34 4D PLANNING AND SCHEDULING (4D-PS): GROUNDING CONSTRUCTION IT RESEARCH IN INDUSTRY PRACTICE

Leonardo Rischmoller[1], Martin Fischer[2], Robert Fox[1] and Luis Alarcón[3]

(1) Bechtel Coorporation Inc., (2) Stanford University, (3) Pontificia Universidad Catolica de Chile

lrischmo@ing.puc.cl, fischer@ce.stanford.edu, rnfox@bechtel.com, lalarcon@ing.puc.cl

Abstract

Several authors have lamented that research efforts in construction IT have not embraced the issues associated with implementation and industry practice (Betts, 2000) and that the rethoric and visions associated with construction IT are sometimes distant from the reality of construction usage (Koskela, 2000).

This paper discusses the observation-participation method (Yin, 1994) as a way to ground construction IT research in industry practice. This research methodology considers the industry as a point of departure, followed by examination of a case study using the observation-participation method (Yin, 1994). In this methodology, the researcher is not merely a passive observer, but assumes a variety of roles within the case study and participates in the studied activities. The observation-participation method application to the case study offers the opportunity to see what others have not yet seen (Stake, 1998) and allows gaining access to events and groups, which, in other ways, are innaccesible to scientific research. The researcher perceieves reality from the point of view of someone "in" the case study instead of someone "external" to it.

The research goal was to test 4D Planning and Scheduling (4D-PS) to demonstrate its benefits as a CAVT (Computer Advanced Visualization Tool) applied to the case study. The objective was to find out how 4D model reviews can help generate more constructable projects by assisting construction planners in optimizing construction sequences, identifying and resolving schedule conflicts and providing feedback from construction teams to design teams. To get tangible results, 4D-PS needed to be researched in a real life context. Hence, the observation-participation method was the most suitable research methodology to accomplish this task. This paper presents our experience with the observation-participation approach on a large construction project. It details some of the organizational and business challenges of creating synergies between a business and a research focus.

4D-PS uses 4D models to accomplish construction planning and scheduling tasks. It was applied on the case study project by the first author in collaboration with other project construction planning team members. The result was an optimized, detailed, construction schedule for 100,000 cubic meters of concrete that was verified and visualized by using the 4D-PS methods developed by the team. Opportunities for improving the schedule were detected through 4D

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simulations, and the sequence of activities was quickly adjusted in response to feedback from the project planners. The corrected sequence was then again verified using the 4D method.
4D-PS lets planners formulate tighter, more finely tuned construction plans, and it also helps to develop contigency plans to handle delays in material deliveries or unavailability of resources. Important decisions concerning deadlines, sequences, and resource utilization, which ordinarily would have been made later at the job site, were better made ahead of time to avoid rework in the case study project, and the construction team became convinced of the value of improving the construction plan through the use of 4D-PS.

Keywords: *4D-CAD, 4D-PS (4D Planning and Scheduling), CAVT (Computer Advanced Visualization Tools), OPM (Observation-Participation Method).*

IT RESEARCH PROBLEMS

Problems related to IT research in the AEC industry

Turk (2000) argues that after more than 30 years the problems related to IT research have not yet been solved. The rhetoric and visions associated with construction IT have sometimes turned out to be distant from the reality of construction IT usage (Koskela, 2000). Some argue that IT assimilation in the construction industry has been slower than in other industries. Researchers seem to sometimes be under the impression that they have all the fantastic solutions and that all that is missing is a way to make the construction industry use them (Turk, 2000).

Construction IT researchers often appear to be frustrated by the failure of industry to adopt the 'self-evident' advances that the research claims. We and others argue, however, that there is a need for us to adopt a different approach if we are to move forward the uptake of our technological advancements (Betts, 2000). We need to address the needs of the competencies and capabilities of professional engineers, project managers, architects and constructors to operate the technologies we are seeking to develop. Our ability as researchers to partner with industry in undertaking this task will be of key importance in allowing this process to be effective (Betts, 2000).

Case study research in construction IT

Construction IT research has mainly produced prototypes. However, according to Turk (2000), the value of prototypes related with construction IT is doubtful. The results are not validated until a systems vendor implements them, or they are utilized by industry. Prototype experimentation on real life projects in the construction industry has been relatively rare, in contrast with the construction management area, where an important part of the research literature reports on case studies or more extensive empirical research (Bjork, 1999). How IT is used currently has not been adequately developed as a field of empirical research (Bjork, 1999). The extensive attention to technology instead of attention to the context of technology application has created a research and technology transfer bottleneck (Koskela, 2000).

