Theme:

Title: **4D-PS: Putting an IT new work process into effect**

Author(s): Leonardo Rischmoller[(1) (2)] and Luis Fernando Alarcón[(2)]

Institution(s): (1) Bechtel Group, Inc.
(2) Pontificia Universidad Católica de Chile

E-mail(s): lxrichmo@bechtel.con, lalarcon@ing.puc.cl

Abstract: *A leading, international, engineering and construction company has carried out efforts to engage a new tool set and work process. Four-Dimensional Planning and Scheduling (4D-PS) is the new work process that aims toward better, more efficient planning and execution of large construction projects. This paper describes the case history and forecasts how this revitalized technique may ultimately impact the construction industry. Despite academic and practitioners' research and development efforts to leverage from Information Technology (IT) in construction, the industry at large, being generally conservative, has adhered to the values of predictability and existing methods to minimize risk. 4D technology has struggled to find its way into mainstream construction practice for several years, and just recently it has been shown that commercially available software and hardware can be applied effectively toward this end, greatly reducing investment risk. These relatively new tools promise new impetus to the use of 4D-PS in the construction industry. This paper describes how 4D-PS was applied on a major construction project, giving rise to a new work process that proved to be productive and cost effective. Emphasis is made on the fact that those expected to use such technology must have the necessary training and, conversely, near-future versions of computerized tools can be made more intuitive for more widespread use. The use of such techniques will necessarily draw engineering/design and construction entities closer together, essentially improving coordination among them.*

Keywords: *4D, Construction, Planning, Scheduling, Work Process*

Introduction

Traditional revolutions have always been negative: define an enemy and struggle to overthrow the enemy. It is time we developed designs for positive revolutions where there are no enemies but structures for making things better (E. de Bono, 1992). This paper describes how a leading, international, Engineering and Construction Company, Bechtel Group, Inc., is carrying out efforts to engage a new tool set and work process that should provide structure to make things better.

The new work process is the result of the application and study of 4D tools to plan and schedule the construction of part of a major construction project, the case project. 4D Planning and Scheduling (4D-PS) is the new designed work process that aims toward better, more efficient planning and execution of large construction projects, and that proved to be productive and cost effective applied to the case project. 4D tools were applied and studied during three years in the design and construction stages of the case project. Results of 4D application during the first two years, called the attention of Bechtel Technical Excellence Program, that awarded a Bechtel Technical Grant to develop the 4D ideas and draft a Standard Work Process Procedure (SWPP) to apply 4D-PS company-wide based on the case study experience. 4D-PS SWPP is expected to provide a level of work process definition adequate to perform 4D-PS on any Bechtel Engineering and Construction Project. The 4D-PS SWPP draft is currently being routed to regional managers of Construction and appropriate functional managers for review and comment and all comments are expected to be reconciled in order to issue 4D-PS SWPP for final approval.

4D Overview, 4D Models, 4D Planning and Scheduling (4D-PS)

The idea of linking 3D CAD models to the construction schedules (4th Dimension) was conceived back in the 1986-87 time frame when Bechtel collaborated with Hitachi Ltd. to develop the Construction CAE/4D Planner software (Smith, 2001). Although Bechtel has had marginal involvement in the 4D

Planning concept for over a decade, commercially available tools have only recently become easier to use and more readily available. 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 the Primavera CPM Schedule to the 3D model so as to visualize exactly what the plan entails by simulating the scheduled construction events and actually showing which pieces of the project will be constructed in what sequence. Visual 4D models combine 3D CAD models with construction activities to display the progression of construction over time, dramatically improving the quality of construction plans and schedules. Construction people have always used 4D models in their minds to varying extents, but now they can use them explicitly as a common planning environment by implementing 4D-PS (Rischmoller et al, 2001).

4D-PS is a new work process that consists in using 4D models interactively and iteratively to accomplish the project construction planning and scheduling tasks (Rischmoller et al, 2001). 4D-PS allows simulating and interacting with construction sequences (schedules) through interactive graphic display devices. If the sequence is not just right, the schedule can be easily adjusted and the simulation re-run for verification (Rischmoller et al, 2001). Figure No. 1 shows a simplified work flow diagram of the 4D-PS new work process.

