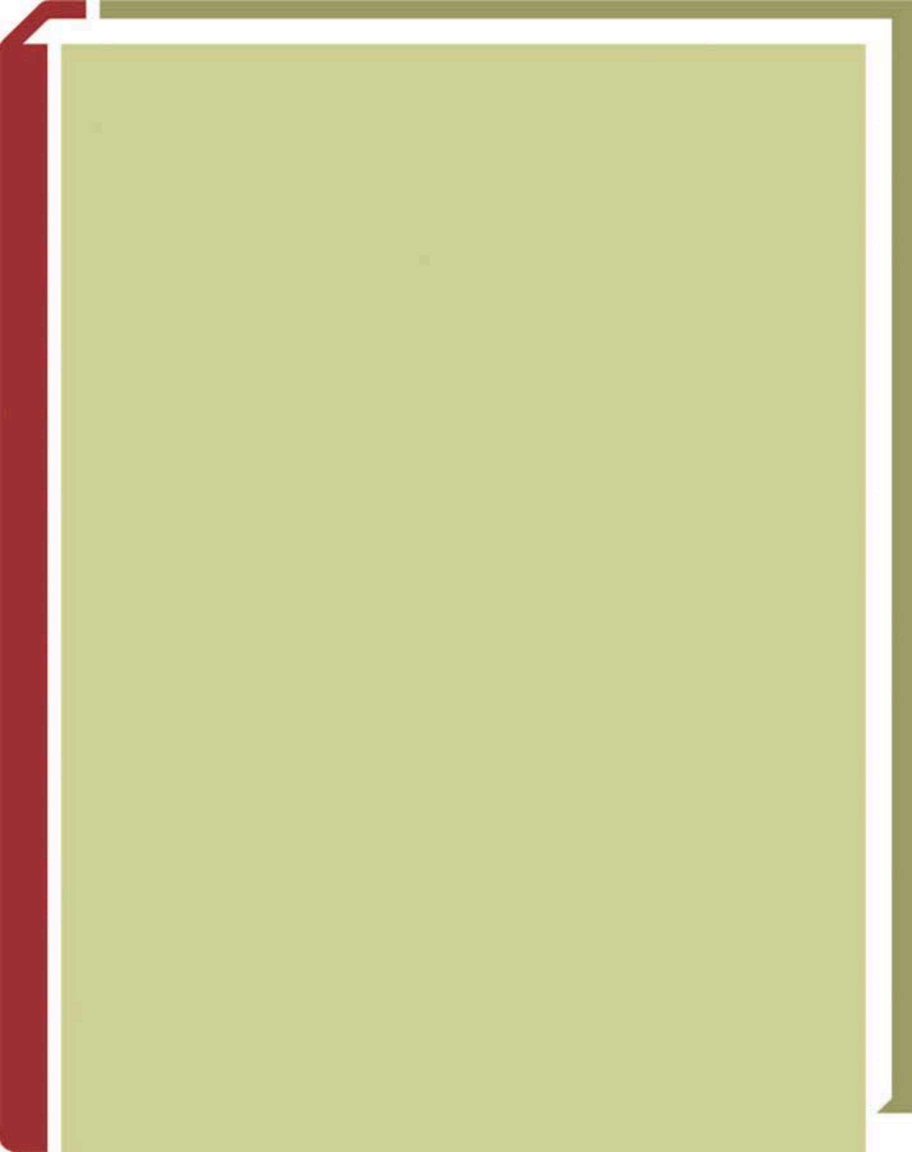

# Tools for Evaluating the Metropolitan Medical Response System Program: Phase I Report


Committee on Evaluation of the Metropolitan Medical Response Program

Board on Health Sciences Policy

INSTITUTE OF MEDICINE

Frederick J. Manning and Lewis Goldfrank, *Editors*



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*Knowing is not enough; we must apply.*
*Willing is not enough; we must do.*
—Goethe

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## INDEPENDENT REPORT REVIEWERS

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations nor did they see the final draft of the report before its release. The review of this report was overseen by **LESTER N. WRIGHT,** Chief Medical Officer**,** New York Department of Correctional Services, Albany, New York, appointed by the Institute of Medicine, who was responsible for making certain that an independent examination of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

This report is dedicated to Ray Downey, Chief of Rescue Operations, Fire Department, City of New York, our friend and colleague on this Institute of Medicine committee, lost to us while leading rescue efforts at the World Trade Center after the terrorist attack on September 11, 2001.

# Preface

When our committee began in the fall of 2000 to evaluate the potential of the Metropolitan Medical Response System (MMRS) program to enhance local ability to respond to the consequences of weapons of mass destruction terrorism, I could not have imagined the tragedies that would befall us as committee members and as a society.

Many of us on the committee have had personal losses from the assault on the World Trade Center and on our sense of physical and psychological safety. We are all deeply saddened by the death of Raymond Downey a longtime fire department veteran and expert in urban search and rescue who was a key committee member. His death is a great loss and his wisdom and leadership on our committee will be sorely missed. My department of emergency medicine at New York University Medical Center was among the hospitals that treated the critically ill and injured on September 11, 2001 and helped many individuals cope with traumatic stress in the ensuing weeks. Now the department is focusing immense energy on preparedness for potential future terrorist actions. Committee member Fred Henretig was involved in the care of victims and rescuers in New York as a member of a Disaster Medical Assistance Team from the Philadelphia area, and committee member Joe Barbera provided on-site advice on search and rescue operations at both the World Trade Center and the Pentagon.

Although much of the work described in this report was completed prior to September 11, 2001, our analysis of the MMRS program and means to assess it remain valid. This disaster has taught us: that decentralization of our resources is essential; that communications with rescue- and hospital-based systems are fragile; that the psychological impact on the families, friends, coworkers, city and country members cannot be overestimated; that hospital readiness may be far greater than is widely believed, even if severely compromised in the midst of disaster; that massive private and public resources can be mobilized very rapidly and very effectively in the face of a disaster; and that the enormous altruism and humanism of Americans permit a civic response that rapidly leads to optimism in the face of crisis and reaffirmation of the power of a democratic society.

This horrible event has allowed those of us working in New York City hospitals to understand terrorism better through the actions of our patients: the walking wounded who stayed away from healthcare for several weeks, the seriously ill who waited hours so as not to burden us, and the many suffering people who wished to talk, cry or sit in our healthcare centers.

The events of this Fall will allow people at all levels in our society to appreciate the importance of the MMRS concept. It is my belief that our committee's work will greatly aid the efforts of the Office of Emergency Preparedness (OEP) to analyze the disaster readiness of our cities. It is obvious that greater resources, stronger commitment to broader preparedness involvement and the study of terrorism, clearer understanding of the issues in question, and true interagency collaboration should follow logically from the recent terrorist assault. These changes in governmental vision and leadership will be essential to not only meet the letter, but the spirit of the contracts OEP has been signing with major cities. It is our hope that by analyzing preparedness we will decrease the risk from natural and intentional assaults on our environment and our well being.

We look forward in the second part of our project to developing creative strategic mechanisms for improving OEP analysis of preparedness for biological, chemical, and radiological terrorism. Our country and our people are entitled to a national approach to these problems based on a strong public health system. We, as a committee, are more motivated than ever to enhance mechanisms for assessing our country's preparedness.

Lewis Goldfrank
Chair
October 10, 2001

# Contents

# 1

# Introduction

## BACKGROUND

Information technologies include the entire field of computer-based information processing (i.e., hardware, software, applications, and services, telecommunication links and networks, digital databases, and the integrated technical specifications that enable these systems to function interactively). Information technologies are a major force in the U.S. economy and new applications are being developed and deployed into the marketplace on an 18- to 24-month cycle. Government, industry, and academia are investing millions of dollars and thousands of hours researching and developing information technologies to serve a wide spectrum of purposes. Available and emerging information technologies are changing business processes and practices; how products and services are manufactured, purchased, and delivered; and how people live, learn, work, and communicate.

The architecture-engineering-construction (A-E-C) industry, is also a major force in the U.S. economy. The sector is comprised of about 1.25 million companies, generating about 6.7 percent of U.S. employment. New construction accounted for about $705 billion of the Gross Domestic Product in 1999, $1.07 trillion if repair and maintenance expenditures are included.

Information technologies have the potential to transform the A-E-C industry and facilities management in the twenty-first century by changing the processes through which buildings are created, operated, and managed. It is estimated that more than $600 million was invested in dot.com and technology-related ventures in the A-E-C industry in 1999, with an additional $600 million invested in the first nine months of 2000.

Buildings, in contrast to software applications, take 2-5 years to design and construct and are built to last at least 30 years, although many are used 50-100 years or longer. The federal government owns more than 500,000 facilities worldwide and spends upwards of $20 billion per year on building design, construction, and renovation. It spends additional billions on information technologies and the salaries of the 1.9 million people who work in federal facilities.

Available and emerging information technologies hold the promise of enhancing the quality of federal workplaces; supporting worker productivity; improving capital asset management, programming, and decision making; reducing project delivery time; and changing how buildings are constructed and operated. Federal agencies, however, face a significant challenge in identifying technologies that will justify the investment of time, dollars, and resources, will have the flexibility to adapt to changing circumstances over the longer term, and will not be obsolete before they are deployed.

## PURPOSE OF THE SYMPOSIUM

To begin to address these challenges, the Federal Facilities Council (FFC) sponsored a symposium entitled "Emerging Information Technologies for Facilities Owners: Research and Practical Applications" at the National Academy of Sciences in Washington, D.C., on October 19-20, 2000. The symposium featured speakers from academia, the public, non-profit, and private sectors. It was attended by some 175 people representing 27 federal agencies, private sector firms, local governments, and professional societies. The FFC is a cooperative association of federal agencies having interests and responsibilities in all aspects of federal facility acquisition, operation, and management. The mission of the FFC is to identify and advance technologies, processes, and management practices that improve the planning, design, construction, maintenance, management, operation, and evaluation of federal facilities.[1]

The purpose of the symposium was to bring together building industry stakeholders from government, the private sector, and academia to begin to identify:

- information technology trends;
- the potential impacts of information technology on facility planning, design, construction, and operation processes, and the people involved in those processes;
- issues facilities owners should consider when planning and purchasing information technologies;
- issues facilities owners should consider in managing the impacts of information technologies on people and processes;
- information technology initiatives being developed by government, academia, and the private sector to support various aspects of facility management; and
- research needs and opportunities for additional collaboration.

## RECURRING THEMES

Neither the speakers nor the members of the audience were asked to arrive at a consensus on emerging information technology issues for the A-E-C industry or the federal government or to make recommendations for resolving such issues. Over the course of the two-day symposium, however, a number of recurring themes and issues emerged.

**Information technologies and applications promise to transform facilities design, construction, and management but are still in the early development and adoption phases.** Computing power is increasing exponentially; one speaker projected that by 2015 microprocessors will have one million times the power they have today. Computer memory, bandwidth, storage capacity, and graphics processing technology will see similar increases in capacity over the same period, and advances will be made in display resolution. Digital cameras that can capture images and geometric data simultaneously will be developed. Wireless technologies, such as Palm Pilots and cell phones, will link into computers and thus provide mobility by allowing people to input or access data from the field. Ongoing initiatives in data standards include interoperability (defined as the development of object class libraries to enable integration at the application programming interface level) and aecXML, a computer language that supports the use of the World Wide Web as a giant database by tagging information so that data can be shared, moved around, and used in intelligent applications.

[1]The Federal Facilities Council sponsor agencies are the U.S. Air Force, Air National Guard, U.S. Army, U.S. Coast Guard, U.S. Department of Energy, U.S. Department of the Interior, U.S. Navy, U.S. Department of State, U.S. Department of Veterans Affairs, Federal Aviation Administration, Food and Drug Administration, General Services Administration, Indian Health Service, International Broadcasting Bureau, National Aeronautics and Space Administration, National Institutes of Health, National Institute of Standards and Technology, National Science Foundation, Department of Defense, Smithsonian Institution, and the U.S. Postal Service.

For the A-E-C industry, some application developers are stating they will have computer-aided drawing applications on the World Wide Web by 2003. In the longer term, advances in processing speeds and new display technologies will help enable designers to move from modeling and then rendering to rendering while modeling: Software is being developed that will transform an architect's sketches into preliminary drawings and simulations that can then be reviewed and ultimately turned into working drawings and construction documents. The next generation of digital cameras will allow designers working in an urban environment to take pictures of the surrounding buildings and have the information automatically become a database that can be used to design in context. New display and projection systems will allow architects to immerse themselves in the space they are designing. A number of these new technologies are being developed, tested, and used in academic settings today.

A government-industry consortium is considering development of cost-effective technologies for collecting, compiling, and maintaining field data for actual representations of buildings. Advanced sensing and scanning tools would be used to collect the data, wireless technology for moving the data where they are needed, visualization software for providing meaningful representations of the data, and analysis software for verifying the results. High-quality, interactive simulation tools would be used for developing three-dimensional models of facilities, checking out operating procedures for new facilities, and gauging the impact of introducing a new technology. A design team, owners, and contractors would immerse themselves virtually in a proposed design to determine whether the design meets their needs.

Traditional computer-aided facility management (CAFM) applications (lease management, maintenance management, space inventory, asset management) are all migrating to the World Wide Web to be joined by new applications, designed for energy management, e-commerce, and assessment of facilities for portfolio management. The objectives are to provide for information integration and improved facilities management.

By 2002 most CAFM applications will be offered by application service providers (ASPs), a third party that provides the telecommunications infrastructure and operates and maintains a database that users can access via their browsers for a fee. For data users, contracting with an ASP can eliminate some costs for computer hardware, memory, data management, and training. The financial models for such application service providers, however, have not been well developed, and there are few profitable ASPs in the market today.

Interest in developing e-commerce, e-business, and e-process applications for the A-E-C industry is high because of the size of the industry and its potential market. E-commerce was defined as conducting business communications and transactions among companies over the Internet. A survey of Fortune 500 companies focusing on the impact of e-commerce on facilities management practices found that the use of business-to-business e-commerce is just emerging. The top uses of e-commerce were purchasing supplies and materials from a specific vendor or through an Internet service that connects buyers and sellers; accessing facilities manuals; publishing static project information; and taking interactive courses. There is a pattern of increasing use of the Internet to do more traditional facilities management activities, but purchasing seems to be a core use that is providing payoffs. About one-quarter of the responding companies reported that e-commerce will change their facility management departments "a lot" by 2003. One of the biggest issues and barriers to implementing e-commerce is integrating existing legacy systems into newer, Internet-based applications.

