INFORMATION TECHNOLOGY APPLICATIONS IN THE MANAGEMENT OF CONSTRUCTION: AN OVERVIEW

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ABSTRACT

Utilization of information technology to assist in planning, organising, leading, and controlling construction work is increasing in parallel with similar trends throughout all industries. A sampling of the current status includes a review of scheduling/programming, cost estimating, document management and operations simulation software, project web sites, and such hardware as palm-held technology and web cameras. Several additional sources of information on this evolving topic are available.

Keywords: information technology, construction, management, computers, software, hardware, web sites

1. INTRODUCTION

The purpose of this paper is to review the current status of the application of information technology (IT) to the management of construction organizations, projects and operations. Because IT is evolving so rapidly, this status report is valuable as a “snapshot” against which future developments can be compared. IT includes a diversity of hardware and software, so it is important to understand the wide range of construction management applications and then some details of selected aspects. The paper presents an overview which readers may use to gain a general understanding of the topic and a set of references through which the topic may be pursued in greater depth.

We begin with definitions of both information technology and construction management and an indication of the use of IT in the several management functions. We then describe six applications that are representative of IT’s widespread use and follow that description with brief mention of several other applications. Finally, we discuss a number of sources of additional information.

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2. DEFINITIONS

There is no single widely accepted definition of information technology. The Academic Press Dictionary of Science and Technology [14] defines it as “the use of computers and telecommunications for the processing and distribution of information in digital, audio, video, and other forms;” key words here seem to be “processing” and “distribution.” This paper adopts a wider range of activities; note the words “create, store, exchange, and use” in the following definition and description: “IT (information technology) is a term that encompasses all forms of technology to create, store, exchange, and use information in its various forms (business data, voice communications, still images, motion pictures, multimedia presentations, and other forms, including those not yet conceived). It’s a convenient term for including both telephony and computer technology in the same word. It is the technology that is driving what has often been called ‘the information revolution.’” [40]

Management is often defined by describing its various functions. Henri Fayol [17], a French mining engineer, is widely credited as the founder of modern management theory [10]. He described five basic management functions or elements, as planning, organizing, commanding, coordinating, and controlling [1]. Others, recognizing the basic wisdom of Fayol’s distinctions, have modified these descriptions only slightly over the years. One currently popular classification utilizes four categories as follows: Planning, Organizing (including Staffing), Leading (or Directing or Integrating), and Controlling (or Measuring) [21,22]. A convenient and helpful definition of construction management, then, is the planning, organizing, leading and controlling of construction organizations, projects and operations.

3. A WIDE RANGE OF APPLICATIONS

Since our objective in this paper is to describe the technologies currently used to “create, store, exchange, and use” information in managing the various construction management functions, it will be helpful to categorize those technologies by function. Table 1 indicates current applications of information technology in the four functions of planning, organising, leading, and controlling. The author has taken some liberties with this portrayal. Note, for example, that the use of “software” in the form of videos requires “hardware,” not shown, to display the material. Furthermore, the distinction between standalone software, used internally within an organization, and network- or web-based software, shared throughout or beyond a project, is somewhat arbitrary.

Nonetheless, the table is an appealing means of demonstrating the widespread use of IT in many facets of construction practice. A review of the table leads to at least two common sense conclusions. First, the use of standalone software is more prevalent in the early phases of a project, when such internal activities as cost estimation are being performed. As the project proceeds and “leading” and “controlling” become more active functions, information tends to be shared more widely through network- and web-based methods. Second, the control function seems to rely extensively on IT, both as software and hardware.

This paper will describe some details about six selected applications, as well as limited information about many of the others listed in Table 1.
Table 1. IT Applications in Construction Management, by Management Function

<table>
<thead>
<tr>
<th>Management Functions</th>
<th>Software-Standalone</th>
<th>Software-Network-or Web-based</th>
<th>Hardware</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Scheduling/Programming Estimating &amp; Bidding Document Management Operations Simulation Word Processing</td>
<td>Electronic mail On-line meeting</td>
<td>Digitisers Scanners</td>
</tr>
</tbody>
</table>

