how to represent textual and tabular information and externally directed contractual provisions could expedite integration of information into a facility management information system.

Linkages between CAD and databases. Facility management has long taken advantage of linkages between CAD drawings and databases. Furniture inventories, mechanical equipment tag schedules, and finish schedules may all be represented using a SQL DBMS. Users may access the information from the CAD software. AutoCAD SQL Extension (ASE) is a well-established technology that allows AutoCAD drawings to be linked to SQL databases. Queries may be initiated from AutoCAD and the data incorporated into the AutoCAD drawings as textual attributes. The ASE interface provides ways to generate queries by clicking on AutoCAD entities and even editing the fields and values in the database.

Integrated vector and raster drawings. AutoCAD in its Release 14 version provides good tools for inserting raster graphics, such as scans or digital photographs, into drawings. The raster image may be displayed while a user creates new vector entities as overlays upon the image. The image may be sized to enable scaled dimensions and locations to be traced from it as a simple approach to photogrammetry. Facility managers can take advantage of these new capabilities of AutoCAD by integrating photographic surveys of facilities with CAD drawings. In particular, cable locations could be recorded with this technique, either by photographing cables before they become enclosed or even by using infrared photography to record "hot" wires that have already been enclosed.

VRML. Virtual Reality Modeling Language is a text format for representing 3D geometry that is adapted for distribution on the Web. Browsers such as Netscape and Internet Explorer have built into them the ability to display VRML models. A user can navigate through the virtual space, with perspective views changing dynamically as the user issues movement commands. VRML models may

also have links to other Web documents and may have code that performs animations or calculations embedded in them.

Although VRML is a very exciting technology, it currently pushes the processing power limits of desktop computers. Editing software for creating and modifying VRML models is still immature, although Autodesk has incorporated VRML editing into their 3D Studio Viz product. Most facility documentation is represented in two dimensions rather than three. Adding the third dimension often means entirely redrawing the facility. While standardizing all facility spatial documentation upon VRML is not practical, there may be some isolated applications that provide good returns. Use of VRML for showing customers the future layout of an office may enable customers to make decisions more rapidly in interior design projects. VRML models of distribution systems may be helpful in training. A riser diagram represented in 3D may be very helpful for new operations employees in understanding the systems and the connections.

SGML. Although Standard Generalized Markup Language (SGML) has rarely been thought of as a way of organizing drawings, it has been widely accepted as a technology for specifying the format of textual documents. Some of the principles of SGML could be useful in thinking about facility documentation. Specifying the format of documents independently of content allows the same content to be repartitioned and organized for different users. SGML provides a standard way of expressing the semantics and syntax of document components that could serve as part of the specification of an owner's formats. Some of the challenges with facility documentation involve sharing information among different users with different requirements for expressing the information. SGML has been widely fielded and good references are available (Travis and Waldt 1995).

example practices

Processes that strongly involve customers or use facility documentation as a resource might best be implemented with intranet technology. More complex processes that are undertaken by specialized facility management personnel may best be assisted by proprietary technologies.

We have prepared four scenarios of revamped processes that involve operational documentation. The preparation of these scenarios is a first step in rapid prototyping. The scenarios help to define the range of possibilities as well as develop a sense of cost and amount of effort needed for implementing a technology.

Scenario 1: Adapting data for integration. We undertook a test case to gain an understanding of the process by which facility documents that are provided by consultants could be imported into a more sophisticated facility documentation repository. The information from mechanical schedules in record drawings was moved into a combination of CAD, Web and database systems. The following steps were used:

1. The drawings, as delivered, were studied to determine their structure. We found that the information, although visually expressed as tables, was not represented using coherent records in AutoCAD. For example, an AutoCAD text entity might represent a single field in a table, several fields or a single record.
2. We wrote an AutoLISP routine to extract the fields from the schedules and write them to a text file using comma-delimited format (a comma was used to separate one field from another).
3. The comma-delimited tables were imported into Microsoft Access to create database tables, illustrated in Figure 1. As a test, the files were also imported into Excel.
4. The Access database tables were modified and adapted to provide primary keys and common field names to permit more optimal and sophisticated queries.
5. A Web browser interface to the database was prepared. DWF drawings were saved from AutoCAD with appropriate links embedded in them to allow queries to the Access database via the browser interface.
6. AutoCAD initialization files were modified to permit queries to the database directly from AutoCAD.

The process was moderately difficult in that it requires deep and broad knowledge of many dif-

ferent software tools. However, in terms of effort expended versus downstream benefits, reformatting the information in CAD drawings using these tools is a very realistic approach.

