# OPERATIONS DOCUMENTS: ADDRESSING THE INFORMATION NEEDS OF FACILITY MANAGERS

Operations documents

M. J. CLAYTON, R. E. JOHNSON, and Y. SONG
CRS Center, Department of Architecture, Texas A&M University, College Station, TX, USA

Durability of Building Materials and Components 8. (1999) *Edited by M.A. Lacasse and D.J. Vanier*. Institute for Research in Construction, Ottawa ON, K1A 0R6, Canada, pp. 2441-2451.


## Abstract

We have reviewed intranet technologies as a strategy for improving the availability and quality of building information to support operations. Discussions with facility managers and design consultants have revealed problems with the as-built documents that are typically provided by the AEC team. Experiments with intranet technologies have led us to a concept of just-in-time operations documents that can be implemented using Web technology. The paper examines formats, structure and content for these operations documents. It describes an early prototype implementation that tested the feasibility of our concepts.

Keywords: as-built drawings, facility management, facility operations, information technology in facility management, maintenance management.

## 1 A mismatch of formats, structure and content

In the life cycle of a building, authorities suggest that the overwhelming majority of expenses occur during the operations stage. Arguably, facilities are the largest asset of many businesses (Rondeau, Brown and Lapides 1995). Maintenance, remodeling, replacement of components and daily facility operations consume a large portion of the cost of doing business. In comparison to the needs of design and construction, little attention has been paid to information needs of facility operators. Perhaps as a consequence, the topic of "as-built" information strikes a chord of concern among many facility managers. The "as-built" drawings or "record" drawings that are commonly delivered by designers are not an adequate information base for operating a building. The AEC industry needs new approaches to delivering and



structuring facility information for use by owners and operators.

These perceptions are supported by several research explorations. In a survey of master planners, facility managers and maintenance personnel at Army installations, researchers found that the as-built documents were often incomplete, inaccurate and poorly structured for supporting operations (Liu et al. 1994). In other discussions with facility managers, the issue of as-built drawings emerged as a problem area of widespread and intense concern (Johnson and Clayton 1998). The use of new information technologies to address these problems has led to our formulation of "operation documents" to specifically address the needs of the operations phase of a building (Clayton et al. 1998). While as-built drawings or record drawings are intended to document the constructed state or designed state of a facility, operations documents are intended to be dynamic, living records of the evolving state of a facility to support operations, maintenance and renovation.

The dissatisfaction with as-built drawings arises from multiple flaws. At a simple level, *formats* may be inappropriate. The medium for the representation may be wrong. The information may be delivered only as paper documents. Even digital documents may require a conversion effort to adapt the information to the operators' software systems. Beyond format problems, there may also be a mismatch in information *structure*. Structure is a meta-level characterization of general content that helps to define the semantics of the information. For example, layers in CAD drawings provide structure to the graphic information. However, layering conventions that support a design-oriented view of the information may not support the needs of owners and operators. Finally, there may be a mismatch in *content*. Information needed for operations may simply be missing. Almost as bad, there may be an overwhelming quantity of irrelevant information.

This paper describes a research effort to define better 1) the information needs of facility operators, 2) the delivery step by which that information may be collected from designers and other consultants, and 3) the opportunities afforded by new information technologies. The research was undertaken as a partnership with the Facility Operations Department of USAA, a Fortune 500 financial services enterprise. Although we have focused strongly upon the needs of USAA, we believe our conclusions are generalizable to other owners of large facilities. Within USAA, we focused upon mechanical, electrical, plumbing and control systems.

Our methods were the following. To define the issues and identify problems, we conducted discussions with USAA personnel and various design and construction consultants. We also familiarized ourselves with intranet technologies by review of literature and practical application. These studies helped us to conceive and clarify a vision of information systems to support operations. Rapid prototyping of that vision enabled us to prove the concept and demonstrate its feasibility.