4. PROJECT SCHEDULING/PROGRAMMING

Along with accounting and payroll applications, project scheduling software packages were among the earliest uses of IT in construction. The initial development of network-based scheduling methods in the late 1950's made software a practical necessity for processing scheduling data for any but the smallest of projects. Early programs performed calculations to determine early and late start and finish times, calculated float (slack), identified critical activities, matched activity times with calendar dates, and organized the output into tabular form. Project owners began to insert contractual provisions requiring contractors to utilize such methods to plan their work and report progress as a condition precedent for payment.
As software and hardware became more sophisticated, several features were added to scheduling packages. Filters were added to allow the display of selected activities, such as those with less than a specified amount of float. Resource analysis permitted estimates of labour and other resource requirements for each activity, determination of the effect of these requirements on the overall project including possible needs in excess of those available during some time periods, and means for scheduling delays into non-critical activities in order to smooth the resource requirements throughout the project. Programs also incorporated activity costs, both to allow the projection of cash flow requirements over the project life cycle and to provide a means for tracking earned and actual project costs on the basis of individual activities. With increasingly sophisticated graphics capabilities, scheduling software now includes features that produce time-scaled bar charts, network diagrams, and various graphs such as those showing resource requirements or cash flow projections.

Figure 1 Cost-Time Envelope from Monte Carlo® 3.0 analysis; courtesy of Project Systems Solutions Ltd.

Three features characterize the most recent trends in project scheduling software. First, many packages provide for electronic data transmission using electronic mail, company internets, and/or the Internet; an example is Primavera’s Webster® [33], which gives project team members access to schedule information and allows collection of progress data for use in monitoring and updating the project schedule. A similar feature is found in Microsoft Project 2000’s Project Central® [27]. A second recent trend is the application of scheduling packages
to all of an organization’s projects in a way that they are linked together; thus, the impact of all projects on a company’s resource needs can be predicted. An example of this “enterprise-wide” project management approach is Primavera’s TeamPlay® [35], which also permits workgroup collaboration and easy access to project status information. Finally, computer simulation is a powerful tool that allows project planners to assess the effect of variations in activity durations on overall project progress. When the relationships between activity durations and costs are modelled, such software can provide cost/time risk analysis to aid in setting both cost and time contingencies. Another Primavera product called Monte Carlo® 3.0 [32] performs such calculations; Figure 1 is a sample cost versus time graph from this package. The predicted time and cost status at the end of the project from each simulation run is plotted in the upper right hand corner of the graph. The circle encompasses approximately 90% of the cases. The graph also indicates the likely range of spending throughout the project.

5. COST ESTIMATING AND TENDER PREPARATION

The need to manage large amounts of data in a simple, logical manner when preparing cost estimates for construction projects has led to the development of a number of software packages to assist in this task. Many contracting organizations use simple spreadsheets to perform this work, with a row for each of the several work items and columns for quantities, unit cost estimates, and total item prices. Further details may be included for subdivision of costs by labour, materials, equipment and other elements for each work item.

Several commercial packages now provide a means of combining the spreadsheet concept with databases of work item costs to produce well-structured cost estimates at several levels of detail. An example is WinEst Pro Plus 4.1® [41], which is available with several cost databases for general construction, electrical, mechanical, and other types of construction. In addition, one can import other databases from such sources as the R.S. Means Company [23] or develop and utilise one’s own set of historical cost data. The user selects the various work items and supplies their estimated quantities; for many items, the program can calculate quantities, such as the volume of a concrete footing based on its length, width and thickness. In turn, the distance dimensions can be measured by hand, determined by the use of digitisers applied to the drawings, or calculated directly from digital versions of the drawings.

As the work item quantities are determined, the selected database supplies unit cost data and completes tabulating total cost information for the item. After the basic cost estimate is developed, the program permits the user to add such additional items of cost as bonds (with user-supplied rate schedules), sales taxes as lump sum or percent of project cost, and various “mark-ups” for overhead and profit, either on a lump sum, percent or per-hour basis. Cost estimates can be displayed in a large number of forms, from a sheet that gives only totals for labour, materials, and other categories to a series of pages with details for each specification section. In Figure 2, we show a sample Totals Page from the WinEstimator® software, while Figure 3 contains a cost estimate subdivided by trade description as generated by the Global Estimating® program of the BuildSoft Pty. Ltd. [4].
### Concrete Wall Project