4D TECHNOLOGY ISSUES

Background

4D-PS offers a way to carry out construction planning and scheduling in a different way compared to traditional approaches (i.e., bar charts, etc.), taking advantage of commercially available tools and 4D knowledge gathered over the past decade. 4D models inside and outside of Bechtel have been used as a supporting tool, a checking tool, a communication tool, and as a parallel effort to help improve construction plans and schedules that were developed with conventional tools (i.e., scheduling software). However, construction planning and scheduling using 4D models interactively in real time as the prime driver tool, and carried out by construction team members has rarely been accomplished at the scale of the Escondida IV project.

There has been contact between the Stanford Research group and the Catholic University of Chile since 1996 regarding 4D issues. Exchanges on the experience of Bechtel's application of 4D-PS on the Escondida IV Project with M. Fischer and his research group started in 1999.

4D Models

The idea to link 3D CAD models to construction schedules (4th Dimension) was conceived in 1986-87 when Bechtel collaborated with Hitachi Ltd. to develop the Construction CAE/4D Planner software (Cleveland 1987, 1989, Simons at al. 1988). Although Bechtel has had only some involvement in the 4D Planning concept for over a decade (Williams 1996), commercially available tools have recently become easier to use and more readily available (Skolnick 1993).
The spatial and temporal dimensions, or four-dimensional (4D) aspects of construction schedules, are not effectively represented and communicated by traditional construction planning tools, such as bar charts and network diagrams. A 4D model involves linking of the CPM Schedule to the 3D model to visualize exactly what the plan entails by simulating the construction schedule and actually showing which pieces of the project will be constructed in what sequence (Adjei Kumi and Retik 1997). Visual 4D models combine 3D CAD models with construction activities to display the progression of construction over time, sometimes dramatically improving the quality of construction plans and schedules. Construction people have always used 4-D models in their minds to varying extents, but now they can use them explicitly as a common planning environment by implementing 4D-PS.

4D Planning and Scheduling (4D-PS)

4D-PS consists in using 4D models to accomplish the project construction planning and scheduling tasks. 4D-PS allows simulating and interacting with construction sequences (schedules) through graphic display devices. If the sequence is not just right, schedulers adjust the schedule and rerun the 4D simulation to verify it. 4D-PS gives planners the ability to improve construction sequences, identify and resolve schedule conflicts, track and manage workers and resources such as formwork, scaffolding, and cranes, to make sure they are all applied effectively and don't conflict. It lets planners formulate a tighter, more finely tuned construction plan. 4D-PS can also help develop contingency plans to handle delays in material deliveries or address the unavailability of resources. To avoid rework, important decisions concerning deadlines, sequences, and resource utilization, which would ordinarily be made later at the job site, are better made ahead of time. Feedback from construction to the design team resulting from 4D model reviews can often lead to a more readily constructible, operable and maintainable project. Exhibit A depicts the basic workflow to carry out 4D-PS using commercially available software.

4D CAD Research at Stanford University

At the Center for Integrated Facility for Engineering (CIFE) in Stanford University, Associate Professor Martin Fischer (http://www.stanford.edu/group/4D/index.shtml) has lead research projects related to 4D CAD since 1993. Fischer's team has tested the usefulness of visual 4D models in planning the construction of a hospital, a university building, a commercial building, two Frank Gehry projects, and a theme park (Fischer 2000). These cases have shown that more project stakeholders can understand a construction schedule more quickly and completely with a 4D visualization than with the traditional construction management tools. The Stanford research team has been formalizing the construction knowledge necessary to build 4D models and has developed a methodology that guides project planners in generating 4D models from 3D product models. Stanford's approach to 4D CAD has been developed in close proximity to the construction industry, with an important academic component.