## 2 Operations documents issues

Discussions revealed several themes that characterize building documentation to support operations. These are:

1. *Collections of diverse information.* The information used by operations personnel is complex and has diverse origins. Some of the kinds of information are architectural and engineering drawings, equipment schedules, riser diagrams, test and balance reports, equipment monitoring data, maintenance manuals, maintenance schedules, emergency procedures, and design rationale.
2. *Diverse delivery formats.* A wide variety of consultants, contractors and suppliers produce information without being aware of the information needs of operators. Information is delivered piecemeal in formats and structures that may be difficult to incorporate into an integrated information system.
3. *Integrated views across functional systems.* Rarely does the structure of facility documents support easy retrieval of information across discipline or system boundaries. While designers and constructors divide responsibilities to focus upon single systems, the building operators must perceive that all systems contribute to an interrelated whole.
4. *Feedback for document maintenance.* As-built drawings often become out of date with startling rapidity. 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.
5. *Support for training.* A particular problem area has been documents for training. Conceptual overviews, usage scenarios, and emergency procedures must be presented to new or transferred employees.
6. *Inclusion of design rationale.* Missing from current facility documents are clear and complete records of design rationale. Many questions arise during operations regarding the intentions of the designers. Design rationale is also an important component of training.
7. *Approachable technology.* The user interfaces of an operations document information system must be familiar and easy to learn. Operations personnel are not information specialists and should not be expected to master sophisticated but arcane commands, queries and paradigms.

## 3 Intranet technologies

We focused our search for solutions upon emerging information technologies that enable the creation of intranets. An intranet is a secure network that is internal to an organization and uses Web technology to distribute information and services. We have explored several basic technologies that can contribute to an intranet-based facility operations document system. These include:

- *Web browsers and HTML:* These are established and popular technologies for publishing across a network. Information resides on a server computer and is delivered to a client using the Hypertext Markup Language (HTML) format and

the Hypertext Transfer Protocol (HTTP). The server need not be the same hardware or software platform as the client. A Web browser provides a user interface by which people can request information from the server.

- *Relational Database Management System:* RDBMS systems, such as Microsoft SQL Server and Oracle, are a fundamental repository for information that is structured into fields and records. Open Database Connectivity (ODBC) is a widely supported standard for performing queries on many brands of RDBMSs.
- *Active Server Pages (ASP):* ASP is Microsoft's tool for including programming logic into the delivery of information on the Web. 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. Thorough manuals on the use of ASP are available through the commercial press (Johnson 1997).
- *Drawing Web Format:* DWF is a file format established by Autodesk for vector drawing information on the Web. 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:* Extended Markup Language (XML) provides enriched structure to Web documents that enables machine processing to support multiple uses. XML is closely related to Standard Generalized Markup Language (SGML), a proven technology for defining the structure for classes of documents. With XML one can define new, custom tags in a Document Type Definition to enable machine parsing and manipulation.
- *On-line redlining:* A number of tools are 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 the suggested changes.

## 4 Just-in-time operations documents

The use of hypertext for operations manuals has been established in the process plant industry (Tidwell and Leckington 1994). Emerging intranet technologies in the context of operations documents has led us to formulate a concept of "just-in-time operations documents" that extends and refines earlier work. Our vision is that information technologies can actively and automatically retrieve and collect relevant information from data repositories in response to task-oriented requests by operations personnel. Rather than relying upon ill-structured archives of information or at best upon a comprehensive operations manual, operations personnel can be provided with concise, complete documents that are focused upon a task at hand. Emerging Web technologies provide the means for implementing this vision on a corporate intranet.

Our concept relies upon facility information being recorded and stored in electronic formats and structures. Three technologies in particular appear highly relevant. Conventional drafted representations of the facility must be created using Web-

enabled CAD systems with hyperlinks embedded into the drawings. Client-server relational databases provide repositories for tabular data. Text that does not lend itself to a tabular presentation can be tagged using XML to relate it to the information in databases and in Web-enabled drawings.

Key to the concept is the programmatic generation of operations documents that are specific to particular tasks. We refer to this as "task-centric." A person involved in operating the facility can request an operations document by filling out forms in Web documents. The forms collect specifics of task and location. A Web server can then match the parameters against rules to choose a template for the task-centric documents. A script can then retrieve bits of information from various sources and bring them together into a custom document. This document is then delivered in HTML format back to the requestor.