<table>
<thead>
<tr>
<th>Percent</th>
<th>Amount</th>
<th>Category</th>
<th>Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>38.47%</td>
<td>15881.70</td>
<td>Labor</td>
<td>794.1</td>
</tr>
<tr>
<td>34.41%</td>
<td>14207.83</td>
<td>Material</td>
<td></td>
</tr>
<tr>
<td>19.08%</td>
<td>7878.34</td>
<td>Subcontractor</td>
<td></td>
</tr>
<tr>
<td>8.03%</td>
<td>3316.14</td>
<td>Equipment</td>
<td>540.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>User</td>
<td></td>
</tr>
<tr>
<td></td>
<td>41284.0</td>
<td>Net Costs Subtotal</td>
<td></td>
</tr>
<tr>
<td>16.11%</td>
<td>6650.00</td>
<td>On-site Overhead</td>
<td></td>
</tr>
<tr>
<td>4.50%</td>
<td>1857.78</td>
<td>General Overhead</td>
<td></td>
</tr>
<tr>
<td></td>
<td>69791.78</td>
<td>Subtotal</td>
<td></td>
</tr>
<tr>
<td>8.30%</td>
<td>4132.72</td>
<td>Profit</td>
<td></td>
</tr>
<tr>
<td></td>
<td>53924.6</td>
<td>Subtotal</td>
<td></td>
</tr>
<tr>
<td>933.87</td>
<td>933.87</td>
<td>Payment and Performance Bonds</td>
<td></td>
</tr>
<tr>
<td>68.75 cubic metre</td>
<td>54858.33</td>
<td>Total Estimate</td>
<td></td>
</tr>
<tr>
<td>12.50%</td>
<td>6857.49</td>
<td>Goods and Services Tax</td>
<td>$797.94/cubic metre</td>
</tr>
<tr>
<td>68.75 cubic metre</td>
<td>61715.63</td>
<td>Total Estimate with Taxes</td>
<td>$897.68/cubic metre</td>
</tr>
</tbody>
</table>

**Figure 2** Totals Page from WinEst Pro Plus 4.1® Software; courtesy of WinEstimator Inc.

### Full Estimate Summary

<table>
<thead>
<tr>
<th>Job Name:</th>
<th>EXAMPLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Client's Name:</td>
<td>Example Estimate</td>
</tr>
<tr>
<td>Job Description</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Job No.</th>
<th>Trade Description</th>
<th>Hours</th>
<th>Amount</th>
<th>Sub. Total</th>
<th>Mark-Up %</th>
<th>Trade Total</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>PRELIMINARIES &amp; CONTINGENCY</td>
<td>20.90</td>
<td>570.00</td>
<td>3,135,000</td>
<td>3.135,000</td>
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<td>2</td>
<td>SUBSTRUCTURE</td>
<td>9.17</td>
<td>250.18</td>
<td>1,276,015</td>
<td>1,276,015</td>
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</tr>
<tr>
<td>3</td>
<td>COLUMNS</td>
<td>2.07</td>
<td>56.41</td>
<td>310,233</td>
<td>310,233</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>UPPER FLOORS</td>
<td>15.34</td>
<td>418.29</td>
<td>2,300,622</td>
<td>2,300,622</td>
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<tr>
<td>5</td>
<td>STAIRCASES</td>
<td>0.57</td>
<td>13.77</td>
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<td>75,257</td>
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<td>6</td>
<td>ROOF</td>
<td>1.62</td>
<td>44.18</td>
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<td>243,009</td>
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<tr>
<td>7</td>
<td>EXTERNAL WALLS, WINDOWS &amp; DOORS</td>
<td>9.33</td>
<td>245.53</td>
<td>1,399,927</td>
<td>1,399,927</td>
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</tr>
<tr>
<td>8</td>
<td>INTERNAL WAlls</td>
<td>3.78</td>
<td>103.11</td>
<td>567,101</td>
<td>567,101</td>
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<tr>
<td>9</td>
<td>INTERNAL DOORS</td>
<td>2.16</td>
<td>58.86</td>
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<tr>
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<td>WALL FINISHES</td>
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<td>92.07</td>
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<td>11</td>
<td>FLOOR FINISHES</td>
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<td>72.67</td>
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<tr>
<td>12</td>
<td>CEILING FINISHES</td>
<td>1.78</td>
<td>48.75</td>
<td>268,114</td>
<td>268,114</td>
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<tr>
<td>13</td>
<td>FITMENTS</td>
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<td>195.69</td>
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<td>1,076,278</td>
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<td>14</td>
<td>HYDRAULIC SERVICES</td>
<td>4.26</td>
<td>116.13</td>
<td>638,716</td>
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<td></td>
</tr>
<tr>
<td>15</td>
<td>MECHANICAL SERVICES</td>
<td>4.36</td>
<td>119.82</td>
<td>659,000</td>
<td>659,000</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>FIRE SERVICES</td>
<td>1.85</td>
<td>50.45</td>
<td>277,500</td>
<td>277,500</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>ELECTRICAL SERVICES</td>
<td>2.92</td>
<td>80.00</td>
<td>440,000</td>
<td>440,000</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>LIFT SERVICES</td>
<td>2.43</td>
<td>66.27</td>
<td>364,500</td>
<td>364,500</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>SECURITY SYSTEM</td>
<td>0.35</td>
<td>9.45</td>
<td>5,200</td>
<td>5,200</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>SWIMMING POOL</td>
<td>0.81</td>
<td>22.00</td>
<td>12,100</td>
<td>12,100</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>SITE PREPARATION</td>
<td>0.93</td>
<td>25.40</td>
<td>139,685</td>
<td>139,685</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>EXTERNAL WORKS</td>
<td>2.17</td>
<td>59.22</td>
<td>325,709</td>
<td>325,709</td>
<td></td>
</tr>
</tbody>
</table>

