The Impact of Information Technology in Design and Construction: The Owner’s Perspective

Robert E. Johnson
Texas A&M University
rjohnson@tamu.edu

Mark J. Clayton
Texas A&M University
mark-clayton@tamu.edu

This paper reports on findings of a November 1996 exploratory survey of architecture-engineering clients (Fortune 500 corporate facility managers). This research investigated how the practices of corporate facility managers are being influenced by rapid changes in information technology. The conceptual model that served as a guide for this research hypothesized that information technology acts as both an enabler (that is, information technology provides an effective mechanism for managers to implement desired changes) as well as a source of innovation (that is, new information technology innovations create new facility management opportunities). The underlying assumption of this research is that information technology is evolving from a tool that incrementally improves "back office" productivity to an essential component of strategic positioning that may alter the basic resources, organizational structure, and operational practices of facility management organizations and their interactions with service providers (architects, engineers, and contractors). The paper concludes with a discussion of researchable issues.
To many, it is clear that the design and construction industry is undergoing change as significant as that described by Allen and Thomas. As the cost-performance ratio of information technology continues to shrink, information technology is almost certain to become more pervasive and raise at the possibility of new forms of delivering design, construction and facility management services.

The impact of this on architecture has been described by Patrick Macleamy, Executive Vice President of HOK. Macleamy has been quoted as saying: "They [clients] want a full range of services - design, build, repair and manage. This, in turn, requires a change in thinking on the part of designers, contractors, and suppliers" (Teicholz 1995). This theme is echoed by the AIA’s goal statement that “The redefinition of the profession requires a cultural/attitudinal shift that moves from a product-driven through a service-driven to a knowledge/technology-driven strategy. The goal is to find new ways to fulfill developing client needs.” (AIA Board 1996)

Clients are demanding not only that buildings be designed and constructed faster, cheaper, and with improved quality, but that services beyond design and construction also be provided. In short, design professionals are being required to reorient their thinking from a focus on project delivery to a focus on service delivery.

What does this mean for the AEC-FM industry? Clients, as it turns out, have a significantly different view of building information needs compared to architects and engineers. For many clients, the major service delivery issues are “repair and manage” and not “design and build.” For example, AutoCAD documents produced for the design and build process are virtually useless for the repair and manage process. This focus on client needs - in particular Fortune 500 clients - was the subject of this research survey. Our intent was to develop an understanding of how clients, in this case facility managers, are adapting to an industry that is increasingly “knowledge/technology-driven.”

previous research

This section reviews previous research and describes several trends and characterizations that provide general themes for an initial understanding of how information technology might be used in the practice of facility management.

strategic positioning

The impact on competitive strategy appears to be one of the most significant themes that emerges from a research review of how information technology affects corporations. Studies have identified companies who are deploying information technology and transforming their organizations in order to obtain competitive advantage in the market place (Porter and Millar 1985).

One of the widely recognized opportunities that has emerged from the strategic application of information technologies is that of the “virtual corporation” (Davidow 1993). The virtual corporation is a consortium of small, highly specialized companies which together act with the expertise, resources and economies of scale that were once only possible in large corporations. The virtual corporation may be quickly organized for a single project or may persist for several projects. In some ways, the virtual corporation offers advantages over the homogeneous corporation, such as a more nimble operation, lower overhead, greater flexibility, greater responsiveness to customer needs, and diffused liability. Yet a virtual corporation has disadvantages as well, primarily in that the degree of trust and interdependence
among the players is very demanding. Large corporations have identified that, by rethinking their own operations, they can gain many of the advantages of virtual corporations.

It has been suggested that the AEC industry has always operated on the virtual corporation model (Fisher 1993). The project team that consists of an architectural firm, several engineering firms, cost consultants and contractors is often a business entity that must work in close harmony to share information and meet client needs. This common project organization allows an architectural firm to reconfigure itself and the team to provide the expertise that a particular project and particular client desires. Nevertheless, opportunities exist for architects, engineers and facility managers to significantly increase levels of performance by using the virtual corporation strategy leveraged by information and communications technology (Novitski, 1994). Examples of virtual organizations are increasing, and include firms that outsource working drawings to international partners, the increased presence of manufacturers data in the Internet, and software such as AutoDesk’s Design Blocks which is designed to help integrate virtual design information.

