Data solutions for programme management

REZA IRANPOUR, GIL GARNAS, DAVID MILLER, MIKE STENSTROM and BIRGITTE AHRING look at the data system technology that is becoming available to remove the many difficulties managers of engineering programmes have to face.

A 'Murphy's law' for office management might be written: 'Any kind of inconsistency that can occur in duplicated data eventually will.' Nevertheless, in the past there has been no escape from the need for offices doing related work to keep separate copies of certain types of information. Not only did physical separation of desks or offices require duplication for the sake of faster work as long as records were consistent, but different purposes demanded differently organised data. For example, accountants have no need for most of the details of a design, while designers need to estimate probable costs but do not need to deal with the many details of taxation and fringe benefits that concern accountants. Thus, in many cases corresponding records in different offices are not intended to be exact duplicates, but are adapted to each office's needs.

The rise of networked office systems, particularly the client-server structure, has radically changed this situation. A single set of files, kept on one server computer, can be accessed through a network by client computers operated by users in many offices, with appropriate processing at each client to display the information in the form needed for that office (see Figure 1).

This improvement in data handling has been available for most of the past ten years for the kind of tabular data typically kept in spreadsheets and relational databases. But it has only been available more recently for the other types of data needed by engineers, and development continues on new types of software to improve convenience and meet previously neglected needs. We will review a few of these developments to show the context in which efforts to assess programme progress will be carried out in the future.

Networking and novel graphics

Denning (1997) provides an encouraging description of the environmental engineering use of networks, with rises both in the volume of information transferred and also in its complexity and sophistication. As this article shows, engineers are now using not only intranets within offices and organisations but also the internet, for long distance transmission and for access to information from others, such as the most current specifications and prices from suppliers. Likewise, the internet allows access by customers to progress reports on their projects, and gives them rapid communication with engineering company officials, wherever they may be.

The increasing bandwidth of these networks allows increasing use of three-dimensional design drawings and other types of improved graphics. CAD systems had been used by engineers for many years, giving vast improvements in efficiency (Mills, 1997), and a large amount of programming effort has been spent on refining them. Nevertheless, conventional CAD systems primarily provide automated versions of the two-dimensional plans and schematics that engineers were accustomed to use before computers became available. This means they have limitations as tools for planning the order in which a large structure is to be built.

In the past, for projects where the expense was justified, engineers have planned the sequencing of construction by building models of structures out of plastic and photographing the models as they were built. As Coles and Reinschmidt (1994) show, three-dimensional graphic software now permits construction not only of electronic equivalents of these models, but allows designers to investigate alternative sequences. And when one is finally chosen, detailed schedules can be generated for construction, with calculations of dimensions, cubic feet of concrete, tons of steel, and so on. This not only eases the work of design engineers, but invites more involvement by the people who perform the construction, reducing interference between disciplines such as plumbing, electricity and HVAC, and otherwise reducing time and costs of construction.

Geographic information systems (GIS) are still another relatively recent innovation adding considerable value to large engineering programmes, especially those that deal with geographically extended structures such as wastewater and stormwater collection systems. Several briefly-described examples of such uses are described by Goldstein (1997), and Wong et al (1997) provide a more extended discussion of a particularly large and complex application of a GIS for a model of non-point source pollution in Santa Monica Bay. The drainage basins that discharge stormwater into the bay are defined by a combination of natural topography and the collection systems built by the various coastal cities over roughly a century. This meant the software had to be able to produce a useful depiction using both land elevations and data from municipal storm sewer maps. Such complexities are the reasons that GIS systems are only now being adopted by many organisations (Goldstein, 1997).

Planning challenges and software development

Even with these kinds of system capabilities available, assembling an information system that meets the requirements for planning a large environmental engineering programme is no easy task. Consider, for example, the many dependencies and constraints that must be taken into account. In addition to the obvious physical dependencies, such as pipes that cannot be laid until the trenches for them are dug, there are less tangible dependencies. These include scheduling of equipment or key personnel that are needed at several projects, and cash flow in a programme financed on a pay-as-you-go basis. Software has been available for a long time that simply displays a PERT chart or Gantt chart produced by someone who takes such dependencies into account, for these are simple graphic displays. It takes a more sophisticated programme to examine databases and construct such a chart on its own, using searching and scheduling algorithms.

However, a sufficiently powerful information system can provide crucial flexibility in planning, for planners make their decisions based on a mental model of a programme's context and initial conditions that always contains at least a few errors, and revisions are usually necessary when these errors are discovered. Sometimes the errors are not very important, as in Kerr (1997), when the culvert project encountered a gas line that the gas company was not willing to move, so a section of the culvert had to be installed under the line, below its planned level. Sometimes the erroneous beliefs have large consequences, or would if not corrected in time, as exemplified in Bagstad (1997). This article describes how an initial plan to build overflow control projects for Houston's sewer systems was based on overestimates of the storm flows in many sub-basins of the system. When more comprehensive measurements provided better estimates it was possible to revise the design to save $77 million out of a $1.16 billion programme.

At present the information systems that provide the most comprehensive services in support of large engineering programs are proprietary to large firms, such as PowrTrak at Black and Veatch (Denning, 1997), and COMANDS at Stone and Webster (Coles and Reinschmidt, 1994). These companies may eventually license this software for others to use, or an entrepreneurial software company such as Autodesk, the publisher of AUTOCAD, may provide such services in a generally available product.