Task-centric documents may be explained using an example. One task that operations personnel may face is the repair or replacement of a faulty fan-coil unit. Upon discovering that a unit is performing poorly, a technician must inspect a variety of documents to troubleshoot the problem:

- the drawings of the mechanical system,
- the manufacturer specifications,
- the test and balance reports for the distribution tree,
- diagrams of the electrical circuits that feed the unit,
- diagrams of the chilled water delivery pipes,
- the performance record produced by monitoring and controls systems,
- the maintenance records and
- the design intent for the unit.

At present, this information must be collected from a variety of drawings, memos, binders and documents, most of which exist only on paper and buried within irrelevant other information. A task-centric document would filter out the irrelevant information and collect these and many other pieces of information into a single project manual. The technician could then refer to the task-centric document for most or all of the information for the project. The concept of just-in-time operations documents adds to this task-centric approach automation that collects the many pieces of information on demand by the user.

## 5 Implementation

Emerging intranet technologies provide a technical foundation for implementing an effective information system for operations. We have conducted tests in the form of rapid prototypes of software to establish architecture and design principles for such an information system. Some of the major components of the system as we envision it are 1) generic repositories of facility information; 2) a link farm; 3) XML documents recording design rationale; 4) server procedures that generate Web pages; and 5) electronic redlining. Although the creation of a prototype is still underway, these concepts appear to us to be likely or inevitable parts of an information system that is a solution to the needs of facility operations.

### 5.1 Generic repositories

The problems of coordinating the delivery of facility information suggest that a successful information system will impose minimal restrictions upon outside information providers such as design consultants and construction contractors. Rather than mandating delivery of information in sophisticated standard formats and structures, we suggest that outside providers can employ tools that are widely accepted and deliver facility information in simple and straightforward formats and structures. The adaptation of the information for use in internal information systems can be deferred to the owner/operator organization. As long as information is delivered in digital format, it can be massaged to conform to the needs of internal information systems.

We suggest that an owner organization should emphasize delivery of information in "natural" formats. For example, drawing information should be delivered in a vector format such as Autodesk's DWG or DWF. Schedules, such as door schedules, window schedules, and pump schedules, are tabular information. They should be delivered not as images drawn in the CAD system but as spreadsheet or database tables. Test and balance reports are also tabular by nature and should be delivered as spreadsheets or database tables. Design rationale or operations procedures should be delivered as word-processed documents. These formats and structures place minimal or no demands upon consultants. In some cases, use of the appropriate format may even lead to savings to the consultants.

The degree of structure that should be provided by consultants is an open question and also a moving target. At one extreme is the idea of very little structure to information when it is delivered. Structure must be applied either as a "data scrubbing" step by the internal personnel or must be created on the fly by scripts. This pole requires little expense on the part of the external organizations but a high degree of expertise on the part of internal personnel. At the other extreme are strict requirements for format, structure and content to which consultants must conform. Outside consultants may demand increases to fees to offset perceived effort and risk. The second approach also requires a large degree of up front effort to formulate the standards. As consultants become more savvy with Web technology there should be an opportunity to out-source more of the responsibility for structuring information.

At this time we suggest that a facilities organization can collect facility information from consultants in appropriate formats but with a relatively low level of structure. After receiving information in these natural formats, personnel in the owner/operator organization can place it into repositories by type, such as a directory of drawing files, or a database of pump data, or a directory of design intent descriptions. By using scripts, macros and automatic conversion utilities, the owner organization can convert the data into the specific formats and structure required by the information system. Scripts can carry out further manipulation and refinement of facility information at time of use under the concept of generating task-centric documents.

### 5.2 Link farm

Key to making use of the generic repository of information is the application of powerful data management tools to the hyperlinks themselves. The term "link farm" refers to a collection of hyperlinks that can then be incorporated into one or more documents (Light 1997). A level of indirection in links adds utility to the links. The apparent link, embedded in an HTML document, actually points to the link farm. The link farm retrieves the actual link and delivers the requested document. By implementing the link farm using a relational database, sophisticated operations upon selection sets of links may be used to increase the utility of the link mechanism. One-to-many links, many-to-one links and context-sensitive links can be easily implemented to provide users with an enriched access to information. The database can also be used to manage links, such as redirecting links to accommodate changes in file locations, and global substitution of links to up date information.