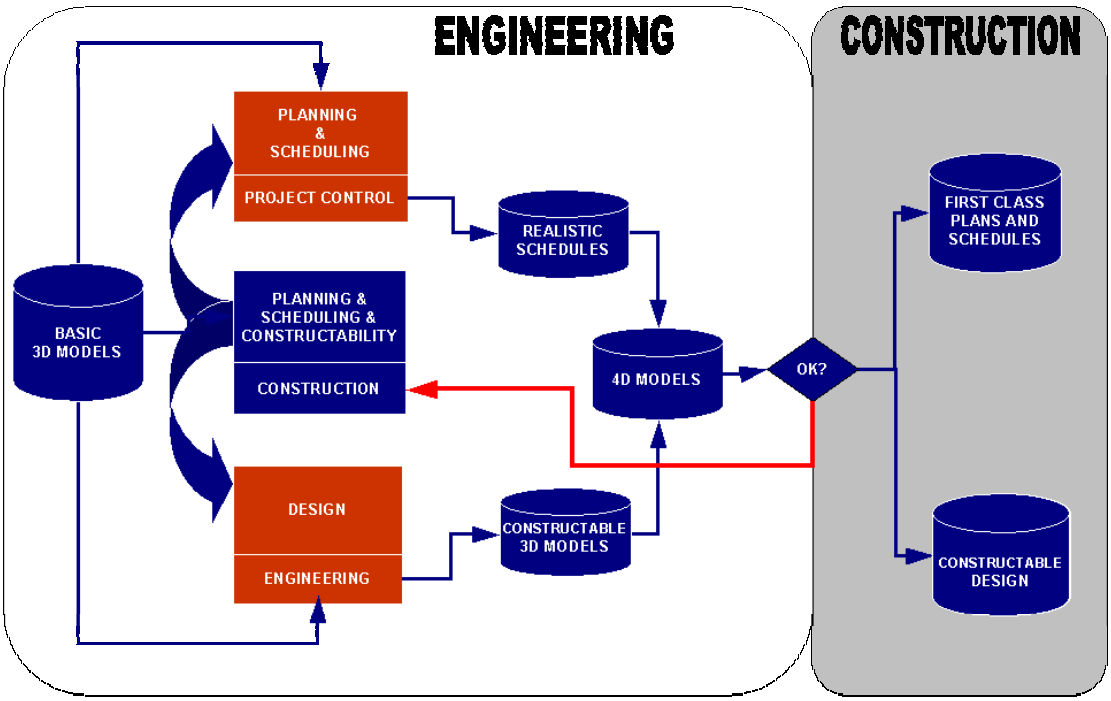

Figure No 1: 4D-PS Simplified Basic work flow diagram

4D applied to the case study

History

The basic capability of linking a scheduling environment with a CAD model has been around for about ten years. Since 1996 the first author of this paper has been investigating the impact of 4D and other Computer Advanced Visualization Tools (CAVT) in the construction industry as part of his Ph.D. studies. In 1999 contact with Mike Williams, Bechtel IS&T LAR Manager, led to hire Leonardo Rischmoller to work at the case project and try to take advantage of available tools, to link the construction schedule (Primavera) to the 3D model, essentially upgrading it to a 4D model. Mike Williams had lead a previous

effort to apply 4D in Bechtel through an in-house software development named 4D Planner. Leonardo Rischmoller worked at the case study project with Robert N. Fox, Project Engineer, who was also involved with pioneering 4D in Bechtel more than a decade ago at the Bechtel Norwalk, California office. 4D application on the case project was successful but limited to the concrete foundations. Leonardo Rischmoller, working with the project construction manager and the civil works superintendent, as part of the construction planning team, developed a complete plan and 4D model for 100,000 m3 of concrete foundations for the case project. The engineering team, as well as the construction planning team involved in this exercise became convinced of the value of optimizing the plan through the use of the 3D model and streamlined technique. However the construction team was de-staffed due to budgetary constraints and the 4D Planning and Scheduling task was stopped on the project. Leonardo Rischmoller's involvement with 4D then became relegated again only to his academic research until the Bechtel's Technical Excellence Program, through its Technical Grant Program, offered the opportunity to apply for a grant to revitalize 4D in Bechtel, leading the company to embrace the current efforts to put 4D-PS, a new IT work process, into effect.