Internet portals, or extranets, offer the opportunity to integrate technology services and information that professionals can use to design a building, manage a geographically dispersed project team, bid on and procure building materials and services, access building product specifications from manufacturers, and manage completed facilities. Project extranets—defined by one speaker as project management and project-specific Web sites that encourage interdependence, flexibility, and partnership—are in the early stages of adoption. The speaker cautioned that the first generation of extranets is so pioneering that users should carefully consider a range of issues, including data security and trusted content, process, business relationships, mobility, linkage with legacy systems, customer support, and the ability to customize interfaces, before contracting for an extranet service.

**Information technologies have the potential to seamlessly connect facility management processes and practices and to enhance productivity, but barriers remain to the realization of these objectives.** There is a growing gap between an architect's design and its realization during construction because of the large number of complex systems and processes involved in creating a building. Fully integrated and automated project processes—the seamless integration of information flow throughout a facility's life cycle—from concept to design, construction, operation, maintenance, and dismantling—is a vision supported by stakeholders in the building industry. The technologies for such systems would be characterized by one-time data entry; interoperability with design, construction, and operation processes; and user-friendly input and output.

The projected benefits of fully automated and integrated systems include reduction of design changes and rework; improved project scheduling and control; improved supply chain management; improvements in construction safety; development of accurate as-built information for future operation, maintenance, and renovation processes; and a reduction in the total life-cycle costs of facilities. However, a significant number of obstacles must be overcome before the vision of seamless connectivity with a concomitant increase in productivity can become a reality.

One obstacle is the nature of the A-E-C industry, which is fragmented, local, and lags behind other economic sectors in the introduction of technology. In the United States, there are 1.25 million companies in the A-E-C sector, the majority of which operate in a local or regional market. Ninety percent of these firms employ 10 or fewer people, and a typical firm has only one computer. The average life of a subcontracting firm is less than three years, thus firms are entering and exiting the industry on a regular basis. For those reasons and others, productivity in this sector has actually declined since 1965. At this time, there is no common, single voice for the industry or a roadmap for developing fully automated and integrated project and process systems, although a consortium of public- and private-sector entities has been established to take on these responsibilities.

The development and deployment of new technologies requires substantial investments, but few A-E-C firms invest in research and development. Most operate with a short-term outlook and are susceptible to downturns in the economy. The research and development that is taking place is primarily funded by the government and is occurring in academic settings or is being funded by private-sector technology firms seeking to market their products to the A-E-C industry. Even when an innovative technology or process is developed, it is difficult to get people to commit to it because of the high degree of risk and uncertainty associated with changing long-standing processes and practices.

The development of fully automated and integrated applications requires substantial bandwidth, which is not yet routinely available. Interoperability standards—to promote compatibility among various computer platforms, languages, and applications or that will allow private-sector individuals and companies to build proprietary technologies on an open platform—are still in the early development stages. Although standards are a fundamental requirement in developing fully automated and integrated systems, only a few organizations are investing time or money in standards development.

**Integrating technology infrastructure with the social and physical infrastructure of an organization presents major challenges.** Today, information technology infrastructure is typically in one part of an organization, human resources in another, and facilities operations in a third, with little interaction among them. To reap the full benefits of information technologies, organizations need to understand where these functions overlap and to systematically design for them as an integrated whole.

Managing the impact of information technologies on an organization's processes, people, and culture will require new skills and training on the part of facility managers. An organization or manager first should understand the nature of the work and then determine how information technologies can help and when they can hinder interaction and understanding. As organizations employ technologies that move information from "stove pipes" owned by individuals to the World Wide Web, where information is shared, managers need to understand that traditional relationships among people and offices will change. If managers do not anticipate and plan for these changes, they are likely to encounter resistance to adopting the new systems and even the undermining of such initiatives by individuals who view the systems as a threat.

To use new technologies effectively managers should consider who will be using them, where, and how they will be used. For example, research is finding that people spend much more time in solitary work than in teamwork. Procedural work (such as status checking, report writing, schedule coordination) can be done independently at any time by individuals, and information technologies can be useful in these activities. One key factor in using information technologies effectively is to network people who work independently with those who work in teams.

Information technologies can also enhance collaboration processes, but there must first be a reason to collaborate. Collaborative, interactive processes themselves require interactions and debate that is often better done face to face than electronically. Face-to-face social interactions involve eye contact, gestures, body language, and other senses that allow one to judge how people are reacting to an idea. Such social interactions allow team members to build relationships and establish trust. Electronic interactions, in contrast, are very task focused, lack a context, and have less accountability. Work is being done in universities and elsewhere to add social and emotional context to electronic interactions.

**Understanding how to use information technologies to leverage and manage institutional knowledge is a significant challenge for organizations.** The essence of information is that it can be readily translated into bits that can be detached, moved around, and transferred across time and space. For transferring information the Internet is ideal. Knowledge, in contrast, is connected to a person. Knowledge is cognizance or understanding gained through relationships, communication, mentoring, and experience. When an organization fails to recognize the differences between information and knowledge its people will spend too much time exchanging bits of information (because it is easy to do so) and insufficient time analyzing the information to understand what it means to their work.

Organizations are seeking to develop ways to capture and institutionalize the tacit knowledge that resides in their people through the use of information technologies. The objectives of knowledge management systems include leveraging experience by interaction among peers; retaining knowledge in anticipation of retirements; facilitating customer support, improving response to calls for information; enhancing decision support; and improving linkage with operations. Knowledge management systems that limit access to sensitive information can create conflicts between those seeking to collaborate and those striving for security of sensitive information.

## ORGANIZATION OF THIS REPORT

Summaries of symposium presentations are contained in the following chapters. Chapter 2 provides an overview of emerging information technologies for facilities owners. Chapter 3 looks at how information technologies may change the A-E-C industry. Knowledge management is the focus of Chapter 4. Chapter 5 provides a sampling of new information technology tools that support the development of fully integrated and automated facilities management processes.

# 2

# Emerging Information Technologies for Facilities Owners

Mr. Eric Teicholz of Graphic Systems, Incorporated, reviewed the migration of computer-aided facilities management (CAFM) applications to the Internet. Dr. Donald P. Greenberg of Cornell University outlined emerging trends in computing, person-machine interfaces, and display technologies. Mr. Paul Doherty of The Digit Group discussed how extranets are changing design, construction, and facilities management.

## COMPUTER-AIDED FACILITIES MANAGEMENT AND THE INTERNET

### Summary of a Presentation by Eric Teicholz President, Graphic Systems, Inc.

The history of computer-aided facilities management (CAFM) dates back to the early 1960s when space forecasting and inventory applications were first run on expensive mainframe computers by people writing their own programming code. As time went on, architectural planning and construction project management were added to the suite of applications running on the systems, as shown in Figure 1.

The number of people writing their own code based on office automation software (e.g., spreadsheets and database management systems) increased dramatically with the advent of smaller computers. "Islands of automation" began to appear in offices. During the 1970s and 1980s, CAFM began to be used for such additional applications as furniture inventory, asset management, lease management, and building cost accounting.

Computerized maintenance management system (CMMS) applications, such as maintenance management, telecommunications, cable management, and security began to appear during late 1980s and 1990s as the enterprise client-server

**Eric Teicholz** is the president and founder of Graphic Systems, Inc., and has a 25-year history of consulting, education, and writing in facilities management and technology. He lectures internationally, is a contributing editor at *Facilities Design & Management and Commercial Buildings* magazines, and is the author of hundreds of articles and several books on computer graphics, facility management, computer-aided design and architecture, computer-aided facilities management, and geographic information systems technology. He is a member of the Board on Infrastructure and the Constructed Environment at the National Research Council and the Advisory Board for Facilities Management at A/E/C SYSTEMS.

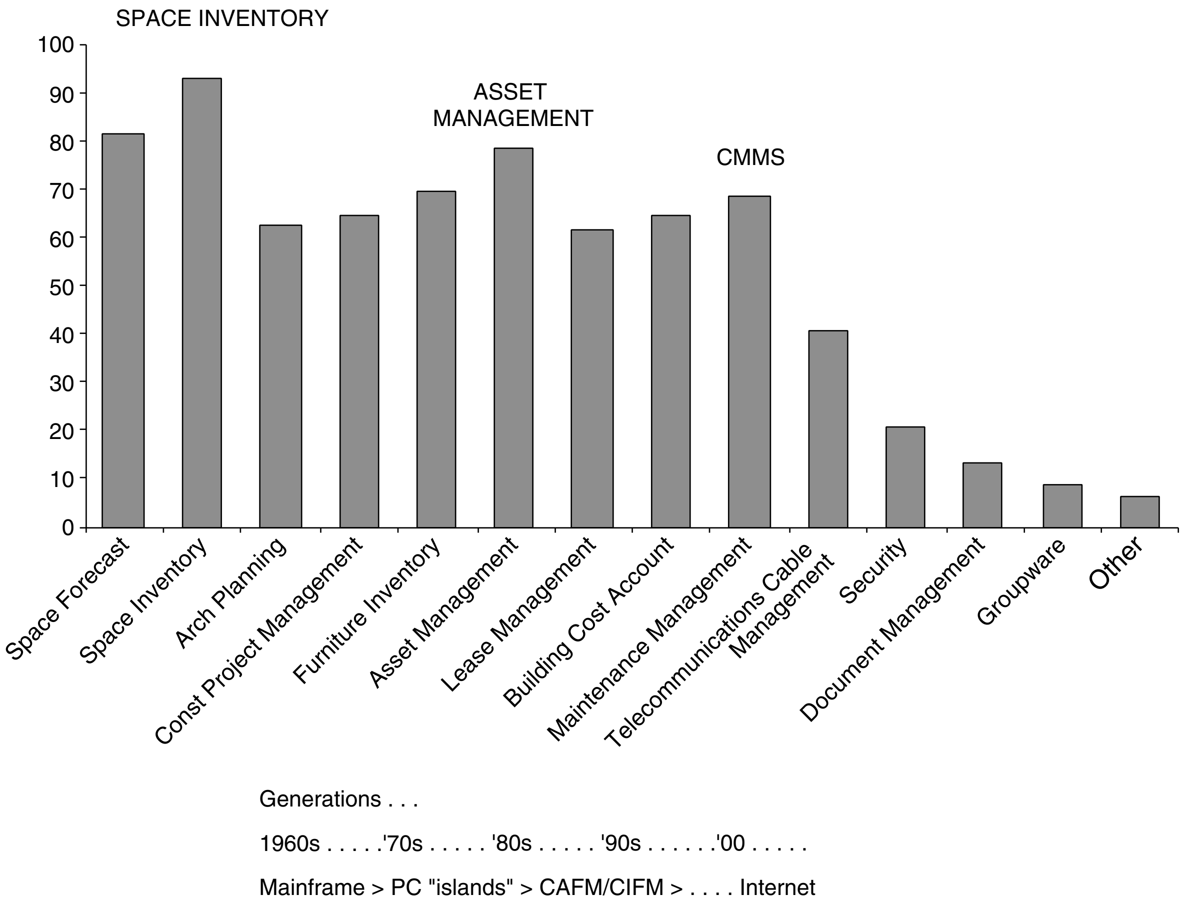


FIGURE 1 Computer-aided facilities management applications
SOURCE: Graphic Systems, Inc.

environment became dominant. More recently, document management and workflow have been added to this list of CAFM applications. Now all of the traditional CAFM applications are migrating to the Internet, where they will be joined by new applications, such as energy management, e-commerce, and assessment of facilities for portfolio management. Full functional computer-aided drawing (CAD) is still not purely Internet-based, although Bentley, AutoCAD, and Visio are all promising pure Internet solutions coming online within the next year to year-and-a half.

Since 1997 there have been three trends in Internet CAFM products: “brochure ware,” or static and dynamic Web pages and Web-enabled applications; e-commerce, including portals, marketplaces, and application service providers (ASPs); and information integration, including emerging e-business and e-process applications.

CAFM applications being offered by ASP vendors represent the current industry goals. With ASPs, users access the software product with their browsers. Telecommunications are provided by the ASP vendor. Front-end hardware costs disappear for users. Within 12 months most FM products and services are going to be available in some kind of ASP mode. The cost/benefit financial models have not been well worked out, and there are not very many profitable ASPs at this time. There are, however, some very real advantages to moving to the ASP model.

The trend now emerging is e-business and e-process applications that incorporate work flow and commerce. There are not many FM examples of this on the World Wide Web at present. But that clearly is how FM vendors and portals are evolving. Interest in developing portals and other products and services associated with construction is high because the potential market is so large. There is as much as $1 billion in venture capital invested or seeking investments in this marketplace, most of it focused on the development of portals serving the construction market. However, the e-business marketplace is in a state of extraordinary flux, with several vendors discontinuing service in recent months as they run out of venture investments.

Adding to the complexity of selecting an e-business or ASP vendor are the application vendor partnerships that go with each choice. The ASP partner typically provides the FM applications, but the partners, whether they are commerce partners or Web-hosting partners, are usually other third parties. Determinations of costs are very different in the e-business world than they are in the traditional design and construction market.

Users surveyed by Graphic Systems believe that the Internet has very strong and compelling benefits. Most of the application developers will be moving products and services to the Internet, although there are some very real impediments. Some of the portals are in serious financial trouble, and as mentioned, several have shut down their Web sites.

Users say that unquestionably the largest factor limiting their use of the Internet for e-business or ASP service is data security. Physical steps, such as firewalls, will not make this issue go away. What users object to is the storing of common project information on the same server as their competitors and the potential for unauthorized access to that information.

To effectively use e-commerce, you must think differently about business processes, procurement, and supply chain management. There is a need to redefine business processes, but getting companies to change the way they do business is always difficult. Using the new information technologies is going to require different management skills from facility and property managers and from the educational institutions that train them.

Graphic Systems maintains a list of two hundred or so facility management and real estate application vendors moving into the e-business market in seven main categories:

1. space and asset management;
2. real estate and property management;
3. facility assessment;
4. maintenance and operations;
5. building systems energy management;
6. computer-aided design and construction; and
7. support functions (see Figure 2).

In recent months Graphic Systems has selected vendor examples from these categories and developed case studies to illustrate the state of Internet technology in major CAFM categories.