GFA: 5,500 m2.

Final Total: $15,000,000

**Figure 3** Full Estimate Summary Subdivided by Trade Description from Global Estimating® Program; Courtesy of BuildSoft Pty. Ltd.
6. DOCUMENT MANAGEMENT

The number of documents associated with a major construction project can easily number in the thousands. The organization, tracking, use, and archiving of this paperwork is a critical management challenge. Consider the following incomplete list of the types of documents that flow into, around, and out of the construction project office: purchase orders, requests for information, responses to requests for information, change order requests, change orders, meeting minutes, letters and memoranda, daily reports, telephone logs, subcontracts, contract drawings, shop drawings, invoices, payment requisitions, submittals, cost reports, and punch lists.

Database concepts have been successfully implemented in several software packages to allow the construction manager to know the status of each piece of paperwork related to the project. Two types of software are currently in use. One type maintains records of each of several categories of documents, with its status information, without archiving the documents themselves. For example, a portion of a program may track the status of all shop drawings and material samples, subdividing the list by type of work, vendor and/or location, and showing whether each drawing has been submitted for approval, returned for revisions, returned to the supplier, or approved. The program may signal automatically whether due dates are approaching or have been overrun. Construction Software Services Partnership [13], with offices in Australia, Southeast Asia and the United Kingdom, developed and supports a project and information management system called CLIENT. Its correspondence module maintains a searchable database that allows the contractor to record, find, and follow up on all incoming and outgoing correspondence related to a project.

The other type of document management software is utilized for documents that are imported into or produced by the computer system and maintained and stored ("managed") by the system. An example would be the contract drawings that are imported into the system; each time they are changed, the software updates its status records. Another example would be meeting minutes; as they are produced on the computer after each meeting, a record of the document, its distribution and any revisions is automatically produced. PAFEC EDM is a document management system written by PAFEC in the United Kingdom and distributed and supported in many locations worldwide, such as in Australia, by CEANET [8]. This product is specifically designed for managing and controlling engineering documents. In this program, "documents" are any data files generated by any computer application; the system stores and then "supervises" the file without regard for where it was created. In the United Kingdom, use is also made of the PIMS Project Information Management System [31]. It captures, distributes and retrieves scanned images and other electronic documents, especially in construction situations with high volumes of correspondence and tight timescales.

Several document management packages track both types of documents described above, those stored internally such as digital drawings and meeting minutes, and those external to the system such as product samples and external correspondence. Prolog Manager 6® is a product of Meridian Project Systems [24], can manage most of a project's documents, by performing such tasks as logging and tracking revisions to drawings and specifications, generating and tracking requests for information, and maintaining a schedule of required submittals. A sample from Prolog Manager 6's Prolog Today® module is shown in Figure 4; this screen summarizes the
status of Requests for Information, subcontract change orders, and the project budget. Primavera's Expedition® 7.0 [34] is designed in a similar fashion; both packages monitor deadlines and can automatically produce such documents as dunning letters at a suspense date. An additional advantage of such software is the ability to archive documents and the documentation records automatically upon project completion.