Case study description

The case study project is part of a major project that involves mining facilities that together form the largest single-phase expansion of any copper concentrator in Chile's history.

To increase the mine's throughput, the contract called for a huge new copper concentrator facility to be built some 10 kilometers from the existing mine and concentrator, plus a new tailings storage facility another 24 kilometers distant. To provide electricity to those areas, the contractor built a new power transmission system. To carry copper ore from the mine to the new site for processing, the contractor team designed and built a 9.6-kilometer overland conveyor. The project also includes a pipeline to the tailings site and an 164-kilometer pipeline to carry copper concentrate to the nearest port for shipment. In addition, living and recreation facilities had to be fabricated for the approximately 7,500 construction workers on site at any given time. At the end of the long conveyor, the new concentrator facility almost resembles a station at the end of a subway line. The covered building can hold some 400,000 metric tons of ore. Underneath the building, a system of conveyor belt hoppers and chutes extract the rock and deliver it to an 11.6-meter-in-diameter, 26,000-horsepower SAG (semi-autogenous grinding) mill, three 18,000-horsepower ball mills, and a set of 110 flotation cells. The concentrator facility separates copper sulfide ore from waste rock in several steps. The SAG mill and then the ball mill grind the ore into a powder, that then passes through the flotation cells for chemical extraction of the copper from the ore, a process producing a concentrate of approximately 40 percent copper grade. The copper concentrate, which resembles thick slurry, is piped to the port of Coloso on Chile's west coast, where it is filtered, dried, and stored for shipment.

3D Application

Instead of the traditional two-dimensional drawings approach , the Plant Design System (PDS) software was applied to carry out in 3D, the design of the concentrator area and the filter plant exclusively. The primary crusher, overland conveyors, tailings dam, pipe-lines, pumping stations and port areas were not modeled in PDS. The rationale was that only those areas where the project stood to gain the most from 3D would be modeled, and leverage on the fact that the "infrastructure" (non-3D) part of the scope could proceed without the overhead involved in applying PDS.

Each design group (structural, piping, mechanical, electrical, and instrumentation) created its own models, which were fitted together like a giant 3D jigsaw puzzle. That allowed engineers—prior to construction— to avoid costly rework by ensuring there were no unforeseen design clashes, such as pipes running through steel columns. It also permitted them to produce at the push of a button the quantities of all construction materials needed, and help workers "walk through" their daily work plan. "We used the model in many new ways, thereby saving a lot of time during construction," says Engineering Manager. At completion, the customer will get a complete model of the plant for use in training, maintenance planning, and any future expansion.