In the space and asset management category Graphics Systems selected for its case study applications developed by Facility Information Systems, Inc. (FIS), a venture-capital-backed firm with offices in Camarillo, California (www.fisinc.com). FIS was unique in that it uses Oracle 8i for its backend database, which means that as long as database standards are supported their entire application can automatically be offered over the Internet. FIS is also progressive in that its software integrates CAFM and geographic information systems technology, which allows spatial queries of the data. FIS had developed links through an application program interface with partners in the world of space and asset management. In the computerized maintenance management world, the primary link is with Maximo software. In human resources and other enterprise applications FIS links readily with leading enterprise solutions by PeopleSoft and SAP. FIS is beginning to add linkages with enterprise resource portal solutions being offered by SAP, Oracle, and PeopleSoft.

With software like that offered by FIS and its competitors, one can query entities like a virtual room, and ask who's in the room? What assets are in the room? It can indicate moves, generate various move scenarios, analyze the cost for a relocation, and tie the move to a schedule of other events occurring over time.

Graphic Systems estimates that the one-year cost of using FIS software for a user with a portfolio of 125 buildings totaling 10 million square feet would be around $105,000. That would provide 10 concurrent licenses

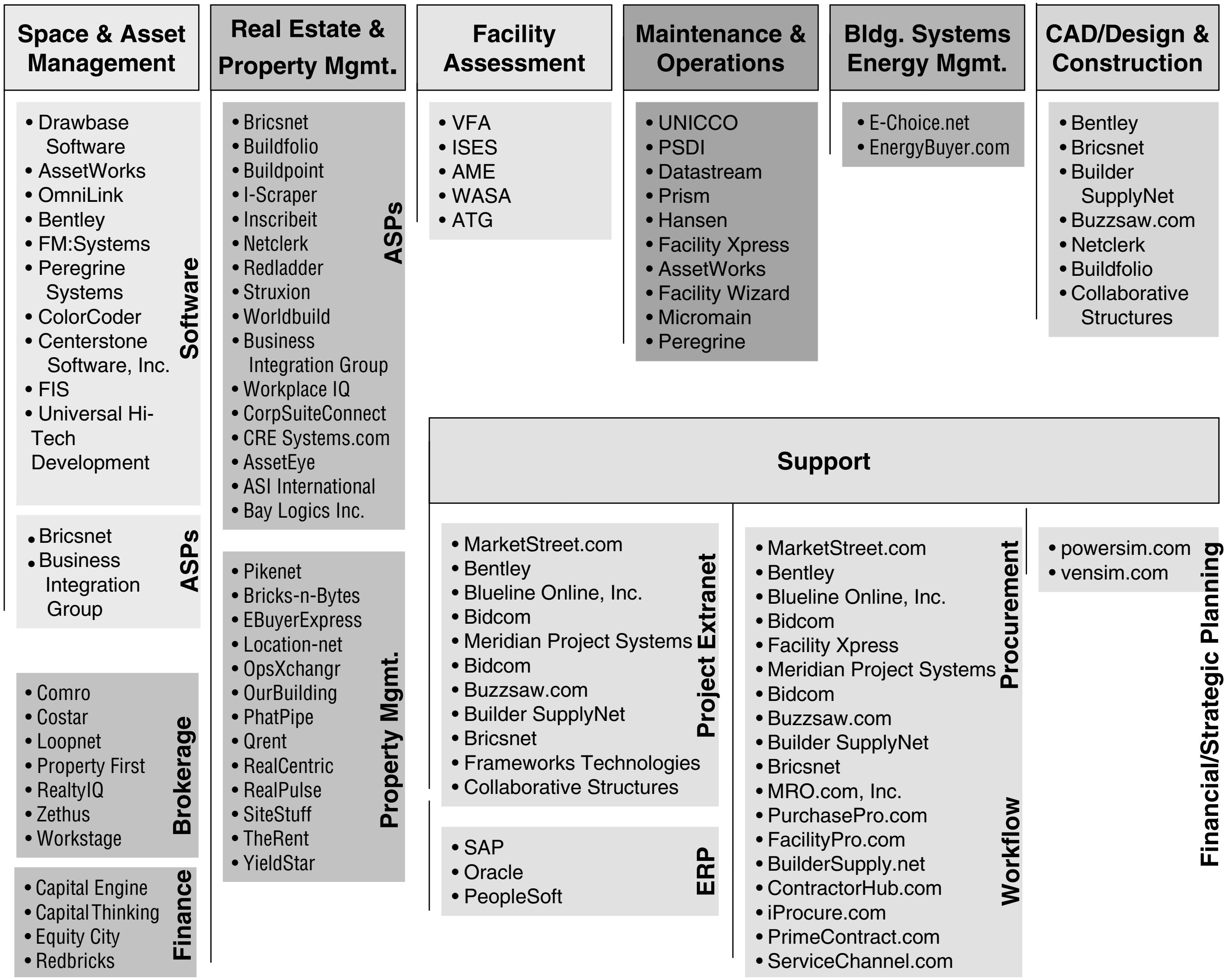


FIGURE 2 CAFM-business market and product segments
SOURCE: Graphics Systems Inc.

working in either a client-server environment or with Internet browsers, Web access for 35 users, and training. Management would have access through browsers to graphics-based reports, queries, floor plans, and planning tools. Entering inventory data, CAD, and drawings could result in significant additional first-year costs.

In the building system and energy management category the example selected is Silicon Energy Corporation, a venture-capital-backed firm with headquarters in Alameda, California. The company has developed a collection of integrated software modules that enable enterprises and energy service providers to efficiently manage consumption, procurement, and distributed energy assets in a deregulated environment (www.siliconenergy.com).

Silicon Energy has developed energy demand models that take into account energy use data measured at meter points and monitored over the Internet. They then go to energy providers in a number of states with the customer's energy profile and get real-time bids.

The Silicon Energy software enables asset managers to answer such questions as: How closely does peak energy consumption correspond with energy rates? Which meter points contribute the most to peak consumption hours? How do sites compare in terms of energy and demand intensity levels? The company has linked its software with CAFM systems offered by developers such as Peregrine Systems, Inc., of San Diego, California, so that energy use can be modeled inside the CAFM system; it is now developing the capacity to control energy subsystems such as lighting and mechanical over the Internet through software that will be provided by Silicon Energy.

The example for the computer-aided design and construction category is Bricsnet. Through its Web portal Bricsnet integrates the technology, services, and information that professionals can use to design a building, manage a geographically dispersed project team, bid on and procure building materials and services, access building product specifications from manufacturers, and manage completed facilities. Bricsnet maintains corporate headquarters in Wakefield, Massachusetts, and Ghent, Belgium. The company went public during the stock market's peak. It therefore has the resources and will to deploy an infrastructure to support a broad range of applications (www.bricsnet.com).

One of the companies Bricsnet has acquired is RELMS (Real Estate Lifecycle Management Services), a real estate application for property management, lease management, work order management, and even a limited procurement component that works inside its site. The RELMS system can be used for lease and property management and occupancy analysis. It rolls up those data into projects, and the projects can issue work orders. Work orders have work flow that can be triggered, for example, by a lease abstract. The day the lease comes up, it will automatically notify the appropriate person and take a series of escalated actions if that person does not respond.

Bricsnet intends to establish itself as the link between the design world, the construction world, as-built drawings, and facility management needs. That's an important start and not many companies are trying to realize such an ambitious goal.

Bricsnet told us that the cost of using RELMS as an ASP is on the order of $60,000 to $180,000 per year or two to six cents per square foot of building being managed. The cost of data creation, conversion, maintenance, training, and other implementation costs would be on the order of three times the ASP cost. Data from Bricsnet and other vendors suggest that users will recover their investment in about two years if they choose to buy their hardware and software instead of subscribing to an ASP.

Because of their subscription cost structure—project extranets like Bricsnet or Buzzsaw most often charge by the gigabit of storage—the cost of putting whole portfolios of buildings on the system can be almost prohibitive. The users surveyed said that they had been able to negotiate lower fees than those posted on the Web site.

The facility assessment example is VFA (formerly known as Vanderweil Facility Advisors) of Boston, Massachusetts. This software, and other similar systems, was developed to help architects and engineers report on the different subsystems that make up a building, such as accessibility, aesthetics, building integrity, code compliance, energy, functionality, and hazardous materials (www.vfa.com).

Developing databases for a building is the first step in the process. In the end, this often leads to procurements and the process is facilitated by the many databases that can estimate time and materials needed to correct deficiencies. This is a labor intensive, expensive process. VFA and the General Services Administration are now working on a project in which artificial intelligence is used to reduce the labor needed to develop databases. Vendors such as VFA are linking the development of the databases to CMMS or even CAFM systems. They are starting to provide ASP services on the Internet.

For maintenance and operations, the example is a CMMS vendor called Datastream MP2, which has developed middleware for an event-driven application offered as an ASP (www.dstm.com). Building managers using this service might, for example, be notified when their inventory of motors for a particular kind of compressor reached a certain threshold. The service would automatically come up with several options from its catalog, which has hundreds of thousands of items. On the basis of customer profiles the service might tell managers that they have bought this motor in the past and they work, and it might add that Datastream has a sale on this motor from this company.

## INFORMATION TECHNOLOGIES: AN OUTLOOK

### Summary of a Presentation by Donald Greenberg
### Director, Computer Graphics Program, Cornell University

Moore's law holds that the density of microprocessors doubles every 18 months, leading to a doubling of processing power in the same period. The semiconductor industry has already done testing on the types and size of micro features needed to continue advancing the technology at the rate described by Moore's law until 2011 or 2013. This means that in 2015 microprocessors are going to have a million times the power they have today. The same holds true for memory and more so for communications bandwidth.

Mass storage is advancing at an even faster rate, as is graphics processing technology. Sony's Playstation 2, which came to the market in October 2000 and sells for $299, has three processors. One has five times the floating-point processing power of the fastest current Pentium III chip. Soon, processing, memory, storage, and bandwidth will be essentially free. So what are we going to do with it? Assuming that it is free and assuming that we are going to deal with things pictorially, what is missing and how will the system grow?

**Donald P. Greenberg** has been researching and teaching in the field of computer graphics since 1966. During the last 15 years, he has been concerned primarily with research advancing the state of the art in computer graphics and with using these techniques in a variety of disciplines. He is the author of many articles on computer graphics and has lectured extensively on the uses of computer graphics techniques in research applications. He is the director of the program of Computer Graphics and is the originator and former director of the Computer Aided Design Instructional Facility at Cornell University. Dr. Greenberg was involved with the design of numerous building projects, including the St. Louis Arch, New York State Theater of the Dance at Lincoln Center, and Madison Square Garden.

Many changes in the near- to midterm will come from novel ways for entering and displaying data under development in laboratories. Advances in imaging are of particular interest to design professionals. Current generation digital cameras take pictures; the next generation is going to collect data. If we take two pictures from closely related spots and there is some kind of gyroscope or tracking device on each camera (so we know exactly where we are in space and in which direction the camera is oriented) we will capture images and record the geometric information. This will allow a designer working in an urban environment to take pictures of all the surrounding buildings and have that information automatically become the database the designer uses to design in context.

Dramatic changes are on the way to improve display resolution. Texas Instruments has developed a device that uses 16- by 16-micron mirrors to reflect light from a source to individual pixels on a display. The mirror can be switched so that its pixel is either illuminated or not illuminated. The display has much better resolution and is much brighter than CRT displays. Plus, today we can get theater projection quality over a large screen at the cost of a chip plus a projection system. Soon, all home entertainment centers more than 30 inches diagonal will be either this type of technology or a similar technology using liquid crystals. I have three projection systems of this type in my classroom, and students use them to immerse themselves in the space they are designing. NASA Ames will be using the technology in its flight control center. The trend has started.

Advances in processing speeds and new display technologies will enable designers to dramatically change from modeling and then rendering to rendering while modeling. Doing this accurately and predictively is a complex problem. If I had 100,000 points in this room, I have to find a relationship between each one and every other one and then solve the matrix, which is 100,000 by 100,000. And I want to solve it in real time. I then want to take the physics and run it through a model of the visual system such that I am creating a picture on the screen that basically tells your brain that what you are seeing is the same thing you would see if you were in the real world.

To do this, Cornell is developing parallel rendering techniques that include all the interactions between reflective surfaces. For real time, these calculations will take a $10^7$ increase in processing power. A major sponsor of Cornell in this effort is Intel Corporation. Currently, the university has 32 processors running in parallel to support the effort and can perform sub-second renderings on moderately complex scenes.

Another major effort under way is designing software that architects can use intuitively. If I had a dream, it would be to sit in a nice soft chair in the woods, possibly with some classical music playing, with a sketch pad and charcoal pen or a Pentel and tracing paper and doodle and sketch. That's where I can do my most creative thinking. I would like to have those ideas transformed into preliminary drawings and simulations that can be reviewed and ultimately turned into working drawings and construction documentation. When the project is being built, I would like to have an automated system show changes made in the field and actually create construction documents.

The way architects actually work is to use all sorts of pictures and props for ideas. They build crude and abstract models. They like to doodle and sketch the preliminary design ideas.

Why can't computer-aided design do this? Do you want to be stuck with the types of hardcopy line drawing that we currently use in all systems that are available for CAD? There is no creativity in that mode. What I want to do is develop tools to put greater creativity in the hands of the architects so that in fact we might improve the built environment for the future. A new type of drafting software being developed at Cornell facilitates this ideal process. Instead of a mouse it uses a wireless pen that can be used to sketch in three dimensions. This information should then automatically be translated into CAD data. It should be ready for use in five years.

## EXTRANETS FOR PROJECT MANAGEMENT AND COLLABORATION

### Summary of a Presentation by Paul Doherty
### Principal, The Digit Group

The large investment in Internet firms serving the A-E-C industry during the past two to three years is forcing a fundamental change in the way people view collaboration. There has been an explosion in the world of extranets (e.g., the project management and project-specific Web sites).

In the past, children in our culture were trained to hoard information from the time they entered elementary school. We are not supposed to share. After all, when I share, then I am diminished in what I know. I do not get the higher grade in school, the promotion at work, the title or the extra money, because when I hoard my information I am important. People want to come to me. What extranets have done is to explode this myth into an idealistic notion of interdependence, flexibility, and partnership: the essence of knowledge management.