![Prolog Manager 6® Prolog Today Summary Screen; from Meridian Project Systems http://www.mps.com](image)

7. PROJECT WEB SITES

The widespread availability and use of the Internet, coupled with the growing number of company intranets, has resulted in an explosive growth in the use of web sites for individual construction projects. Doherty [16] lists five important reasons for such web site use: 1) Fewer communication errors between project team members, 2) Up-to-the-minute intelligence on all the decisions and collective information relating to the project, 3) Less expense for messengers, couriers, copying, and blueprints, 4) Customized sites for each project and customized access for each user, and 5) Security. The core advantage from adopting this technology centres on enhancing project communication. The term “collaborative management” has been used to describe this method of communicating project information quickly, efficiently and cost-effectively.

Construction project web sites typically consist of a home page, containing general project information, plus hyperlinks to a number of supplementary pages. These pages might contain
such information as schedule/programme status, cost reports, meeting minutes, daily reports, progress photographs, design drawings and models, specifications, and personnel directory, plus means to post and read messages and notices and to conduct on-line meetings. Each of these types of information could be handled individually utilising information technology (digital versions of drawings, for example, can be available in electronic format and can be transmitted electronically), but a project web site allows the project team to assemble the information in one location, on a web server, and thus make it available to all project participants. Availability of sensitive information can be restricted by the use of passwords; if the web site is available on the Internet, members of the public interested in general project information can access portions of the site, while all pages on the web site are made available to the project team.

Project web sites can also provide links to related external sources of electronic information such as weather forecasts and government safety standards, and they can also permit readers to respond by sending electronic mail to a contact person on the project team. When a project is completed, all web site information can be archived to provide a permanent electronic record of its various documents.

Construction organizations currently have choices regarding how they will develop and maintain their project web sites. They can develop their own web sites using such general web builder software products as FrontPage 2000® [6]. After such a site is developed, it can be published on a company web server and made available via the company intranet. The other extreme is to engage the services of a commercial service provider, which will utilise its own web site package to develop the site, based on the project’s data. In this case, the provider will most likely host the site on its own server and thus make it available via the Internet to at least the project team if not the general public. Another option is to procure project specific web site software and either engage consultants to develop the site or develop it in-house. Then it would be published either on the company web server and made available on the Internet or published on the company’s intranet.

Two examples of commercial products whose developers provide hosting services are MPInteractive’s e-Build® [28] and BricsNet’s ProjectCenter 3.0® [2,3]. Both are described as “extranet” services on the Internet, meaning that the web sites are stored on these companies’ servers and are accessible to the public and project team not through company intranets but via the Internet. e-Build® allows users to hold live group discussions and can be configured with a camera that provides live project images on the screen. Both products permit the “red-lining” of graphic information such as drawings and the transmission of those comments to others on the project team. Users must provide a computer with Internet access, an e-mail account, and web browser software. They pay a one-time set-up fee and a monthly user fee. Figure 5 shows a web page from a sample ProjectCenter 3.0® web site; it contains a portion of the project schedule in the main frame and, on the left hand side, a list of hyperlinks to other pages in the site.

Prolog Website® [25] is a product which the project manager would use to develop a project web site and publish it on the company’s intranet. It allows access to more than 400 user-prepared reports; collaboration over meeting minutes, requests for information, submittal packages, and punch lists; and the use of daily work tracking and “HotList” action items.
Figure 5  ProjectCenter 3.0® Web Page with Schedule Report; from Bricsnet
http://corporate.bricsnet.com

For an informative case study of the use of web sites for capital project management as used by a local school district, see Stevens [39]. Those considering implementing project web sites, and those already using them, may wish to heed some practical advice offered by O'Brien [10]. Among the cautions listed by O'Brien are the inevitable resistance to change when new technologies are introduced; the attendant need for new job descriptions; the exclusionary nature of the issuance of passwords to selected parties, thus violating the desired holistic team approach; the presence of yet another communication channel; the lack, oftentimes, of common tools for accessing documents; and various legal issues surrounding the status of electronic documents.