Not only does the link farm play a role in managing links, it can also provide strategic information for the continued growth and refinement of the information system. The link farm can log link traversals and collect data from the users regarding usefulness of information. Developers and maintainers of the system can use the automatic feedback to anticipate information needs and prioritize conversion of existing documents into the information system.

A link farm for operations documents is illustrated in Figure 1. It has been implemented using a Microsoft Access relational database. Each link is represented by a record in the table. Many links that are embedded in drawings or text files can be represented by the same record, providing many-to-one linking. Also a single link in a drawing may lead to more than one record in the table, providing one-to-many linking. Links may be retrieved by queries upon any field or combination of fields. Side effects of queries also create records in another table to log the use of links.

### 5.3 XML for design rationale

Documentation of design rationale for use in training manuals, troubleshooting and redesign is important enough to warrant special consideration. XML could be an appropriate technology for addressing design rationale. Using XML would require developing a document type definition (DTD) that can be used to express design rationale. A DTD defines the semantics and syntax of tags that can be embedded in a text document to indicate structure and meta-content.

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 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.

Additional research is necessary to establish useful standard structure and content for design rationale. We are exploring the use of concepts of form, function and

behavior as guiding principles for documenting design rationale. Form (sometimes termed "structure"), function and behavior have been established as a useful formalism for representing design reasoning (Kuipers 1984, Gero 1995). Text could be tagged both by component and as form, function or behavior. Scripts could then retrieve from the XML document the appropriate information to compose "just-in-time" training manuals or task-centric explanations of design intent.