**Paul Doherty, AIA,** is a registered architect and one of the industry's lead consultants and integrators of information technology and the Net economy. He is the principal partner of The Digit Group, a management consulting and information technology firm based in Memphis, Tennessee. He is an author, educator, analyst, and consultant to Fortune 500 organizations, government agencies, prominent institutions, and architectural, engineering, and construction firms around the world. He is the author of multiple sections of the *AIA Handbook of Professional Practice* and the author of three books, including *Cyberplaces, The Internet Guide for Architects, Engineers and Contractors,* and *Cyberplaces 2.0.*

Largely because of the $3.2 billion invested in A-E-C information technology ventures since 1997, people in the industry now have the tools and the incentive to ask: What if information were shared throughout the life cycle of a facility?

We are moving from this whole idea of ownership—It is mine. If I own it, I can maintain it, I can control it—to an Internet world where everything is shared. That is a relationship issue rather than a technological one. Any technology will show a bad process 10 to 100 times worse than it really is, so it is like putting a slide under a microscope. It will show good processes. There is no gray area. We are now reexamining what these project extranets are bringing to the forefront. And they are allowing us to think beyond documents, like schematic designs, to information.

With a data flow comes the possibility to change the industry. When you are in design and construction, architects, engineers, or contractors should be feeding a database every time they submit a document. If documents are feeding a database you are creating "digital DNA" that is attached to the facility and the property for its life. There are many applications for this information.

One powerful use is to provide the information to the real estate finance industry for use in its due diligence. In the private sector numerous buildings are built because of Wall Street. Certain design and construction information now is going to be driving the secondary paper market because of very simple tools, like electronic closings online that capture due diligence reports, environmental Phase I reports, record documents, past tenants, and utility use.

The developers of the world are starting to take a look at design and construction in a much different way because they do not have to hire out another person for due diligence. It is already done. The documents themselves will not go away any time soon, for legal reasons among others, but the data will be more readily available.

Project extranets are now in the early adoption phase. The first generation is so embryonic and so pioneering that I would be very careful about what you choose. Attention has to be paid to a host of issues ranging from security to process, with relationships being particularly important.

The Internet and extranets are starting to reassess where the value is, and it starts with a three-tiered architecture, meaning browsers. These are not browsers like Netscape Navigator or Internet Explorer but Palm Pilots and cell phones. Browser mentality says you do not need central processing units or RAM in the device because all you are doing is requesting information. Now these applications can reside on your computer or be outsourced to an application service provider. Data generated by wireless data links with the field is an important development that is going to allow these project extranets to thrive. If you are considering a project extranet that does not have a mobility function built into it, run quickly, because it will not serve you well.

The most important element of the three-tiered architecture is a database that can be continually updated by the application you buy or subscribe to. For people who manage multiple projects, one of the biggest frustrations is people working in individual "data silos." The group that figures out how to build horizontal tools that report progress, show performance—like "How many change orders did I have last week on a project"—for one project manager, and allow you to evaluate performances measured with a mouse click is going to win the market. Certain groups are developing these types of tools. The breakthrough will happen when we start moving from design and construction into seamless facilities management and operations.

The information system developed for 3-Com (the manufacturer of the popular Palm pilots) for its Santa Clara, California, manufacturing complex allows employees to use global positioning systems to bring up location information about employees and facilities within the plant and find out where they are within the complex. The system routinely instructs security employees on what rounds they should make and what tasks they should perform while making their rounds. They also use it to file incident reports. So they are looking at a new way to push information out into facilities management and operations.

For organizations looking to use extranets, I suggest that they consider the following:

- Do their online services link into legacy software systems like AutoCAD or Primavera?
- Do they provide trusted content?
- Do they allow for customized and personalized interfaces?
- Do they have customer support 24 hours a day, every day of the year, that resolves issues?

# 3

# Information Technologies and the Architecture-Engineering-Construction Industry

Mr. Kenneth Brown of Skidmore, Owings, and Merrill, LLP, identified issues the architecture community and individual firms face in using information technologies more effectively and ways in which information technologies may change the architecture industry. Mr. Norbert Young of the McGraw-Hill Construction Group reviewed issues for the construction industry and some initiatives that may help to resolve them. Dr. Robert Johnson of Texas A&M University presented the results of a survey of Fortune 500 companies about the impact of e-commerce on facilities management practices.

## INFORMATION TECHNOLOGIES AND THE ARCHITECTURE COMMUNITY

### Summary of a Presentation by Kenneth C. Brown
### President, Skidmore, Owings & Merrill, LLP

The architecture industry has structural problems that add to its business difficulties, but it has some potential advantages that could be quite useful in the new economy. On the minus side, the industry is:

- Fragmented and small. There are 17,000 firms operating in the United States sharing $17 billion in fees. The total number of architects employed in the United States is probably about one-half the worldwide employment of General Electric.
- Volatile. While we have had a good six-year run, the back-of-the-mind fear is the next big economic downturn and the reality of what a downturn can do to this industry. It has an effect on the ability to make decisions.
- Local. Some firms like Skidmore, Owings & Merrill (SOM) and Hellmuth, Obata & Kassabaum, Inc. (HOK) have become more global, but looking at how global we are, compared to really global firms like Sony and Ford and General Electric and IBM, we are nowhere near what we should be.
- Limited access to capital. The profit margins are not terrific, but over the last few years they have gotten much better; however, those margins do not translate into access to the capital market. Thus, those margins go to taking care of day-to-day, year-to-year problems. There is no long-term access to capital to really change the industry. So we are always looking to people outside the architecture community to provide new tools and sources of change.

On the plus side, architecture has many of the characteristics that *Business Week* says the world's top-rung companies will share in the twenty-first century.

- It will be based on information and talent. Top-rung companies will be focused on leveraging of intellectual capital and human knowledge. Architecture is like that.
- It will be positioned to develop a brand.
- It will not be capital intensive. This is an offsetting issue to the problem the industry has in generating and raising capital. Microsoft only uses about 5 cents in capital for every dollar of sales. Other software companies use about 20 cents per dollar and that is about where we are, at least at SOM. Manufacturing is typically a dollar of capital investment per dollar of sales.

**Kenneth C. Brown** was named to the newly created role of president of Skidmore, Owings & Merrill LLP (SOM) in June 1999. With offices in New York, Chicago, San Francisco, Washington, D.C., Los Angeles, London, Hong Kong, and Sao Paolo, SOM has undertaken more than 10,000 architecture, engineering, interior design, and planning projects in more than 50 countries during its 64-year history. Prior to joining SOM, Mr. Brown was a vice president of the General Electric Company (GE), where he was responsible for its operations in Southeast Asia, Australia, and Mexico, and served as manager of worldwide business development for GE Industrial Systems. His career spans corporate and operating jobs in mining and agricultural chemicals, engineering, and management consulting with Price Waterhouse, and energy research and development with Science Applications International and the Solar Energy Research Institute (now National Renewable Energy Laboratory).

Competition is driving change in the architecture community. Competition from within the fragmented industry is not the real threat. The threat is from outside firms like Andersen Consulting, technology firms, software firms, and dot.coms, that know how to leverage the system and are entering the field. Engineering firms that have grown by acquisition and by diversification at rates that make architectural growth absolutely anemic have a great deal of bargaining power.

The number-one issue for every large architecture firm is getting and keeping the best talent, keeping them motivated, and working in teams. This is not just architecture. It is every business today. But it is extraordinarily crucial for us, because we absolutely depend on human talent to do whatever it is we offer as added valued. We also need to operate more globally, not for diversification or leveling out economic cycles but because our customers are global. We must have a system to deal with global customers whether or not our firms are located in those areas.

The number-two issue is working harder on fixing the project and work processes within the firm. Picking the right work to do. Doing it more efficiently and, from a pure business point of view, managing the revenue capture cycle (i.e., collection) more effectively. It is killing architecture firms not to select the right projects or manage collections effectively.

Finally, architecture firms need the right resources and the right tools to work with. Ironically, a key problem for architecture firms is the physical space they are using. The space we have is not designed for the technology we use for design today. It is a mix between paper design and machine design processes and it is sub-optimal.

We are renting space on a short-term basis because we are afraid of the economic cycles, and we are not really thinking broadly about the kinds of spaces we need to operate optimally. We are not taking advantage of the virtual market because we are operating out of habit, not thinking forward.

The building Skidmore, Owings & Merrill is designing for Andersen Consulting looks like it will be an efficient work environment where they are going to leverage technology, but architectural firms are not doing this for themselves.

Much of the information technology work to be done in the near term involves expanding the use of technology beyond design processes to incorporate project management, human resources, finance, communications, and knowledge management. We also need to deal with nontechnical issues such as removing organizational inertia and barriers, or, in other words, people, training, and standards.

How could information technology change the architecture industry? First, it could enhance the internal collaboration processes of design from schematic to conceptual to final drawings. Efficiencies can be gained in the transfer and use of information. Information technology can also allow us to focus on core competencies by encouraging strategic outsourcing of our indirect supplies and services. We can create meganetworks of specialties. The trick is to network people who want to work independently and people who want to work in organizations. But let's get them all together in the same network so we can access all that great special knowledge in a seamless system.

Finally, information technologies can change the physical constraints of the way we work, from the way we work on machines to where we work, such as in our customers' offices or in a different environment entirely.

## INFORMATION TECHNOLOGIES AND THE CONSTRUCTION INDUSTRY

### Summary of a Presentation by Norbert W. Young, Jr.
### President, McGraw-Hill Construction Information Group

Let us first examine the impact of the Web. Clearly, there are hundreds of applications and hundreds of dot.com companies out there. There is a promise of connectivity and of productivity enhancement; but neither promise is in place today, because the construction industry is fragmented and is not totally computer enabled. Equally important, unless there is the bandwidth for communication to be able to move information, we will not be able to leverage the information.

Nonetheless, we are seeing incredible investment coming into the construction industry in the form of venture capitalists. Over $600 million was invested in dot.com and technology-related ventures in the A-E-C industry in 1999. That sum was matched in the first three quarters of 2000. I look at that in many ways as being research and development (R&D) dollars.

But more than R&D will be required to bring the power of computers and communications to the A-E-C industry. Ninety percent of the 1.25 million companies in the industry have 10 people or fewer. Although 95 percent of the firms have e-mail, a typical firm probably has only one computer. Compounding difficulties, the average life of a subcontracting firm is 2.8 years, which means there are many companies leaving the industry on a continual basis. Until we make it incredibly intuitive and very easy for this base, which is the core of this industry, not much is going to happen.

**Norbert W. Young, Jr., FAIA,** is president of the McGraw-Hill Construction Information Group. The Construction Information Group is a source of project news, product information, industry analysis, and editorial coverage for design and construction professionals, and is comprised of such brands as F.W. Dodge, Sweet's Group, Architectural Record, Engineering News-Record, and Design-Build and Construction. Prior to McGraw-Hill, Mr. Young spent eight years with the Bovis Construction Group and in 1994 was appointed president of the newly created Bovis Management Systems, which was established to serve the construction and project management needs for both private and public sector clients. He is a member of the Urban Land Institute, the American Institute of Architects, and the International Alliance for Interoperability, where he serves as chairman of the IAI North America Board of Directors.

On the other hand, the A-E-C industry is fundamentally a project-centric business. Secondly, it is an industry that is always organized virtually, so if there is any industry that is right for the Web and technology, it is construction. It is an industry that has an incredible number of intelligent applications. Sadly, it is an industry that operates with very little efficiency. Productivity has actually declined since 1965.

Two applications are emerging out of the pack and will make a difference: a collaboration and communications application and a trading platform application that allows connectivity among the participants.

To date there is no seamless, end-to-end collaboration in the three phases of a project (i.e., design, construction, and operation of a facility). The work in each phase occurs collaboratively. It always has. Unfortunately, the work done in each phase becomes static and devoid of intelligence when it is handed off to the next link in the chain, where people must recreate much of the work already done. Until we begin to really go back and look at the work processes, there is not much hope that Web technology is going to do much to change this.

There will not be one magic computer application that will solve everyone's problems, but much could be gained if we could just share the information. When I begin to look at connecting the project, the participants, the intelligent applications they use, and their information needs, then I see the promise of the Web as the glue that binds them together.

Wouldn't life be great if architects could create CAD drawings on their platform of choice and move them dynamically to the platform the contractor uses for estimating, which would in turn pass the information on to the financial and project management people? But this will require data standards.

There are two major initiatives in data standards. One is called interoperability, and it is taking place on a global scale. It is all based on a fundamental shift to thinking of applications based on intelligent objects; instead of static lines on CAD, a door has intelligence embedded in it.

The second initiative is using Web-based aecXML, a framework for using the eXtensible Markup Language (XML) standard for electronic communications in the A-E-C industry. The concept is to use the Web as a giant database by tagging information so that it can be used for intelligent applications. It includes an XML schema to describe information specific to the information exchanges among participants involved in designing, constructing, and operating buildings, plants, infrastructure, and facilities. The various software applications used by these participants can transfer messages formatted according to the aecXML schema to coordinate and synchronize related project information. In addition, a standard aecXML specification will facilitate e-commerce among suppliers and purchasers of equipment, materials, supplies, parts, and services based on that same technical information.

The federal government is a huge owner of property and consumer of services. I think federal agencies need to demand that their service providers use certain standards. From my perspective, federal agencies are in the driver's seat. Demand interoperability. Be willing to say that in order to work for our agencies, you must provide information in a way that can be shared.

When I directed the design and construction of the facilities for the Summer Olympic Games in Atlanta in 1996 while working for Bovis Construction Group, I told contractors they were going to deliver CAD documents in an AutoCAD format and that all schedule information would be in Microsoft Project. We, as the owner, said we want to take advantage of all the information we are using and then be able to aggregate it to look at our portfolio. I think federal agencies are in a perfect position to be able to do the same. And I say, what is the risk?

## THE IMPACT OF E-COMMERCE ON FACILITY MANAGEMENT PRACTICES

**Summary of a Presentation by Robert Johnson**
**Director of the CRS Center, Texas A&M University**

The CRS Center conducted a questionnaire survey about the impact of e-commerce on facilities management practices for the IFMA Foundation, a not-for-profit group affiliated with the International Facilities Management Association. The goals of this survey were to develop a rigorous and factual description of how business-to-business e-commerce and Web-based technologies were being used by large building owners and assess how those uses were projected to change over the next two years.