8. OPERATIONS SIMULATION

The applications discussed thus far have dealt with construction project management - techniques for dealing effectively with the planning, coordination and control of the overall project. This section considers recent developments in the analysis of individual operations, and the impact on their productivity of alternative techniques and resource commitments. For example, in the manufacture, transportation and placing of concrete, several options are possible. In planning that operation, a contractor might want to know the effect on productivity
of different numbers of delivery trucks, different crew sizes and different placement methods. A key issue in such a problem is that the time required to perform individual components of construction operations cannot be known in advance with certainty. A typical analysis treats those times as random variables subject to known or assumed probability distributions.

One software package available for such analyses is the CYCLic Operations NEtwork (CYCLONE) modelling scheme developed by Halpin [19]. A set of graphical modelling elements is used to represent such features as work items (loading, travel, unloading, for example), queues, and counters. After simulating the durations for each work item, the programme determines total cycle time for an operation and the start and finish time of each item. When the model has been run for a specified number of iterations, active production states, as well as delay states, can be approximated. Thus, the analyst can identify under-utilised resources and bottlenecks caused by shortages of resources. Variations in sequence, number of pieces of equipment and average time requirements allow the analysis of alternative schemes.

Figure 6 CYCLONE Operations Simulation Network; Hewat [20]
The Simphony [38] library of construction simulation programmes contains both general purpose modelling constructs such as CYCLONE as well as specialised models for such methods as earthmoving and aggregate production. The various modules produce both tabular and graphical output. A sample of a concrete batching and placing operation modelled using the CYCLONE module within Simphony is included as Figure 6 [20].

An extension of the CYCLONE modelling approach, developed jointly by the Planning and Methods Unit of Dragados y Construcciones, Madrid, Spain, and the Division of Construction Engineering and Management at Purdue University is called PROject SImulation Dragados Y Construcciones (PROSIDYC) [36]. Its modelling framework results in multi-activity charts that show in detail how the sequences of work should be organised. The programme has been used to analyse and improve such construction processes as tunnel excavation, the renovation of train tracks without traffic interruption, and the installation of large floating caissons.

9. PALM-HELD TECHNOLOGY

One example of new hardware that can improve the site management of construction projects is palm-held devices, or personal digital assistants (PDAs). Using a stylus to enter data by tapping or writing on the device’s screen, the user provides information on field conditions, progress status, and the like that is later downloaded to a personal computer for review, analysis and archiving. Without such technology, the manager typically records such information in a notebook or on a form and later transfers it to a computer in the office. Now, with compatible software, the original recording is completed more easily and the transfer step can be done electronically.

![Sight Manager Palm Held Device; Courtesy of Buildsoft Pty. Ltd.](image)

The owner’s field representative is usually required to document field conditions, quantities installed, and schedule information. Palm-held procedures can minimise duplicate data entry, utilise existing computer hardware, and allow for easy data sorting and retrieval; they are
relatively inexpensive, and are easily learned and accepted. One application includes a personal information manager (PIM) with the capability for address lists and to-do lists [29]. Prolog Pocket® [26] allows the contractor to track punch list items, material inventory, daily details, and inspection information. Updater [12] is a palm-held computer software program that makes it possible to update a project schedule directly from the field. Contractors use the program’s two parts, one to enter progress data into the device in the field, and the other on the office computer as an interface between the device and the contractor’s scheduling software.

Buildsoft Pty. Ltd. [5] markets a device called Sight Manager for performing the tasks described above. Figure 7 shows the various features of this palm-held appliance.

10. OTHER TRENDS IN CONSTRUCTION INFORMATION TECHNOLOGY

Space permits only a brief mention of other recent developments in the application of information technology to improving the way construction projects are managed. In the software area, job cost programs provide automated means of tracking actual costs; they are often based on the framework provided by the software utilised to prepare the cost estimate. The estimate is exported to a parallel database as the project budget, and actual cost data are recorded and compared with the budget. Contractors also utilise various software to maintain records of equipment usage, material inventories, and personnel data. Increasing amounts of purchasing are being accomplished on-line, followed by computer-based methods of tracking, expediting and receiving purchases for improved status control.