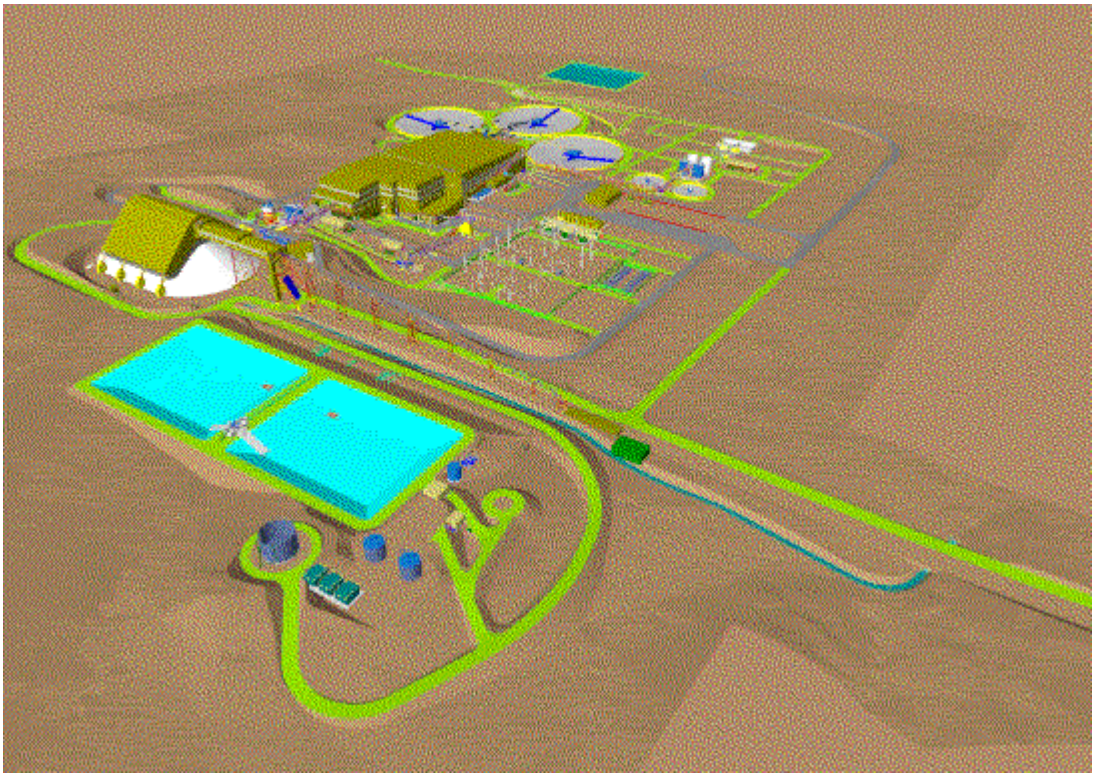

Figure No. 2: PDS 3D model of the case study project

Adding the fourth dimension

Nothing currently available beats the power of 3D visualization when it comes to planning the design construction phase. Schedules are made to be kept - to get the job done - on time and within budget.

Visual 4D models combined 3D and applying design automation technology at the case project, never before tried in South America. Using PDS and 4D modeling as a new powerful weapon in the region, allowed engineers to build three-dimensional computer models of the entire project, and provided construction teams the ability to develop visual simulations of construction over time, the fourth dimension. Through 4D-PS the sequence of the construction effort is easily viewed and modified giving planners the ability to optimize 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 without conflict. It allows planners formulate a tighter, more finely tuned construction plan. 4D-PS also helps to develop contingency plans to handle delays in material deliveries or unavailability of resources. Important decisions concerning deadlines, sequences, and resource utilization, which would ordinarily be made later at the job site, are better made ahead of time, often avoiding rework. Feedback from construction to the design team resulting from 4D modeling reviews can often lead to a more readily constructible, operable and maintainable project.

Benefits of 4D-PS application to the case study project

General benefits

The experience with 4D-PS indicates that, more than a simple and relatively new technology, it is a new way of doing our work. 4D-PS combines Computer Advanced Visualization Tools (CAVT) with project management knowledge, attaining a synergistic effect that has proved to dramatically improve work performance, specifically for the concrete foundation works, leading to the following achievements:

- Reduction of 10% in cost

- Reduction in schedule, from 18 to 16 months
- Improved design reflected in a reduction in errors during construction
- Reductions in uncertainty and risk reflected in 90% of fulfillment of the construction schedule

Benefits during the engineering phase

4D-PS applied early during the design stage led to studies of assembly and erection tasks and construction sequences supported by a complete visualization environment to interactively review the large and complex design of the project. The original and official approach in which 2D drawings were the main source of design information was not disregarded, but was dramatically enhanced with the new, 3D CAD approach and 4D-PS at the job-site. The utilization of CAVT allowed the construction teams to focus in planning instead of the traditional focus in constructability. Nevertheless, the quantity and quality of constructability suggestions increased, arising in an almost "natural" way and providing very timely feedback to design

Benefits during the construction phase

During the construction stage, at the job-site 4D-PS application at the case project allowed the crafts at the, the superintendents, the field engineers and general performers, to be able to visualize what schedule they were requested to complete before actually starting the work. They could see the sequence how the structural steel was going to be erected, how the equipment was going to be inserted, they were able to try to find or look for any potential interference in the execution plan for construction. And they were also able to review to make sure that the execution plan was the most cost-effective method to do the work that was on the table to do.

Benefits for the client

4D-PS proved that quality of the product and services offered to the case project client could be improved through better construction planning and scheduling, and resource management, while also offering opportunities to improve profit margins of the project.