For the purposes of the survey, e-commerce was defined as conducting business communications and transactions among companies over the Internet. Fortune 500 companies were the focus of the survey and all the respondents were IFMA members. About 1,700 questionnaires were mailed out and 578 were returned, for a response rate of 33.7 percent. Almost one-half of the respondents managed more than 1 million gross square feet of space.

**Robert E. Johnson, AIA,** is a professor of architecture and director of the CRS Center for Leadership and Management in the Design and Construction Industry at Texas A&M University. The mission of the CRS Center is to create useful knowledge in leadership and management that applies to both individual projects and firms and organizations in the design, construction, and facility management industry (http://crscenter.tamu.edu/). Dr. Johnson also serves as chair of the College of Architecture's Facility Management Certificate Program. His current research has focused on the impact of information and communication technologies on the design and construction industry, with particular focus on facility management organizations.

Of the total respondents, 5 percent said they used e-commerce a lot to help manage their facilities, 31 percent said they used it some, and only 4 percent said they were not using it at all.

Top uses of e-commerce listed by respondents were:

- Purchasing supplies and materials from a specific vendor;
- Accessing facilities manuals (e.g., maintenance or training);
- Publishing static project information;
- Taking interactive training courses; and
- Purchasing supplies and materials through an Internet service that connects buyers and sellers.

Within the next two years, more than 8 out of every 10 respondents said they would be purchasing supplies and materials on the Web from a specific vendor; 9 percent said they anticipated purchasing a lot of facility services over the Internet; 7 percent said they planned to purchase a lot of energy on the Internet; and 3 percent said they would be leasing a lot of space by using the Internet.

What we are seeing is a pattern of increasing use of the Internet to do more traditional activities. The activity with the greatest payoff for facility managers appears to be using the Internet for purchasing.

In the services sector, telecommunications and information companies are the leading users of e-commerce for managing facilities, followed by utilities, banking, and health and hotel companies. E-commerce was less frequently used by facility managers in the trade and insurance sectors. In the manufacturing sector, electronics companies used e-commerce most often, followed by vehicles, energy, chemicals, and consumer companies.

Almost one-quarter of the respondents thought e-commerce would have a big impact on their departments over the next two years, and 52 percent said it would have some impact.

Is e-commerce effective for managing facilities? About 47 percent said it had decreased the total annual cost of facilities and 80 percent agreed or strongly agreed it would decrease costs within two years. About 67 percent said it was decreasing the cost of buying supplies and materials, and 50 percent said it had decreased the time required to complete projects. About half said e-commerce was decreasing the cost of facility maintenance and operations and almost one-third agreed that it decreased the overall cost of space management. About 30 percent said it has decreased the cost of new construction projects.

More than one out of every 10 respondents said implementing e-commerce was a big problem and one-half said it was somewhat of a problem. Almost 60 percent of respondents mentioned that their biggest barrier to the use of e-commerce was the difficulty of integrating legacy systems. Other top-rated barriers cited were:

- Funds required to invest in e-commerce were not available;
- Software upgrades were too costly;
- Too hard to customize software to meet needs; and
- Too costly to keep building data current in facilities management systems.

One of the objectives of this research was to learn if it was possible to identify the type of organization that is more likely to use e-commerce. The survey found that those organizations using systematic work processes were more apt to adopt business-to-business e-commerce. Work processes that were associated with e-commerce use were ISO 9000 certification, the use of continuous improvement processes, the use of continual retraining of employees, and the use of modeling work processes using charts.

Overall, this survey found that business-to-business e-commerce appeared to be emerging as a major change agent in facility management. Facility managers reported that e-commerce will significantly affect facility management practices. Although business-to-business e-commerce had not yet resulted in significant improvements in facility practices, facility managers expected this to change in the next two years, resulting in practices that lowered costs and reduced the time required to complete projects. E-procurement was the most frequently used application. It also was the most effective in reducing costs.

# 4

# Information Technologies and Knowledge Management

Dr. Judith Heerwagen, an environmental psychologist with a Seattle, Washington-based consulting and research practice, discussed the differences between information transfer and knowledge work and the implications for managers and others planning for and using information technologies. Dr. Karen Stephenson, a corporate anthropologist and the president of Netform Inc. of New York, described how informal networks of trust can be visualized and used to better integrate work space, information technology, and human behavior. J. Clay Dean, a consultant with the Naval Facilities Engineering Command, discussed what can be done to facilitate the capture and dissemination of knowledge within organizations through facility design, intranets, and extranets.

## INFORMATION TECHNOLOGIES AND KNOWLEDGE WORK

### Summary of a Presentation by Judith Heerwagen
### Principal, J.H. Heerwagen and Associates

When non-military, non-academic people began to use the Internet, there were great expectations of change in how work would be done. This, in turn, would result in increased innovation and productivity because there would be more information flow and communication. There was also the sense that, if people could communicate better and have more information, their knowledge would increase. At the same time, the need for physical space to work in and the need for face-to-face interaction would decrease, because they would be working in a virtual environment. Have these expectations been met?

Information technology has improved efficiency and productivity in such fields as sales and product delivery by improving work processes, but there is much less evidence that it has increased knowledge work. Although we have more ways of communicating—e-mail, cell phones—we spend more time managing this information rather than using it. We are also finding that electronic collaborations supplement but do not replace face-to-face communications.

Although the early thinking was that improved communications would reduce the need for physical space, we are finding that physical space may be more important, not less important, to knowledge work. Research indicates that memory is linked to features and attributes of the environment in ways that are not yet understood. Most of the

**Judith H. Heerwagen** is an environmental psychologist whose research and writing have focused on workplace ecology. She has her own consulting and research practice in Seattle, where her current projects emphasize designing for teamwork and creativity. Prior to starting her practice, Dr. Heerwagen was a principal with Space, LLC, a strategic planning and design firm. At Space, she was codirector of research and helped develop metrics for the Workplace Performance Diagnostic Tool, which is being developed under the auspices of the Workplace Productivity Consortium, a national group of high-tech and financial firms. She was also a senior scientist at the Battelle Seattle Research Center, where she developed a protocol to assess the human factors and organizational benefits of green buildings.

research has been performed on computer-user interface issues, but this has implications for real physical space as well.

We are also finding out that the environment—how we lay spaces out—has a great deal to do with social relationships and social networks. Design factors, such as the width of corridors, influence the communication potential of the space (i.e., the types of interactions people have, the potential to see people and meet spontaneously).

Researchers at Georgia Tech are examining this relationship, which they call spatial syntax. University researchers have developed software that analyzes floor plans to determine the communications potential of floor layouts. In Great Britain, researchers have found that the greater the communications potential the more likely a worker is to have useful interactions with other people. Physical space also affects a sense of belonging, the development of working relationships, and cognitive functioning.

Some of the key issues and challenges of integrating information technologies and collaborative social interactions include understanding the distinctions between information and knowledge, understanding what computers do best and what people do best, and integrating the technological infrastructure with the social and physical infrastructure.

The essence of information is that it can readily be translated into bits that can be detached, moved around, and transferred across time and space. This is the essence of the World Wide Web: information transfer and databases. They can be accessed instantly and are available 24 hours a day, 7 days a week.

Knowledge, on the other hand, is connected to a person. It resides in our brains, not cyberspace. It is much more difficult to transfer. It requires relationships, talking, dialogue, mentoring, experience, what psychologists call tacit knowledge—knowing how to do something. It is associated with meaning, making sense, and understanding what it means. Knowledge cannot be produced or downloaded instantly, unlike information. What is produced when we click on a Web page is not knowledge. It is just information until we use it to change the way we think, change the way we do something. Once it is used, it becomes part of our experience, our way of doing things, our knowledge.

We frequently confuse the differences and think that if we send out information, we are sending out knowledge. The real challenge is to truly understand how we capture knowledge, not just information.

What are the implications of not recognizing these differences? One primary implication is that, because information exchange is so easy, we spend too much time sending e-mails, searching the Web, and downloading, and we do not spend enough time analyzing this information, understanding it, asking what it means for our work, for what we do, for what we produce and why.

Another concern is that this information frenzy is leading to a culture of urgency and a deficit of attention in the workplace. We have information anxiety, information overload, information addiction. We have a sense that we should be available all the time; because we have cell phones, it is okay to be interrupted everywhere we go.

This has serious implications. One of these is that we are losing the inherent rest cycles in work. The kind of downtime when we think, maybe just tune out, just go sit somewhere and watch the people go by. When we do that today, we are considered to be loafing.

When I worked at a research center in Seattle, there was a new facility with spaces between offices that had great views of the outside, comfortable chairs, lounges and tables, but no one ever used the space. I asked the center's researchers why they did not use the informal group spaces. I was told that, if they sat in those spaces, managers would think they were not working, because the definition of working was being in your office sitting at your computer.

We are thinking of downtime for workers as being downtime in a computer (i.e., when it is not working). But downtime in humans is important, because creativity draws on the non-conscious mind for the kind of thoughts and ideas that are accessible to us primarily when we are relaxed, when we are in a totally different state of mind.

There is good psychological research being conducted on how the brain operates when people are doing non-conscious lateral thinking, which is what creativity is, as opposed to very focused analytical thinking. It shows that brainwaves during lateral thinking are much more like the patterns under relaxation conditions. So there is a need for these rest cycles, these downtimes, that we are eliminating to our own detriment.

If we look at the differences between social relationships in physical and electronic relationships, there are some real implications for the use of collaborative technologies. Social interactions in real space have "broad bandwidth" (i.e., eye contact, gestures, facial relationships, voice, smells). We can look at how others are responding. Even if we are just passively watching things go by, there is a very rich information intake that computers cannot do.

There is a rich context to our work in real space. There are stories, myths, interactions, past experience, history that wends its way into relationships and helps them make sense. In this environment, we use both central and peripheral processing, which enables learning by osmosis. And we allow people to signal their availability to others. If we do not want to be interrupted, we close our door, we sort of tune out, we turn our backs.

Electronic social interactions, on the other hand, are very task oriented. They lose the informal sociality that is associated with human interactions that turn out to be very important to relationship building. They lack a context. There is reduced peripheral processing, because all we can see is what is on the screen at that particular time. Turn taking is difficult and awkward.

It is also easier to lurk, vent, be angry, ignore, or withdraw from interactions in cyberspace, because there is less accountability.

Much work is being done in new technologies to add social and emotional context to electronic interactions. New collaborative technologies often have rooms with tables. People have little pictures they put at the virtual table to represent themselves. Some even allow people to put different facial expressions on their pictures to show if, for example, they are amused or irritated. Other technologies are trying to capture the information flow and knowledge behind discussions so that we can track how an idea evolved. At MIT's media lab, researchers are analyzing the emotional characteristics of words used in chat rooms. They print these out as bandwidth so that they can see the emotional intensity and level of communication.

A key challenge is trying to understand when information technology helps and when it hinders interactions and understanding. We need to assess available and emerging tools and try to identify the technologies that best fit a particular process. Currently, technology infrastructure is typically in one province within organizations, social infrastructure is in another, and physical infrastructure is in a third. They are all dealt with separately, by separate people, separate issues, and there is very little interaction. Organizations need to understand where these functions overlap and to design for them. And they need to see them with a systems perspective, where they are all dealt with simultaneously. How do we get there? First, we have to understand the nature of work. What type of collaborative process are we talking about? How frequently is collaborative work being pursued? For what purpose, with whom, and how much time is spent in solitary versus teamwork?

Research on teamwork is producing interesting results. At Fidelity Investments and Sun Microsystems we found that people spend much more time in solitary work than in teamwork. There was a sense that they were always working in teams, but they were not.

At Fidelity I studied spaces they had designed to enhance collaboration. They had many open spaces; a very pretty, new facility. People said they liked the spaces, they were fun to be in, but they did not use them very much for the collaborative activities they were planned for because they did not have any reason to collaborate. Thus, the organization and its leaders have to engineer that collaboration by giving people a reason to work together, and then the tools and spaces will come together.

Information technologies that help one kind of process are not necessarily useful to another. Procedural work—tasks such as status checking, integrating tasks, coordinating schedules, reporting writing and revision—

can be done asynchronously; many of these are the kinds of activities for which information technologies are extremely useful.

Analytical processes have to do with problem identification, problem and data analysis, deciding how to proceed, selecting strategies, getting and giving help quickly. These processes can be both asynchronous and synchronous and again are useful applications for information technology.

But the collaborative, creative process requires much interaction and debate. Electronic brainstorming tools can be useful with these processes, but much of this effort is going to have to be face-to-face, people really discussing ideas and looking at what works best and why. When there is much interaction and social bandwidth, it's a more difficult process to do electronically.

For each of the collaborative processes there are different social needs and characteristics. If there is no existing group, it is going to be difficult for the people to have good discussions, because we need to establish those kinds of initial relationships before people are really willing to go much farther in terms of letting their ideas out, of trusting somebody. So there has to be a natural development of relationships.

Researchers have barely dealt with the issue of physical supports. What do we do with new technologies? How do we integrate them into space?

Maybe we need a special room where we can use desktop video or not use it. Location, sound, lighting—all of these become important, as well as big displays. If we are going to have much more display on walls, the space has to be different to accommodate that kind of technology.

There are many technological tools out there that promote collaboration, but which is best depends upon a thorough analysis of the cognitive and social aspects of the collaboration. It comes down to understanding people and how they work.

## HUMAN RESOURCES, ORGANIZATIONAL BEHAVIOR, AND ORGANIZATIONAL CHANGE

### Summary of a Presentation by Karen Stephenson
### President, Netform, Inc.

When we move people in and out of facilities we can measure those facilities and put a number on them. We often cannot, however, put a number on the impact on our culture or on the operations or on the business when we physically move people from place to place. The idea that we can measure human resources as an asset on the balance sheet has been much talked about but rarely converted to action. At Netform, Inc., we have taken 25 years of research and have looked at macro patterns and micro rules. We have put them together into an application service provider (ASP) with which we can now measure the human asset—what we call intellectual capital—and look at the impact that physical space has on it. We can change those environments and measure the impact the change had on productivity and the bottom line to the business.

> **Karen Stephenson**, president of NetForm, Inc., is a corporate anthropologist and a professor of management. She speaks on the scientific principles of network management at several universities, such as California State University, Columbia, MIT, and the University of California, Berkeley and Los Angeles. Dr. Stephenson researches and publishes in the areas of scenario planning, the networked organization, and organizational innovation and change. She has transformed an academic methodology called "network analysis" and uses it to reveal the often unseen interrelationships of human or knowledge capital in organizations.