With respect to information technology hardware, cellular telephones, facsimile transmission equipment, digital scanners, and digitisers (mentioned earlier in connection with quantity surveying and cost estimating) are so commonplace as to be often forgotten when compiling such lists. More recent developments include the use of bar coded labels or radio-frequency transponders (RFID) attached to construction components as a means of tracking their location; coupled with global positioning (GPS) equipment, information on these labels can be scanned into a portable computer and relayed to a remote database. Systems are being developed to allow point-to-point and point-to-multipoint wireless data communication that can have widespread usage on a construction jobsite; bar-coded information noted above, as well as may other types of data, can thus be communicated efficiently and effectively. The “digital hardhat” concept, in which multimedia information (text, sound, video and images) is captured and saved in a project-specific database, will make project information from dispersed members of the project team available through the World Wide Web [15]. Project web sites often incorporate web cameras, which provide either a continuous stream of images of the project site and its various sections or images captured at periodic frequencies such as every ten minutes; in addition to being an effective public relations device, this technology is frequently used by the project team to ascertain progress, identify and solve co-location problems, and study equipment effectiveness.
11. SOURCES OF INFORMATION ON CONSTRUCTION INFORMATION TECHNOLOGY

An overview paper of this nature can provide only a brief status report on this rapidly changing technology. The paper will be successful if it has conveyed something of the recent trends and present applications and if it has suggested sources of information where the reader may keep abreast of the latest developments. To that end, the following sources may be of interest:

Purdue University’s Construction Engineering and Management program maintains an Emerging Construction Technologies (http://www.new-technologies.org/ECT/) web site, whose stated purpose is to present such technologies that could produce a "high impact" in the construction industry. Early in this paper, we have referred to two applications from that web site, another helpful entry is its compilation of Features of Internet-based Services for Construction [18], with information about web-based project management, Internet-based information services, and web-enabled project management software. The Construction Engineering and Management program at the University of Alberta maintains a similar listing in the research section of its site at http://cem.civil.ualberta.ca [11].

Working Commission W 78 of the International Council for Building Research Studies and Documentation (CIB) is CIB’s commission devoted to information technology for construction. As shown at its website [9], it goals are

- To foster, encourage and promote research and development in the application of integrated IT throughout the life-cycle of the design, construction and occupancy of buildings and related facilities,
- To proactively encourage the use of IT in Construction through the demonstration of capabilities developed in collaborative research projects, and
- To organize international cooperation in such activities and to promote the communication of these activities and their results.

Its work relates primarily to the integration and communication of data, information and knowledge in the facility's life cycle.

The Electronic Journal of Information Technology in Construction [7], sponsored by the Swedish Council for Building Research, is a peer-reviewed journal featuring papers on the use of information technology in construction. Affiliated with CIB W 78, it publishes about five papers per year electronically in printable and hypertext formats and makes them available over the Internet at http://www.itcon.org. Typical of recent papers is a contribution by Rivard [37] that surveyed the impact of IT on the Canadian architecture, engineering and construction industry.

12. SUMMARY AND CONCLUSIONS

Information technology is impacting the way organizations conduct their affairs in substantial and long-lasting ways, and the construction industry is no exception. Despite our industry’s
conservative nature, there is clear evidence that the management of construction is being made more effective through such tools as scheduling and cost estimating software, document management programs and operations simulation packages. Hardware such as personal digital assistants, wireless data gathering and web cameras are modifying the way construction sites are managed. Project web sites allow most of these software and hardware developments to be integrated into a single central means of cataloguing and transmitting project information.

The common theme seems to be the enhancement of communication. In all of its functions – planning, organising, leading and controlling – management needs accurate, fast, effective and efficient communication of the ideas, data, and images that are the heart of an organization’s information base. Current technology provides a host of tools of value in the communication process. Future technology will no doubt provide further assistance. Those who ignore IT’s potential do so at their peril.

At the same time, caution is advised. A reasoned approach to the adoption of any new technology is essential to the building of strong projects and organizations. There must be a need. The need must mesh with the organization’s strategic goals. There must be a clear means of meeting that need. Potential benefits must outweigh potential costs. Impacts on an organization’s culture and values must be considered.

This paper has indicated some technologies that may be useful. It is impossible to speculate exactly about the future. However, if a similar report is prepared four or five years hence, it is likely that more contractors and others in the project team will be using more of these tools and some others not yet invented.

DISCLAIMER

The use of product names is for illustrative purposes only and does not imply endorsement of the several products mentioned.

REFERENCES