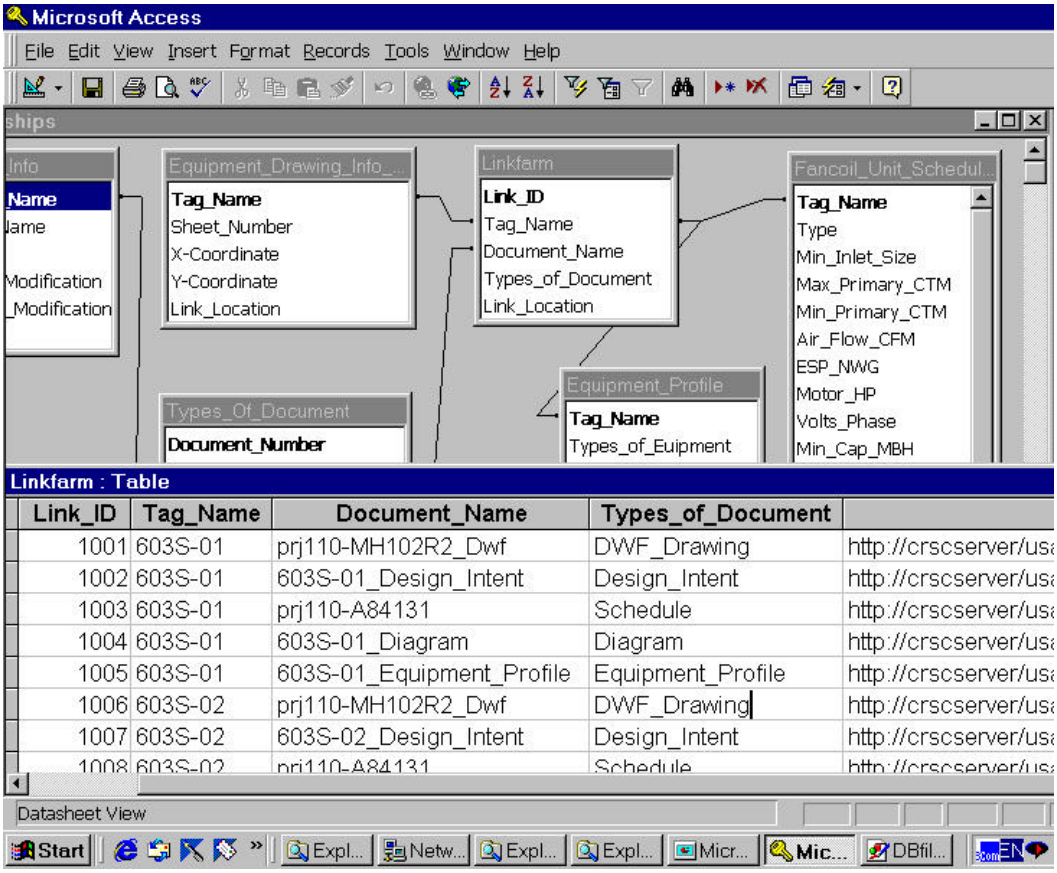


**Fig. 1: Link farm for just-in-time operations documents**

### 5.4 Generated intranet pages

Our experiments have employed Microsoft's Active Server Pages to generate HTML documents on the fly. Links to records in the link farm are embedded into drawings and text documents. JavaScript and VBscript are used to define templates that receive arguments declaring the project and the context for the requested information. Upon traversing a link, the scripts take over to produce customized HTML documents that are delivered back to the requestor. The script can retrieve data from a database, drawing files, and images and blend them with fragments of HTML code. An example of a just-in-time operations document is shown in Figure 2.

The operations documents created with this system are tailored to the particular needs of the operations personnel. Of course they can be printed, but they may also

exist only as digital documents for the moments that they are referenced. The operations documents are transitory and are delivered just in time to support a particular task.

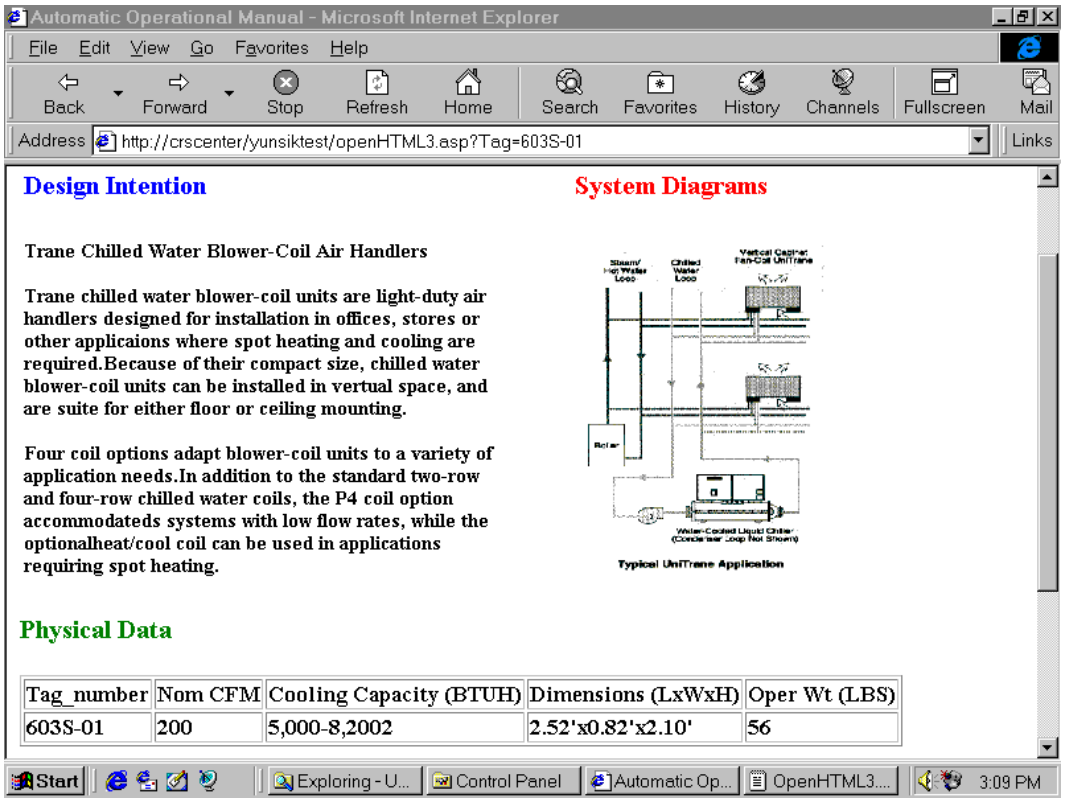


**Fig. 2: Example of just-in-time operations document showing the design intent, system diagram, and scheduled information.**