An organization's culture is not an abstract concept; it is the networks of trust that bind people together. In any organization there are two parallel universes: one of authority from which unfolds formal rules and procedures and a second through which trust and informal understandings are transmitted and a good portion of the real work is done. The former is characterized by a hierarchical structure and the latter by networks.

Hierarchical structures are designed to build rules, procedures, and policies with which we get work done. The purpose is to eliminate uncertainty, to provide certainty to daily routine. Bureaucracy is not hierarchy but is the combination, usually dysfunctional, between a hierarchy and a network.

Traditional managers understand the hierarchy. What they fail to see is the network of relationships that runs through their hierarchy, because networks are built from trust and trust is invisible and ubiquitous. Collegiality characterizes these networks and is evidenced in such factors as innovation and elevator conversations. The water-cooler phenomenon—at one time considered insignificant in business and government—is now understood from research to be an important font of early innovation that is often untapped and lost because it is not recognized.

Hierarchies can be managed explicitly, but networks must be managed implicitly. The wise leader knows how to invoke one of these structures relative to the other and when to do it. Facilities planners and designers who understand the dynamics of these networks can develop better environments for their organizations by looking at the built environment both from space planning and from the interior architecture of knowledge.

Trust is an invisible human utility. Within it flows shared knowledge linking people together, but like an underground utility, people do not see where the lines are buried. Distinguishing trust from traffic is critical to understanding networks. First, if you truly have bonds of trust, then like a rubber band, the trust can be stretched through space. Although it may be stretched and stressed, the linkage is there, is strong, and will snap back in place.

Hence, in moving knowledge around, those we most trust with knowledge are often better placed in different and disparate locations (geographical regions, different buildings) where their knowledge is best transferred to those who most need it. Secondly, mobility may be less important in "fast companies" than directionality (e.g., the desire to run to, not away from, problems). This means that new measures can be put in place to target new behaviors. Solutions range from managerial interventions to changing the way we occupy space in the office. For example, when looking at organizations undergoing mergers or acquisitions it is important to know whether the cultures will assimilate rapidly or slowly. If they do not assimilate rapidly, potential profits will be lost. By looking at the key knowledge holders in an organization and involving them in the change management process you can facilitate such an assimilation.

Office layout can become a barrier separating people. I begin analyzing an organization by distributing a questionnaire to its employees that asks about which people they have contact with: Whom do you like to spend time with? Whom do you talk to about new ideas? Where do you go to get expert advice? The idea here is that interior space can stimulate productivity and actually affect business results in a measurable way.

Every name in the company becomes a dot on a graph, and lines are drawn between all those who have regular contact with each other. People in the organization fit into one of three patterns.

The first pattern is a hub, as in a hub-and-spoke system. People at a hub have connections to many more people than anyone else and on my charts, lines radiate from them like spokes on a wheel. These are the ones other people go to in order to get information. Organizations need to give them an environment that allows access. There are also going to be times when they need to have control, so give them a place where they can get away.

The second pattern is the gatekeeper who serves as a bridge between hubs. Although not connected to as many people, gatekeepers are strategically connected. They control access to critical people and link together a few disparate but strategic groups. Gatekeepers can block information and they can transmit ideas. They are brokers; so you might want to put them at the perimeter and give them adjoining areas with tables and chairs, and white boards.

The third pattern is the pulsetaker, someone who is maximally connected to everyone via indirect routes. The pulsetaker is a behind-the-scenes person, unseen, but all seeing, a touchstone for culture. When you analyze the charts there are always people who seem to have many indirect links to other people, who are part of all sorts of networks without necessarily being in the center of them. They are roamers. Rather than give them one fixed work location, you might give them a series of touchdown spots where you want them to stop and talk. You want to enable their meandering.

If you ask people who they want to sit next to, they will pick out someone they trust. What managers should do is put people who do not trust each other in the vicinity of each other, close enough so that they are in your path. To get the knowledge indirectly communicated to many people, think about placing a hub in an innovation network next to the pulsetaker in an expert network. In this way you can thread innovation through a culture, a building, even one floor of a building.

Smart designs of new offices and new facilities help people behave and socialize in ways that they otherwise would not. We know two truths: (1) humans are contextual and (2) work is fundamentally social. The challenge before us then is to design serendipitous interactions in a way that make people both productive and happy wherever they are and whenever they interact, from 9 to 5 or 24 hours a day, 7 days a week.

## KNOWLEDGE MANAGEMENT AT THE NAVAL FACILTIES ENGINEERING COMMAND

### Summary of a Presentation by J. Clay Dean
### Consultant to the Naval Facilities Engineering Command

Knowledge management is at the intersection of culture, philosophy, and technology. It is what we know, how we know, and how we share. The concept is to combine information from a number of sources so that the whole is greater than the sum of its parts. The Naval Facilities Engineering Command (NAVFAC) is developing a means of capturing and institutionalizing the knowledge gained by the hard work of many so that it can be used to help facilities managers take control of the process of resource management and change.

To this end NAVFAC has launched a knowledge management program with two principal elements:

**J. Clay Dean, P.E.,** assists the Naval Facilities Engineering Command (NAVFAC) Chief Engineer in establishing a knowledge management program for the facilities engineering community across NAVFAC. Mr. Dean was chief knowledge officer for a defense contractor firm. He spent 25 years in the Navy, where he was the senior leader of three public works organizations. As a result of his reengineering efforts (through the use of technology applied to customer service), Vice President Al Gore awarded Mr. Dean and his team the Hammer Award in 1996. Other assignments included the Joint Staff in Korea, State Department, and Department of Defense Installations Management Office.

1. Participation in the foundation knowledge portal at the CADD/GIS Technology Center at the U.S. Army Engineer Research and Development Center, Information Technology Laboratory in Vicksburg, Mississippi (http://foundationknowledge.com). The portal is designed to capture, leverage, and share knowledge among the government facilities management staff. The desire is to eventually have greater industry collaboration in public settings.
2. Creation of the NAVFAC engineering network (E-net), a group of 31 technical discipline leaders and their communities, supported by an intranet serving NAVFAC customers around the world.

There are a number of reasons for the interest in knowledge management, including:

- leveraging experience by interaction among peers;
- retaining knowledge in anticipation of retirements;
- facilitating customer support; sharing and retaining corporate and individual knowledge;
- improving response to data calls;
- enhancing decision support; and
- improving linkage with operations.

In developing knowledge management tools NAVFAC will apply a building-block approach that will allow novices to look at briefings and reports on given subjects. As interest increases personnel will be able to collaborate and engage in knowledge sharing activities.

The initial focus of knowledge management in the E-net is theNAVFAC's Engineering Service Center's engineering field divisions and activities. The emphasis is on engineering, community, succession, and expertise management.

The E-net collaboration structure is led by 31 technical discipline leaders (TDLs). These leaders were identified as part of the engineering core competency (see Figure 3). The TDL's are aligned with functional areas

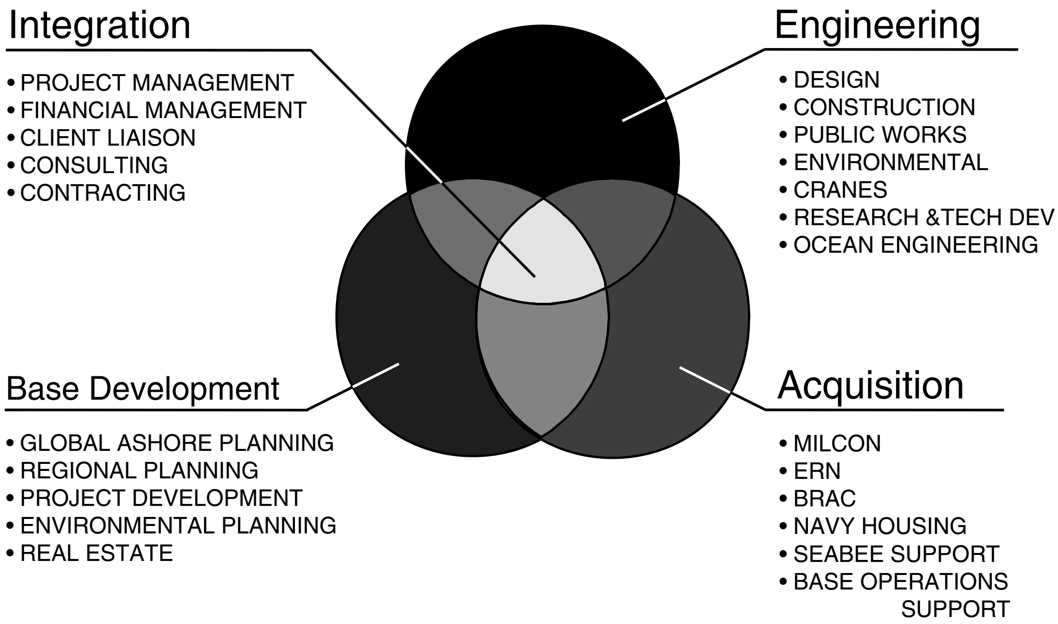


FIGURE 3 The collaboration structure based on core competencies.
Source: Naval Facilities Engineering Command Community Management Program.

and competencies. This provides the essential reason to collaborate. We have defined the roles and missions of engineering communities. An example of an E-net community of practice could be pavements or environmental cleanup. The community can focus this talent on resolving specific problems identified by a customer or from within the group.

A technical discipline leader will coordinate the efforts of subject-matter experts, called technical centers of expertise. The technology is a simple one: threaded e-mail; however, people must use it and leave their e-mail so it can be saved.

Technical discipline leaders may sponsor online forums using threaded e-mail. This tool helps capture knowledge because dialogues can be saved to form a searchable database. NAVFAC will assess collaboration tools for increased functionality on the E-net based on technical discipline leader requirements.

Subject matter experts are also forming communities of practice to discuss specific problems or issues within specific areas. A contractor is supporting NAVFAC in the creation of an environmental GIS community of practice that is based on a NAVFAC study on best practices. Additional information about the study is available online at <http://foundationknowledge.com/library>.

Lessons learned are an important part of knowledge management, but they are not easy to capture unless there is a reason to submit one. But, if capturing the lesson is embedded in the process, then the chances of capturing a lesson increase because you have already typed out something (e.g., this bolt shears off at this force; do not use that bolt). You can capture that text, drop it into your lessons learned form, and submit it. NAVFAC is implementing the Army Corps of Engineers' DrCheks program for design management and review, which has a lessons-learned feature. It is also studying Web-based tools for E-net process support and collaborating with the CADD/GIS Technology Center to tie the previously mentioned elements together.

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# New Tools for Fully Integrated and Automated Facilities Management Processes

An industry-sponsored program for implementing promising technologies in the construction industry and a study that estimated the economic gains achievable through their use were outlined at the conference by Dr. Richard H.F. Jackson, Managing Director of the FIATECH (Fully Integrated and Automated Technology) Consortium, and Dr. Robert E. Chapman, an economist with the Office of Applied Economics at the Building and Fire Research Laboratory at the National Institute of Standards and Technology (NIST). New technologies for managing the design of fast-track, capital projects were discussed by Dr. Ray Levitt, Director of Stanford University's Center for Integrated Facility Engineering. Dr. Sarah Slaughter, President of MOCA Systems, Inc., described a model of construction activities that reintroduces the link between design and construction. Mr. Rick Hendricks of the General Services Administration reviewed how an information technology application was used to plan for the relocation of the U.S. Patent and Trademark Office from 34 leased locations to a new 5-building campus.

## FIATECH CONSORTIUM

### Summary of a Presentation by Richard H.F. Jackson Director, FIATECH Consortium

The construction industry is being challenged to build and maintain facilities more rapidly, at less cost, that are sustainable, safer, more integrated, more performance driven, and more flexible. The industry needs both basic technology research with long-term horizons and applied research that helps deploy existing and emerging technologies more effectively and more imaginatively. The FIATECH (Fully Integrated and Automated Technology) Consortium was formed in late 1999 to accelerate the deployment of advanced technologies that will improve profitability in the construction industry.

FIATECH is an industry-led, collaborative, not-for-profit research and development consortium launched under the auspices of the Construction Industry Institute and in cooperation with the National Institute of Standards and Technology (NIST). It currently has more than 40 members, including some of the largest chemical and pharmaceutical firms; many of the leading architect-engineering, computer-aided design and manufacturing software firms; the U.S. Army Corps of Engineers; and NIST's Building and Fire Research Laboratory.

The FIATECH vision is to bring owners, operators, contractors, and suppliers together from all across the industry to achieve this vision of full integration and automation. The problems involved are too complex for any one organization. Competition has taken on global dimensions. The basis of the competition has broadened from price to quality, to time to market, to innovation, to design in dexterity of supply chains. It is only by working together that we can get to the seamless integration of information flow and from all participants throughout the entire project life cycle, from concept to design, to construction, to operation, to maintenance, and even to decommissioning and dismantling.

The consortium is modelled after the highly successful National Center for Manufacturing Sciences and SEMATECH, a group formed to reinvigorate the semiconductor industry. FIATECH will operate by forming, managing, and deploying complex, multi-partner research, development, and deployment projects. It will have a full-time staff that will develop leveraged funding opportunities and manage the technical projects, including:

- seamless integration of information flow among all participants throughout entire project life cycle;
- application of the latest available proven technologies;
- computer-aided drawing and computer-aided engineering;
- advanced communications;
- field sensing and tracking;
- field automation;
- construction automation;
- breakthrough improvements in quality, schedule, and cost, resulting in improved return on investment;
- pre-construction; and
- modularization.

The construction industry has not been able to benefit fully from these technologies, largely because it is a highly fragmented industry with a short-term project orientation and low research and development (R&D) budgets. It spends less than one percent of its revenues on R&D.

There are few broad industry standards. There is no common industry voice to deal with development. Even if there were, some of the costs in these areas are too high for any one company to bear. There is no common vision for full integration and automation. And there is yet no common roadmap to guide us.

It is our intention in the FIATECH Consortium to address these roadblocks head-on and by doing so, to help achieve reductions of 30 to 40 percent in cost and schedule time. These improvements will reduce design changes and rework through concurrent engineering and better control of project scheduling and cost, improve supply chain management, detect differences between designer intent and construction, develop highly accurate as-built information for operation, maintenance, and renovation, and ensure that the right data are available when and where they are needed.