The grant and the technical excellence program

The Technical Excellence of Bechtel's employees has been a cornerstone in the success of the company and a critical element in the engineering-construction industry. The Bechtel Technical Grant Program is part of Bechtel Technical Excellence Program, and provides the funding and support to convert a few promising new ideas of Bechtel scientists and engineers into technical reality. Each year, several highly creative Bechtel employees are awarded grants that enable them to explore their ideas in depth for a full year. The selection is carried out by the Bechtel Fellows, based on technical merit and potential benefit to Bechtel and its customers. Chosen for their substantial technical achievement over the years, the Bechtel Fellows advise senior management on questions related to their areas of expertise, participate in strategic planning, and help disseminate new technical ideas and findings throughout the organization. The purpose of the Technical Grant Program is to help convert promising new ideas into technical reality. Since its inception, the program has given some of Bechtel's most creative people the time, the money, and the resources to make their ideas a reality.

The proposal "4D Planning and Scheduling (4D-PS) using 4D Models" was selected as a winner of a 2001 Technical Grant award. The Bechtel fellows who reviewed all the proposals, were very impressed with the 4D-PS ideas, and considered that the concept had a high probability of being both successful and of significant value to the company. The grant work was carried out during 2001and led to writing a 4D-PS SWPP draft, that is currently being routed to Bechtel's regional managers of Construction and appropriate functional managers for review and comment and all comments are expected to be reconciled in order to issue 4D-PS SWPP for final approval.

Putting an IT new Work Process into action

Reviewing the road that 4D CAD has traveled from early days at Bechtel, it is clear that the technology has grown significantly in response to the high demand for powerful tools for complex projects (Smith,

2001). The price of admission to what has been, until now, an exclusive club, is coming down, while the computer-savviness of construction professionals is on the upswing (Goldstein, 2001). Readily available technologies combined with inductive thinking have led to develop the 4D-PS new work process. However, envisioning, designing, and then operationalizing a new work process into an organization is not an easy task. Fundamental changes in business processes produce consequences in many other aspects of an organization; really, in all the organization (Hammer and Champy, 1990). Emphasis is made on the fact that those expected to use such technology must have the necessary training and, conversely, near-future versions of computerized tools can be made more intuitive for more widespread use. The use of such techniques will necessarily draw the engineering/design and construction entities closer together, essentially improving coordination among them.

4D-PS piloting application proved the existence of advances that have had an impact on the product and services offered by the case project contactor. Support for innovation from senior management, through the Bechtel Fellows and Technical Excellence Program, is allowing the extension of this major opportunity to be exploited orderly and coherently by the rest of the company. The 4D-PS SWPP draft, based on 4D-PS experience captured during the case project Engineering and Construction phases, as well as over a decade of Bechtel´s involvement in 4D and recent advances in 4D academic research, is paving the road to put an IT new work process into action in a leading engineering and construction company.

Conclusions

The ability to create new a wholly-renewed process is a critical “core competency” for 21st-century organizations (Pande et al, 1999). The work carried out by the technical grant, presented in this report, shows Bechtel's awareness of and readiness to take advantage of a new emerging tool set and work process. 4D-PS is not to a tool to analyze and fix problems, but a new work process to design and bring to fruition a new way of doing key work in the organization. Bechtel stands for a long list of turning new technologies into reliable tools. The relatively new available tools promise new impetus to the use of 4D-PS in Bechtel, and this revitalized technique may ultimately impact the construction industry as a whole.

References

1. E. de Bono, **Teach your child how to think,** Penguin Books USA Inc.,1992
2. H. Goldstein, **4D: Science Fiction or Virtually Reality?**, www.construction.com, April 16, 2001, (http://www.construction.com/NewsCenter/it/archive/01-20010416pf.jsp)
3. M. Hammer and J. Champy, **Reengineering the Corporation: A Manifesto for Business Revolution**, Harper Collins Publishers, Inc., 1993
4. P. Pande, R. Neuman and R. Cavanagh, **The Six Sigma Way-How GE, Motorola, and Other Top Companies are Honing Their Performace**, McGraw-Hill, 2000
5. L. Rischmoller, M. Fisher, R. Fox and L. Alarcon, **4D Planning and Scheduling (4D-PS): Grounding Construction IT Research in Industry Practice,** Construction Information Technology CIB W78 International Conference – IT in Construction in Africa, Mpumalanga, South Africa, 29 May – 01 June
6. S. Smith, **4D CAD Goes Beyond Mere Representation, "4D is far ahead of where most of the construction industry is willing to think"-Dr. Joel Orr**, www.aecvision.com; October, 2001, (http://www.aecvision.com/October2001/1_feature_full.pdf)