4D-PS and Escondida IV Project

The Escondida Phase IV expansion project is the largest single-phase expansion of any copper concentrator in history. For the first time, the 3D Plant Design System (PDS) is being used in Chile along with Primavera (P3), a planning and scheduling tool. Combined, the systems provide sequencing assistance and 4D models that save time and resources in the field. Plant Design System (PDS), Primavera Project Planner (P3) and SmartPlant Review (SPR) are the main commercial software tools used to develop 4D-PS at Escondida. All these powerful tools are well known within the Bechtel community, however they had not been integrated before to the extent achieved at Escondida IV. When using these applications as an integrated toolset, a synergistic effect is attained, rendering many opportunities for better project planning and execution.

Through computer simulation to support 4D-PS, a detailed construction plan/schedule was developed for all the concrete (approx. 100,000 m3) foundations of the Escondida IV project concentrator area. The construction planning team involved in this exercise became convinced of the value of improving the schedule through the use of the 4D models and streamlined the technique. The engineering and construction teams agreed on the significant business value of 4D-PS. 4D-PS afforded the planning team the opportunity to evaluate a number of alternatives, which in the past due to the lack of time, technology and resources was imposible. In some cases the team evaluated up to 20 alternatives for parts of the project, as well as for the sequencing of the complete project. The team was also able to visualize brainstroming results. These iterations and visualizations led to near optimum plans and schedules.

THE OBSERVATION-PARTICIPATION METHOD APPLIED TO THE CASE STUDY

The observation-participation method (OPM) was chosen as the main strategy to carry out 4D-PS research in the case study project. This research strategy addressed the complexity and novelty of understanding the impact of 4D-PS in a real life context and on a large scale project.

The case study

Escondida Phase IV Expansion Project was used as a case study to carry out the 4D-PS research. The case study is the first three-dimensional, PDS project undertaken by one of the branches of a global contractor in the Latin American Region. PDS is a comprehensive, intelligent computer aided design and engineering software (application) geared toward the process and power industries. PDS allows for the development of a 1:1 scale digital product model of the project, and also creates and maintains a database of valuable information for specification compliance, streamlining and planning of operations, maintenance, and downstream retrofit projects. No other PDS experience at the designer, supervisory or management level was present in Chile at the beginning of 1998 when Bechtel was preparing to win the project. After more than two years working with PDS on the case study project, the local Bechtel branch has become a nearly full-fledged, PDS-capable organization among the top levels of Bechtel's global community and the industry at large. Fostering further development in the effective use of this technology is now part of the Bechtel's work process development scheme, recognizing that the classical, 2D-bound methods of project execution will soon be a vestige of the past, much as drafting boards are today.

The Escondida Phase IV Expansion Project offered the following special advantages, which lent special potential and relevance to the research results:

- It is a pioneering project in Latin America.
- The scope of the visualization tool's implementation on the project goes beyond what had been applied before.
- The project is being developed by an international leader in the engineering and construction industry (ENR Magazine 2000).
- Most of the personnel working on the project were recruited locally and did not have previous experience using CAVT.

The observation-participation method (OPM)

The OPM is a special mode of observation in which, unlike traditional case study research, one is not merely a passive observer. Instead, one may assume a variety of roles within the case study situation and may actually participate in the events being studied.

The first author of this paper started to work on the case study as a construction engineer during the first stage of the project. The project had all the necessary tools to carry out 4D-PS. However they were not being applied when the first author first joined the project. The merging of the background (which was strongly supported by the Stanford 4D CAD research group) with the available tools led to a proposal, which convinced top management to provide support to give a chance to 4D-PS to be applied in the project.

The OPM applied to the case study allowed the study of a real-life situation that IT Research had only rarely been able to study in the past. See (Haymaker and Fischer, 2001; Staub et al, 1999; and Collier and Fischer, 1996) for other case studies. OPM applied to the case study offered the opportunity to see what others have not yet seen (Stake, 1998) and allowed access to events and groups otherwise inaccessible to scientific research. OPM enabled the perception of construction reality from the point of view of someone "inside" the case study instead of someone "external" to it, as well as the possibility to manipulate minor events in the case and thus influence the outcome. The research carried out using the OPM provided the opportunity to work as part of the project team, doing the research from within the project working daily with the construction and engineering project team. OPM did not simply lead to the evaluation of schedules using 4D models, but instead led to the development of actual plans and schedules through the basic 4D-PS process developed and shown in Exhibit A.