FIATECH has a Board of Directors to whom I report. Strategic Focus Areas, or SFAs, will be the essential operating units of the consortium and will guide most of the consortium's activities. SFAs will function as focus areas or interest groups within FIATECH.

Each SFA will be led by an elected board and charged with developing high-level goals and objectives, along with a strategy for accomplishing them. Membership dues will be used to provide administrative support of most SFA activities, but SFAs will usually seek sponsors for projects. One important sponsor is likely to be the federal

**Richard H.F. Jackson** is the first director of FIATECH (Fully Integrated and Automated Technology), a not-for-profit research and development consortium launched by the Construction Industry Institute in cooperation with the National Institute of Standards and Technology (NIST). Before coming to FIATECH, Dr. Jackson was the director of the Manufacturing Engineering Laboratory (MEL) at NIST. During a career at NIST that spanned almost 30 years, he held numerous scientific and management positions prior to being appointed director of the MEL. He has also been a member of the National Industrial Information Infrastructure Protocol Consortium Board of Directors and the National Conference of Standards Laboratories' Board of Directors. Dr. Jackson has published over 100 technical papers.

government, which spends $500 million a year in construction-related research. Project participants will cover the cost of the research and deployment, which will allow for differential allocation of intellectual property that provides the profit motive for company participation. We expect some projects and products to be made generally available, but the participants will decide what will be disseminated freely and what will be proprietary, licensed, or sold.

The five members of the former Owner/Operator Forum (Air Products and Chemicals, BASF Corporation, Dow Chemical Company, DuPont Company, and Merck & Company) recently joined FIATECH en masse. They will be managing the consortium's first strategic focus area: defining business drivers and requirements for software related to the life cycle of capital equipment.

We are also starting a development cycle for several other projects. We will be working with the Construction Industry Institute to identify a project related to electronic commerce. We are talking with the Army Corps of Engineers and NIST about an effort that will help support the Corps of Engineers' desire to integrate their projects.

Interoperability is a very important issue. FIATECH is considering development of cost-effective technologies for collecting, compiling, and maintaining field data for actual representations of buildings. These would include advanced sensing and scanning tools to collect the data, wireless technology for moving the data where they are needed, and visualization software for providing meaningful representations of the data and analysis software to ensure you get what you want.

Another idea is that FIATECH should operate a test-bed for fully integrated and automated project processes. This would be a place where researchers and engineers could work together, either collocated or not, to test, evaluate, try out, and demonstrate in a low-risk environment, new ideas, software tools, and best practices for information technology integration. NIST already has this capability and is ready to work with us to put it to use in areas of mutual interest.

In such a test-bed, high-quality interactive simulation tools might be used for developing three-dimensional models of plants and facilities, for checking out operating procedures for new facilities, and for gauging the impact of introducing new technology and conducting performance analysis. A design team, owners, and contractors might come together and immerse themselves in a proposed design to help determine whether it is really what they are looking for. Owners and operators could also use the facility to walk around in both designs and as-builts and determine the differences.

Ways of exploiting information technology in the construction industry are often lumped together under the rubric of electronic commerce. It is important to distinguish between e-commerce, which may be defined as buying and selling on the Internet, from e-business, where you have business-to-business data sharing, requests for proposals, invoices, bidding, some project management, and so forth.

There is also a notion of e-construction, which is actually connecting the front office with information and data and what is going on all the way down to the construction site using radio-frequency identification tagging, bar coding, or global positioning system monitoring.

Much progress has been made in the top two layers by application services providers, but little has been done in the bottom, infrastructural layer. And even in the upper layers progress has been slow because of the lack of industry standards. It turns out that few people and few organizations invest much in standards, although we talk about their importance. Yet it is at that bottom layer that the foundation for progress is laid.

## BENEFITS AND COSTS OF RESEARCH

### Summary of a Presentation by Robert Chapman
### Economist, Building and Fire Research Laboratory, National Institute of Standards and Technology

Fully integrated and automated project processes (FIAPP) technologies are characterized by one-time data entry, interoperability with design, construction, and operation processes, and user-friendly input and output techniques. If implemented, they would result in significant reductions in both the delivery time of constructed facilities and life-cycle costs of those facilities. And cost and cycle time reductions are vital if the construction industry is to remain competitive.

To promote the timely delivery of FIAPP products and services to the construction industry, NIST's Building and Fire Research Laboratory (BFRL) formed the Construction Integration and Automation Program. This program is a interdisciplinary research effort within BFRL—in collaboration with the Construction Industry Institute, the private sector, other federal agencies, and other laboratories with NIST—focused on the development of key enabling technologies, standard communications protocols, and advanced measurement technologies.

**Robert E. Chapman** is an economist with the Office of Applied Economics at the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology. He is currently leading technical projects to identify industries affected by BFRL research and projects in support of the National Science and Technology Council's Subcommittee on Construction and Building. Previously, Dr. Chapman was program manager for the information and outreach branch of the Malcolm Baldrige National Quality Award Program, where he provided liaison to a rapidly expanding network of state and local quality award programs. He has conducted studies on how federal, state, and local technology-based programs were assisting small and medium-sized businesses, the results of which have been published as a formal Report to Congress. He has led technical projects in the areas of fire safety in health care facilities, economics of performance-based standards, software design, development, documentation, and evaluation.

The role of standards is crucial in the implementation of these technologies. NIST is uniquely positioned to take on that role, because it is specifically enabled to develop these infratechnologies—technologies that allow private sector individuals and companies to build their own proprietary technologies on top of it. This contrasts with the role of the FIATECH Consortium, which is more a vehicle for delivering results to the industry.

The stakeholders, in the effort to develop FIAPP, are all the key players in the construction industry: building owners and managers; building materials, equipment, and software providers and innovators; building contractors; and providers of support services. When FIAPP products and services are available commercially, construction industry stakeholders will benefit from reductions in first costs, reductions in delivery time, reductions in maintenance and repair costs, improvements in construction safety, and higher contractor profits. Offsetting these gains are the costs of these new technologies and increased research and development costs.

First costs of construction projects will be reduced because the technologies will result in less rework: better work scheduling, better work packages, being able to do simulations that will allow tasks and crew activities to be compressed and thus reduce delivery (cycle) time. Having electronic as-built information will reduce operation, maintenance, and repair costs. And having the ability to conduct simulations will have a favorable impact on construction safety.

Also we see an opportunity for productivity improvements. Manufacturing productivity has improved over the past 20 years; construction productivity has not. Improved construction productivity and better schedule controls by contractors translate into higher profit margins for contractors.

To quantify these benefits and costs, I authored a microstudy published by NIST in June 2000. The study, *Benefits and Costs of Research: A Case Study of Construction Systems Integration and Automation Technologies in Industrial Facilities*, is available on the World Wide Web at <www.fire.nist.gov/bfrlpubs/build00/PDF/b00025.pdf>.

As the title of the study indicates, it focuses on one segment of the construction industry—industrial facilities. This segment is the smallest of the four segments composing the construction industry—industrial, commercial, public works, and residential—accounting for less than 10 percent of the total value of construction put in place. However, the industrial facilities segment of the construction industry exhibits a number of characteristics that will in all likelihood lead to both earlier and more rapid adoption of FIAPP products and services. First, it is less fragmented than the other segments of the construction industry and tends to be dominated by larger construction companies. Once large construction companies adopt an innovative technology, they are able to leverage their subcontractor tiers, leading to increased levels of adoption throughout the supply chain. Second, the companies who own industrial facilities tend to be large in size, often exhibiting extensive use of information technologies in their core business functions. Thus, they are better able to evaluate the merits of FIAPP products and services and encourage their use by contractors throughout the facility life cycle. Finally, many large industrial companies have actively pursued strategic alliances to promote increased cooperation and reduced confrontation between owners and contractors.

The study finds that the use of NIST's FIAPP products and services is estimated to produce a $2 billion savings nationwide to industrial facility owners, managers, and contractors in the period from 1993 to 2015. The estimated savings are in 1997 dollars calculated at a 7 percent real discount rate. Ranges of 1 to 4 percent reduction in first costs and reduction in cycle time of 12 to 18 percent are projected.

An additional analysis was conducted using information on projected ranges of savings and costs. This analysis concluded that savings to the industrial facilities segment of the construction industry of $3 to $4 billion—expressed in 1997 dollars—were feasible.

## MANAGING SCHEDULE AND QUALITY RISK IN FAST-TRACK PROJECTS

**Summary of a Presentation by Raymond Levitt, Ph.D.**
**Center for Integrated Facility Engineering, Stanford University**

"The Virtual Design Team" (VDI) is a technology developed by the Center for Integrated Facility Engineering (CIFE) to better manage the design of fast-track capital projects. The center is a collaborative effort of Stanford University's civil engineering and computer science departments and innovative companies interested in deploying information and construction technologies.

The commercial version of the technology, which was seeded by small amounts of money from the center and larger grants from the National Science Foundation, is offered commercially as "SimVision™" by Vité Corporation of Mountain View, California.

CIFE was encouraged to develop the technology by companies like Intel and Palm for whom time to market is crucial. For microprocessor vendors like Intel, opening a plant ahead of schedule can be worth $1 million an hour during the few months that new chips sell for premium prices. It is $12 million of profit per day and that market window lasts only about three to four months. The technology is now in common use in the semiconductor, computer, telecommunications, oil, and processing industries, and is beginning to be used in construction projects.

**Raymond Levitt** is a professor in the Department of Civil Engineering at Stanford University and is the director of the Center for Integrated Facility Engineering (CIFE). Dr. Levitt studies ways that artificial intelligence techniques can provide new kinds of non-numerical computing capabilities for engineers and managers. His Virtual Design Team research uses artificial intelligence techniques to analyze and design agile engineering enterprises. Dr. Levitt is a cofounder and chair of Design Power, Inc. He has industry experience in marine and building construction and consulting assignments related to construction safety management, organization design, and information technology in project/matrix organizations, and has also written extensively in these areas.

The major challenge of fast-track projects is their large overhead generated by parallel work processes. The critical path methods developed during the 1950s and 1960s model sequential activities, such as building a foundation and then building the structure, where you have sequential handoffs. They are inappropriate for fast-track projects where there is a great deal of parallel activity. With fast-track projects, people on the project team spend substantial amounts of time coordinating with one another, and more significantly, reworking efforts initially based on partial information, as more and new information becomes available.

Project managers tend to underestimate the resources involved in coordination and rework with fast-track projects. This is because the relationship between the degree of fast tracking and the resources is exponential, not linear. The more you fast track a project the greater the relative amount of coordination and rework required. So the question is, where are you on the exponential curve? Are you on the early part or the middle or are you at the point where the coordination and rework is actually larger than the direct work?

The VDT/Vité design tool allows organizations to predict the amount of coordination and rework as a function of the activities being overlapped, the skills of the people responsible for those activities, the structure of the organization, and so forth. The modelling tool works much like a critical path model except that it looks at work as a volume of information to be processed in parallel, instead of a series of sequential tasks.

We are focusing on knowledge, design, planning, procurement—what happens before construction. The participants can be viewed as information processors with some set of skills and experience that affect two things: how fast they can do the work and the rate of errors they incur doing it. The higher the skills and experience of the team or individual relative to the demands of the task, the faster they go and the fewer mistakes they make. The difference between a highly skilled architect or engineer and a novice can be dramatic.

Fast-track projects are information intensive. Typically they are used to produce high-performance, complex facilities with a high level of interdependency among its subsystems. The fast-track schedule triggers unplanned coordination and rework for the project team, which must process a large amount of information under tight time constraints.

What is happening on these fast-track projects is dependent on the skill and experience of the people doing the work and the structure of the organization—how decentralized or how centralized it is. Rework has to be done when changes are made that affect other people. All of this takes time and this is what delays fast-track projects.

So the information-processing capacity of a project team is really the critical limiting factor for a fast-track project. We obviously need the resources to do the direct work, but we typically make allowances for that based on experience. What we tend to underestimate are the coordination and the rework. The more aggressively we fast track, the bigger an issue this is. Complicating all this are the products that get more and more complex, and the subsystems that interact in more complicated ways.

Yet, we cannot over-design things anymore. The world is too globally competitive. So, we tend to have lean designs with very interdependent subsystems. Now we try to build those in parallel. Every change ricochets up and down the organization and it gets absolutely overwhelmed with information processing. The trick is to be able to anticipate it, plan for it, and take steps in advance to fix it.

How do you handle this need to manage organizational risk in fast-track projects? The traditional way was to learn by doing: trial and error. You set objectives, propose an organization and a work process. You try it, see what happens, and learn from it. Project organizations have trouble learning, because we disband them and then we form them again in different ways. The answer proposed by the designers of the VDT/Vité tool was to design a new project organization the way you design a structure or a foundation or an energy system, that is: set objectives, propose a solution, model or simulate in advance many different solutions to predict the outcomes, and then choose the one that has a good chance of being successful. Of course, it is critical that you have a theory and some sort of mathematical or computational modeling tool that allows you to make predictions about how things will perform.

Vité starts with business milestones and activities needed to achieve them. It adds to the critical path model two other kinds of relationships. The first is called information exchange. If we know that choosing the facade material and choosing the construction methods are highly related activities, we will show an information dependency. The individuals responsible for those two tasks would spend time talking in the real world, so we want to simulate that in the model.

The second relationship is called change or failure propagation. For example, you apply for an excavation permit and discover a problem that will require a change in the construction method. The model will capture statistically a prediction of the rework that might be necessary. This gives a more realistic estimate of how much information it actually takes to get the job done.

The next step is to model the project team and try to understand its information-processing capacity. We define the sets of skills needed for the project and classify the participants in terms of their skills. (McGraw-Hill's Construction Information Group has developed a database that could be used in this application. Many organizations have internal databases they could adapt for this use.) People using Vité then model the reporting relationships on the project. The final item modelled is decision-making policies in the organization: How central is decision making? How formalized is it? How much experience is there on this team? Have they worked together before? How strong or weak is the matrix? Are the specialists collocated or are they in functional silos in different parts of buildings and offices?