work group productivity

A second dimension in recent research has been the ability of information technology to enhance work group productivity (computer supported collaborative work). Here the principal focus has been on communication and coordination. This research has theorized that as the cost of communication and coordination continues to fall, the economic advantage of highly specialized but small, work groups or teams increases. Electronic mail (Crawford 1998), groupware, telecommuting and videoconferencing have become relatively standard technologies to enhance group processes. These technical innovations have made it possible for work teams to communicate anytime, any place, and anywhere. A recent survey of construction industry presidents found that the principal way computer technology has changed relationships with employees has been through enhanced communication and corporate culture effects (Thomsen, 1996). The top three organizational effects were: allowed business to be done at greater distances, shortened work cycle time, and reduced the need for clerical support staff.

Commercial technologies that can aid in work group productivity include CAD browsers for 2D and non-graphics design data, VRML 3D models that can be explored interactively, Java applications that provide design calculations, product data published and distributed on the Internet, and communication tools such as digital whiteboards, and live video (Regli 1997). Experimental research has targeted collaboration for design more specifically. Supporting distributed work groups for mechanical product design was achieved in a test project called PACT (Cutkosky et. al. 1993). Research specifically directed toward supporting collaboration in the AEC industry using distributed software agents (CIFE World), multi-disciplinary explanations of a shared CAD model (ICM) and integrated architectural CAD and construction scheduling also have been reported (Novitski 1994b).

process improvement

A third major dimension that we have identified is the ability of information technology to assist significantly improving or altering existing work processes. Work process improvement is focused on reengineering processes to improve the effectiveness and or efficiency (productivity) of those processes. Although the principal focus is on analyzing and improving work processes, this theme may also incorporate aspects of work group productivity. A major concept in this category is the automate versus informate issue which was first introduced by Zuboff (Zuboff 1988). Her research found that those organizations that simply automate exist-
ing work processes will gain fewer benefits that those who informate processes (that is, redesign the work process at the same time that information technology is introduced).

Some of the best examples in the AEC industry of process improvement through information technology are the many energy simulation tools, such as DOE-2 or Lighting simulation software such as Lightscape (Birdsall et al. 1990). Software such as these may not only speed up orders of magnitude difficult design tasks but make possible design explorations that would be impractical or impossible with manual methods. They may even provide new strategic opportunities by creating new markets (such as energy code compliance) or computer rendering and animation. In facility management, process improvements through the use of computer-aided facility management software have been reported in space planning and management, inventory management, and maintenance and operations management (Teicholz 1997).

**Achieving Specific, Measurable Objectives**

The fourth dimension is the role that information technology can play in achieving specific company objectives. The goal is to define and then use information technology to achieve a predetermined, measurable objective such as "reduce costs by 10%" or "increase productivity by 5% per year." When applications have been used to "automate" existing work processes, it is usually possible to use standard measures such as return on investment (ROI) to evaluate results. However, it has proven to be much more difficult to use standard measures to justify strategic investments. This is because any investment in information technology must be followed or preceded by other investments that sometimes are external to the firm itself: For example, using shared databases to communicate interorganizationally often will require investments by several organizations and quite possibly investment in basic information technology infrastructure (Applegate 1995).

**Integrated Perspectives**

A fifth theme that has emerged is one of how companies have taken advantage of information technology to "radically transform" themselves on all four dimensions: strategic positioning, work group processes, process improvement, and achieving measurable objectives. These organizations "may take a totally different form, being more like a complex network in which communication and authority chains shift around and change according to the requirements of the task and the motivation and skills of people" (Schein 1994).

**Summary**

The picture that emerges from this research is that information technology is no longer just a tool to incrementally improve "back-office" productivity. Information technology has become a strategic necessity because it is beginning to alter the basic economics of AEC-FM organizations by:

- enabling employees to become knowledge workers;
- improving the collaboration and effectiveness of project teams that are dispersed in space and time;
- supporting the transformation of hierarchical companies into flatter, "virtual organizations;"
- creating new services and markets by facilitating the acquisition and conversion of information into knowledge that creates distinctive value for customers.

What seems to be missing from existing studies is an overall understanding of how information technology is affecting the facility management industry and how different industry subgroups within the industry are reacting to and planning for the information age. Therefore, the focus of this pilot study is to better understand how these changes in information technology are affecting the business practices of facility man-

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*Note: The text above is a continuation of the paragraph that started on the previous page.*
agers and to identify potential researchable issues in this rapidly changing field.