GROUNDING CONSTRUCTION IT RESEARCH IN INDUSTRY PRACTICE

Administrative Logistics

The research presented in this paper shows how the IT research using the OPM can dramatically improve our ability as researchers to partner with the industry when grounding IT research in construction industry. The full implementation of 4D-PS on the Escondida IV Project presented an excellent opportunity to pilot this new technology (4D-PS) on a real project where its benefits can be carefully documented and quantified. The OPM allowed addressing the needs of the competencies and capabilities of our engineers, project managers, architects and constructors to embrace and operate the technologies we are seeking to develop, which allowed the research process to be particularly effective.

Grounding 4D-PS research in industry practice lead to the development of a detailed construction plan for all the concrete foundation of this real life project. The construction planning team involved in this exercise became convinced of the value of improving the plan/schedule through the use of 4D-PS techniques. However, after half of the project design, the construction team was de-staffed due to budgetary constraints and the 4D-PS task was stopped. Even though the engineering and construction teams agreed on the significant business value of 4D-PS, the novelty and unplanned/unbudgeted aspect of 4D-PS made it difficult to fit clearly within the existing project organization conventional funding sources.

4D-PS Work Processes Procedure

Even though the 4D-PS task applied to the case study project using the OPM was paused for a short period of time on the project, 4D-PS research did not stop. Instead. the impediments that caused 4D-PS to be suspended on the project were identified, and a proposal was submitted to the Bechtel Technical Grants Program. The Bechtel Technical Grants Program promotes “out-of-the-box” innovation in pursuit of competitive global advantage. This mechanism allowed the research project to be continued without the need to obtain special funding from the project. Aside from facilitating the administrative aspects of conducting research, this allowed the researcher a further degree of autonomy.

Discussion

The construction industry includes a significant amount of inertia that tends to maintain a status quo or allow relatively slow development of traditional approaches to project execution. Successful constructors who are the principal decision-makers on large projects tend to be conservative individuals who are highly sensitized to risk (Fox, 1990). This, coupled with some improvement in overall construction productivity through mechanization and automation, seems to have worked contrary to an embrace of concepts such as 4D modeling. By taking advantage of the unique opportunity to apply the Observation-Participation Method, and in doing so assist in ensuring a successful result, the first author has been able to effect change from within the industry. It is a tremendous advantage for a researcher to be an integral part of the construction organization and demonstrate in practical terms the merits of 4D tools and methods. By contrast, the information and system technologies industry and purely academic research projects have had the disadvantage of trying to pry into the construction organizations and suggest radical change as an outside source. With all due respect to the software industry, many engineering and construction managers have become weary of people who try to sell them new tools that often turn out to be functionally inadequate. There are many stories about attempts at pioneering new technology that resulted in cost overruns and schedule slips, and few managers want to put their project at such risk. The general nature of builders is that they think of themselves primarily as "doers" who are distinct and removed from the theoreticians who are seen to generate little more than paper. It is the challenge of the OPM researcher to overcome that myth and introduce 4D technology by "doing" along side the other "doers" in the field.

CONCLUSIONS

The research efforts presented in this paper have embraced the issues associated with implementation and industry practice in a unique way. Through the observation participation method the distinction between construction reality and IT usage was blurred during the research. IT assimilation (4D-PS) in the construction industry was made a reality as a direct result of the research.

4D-PS as a viable solution has been embraced and adopted by the industry partner in this case.

Bechtel leadership is motivating other firms toward the uptake of research about technological advancements.

4D-PS addresses the needs of the competencies and capabilities of Bechtel's engineers, project managers and constructors to operate the emerging technology.

Our ability as researchers to partner with the construction industry by getting directly involved in the observation participation method and undertaking the 4D-PS task has been of key importance in allowing this process to be effective.

Examination of the context of application of 4D-PS proved that even though the technology was ready to be used and exploited, the work process context was not ready to adopt it. Bechtel as a corporation has not yet adopted 4D-PS. What Bechtel Corporation has adopted is a commitment with 4D-PS. Bechtel's efforts are oriented to write the 4D-PS Work Procedures. This should help them to overcome the "work process context" problem identified when 4D-PS was tried to be applied and introduced within existing "work process context".

Grounding IT research in industry practice has proven beneficial for bringing together industry practice and IT research. However, we must be careful to achieve a balance between research autonomy and practical needs to create the synergies that ultimately benefit practitioners and researchers alike.

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EXIBIT A: 4D-PS Basic Process