Scenario 2: Appropriate formats for delivery of facility documentation. Without making a large demand upon consultants, instructions can be developed that will encourage consultants to represent information in an appropriate format that provides increased flexibility and usability. The OLE technology is a straightforward way of collecting different kinds of information into compound documents. For example, schedules may be very easily represented as spreadsheet tables. These spreadsheets may be printed on 8.5 x 11 paper and included in a project binder or they may be linked into a CAD drawing. illustrates an Excel spreadsheet that has been inserted into an AutoCAD drawing. The spreadsheet may be relocated and resized by clicking and dragging. In appearance, it compares favorably to a schedule represented entirely with AutoCAD. Furthermore, the spreadsheet in AutoCAD is updated automatically when the spreadsheet is changed in Excel. The spreadsheet data can be manipulated with queries and calculations and may easily be imported into a SQL database. The same spreadsheet may be linked into other documents for other reports.

Scenario 3: Retrieving data for operations and maintenance. Figure 3 illustrates the third scenario. It involves the retrieval of information about a piece of mechanical equipment that may need repair or replacement. A mock-up of the scenario uses AutoCAD, Netscape and Microsoft Access database manager to illustrate how operational facility documentation could be delivered. In the scenario, a customer (a person from another department) has noticed that a piece of equipment is noisier than it used to be. The customer generates a request for service on that equipment. In the image on the left, a person from the Operations and Maintenance Department has retrieved a drawing of the mechanical equipment in DWF format using a Web browser. The next step is to find out more information about the equipment, so the person clicks on the equipment in the Web browser to initiate a query of the equipment database. In the image on the right, that information is displayed as a dynamically generated Web page. The person can click on another link to retrieve service records from the service database. The facility documentation is delivered in an integrated fashion to the point of need with an easy-to-use interface.

Other links that are not illustrated could retrieve HTML documents that describe the manufacturer's specifications of the equipment or the design rationale behind its selection. In this scenario, both the person in the Operations and Maintenance Department and the customer for the facility services receive more prompt and satisfying service.

Scenario 4: Retrieval of information during design. In a fourth scenario, Engineering and Construction personnel are studying the equipment in a part of the building to determine what will need to be redesigned. Their tools are AutoCAD and databases of equipment information. The databases are the same as in the third scenario but the querying tool is different: this time, ASE is used from within AutoCAD. A mouse-click on the equipment retrieves the associated record from the database, shown in Figure 4.

priorities and opportunities

Our discussions with facility management personnel have identified five requirements for operations documents:

1. They should describe the processes of operating the building, including the intents of the designers.
2. To allow a wider variety of queries and retrievals, they require less detail than construction documents but greater integration and more structured organization. A digital format is crucial.
3. They must incorporate a variety of kinds of information, including graphics, text, tables and operations manuals.
4. They should be accessible by personnel who are not in the design and construction industries.
5. They must be easy to change to allow incorporation of modifications to the facility, both routine and exceptional.

From our experiments with intranet technologies, we have gained some sense of the relative difficulty of applying emerging tools to problems in facility management. We suggest the following as priorities for more study:

- When facility information is being used as a resource in a process, intranet technology provides a strong set of tools for managing and distributing the information. In particular, the DWF format is a good way of delivering 2D vector graphics across an intranet. HTML may be effective in delivering information about design intent.

- Non-intranet technology has a role to play, especially for processes that primarily involve specialists. CAD software is an appropriate tool for interior designers, engineers and project managers to create and manipulate facility information. A technical drawing management system may also be an appropriate tool for managing updates, coordinating versions and assigning tasks. To a large degree, the CAD software can use the same databases as the intranet–based systems.

- Standards for documentation delivery from AE consultants could greatly ease the process by which consultant information is converted to owner formats. Consultants can use information formats that can easily be converted to internal databases, such as spreadsheets that are embedded into drawings for scheduled information. An owner can establish procedures for converting documents as delivered by architects and engineers to intranet formats, such as DWF, image formats and hypertext HTML.

- Feedback from operations is critical to maintaining the quality and accuracy of facility documentation. A technical drawing management system may help to manage the revision process. Digital redlining can be used to record changes that are made during maintenance and operations and incorporate them into operational drawings. A version management system can help to assure that old electronic drawings are properly stored and the latest changes to the facilities are reflected in current drawings.

- An in-depth study of work processes that involve facility documentation is necessary to determine the content for new information systems and the potential benefits of such systems. Rapid prototyping can be an effective way to involve customers in the development of appropriate and effective systems to support those processes.

In conjunction with Web-enabled CAD and conventional DBMS, Web-based technologies are becoming the medium of choice for facility documentation at the operations and maintenance stage. Familiarity, ease-of-use, versatility in supporting many kinds of information, and adaptability to archives are all contributing to this development. Further study can help clarify explicit practices by which design and construction information may be formatted and delivered for use in the operations stage of buildings. By anticipating the uses and forms of facility information downstream of design and construction, architects, engineers and constructors can more effectively structure and format descriptions of buildings and provide improved services to clients.

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