However, the expense of such system development implies that software companies will need to be assured that there is an adequate market. Environmental engineers are not normally strongly interested in details of computer systems design. But to see the prospects for future development, it may be valuable to understand that GIS development has required adding 'middleware' to the client/server structure (Goldstein, 1997), and that additional integration of graphic and other services is likely to require extensive programming in object-oriented languages like C++ (Wang, 1994). This means that if capabilities comparable to those in COMANDS or PowrTrak are to be available outside the major firms, it may be necessary for smaller firms or municipal engineering organisations to take the initiative in cooperating with software companies.

Conversion to electronic systems

Most municipal departments of public works and other agencies that undertake large environmental engineering programmes date back before the development of network office systems. This means many of them still have their records on a mixture of paper and electronic media adopted at various times in the past as they suited various managers. Converting such a collection of data, suffering from the effects of 'Murphy's law' for inconsistencies, to a unified electronic form for a new network may pose substantial challenges.

Suppose the management office of a large municipal wastewater system improvement programme has a particular project, say 'Sunset Creek liquid process improvement,' with work order (WO) No F1000087, and the accounting office has the same title, but with a WO No SYU22233. Conversely, suppose that both offices have another project with one WO No, SYU22245, but one office calls it the 'Sunset Creek air diffuser replacement,' and the other calls it 'Sunset Creek air headers modification'. Reconciling such inconsistencies would require either human judgment or unusually intelligent and flexible software.

Another difficulty occurs if the actual dates in one document or electronic file differ from planned dates in another, or if confusion arises over when an event actually occurred, and if the actual costs of a project differ substantially from planned costs. For example, one can imagine a situation in which it was initially believed that a problem of heating and cooling a building required a million dollars' worth of ductwork replacement, and the planning records reflected this. However, if a few thousand dollars' worth of cleaning turned out to be sufficient, in offices for which this information is not highly important the records might not have been updated. It might even happen that a hastily established small project would be entirely omitted from some offices' records.

For these reasons, in the next few years agency employees who reconcile records for entry into a networked system may have to approach the task of data collection with some of the spirit of a detective or an archaeologist, cross-comparing records to assemble a consistent data set.

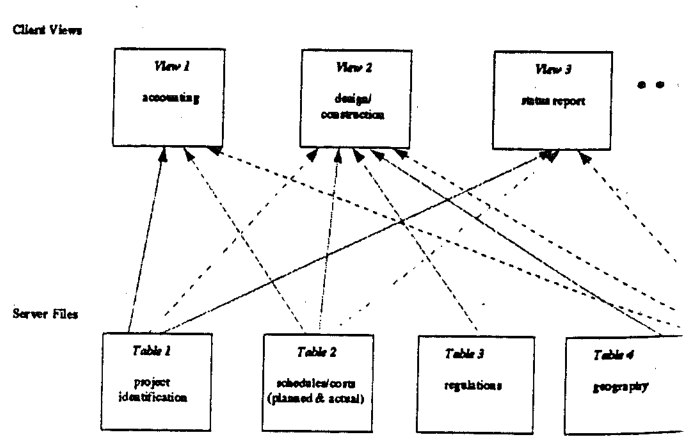
Project progress database (PPD)

On the other hand, once such a data set was assembled, it might support a number of simple but useful statistical analyses if kept in tabular form in a spreadsheet or relational system, with each project as one row and as many columns as needed for the analyses. One could have collections of related projects in groups that might be called 'categories', or something similar. Then the projects for one category would be consecutive rows in the table, and each category would b[e a] new table or spreadsheet. The ite[ms] of information for each project could include an identifying cod[e], title, a status (such as 'in progress', 'future', 'completed', 'cancelled' a[nd] so forth), actual expenditures an[d] schedule, planned expenditures and schedules, and so on. Computing simple measures suc[h] as average ratios of planned and actual costs, or average delays or completions ahead of schedule, b[y] category or for the programme as a whole, is likely to be highly informative, without requiring software that had the sophisticatio[n] and complexity discussed above.

Conclusions

The management difficulties discussed in this feature are to a large extent problems of communication and integration of information. The many people involved in a large, long-term programme work at cross-purposes and duplicate efforts because an engineer or manager may not always keep track of what others are doing, and there is a loss or dilution of experience whenever someone with important knowledge retires or moves to another position. Simple statistical methods can identify questionable situations but by themselves they do not provide solutions, and may not even clearly show the reason for observed discrepancies. For example, if actual construction costs were consistently higher than initial

Client views and server files in a network information system



estimates, more than simple computations of averages would be needed to determine whether this was the result of construction contractor ineptness or of persistent errors in cost estimates. However, performing more informative analyses would also be greatly aided by having a unified data system recording programme progress.

Once this is recognised, it is easy to see that such a data system should not merely be added to an existing haphazardly organised collection of computer and paper records, for such data collections are a major cause of the poor communication and confusion that cause unsatisfactory results. Hardware and software capabilities have now advanced far enough to allow offices to cooperate with each other through a comprehensive data environment that does not have the limitations that previously made it necessary to accept duplication and inefficiency.

In short, our efforts to assess the aggregate progress of large environmental engineering programmes, or of major subdivisions of them, have led to improved understanding of how data system technology is becoming available to relieve many difficulties that managers of these programmes must face. ●

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