**Conceptual Framework**

The overall conceptual framework that emerged from this review of previous research and that formed the basis of the pilot research project is indicated in Figure 1.

This conceptual model hypothesizes that information technology acts as both an enabler (that is, provides a new way for organizations to meet its objectives) as well as a source of innovation (e.g., emerging technology innovations create the possibility for improved access to both quantitative and qualitative information which, in turn, create new opportunities for organizations). This model is similar to that proposed by Markus and Robey (Markus and Robey 1988). This “interactionist” point of view suggests that the result of using information technology “is a complex interaction between what the technology allows and what the organization and the managers want.”

**Business Goals**

We further hypothesize that business goals can be divided into the four major categories outlined in the section on previous research: improving a firm’s competitive position, improving work-group productivity, improving work processes within the firm, and achieving specific measurable objectives. (Figure 2).

The first category, improving a firm’s competitive position, may be of critical importance because information technology may provide a means for firms to uniquely position themselves in the marketplace in a manner that would be impossible without the availability of information technology. Examples of the use of information technology are emerging in the form of “virtual organizations” which provide substantially improved value to customers compared to traditional organizations.

Work group productivity is the second type of information technology. Instead of affecting the entire company, work group productivity affects subsets of a company. The use of groupware (e.g., Lotus Notes or Internet and Intranet collaborative applications) has the potential to empower and integrate project teams for substantial improvements in project productivity and, at the same time, eliminate the need for middle management. The third kind of information technology application is related to process redesign. Process redesign may affect the productivity of one or more individuals as jobs are reconfigured and processes streamlined. Software here may be specific to the pur-

![Figure 1: Conceptual model](image)

![Figure 2: Categories of business goals](image)
pose, such as specialized real estate management or energy analysis software. Finally, the fourth category to be tested is to determine the degree to which facility management organizations use information technology to achieve specific, measurable business objectives.

The organizational structure of facility management departments are also expected to influence their use of information technology. For example, we expect that facility management departments which are managing multiple sites in different countries are likely to plan and implement information technology solutions in a manner that is entirely different from departments that manage space within a single building. Different industry groups may also take a different attitude towards information technology. Therefore, we hypothesize that a number of organizational characteristics may be important factors that moderate or enhance the adoption of information technology.

These concepts indicate that management in the information age may present significantly different challenges and opportunities to business. The challenges and opportunities will also occur to managers of facilities, and can be expected to affect facility managers of different types of organizations in different ways. This research is an exploration of how facility managers are reacting to changes in information technology. Through this study we hope to develop preliminary ideas about research that may improve their practices.

**Methodology**

**Sample design**

This pilot project consisted of a self-administered questionnaire that was sent to facility managers in Fortune 500 firms who were also members of the International Facility Management Association (IFMA). The sample was designed to select companies with larger facility management problems (e.g., larger facilities, more multi-site locations) and therefore it was anticipated that they would have a greater incentive to be interested in the potential of information technology. In addition, it was thought that larger corporations would be more likely to have relatively sophisticated, in-house management information operations and an organizational culture that is more aggressive in pursuing the possibilities inherent in information technology. Finally, individual facility managers were selected who were members of IFMA and whose title was most consistent with having overall management responsibility for facility management. This ultimately resulted in a sample size of 75 facility managers.

**questionnaire design**

The questionnaire was designed to cover four basic categories consistent with the conceptual framework outlined above: 1) the usefulness of information technology to meet business goals, 2) current information technology practices and future directions, 3) barriers to the use of information technology, and 4) background characteristics of the facility management department.