## 5.5 Electronic redlining

Feedback to the information system is crucial to keep the portrait of the facility up to date. Forms to collect feedback for a project can be automated with ASP. Upon a query for facility information for a particular task, a work flow management capability of the information system could monitor progress. The system could produce a form to collect comments regarding the adequacy of the documents that were generated for the project. The software guides the user through updating the documents to reflect new conditions.

Our prototype incorporates CADViewer by ArNoNa Internet Software Inc., an electronic redlining tool written in Java that works with the DWF format (ArNoNa 1998). 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 serve as feedback by which documents are kept up to date.

## 6 Further explorations

Our working prototype has led us to confidence in the vision portrayed above. An appropriate next step is to implement further to sharpen our perception of technical challenges and obstacles. Empirical testing of a trial system can provide subjective evaluations by actual operations personnel. Comparative trials can determine the extent of benefits of such a system in improved performance by building operators. By keeping track of the time that is spent building the just-in-time operations documents system, we can gain quantified indicators of the expense of such a system when it is scaled up. The link monitoring features of the link farm can guide further development.

Once sufficient experiments are executed in the laboratory, the implementation can be moved to the field. Initially, the implementation could address just one unit of the facility, such as a section of a building or a small building. Detailed records of personnel time expended in constructing and maintaining the information system will provide data for cost/benefit analysis of a full implementation. After a time period, field surveys can compare the actual facility against the operations documents to see whether the feedback has been effective. A field survey of a facility unit that has been managed with conventional paper documents can establish a benchmark.

By conducting discussions with industry personnel and examining current documents, we have obtained an understanding of information that is needed to support operations. A thorough survey of intranet technologies has then led us to envision "just-in-time operations documents." Quick experimental prototypes with example facility documents have allowed us to prove the technical feasibility of the concept. The prototypes have led to the clarification of an extensive research program that is likely to lead to quantifiable and significant benefits. The findings can then be directed toward the broader industry and have an impact upon standards that lead to widespread increases in productivity.

## 7 Acknowledgements

This research has been made possible by a partnership between the CRS Center, Texas A&M University, and USAA Facilities and Services. All analyses and opinions in this report are the sole responsibility of the authors.

## 8 References

ArNoNa Internet Software. (1998) http://www.cadviewer.com/

Clayton, M. J., R. E. Johnson, Y. Song and J. Al-Qawasmi. (1998) Facility operations documents using interanets, in *Computing in Civil Engineering,* American Society of Civil Engineers, New York, 868 - 877.

Gero, J. S. (1995) The role of function-behavior-structure models in design, in *Computing in Civil Engineering*, vol. 1, American Society of Civil Engineers, New York, pp. 294 - 301.

Goodman, D. (1998) *Dynamic HTML: The Definitive Reference,* O'Reilly & Associates, Cambridge.

Kuipers, B. (1984) Commonsense reasoning about causality: deriving behavior from structure, *Artificial Intelligence* 24: 169-203.

Liu, L. Y., A. L. Stumpf, S. S. Kim, and F. M. Zbinden. (1994) Capturing as-built project information for facility management, in *Computing in Civil Engineering*, vol. 1, American Society of Civil Engineers, New York, 614 - 621.

Light, R. (1997) *Presenting XML.* Sams.net Publishing, Indianapolis.

Johnson, R. E. and M. J. Clayton. (1998) The impact of information technology in design and construction: the owner's perspective, *Automation in Construction* 8: 3-14.

Johnson, S. (1997) *Special Edition Using Active Server Pages.* Que Corporation, Indianapolis.

Rondeau, E. P., R. K. Brown, and P. D. Lapides. (1995) *Facility Management*, John S. Wiley and Sons, New York.

Tidwell, M., and C. Leckington. (1994) Computerized facility information management systems, in *Computing in Civil Engineering*, vol. 1, American Society of Civil Engineers, New York, 396 - 401.