Essentially, the "engine under the hood" of VDT/SimVision™ is a discrete event simulation where we are passing pieces of information through the virtual actors; they decide what to do, they do it, they make errors statistically, and they communicate with other people. The result is a series of reports that have turned out to be very accurate over and over again. A simulation of Lockheed Martin's attempt to develop a commercial space launch vehicle in a schedule compressed from the typical four to five years to one year predicted that the vehicle would launch four months late. It launched within two days of the time predicted by the model. One of the reports is an estimate of who in the project team will actually be backlogged (i.e., where the bottlenecks will be). This is important because the effects of backlogs cascade. As an example, take a project involving the design of a semiconductor facility where the architect is backlogged 26 days, or 5 weeks, in what should be a four- to five-month project.

The project is delayed because this person's tasks are delayed. Second, other workers' time is wasted because they have to wait to get answers to questions. Third, it affects project quality because when you are five weeks backlogged you keep your head down and do your own work and you give less priority to answering questions and going to meetings, and doing coordination activities that affect the quality of other people's work. All of these result in predictions of risk of process quality, which have been shown to correlate well with product quality problems. By identifying the potential failures, you can find ways to resolve them before they actually occur.

VDT/Vité simulations tend to underline an important lesson. When projects are fast-tracked, the knee-jerk reaction is to add more people to the team. But instead of more people, you might want to put your A-team players on the project because skill reduces the error rate and speeds things up. Higher skill often has a bigger impact on quality than more people. More people will speed up the process but will not improve the quality of the product. So you can consider different kinds of alternatives in advance in a "flight-simulator" mode with this technology.

Often the VDT/Vité team models the efforts of 10 to 20 participants in a project with 30 to 40 activities during start-up meetings for a project team. We build the model. We identify the bottlenecks and then go through alternatives quickly. In the course of a day we can come up with substantial insight into project risk and then iterate alternatives.

In summary, the VDT/Vité methodology and software provide:

- a common language to discuss and understand fast-track project work processes;
- a methodology and software to (re)design and improve those processes;
- a medium to share the results intuitively; and
- a framework to facilitate continual improvement and dissemination of best project designs.

CIFE is now studying the use of the technology in service and maintenance activities, which represent a larger cost for facilities owners, but where work processes are less well-structured. It will require a more branching, dynamic model because you often do not know in advance what the activities are. Models developed for health care, which is people maintenance, appear to be useful in simulating facilities maintenance. CIFE is also working with a consortium sponsored by the National Science Foundation that includes the University of Southern California, the University of Illinois at Urbana-Champaign, and Carnegie Mellon University. The consortium will study the network organizational forms that link knowledge and people throughout organizations and people outside organizations as well, and explore how distributed knowledge may affect the performance of organizations in the twenty-first century.

## MODELS OF CONSTRUCTION ACTIVITIES

### Summary of a Presentation by E. Sarah Slaughter
### President, MOCA Systems, Inc.

One of the things I have found in working in design and construction is that even when innovation takes place, it is not captured and reused. So we are constantly reinventing the wheel. I have also found it is difficult to get people to commit to using an innovative technology or process because there is a high degree of risk and uncertainty. There is a growing gap between design and the realization of that design, particularly in regards to time and cost in the construction industry that is due, in large part, to the large number of complex systems and complex processes. We need a mechanism to tie them together.

**E. Sarah Slaughter** is the president and chief executive officer of MOCA Systems, Inc., a company that models construction processes to analyze and manage the duration, cost, and safety impacts of design and process changes in construction projects. Dr. Slaughter was most recently a professor in the Department of Civil and Environmental Engineering at the Massachusetts Institute of Technology, specializing in innovations in construction. Dr. Slaughter has published more than 50 articles in the area of innovation and change in design and construction projects. She previously served on the Board on Infrastructure and the Constructed Environment of the National Research Council and serves on several editorial boards, working commissions, and advisory boards.

When I was teaching at the Massachusetts Institute of Technology's (MIT) Department of Civil and Environmental Engineering, my students and I conducted time-motion studies and interviews at more than 200 construction sites focusing on the physical components in buildings and the tasks that are done to transform and aggregate those components into finished systems. The National Science Foundation funded the research. We captured the detailed task elements in the language of the carpenters and other people working on the site (the subcontractors, general contractors); tied that in with the knowledge of the architects and structural and mechanical engineers; and finally with the measures that matter most to the owner. The information captured was used to develop simulation models (Models of Construction Activities) that can be used in the early design stages to evaluate design and construction alternatives, examine innovation opportunities, improve resource utilization, plan for constructability, and investigate cost/time trade-offs. Thus it reestablishes the link between a design and its realization in construction.

In 1999 I took a leave of absence from MIT to establish a firm, MOCA Systems, Inc., in Newton, Massachusetts, to commercialize the computer models. MOCA Systems now offers a Web-based service for owners and developers, and their project teams of general contractors, construction managers, architects, engineers, design-build professionals, and specialty contractors. The model allows users to simulate the actual construction of a building from the ground up as it actually would be done in the field. It provides people with a system that corresponds to their tacit knowledge and allows them to run controlled experiments. You can sit down during the early design stages, put in information about the project and get back how much it is going to cost, how long it is going to take, and what the exposure of workers is to dangerous conditions. It can also be used to experiment with alternative techniques that might be used, learn what the impacts might be, and thereby reduce risk and uncertainty.

One model was developed and calibrated during the renovation of the Baker dormitory at MIT in three and one-half months—something that was not possible using standard methods. In planning the project, the dormitory construction team came up with some clever approaches to prefabricate members, which reduced the duration of construction by one-third. These innovative approaches also reduced the cost of the project by 20 percent. The model estimated the actual construction time and cost within 1 percent accuracy.

In another case, approaches developed through the use of simulation identified ways to reduce project duration from 39 days to 27 days to totally renovate a 150-year-old school building. For example, we looked at two processes: walls and plumbing. On a typical construction project the carpenters start on the walls; then they stand around and wait for the plumbers to rough in all the horizontal plumbing for the fixtures. By simulating the process we found that by doubling the number of plumbers, we were able to loosen that constraint and increase the utilization of those resources.

The MOCA Build System has two parts. The core technology, which is licensed from MIT, is a library of construction process information down at the level of every single bolt, every single beam, for every single worker. What the users have is their project data and in that project data they can put all sorts of information. What is the size of the building? How many stories? Is it steel or a concrete structure? Is it a glass curtain wall or pre-cast concrete panels? What is the interior fit out? Do you have hard walls or do you have movable partitions?

All of this information goes into the MOCA Build project analysis. Users can also put in recent bid experience. You can look at the time and cost. What is the exposure of workers to dangerous conditions? The model uses Occupational Safety and Health Administration categories of causes of injury for each task and scales it to how long a worker is performing that task. The index scales by the size and attributes of the project. So if people are carrying things upstairs and downstairs rather than using a lift you are able to capture and compare some of those elements.

The second part consists of individual models for structural steel, cast-in-place concrete and light wood framing, models for glass-metal curtain walls and pre-cast concrete panels, five service models, and two interior finish models. The models are linked so that the user can determine, for example, when the steel is set faster, whether to enclose the building earlier and begin roughing in the systems, or whether the systems should be roughed in from the bottom up or top down. In the early conceptual development stage of a project, the models provide a way to actually test alternative designs and construction techniques. Users find this a great way to test alternative approaches for realizing their program requirements and meeting their time and cost objectives.

During the bid process and once construction begins the model provides details on almost every physical component in the building, and that allows everyone to work from the same database. We can also go into incredible detail and be able to talk about who is actually working where and when. This is an invaluable tool for bidding and mobilization planning.

Optimizing the use of resources can be of great value where expensive resources, such as large cranes costing $5,000 to $10,000 per day, are required. Simulations are also useful where high performance is required or where site conditions are constrained. You may have difficulty getting deliveries. You may have difficulties in moving elements. You may not be able to put the crane anywhere, and in that case the high complexity of the processes themselves cannot be mapped with the human mind. The human mind is a wonderful element but it cannot follow secondary and tertiary impacts down through a complex flow. The model basically keeps track of many of those interdependencies and their impacts on all the secondary and tertiary activities.

Owners who want to improve the development of designs they will be replicating in multiple locations also favor MOCA simulations. Rather than starting from scratch every single time, they would like to have a template and be able to analyze and improve on that template incrementally over time, or to quickly change the template to adapt to site specific issues.

Release of object-based computer-aided design (CAD) programs and CAD programs based on industry standards such as aecXML will only make the MOCA Build models easier to use, because it will potentially enable direct connection between CAD programs and the MOCA Build models. During the next year MOCA Systems will be commercializing a number of research models. We are developing a Web-based interface for inputting data and looking at ways to import information from legacy systems of other vendors.

## INFORMATION TECHNOLOGY FOR MANAGING RELOCATIONS

### Summary of a Presentation by Rick Hendricks
### Project Manager, General Services Administration

One of the most difficult challenges faced by the General Services Administration (GSA) in overseeing the consolidation of the U.S. Patent and Trademark Office's (PTO) operations into a new 2-million-square-foot headquarters in Alexandria, Virginia, was not the planning and managing the design and construction of the buildings. Rather, it was planning the move itself, a move out of 34 leased locations in 18 buildings with myriad different lease expirations, renewal options, and other conditions.

A key objective of the joint move team overseeing the consolidation was to keep the payment of double rent, what the GSA calls "overlap," to a minimum. To this end, they developed an extraction plan to guide them during the move, which will take place over a 40-week period starting in November 2003.

Traditionally, moves of this sort are planned by GSA with customer-agency (PTO) facilities management professionals and consultants. The problem with this approach is no matter how long you study, or how good a program you write, or how smart you are at getting to understand the client, you cannot learn everything about the client in a finite amount of time. So, the plan is inherently flawed. It becomes a no-win proposition. Clients want to be satisfied, but you can never satisfy a client unless you give them everything they want, and the nature of a project is that you cannot give them everything they want. There are too many trade-offs. The real solution then is optimization, not total satisfaction.

**Rick Hendricks** is the project manager for the consolidation of the U.S. Patent and Trademark Office at the Portfolio Development Division of the General Services Administration's National Capital Region. He was previously director of capital development for GSA's National Capital Region. In 1995 he helped establish the agency's Courthouse Management Group. He also managed the lease-construction of the 465,000-square-foot National Science Foundation headquarters building in Arlington, Virginia. Before joining GSA, he worked in industry for nine years in sales and marketing positions related to systems furniture.

Hence, early on in planning the PTO move, the team decided to use a simulation model to test a variety of scenarios. In the process the team shifted its role from expert planner to facilitator and used their experience to keep the project on track and to avoid mistakes. To help visualize the move and engage all elements of the PTO the team decided to simulate the move by setting up the scenario-planning model as a game. Gensler, the space planning and interior architecture consultant on the team, was willing to try this approach and brought their expertise to the mix.

So far, the model has since been run six times and will be run several more times. The results have been better than expected. After using the model the people making decisions or recommendations understand that they are in an environment of trade-offs. They recognize that optimization rather than total satisfaction is the goal.

For instance, for those using the model it becomes quickly apparent that they cannot all have the top floor that faces the Washington Monument. Once they understand that not everyone can have the prime office space, they ask: What are we going to do? How are we going to resolve it? GSA no longer has to sell a solution, because the client understands how they arrived at the overall solution and they buy in to the process.

Team members intervene as little as possible in the scenario planning. In one scenario PTO managers proposed using vacated space still under lease as interim space while new space was prepared, because of the savings that could be achieved. If such a step was unilaterally proposed by GSA it would likely have been resisted. By using the model, everyone understands the rationale and the result.

The simulation also helps agency managers deal with the inevitable issue of the government paying double rent. Simulating different scenarios allows GSA to find out, for example, that $10 million spent on vacant space is much better than the $45 million that might have been spent if the move had been planned in the traditional manner. Without these realistic, quantifiable options, $10 million might look like failure, not optimization.

In running a scenario the objectives are to do so quickly, accurately, and realistically and to fully document the course of the game. The scenario-planning game is played in a large room with three tables. On one side of the room are tables covered with large schematics of the 108 floors in 18 buildings being vacated, and on the other side are the floors of the five large buildings to be occupied in the new complex. Poker chips with a label for each organizational unit in the PTO representing 10 people each are placed on the appropriate floor of the schematics for the existing building. A table on the third side of the room has schematics for expansion space and the requisite chips. (I originally considered using software that would have allowed the whole game to be played in a virtual fashion, but rejected the idea because the tactile game being used proved to be non-threatening, forgiving, and very engaging. It was a social event, like a family puzzle.)

The players and support people are briefed. Flip charts in the room spell out the overall strategy for the game, assumptions, lessons learned, and issues to be resolved. Professionals from PTO, GSA, Gensler, and other consultants are on hand to provide advice on technical issues. Team members are appointed to make sure that elevators and loading docks work within their capacities—a "loadmaster" in the old space, a "dockmaster" in the new space, and several "experts."

The idea of the game is to devise the best way to move the chips from the schematic representing the existing space to the schematic representing the new space at the other end of the room, while taking into account when the newly constructed space will come online and when the old leases expire. Reality and complexity are introduced by also trying to satisfy adjacencies, operational continuity, and information technology needs. Everyone is cautioned to take into account the physical and time constraints. Using real managers subliminally introduces the more subtle and hard-to-define factors like corporate culture, turf issues, unspoken desires, and body language in a creative, manageable way.

Chip moves are devised, negotiated, and agreed on by the "players" (the PTO managers). The chips are manipulated by "croupiers" at the direction of the players during the course of the game. The chips are transferred to the new buildings by people designated as "drivers" who carry 35 chips (the amount of people who can be efficiently moved in a week) in each "moving van" (actually a foam-core carrier with a space for each chip.)

Digital cameras and laptops were used to record the moves in the game. Gensler enters the results into a computer system using a mix of software, primarily Aperture (a computer-aided design/facilities management system that will be used to manage PTO's new space), Excel, and Powerpoint. The software allows the decisions made in the course of the simulations to be documented, displayed, and even replayed. Financial costs like rent, downtime, and move costs are computed and displayed.

PTO and GSA officials will soon be able to develop a comparative analysis of the completed scenarios to arrive at the best all-around solution. They will be using a decision-assistance package called Expert Choice. Participants will be brought together and asked to respond to a series of questions dealing with decisions made during the simulations and the perceived outcomes. Using Expert Choice, they will be able to spot trends, pitfalls, unanticipated consequences, and opportunities. It should assist the move team to rank the scenarios generated and to further optimize the moving process.