**Response rate and description of respondents**

Although this was an exploratory research project, the initial survey was reviewed with several facility managers of three separate Fortune 500 companies to test the relevance of questions. Questionnaires were mailed in November, 1996, and by January approximately 36% had been completed and returned. The industries that responded are indicated in Table 1. Of those respondents, 61% managed buildings in multiple sites, and 55% managed more than 1 million square feet of building area. Those facility management departments that managed multiple sites managed an average of 5.8 million square feet of building area. It seems reasonable to expect that many of the respondents had significant building problems and were likely to use information technology to assist in managing those problems.
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<table>
<thead>
<tr>
<th>Services</th>
<th>Pct</th>
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<tr>
<td>Banking (consumer, commercial and savings)</td>
<td>7%</td>
<td>5</td>
</tr>
<tr>
<td>Information (data processing and services)</td>
<td>3%</td>
<td>2</td>
</tr>
<tr>
<td>Utility (energy-related services)</td>
<td>8%</td>
<td>6</td>
</tr>
<tr>
<td>Media (entertainment and broadcasting)</td>
<td>3%</td>
<td>2</td>
</tr>
<tr>
<td>Health/Hotel (healthcare, hospitality related)</td>
<td>3%</td>
<td>2</td>
</tr>
<tr>
<td>Insurance (life, casualty, and other)</td>
<td>12%</td>
<td>9</td>
</tr>
<tr>
<td>Professional (accounting, consulting, real estate)</td>
<td>1%</td>
<td>1</td>
</tr>
<tr>
<td>Investment (all securities and Investment services)</td>
<td>1%</td>
<td>2</td>
</tr>
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<td>Telecommunications (service providers)</td>
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</tr>
<tr>
<td>Trade (consumer wholesale or retail)</td>
<td>18%</td>
<td>13</td>
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<tr>
<td>Total Services</td>
<td>32%</td>
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</table>

<table>
<thead>
<tr>
<th>Manufacturing</th>
<th>Pct</th>
<th>N</th>
</tr>
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<tbody>
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<td>Vehicles (including aircraft and industrial)</td>
<td>4%</td>
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<td>Chemicals (including pharmaceuticals)</td>
<td>7%</td>
<td>5</td>
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<td>Consumer (products, food or related)</td>
<td>3%</td>
<td>2</td>
</tr>
<tr>
<td>Electronics (including computers and telecon)</td>
<td>11%</td>
<td>8</td>
</tr>
<tr>
<td>Energy (including mining and distribution)</td>
<td>4%</td>
<td>3</td>
</tr>
<tr>
<td>Other manufacturing</td>
<td>10%</td>
<td>7</td>
</tr>
<tr>
<td>Total Manufacturing</td>
<td>38%</td>
<td>28</td>
</tr>
</tbody>
</table>

Table 1: Response by industry type

Information technology: current and future uses

As indicated in Tables 2a and 2b, the most useful information technology solutions were reported to be those that already are in widespread use. By far, e-mail was reported to be the most useful application, with more than 8 of 10 respondents finding it very useful. This was followed by computer-aided design (almost 7 in 10) and sharing files with attachments to e-mail (5 in 10). More advanced technologies such as shared databases and electronic data interchange (almost 4 in 10) were also reported to be very useful, but by fewer respondents. At the other end of the scale, less than 1 in 10 responded that virtual reality, animation, geographic information systems, 3D visualization, multi-media, digital whiteboards, and desktop videoconferencing were very useful. Most of these technologies are still emerging, and have not yet achieved a level of acceptance within the AEC-FM industry.

The most significant result from an analysis of future practices was that, over the next five years, without exception all of the listed information technology solutions were expected to become more useful in the management of facilities. In addition, 9 out of 10 respondents indicated that over the next five years information technology will be very useful in helping them to manage facilities. There is every reason to believe that information technology will increase its use in facility management organizations in the near future.

As was the case with current use patterns, e-mail was very highly rated. Despite the very high acceptance of e-mail, about 9 in 10 responded that it is very likely that e-mail will become even more useful in how they will manage facilities over the next five years. Computer-aided facility management ranked second in future usefulness (almost 8 in 10), followed by project management and scheduling software (7 in 10) and computer-aided design (7 in 10).

Analysis

Strategic advantage

As indicated above, one hypothesis to be investigated was the notion that facility management organizations are increasingly experimenting with interorganizational electronic integration (Venkatraman and Zbier 1995) in order to significantly change the basis of competition. Because of the increased emphasis on outsourcing of facility management services,
more AEs are developing partnering and alliance agreements with facility management departments. Therefore, we expect that facility management departments will place a high emphasis on interorganizational business relationships and therefore on electronic integration with AE firms, including the development of virtual organizations and telecommuting. A principal indicator of this activity was hypothesized to be the degree to which facility management organizations have as a goal the sharing of information with domestic and partner firms.

Sharing information with partner firms and using information technology to assist seemed to be a high priority with the respondents to this questionnaire. Figure 3 shows that 45% of the firms responded that information technology "will help a lot" and 37% indicated that information technology will be essential in order for their organization to share information with domestic partner firms over the next five years. A similar pattern appeared for those who share information with international partner firms.

**Work group productivity**

Information technology can significantly improve work group productivity by increasing the speed and decreasing the cost of communication and coordination. Figure 4 shows that about 7 in 10 respondents indicated that information tech-
technology will be essential or will help a lot to improve collaboration among team members and to improve the productivity of teams.

work process improvements

Information technology has also been promoted as a means to implement process improvement plans. Figure 5 shows that information technology was thought to be most useful in order to improve real estate asset management procedures, and less useful to improve the accuracy of early cost/budget estimates.

measurable objectives

It is a common assumption that businesses use information technology to achieve specific, measurable objectives. Of the 16 items used to define the four categories of business goals, six related to the achievement of measurable facility management objectives. (See Figure 6.) This survey found that all six were in the lower half of the ranking of the 16 original items. Apparently, facility management organizations are finding information technology more useful as it applies to competitive positioning, improvement of work group productivity, and the improvement of work processes. This may indicate that facility managers are accepting information technology on the faith that improvements will result. But in the next section it is seen that measuring results is a major problem. Perhaps there is some real anxiety here.

barriers to the use of information technology

About one-quarter of respondents to this survey reported three issues as “big problems” for their organization: 1) customizing proprietary software to meet their needs, 2) measuring the results of implemented information technology solutions, and 3) evaluating information technology solutions using return on investment (ROI) methods. (See Table 3.) Support from their company’s MIS group, the cost of keeping operations data current in facility management sys-
<table>
<thead>
<tr>
<th>Item</th>
<th>a big problem</th>
<th>somewhat of a problem</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. customizing proprietary software packages to meet your needs</td>
<td>24%</td>
<td>33%</td>
</tr>
<tr>
<td>2. measuring the results of implemented Information technology solutions</td>
<td>24%</td>
<td>40%</td>
</tr>
<tr>
<td>3. prioritizing which information technology should be implemented first</td>
<td>24%</td>
<td>38%</td>
</tr>
<tr>
<td>4. evaluating Info tech solutions using return on investment (ROI) methods</td>
<td>24%</td>
<td>25%</td>
</tr>
<tr>
<td>5. support form your company's in-house information systems group</td>
<td>22%</td>
<td>21%</td>
</tr>
<tr>
<td>6. the cost of keeping operations data current in facility management systems</td>
<td>22%</td>
<td>38%</td>
</tr>
<tr>
<td>7. the cost of acquiring operation data for facility management systems</td>
<td>20%</td>
<td>33%</td>
</tr>
<tr>
<td>8. familiarity of senior management with the use and potential of Info tech</td>
<td>19%</td>
<td>22%</td>
</tr>
<tr>
<td>9. customizing standard software packages to meet your needs</td>
<td>16%</td>
<td>39%</td>
</tr>
<tr>
<td>10. the cost of educating staff to keep up with changing Info tech</td>
<td>14%</td>
<td>33%</td>
</tr>
<tr>
<td>11. the cost of software upgrades</td>
<td>10%</td>
<td>22%</td>
</tr>
<tr>
<td>12. the reliability of software</td>
<td>8%</td>
<td>14%</td>
</tr>
<tr>
<td>13. sharing electronic information with other (Interoperability)</td>
<td>8%</td>
<td>20%</td>
</tr>
<tr>
<td>14. overcoming cultural resistance to the use of Information technology</td>
<td>6%</td>
<td>40%</td>
</tr>
<tr>
<td>15. the reliability of hardware</td>
<td>3%</td>
<td>13%</td>
</tr>
</tbody>
</table>

Table 3: Percent responding that each item was a problem.

Researchable issues

One of the principal objectives of this project was to define researchable issues that cut across the AEC-FM disciplines. It has been exploratory in nature, and many of these findings have emerged through the course of our data analysis. In addition, others have surfaced through more recent case study investigations of Fortune-100 facility management organizations. This section will summarize some of the more significant researchable issues that we have identified.

Integrating "islands of automation"

The increased use of low cost desktop computing has led to a proliferation of local, idiosyncratic databases that sometimes duplicate information, use different data definitions, and cannot be integrated to analyze more strategic facility questions. An integrated database would decrease data entry costs, increase the consistency and reliability of the data, and make data readily available for operational planning as well as for corporate strategic planning. Compound-
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The cost of operations and maintenance data

A significant issue in any database management system is the cost of obtaining data and the cost of keeping that data current. The cost of data also appeared to be a problem for those facility managers responding to our survey. Potentially productive research areas may be to develop new methods of data acquisition and validation; approaches for classifying the critical nature of building systems; and the identification of the temporal nature of different building systems.

The information content of as-built drawings

Intimately related to the previous two issues is the generation, format, content and usability of as-built drawings. Although not directly included in the survey, in our subsequent discussions with facility managers this topic has emerged as one with widespread interest. It also is associated with the information content of CAD drawings and the standards that are used in the development of these electronic documents. The transfer of information from the construction team to the facility operators is often a problem. "As built" drawings may not have accurate information or may not have the right information for use in facility management or renovation. They may have unneeded information that is expensive to obtain and record. They may have too much information which reduces the clarity of useful information. They may have no information that is critical for the on-going management of the facility.

A careful study of the content and use of as-built drawings can lead to guidelines for their production. New information technologies may provide opportunities for improving the storage and retrieval of information for facility maintenance and renovation. Research is needed to evaluate the use of as-built drawings, identify deficiencies in current as-built drawings, and provide solutions to overcome those deficiencies. Ultimately, a better understanding of owner's needs for as-built information can lead to new forms of architectural services.

Computer supported collaborative work

A key to improving the quality and decrease the cost of projects in the AEC-FM field will be through improving work group productivity. Although there are several competing solutions in this arena, it appears that, at least for Fortune 500 companies, intranets will change the way facility managers do business. Intranets will link facility managers, their customers and information in a way that makes the right information accessible at the right time, increases the accessibility of facility management resources throughout the company, and increases productivity. A study released in September 1996 (Hambrecht & Quist) reported that more than 90 percent of Fortune 500 corporations surveyed were deploying intranets. The increased use of intranets among facility management departments in these corporations is likely. It is not yet clear what the best way is to deploy information technology for facility management, but current intranet provider strategies include enhanced browsers, groupware using open Internet strategies, and plug-ins such as Autodesk's Whip! to view geometric information. Research is needed to clarify how intranet technology can help facility management organiza-

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tions achieve cost, customer, service quality and operational objectives. Other research topics include the effective use of desktop videoconferencing and whiteboards.

The overwhelming acceptance of the usefulness of e-mail reported in this study raises some interesting possibilities for enhancing collaboration within the AEC-FM industry. E-mail is simple but effective because a) it is faster and cheaper than other forms of communication, b) it has a low incremental cost per message (that is, it does not cost much more to send e-mail to one person than it does to hundreds of people), and c) because it is an asynchronous method of communication, only one of the parties needs to be present at one time (Crawford 1982). Because of the popularity of e-mail, it has been classified as “killer” application, with one estimate of 75 million users. The integration of “rich” HTML email with Internet browsers raises the possibility of new levels and types of electronic collaboration within the AEC-FM industry. In summary, the survey shows some collaborative technologies as very important, while less mature collaboration technologies are at the bottom. Perhaps as these less mature technologies become more robust some will skyrocket in importance.

the business value of information technology investments

Reasonable information technology investment decisions cannot be made unless an evaluation approach can be devised to clearly explain the probable costs and benefits for each investment. Too frequently, the value of a proposed information technology system or application to a facility management department or to a parent corporation is not evaluated because it is thought to be too difficult. Just as frequently, existing information technology operations (past investments) are not evaluated to determine their effectiveness in achieving expected goals. As a result, there is an increased possibility that resources are not being allocated in a way that optimizes investment decisions. Research is needed to better understand how to assess the value of information technology investments in facility management.

acknowledgments

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Venkatraman and Zahra. 1996. “Electronic Integration and Strategic Advantage: A Quasi-Experimental Study in the Insurance Industry.” in Allen and Scott Morton, Information Technology and the Corporation of the 90s, p. 150. Venkatraman and Zahra define electronic integration as the integration of two or more independent organizational business processes by exploiting the capabilities of information technology.