2007 AACE International Transactions

PS.12

4D Scheduling – A Case Study

Mr. Abhimanyu Basu PE PSP

A '4D schedule' is a 3 dimensional CAD model attached to the fourth dimension of time via a schedule. The concept of 4D scheduling has been around for over 20 years. In the early years, producing 4D schedules was technologically challenging. These challenges lay in developing 3D models from 2D CAD drawings and in relating these CAD elements to real schedules. Advances in technology are now pushing to make 3D CAD elements the norm. Off the shelf software are also making it easy to link schedule outputs from standard scheduling packages like Primavera or Microsoft Project to the CAD elements to produce effective 4D schedules. This article describes the issues faced and lessons learned from a 4D scheduling initiative.

CASE REVIEW

This case study is a 4D scheduling effort for a large construction program. The primary goal of this exercise was to help a group of non-technical stakeholders visualize the scope of design and construction and the phasing of the total building program being funded. Some of the dimensions of the program aimed to be conveyed through this effort were as follows:

- major elements of construction to be performed;
- phasing of program and sequencing of work; and,
- How long would it take.

The initial objective of visualizing the phasing and sequencing of construction and communicating the scope to the lay stakeholders was achieved by constructing a 3D CAD model of the entire program and linking the model to a schedule. As the 3D CAD model created was dimensionally accurate, the project team began to discover many other uses for the model such as logistics planning, site line studies, walk-thrus etc.

CONTEXT OF 4D SCHEDULING

It is important to understand the context of 4D scheduling and some of the concepts and acronyms which are shaping this emerging field. The first is BIM which is short for building information model or modeling. BIM is a digital representation of the building process to facilitate exchange and interoperability of information in digital format. VDC or virtual design and construction is a term coined by CIFE at Stanford University. 3D CAD is three dimensional representations of objects. These 3D objects may simply be renderings or they may be models i.e., made up of components and have properties. The 4D in 4D scheduling is the added dimension of time linked to the 3D Model. 5D is linking both schedule and estimates to a 3D model.

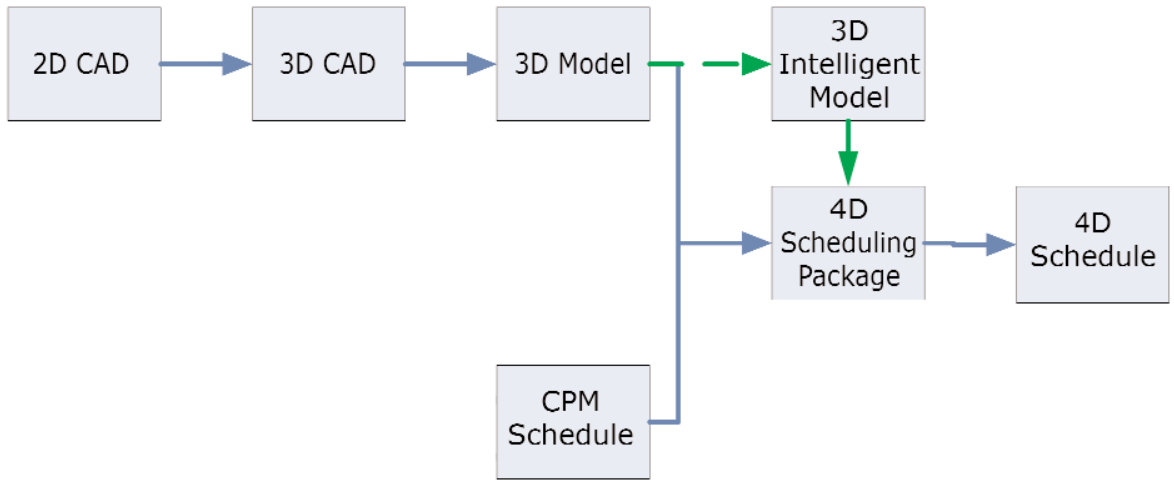

Figure 1—Assembling a 4D Schedule

ASSEMBLING A 4D SCHEDULE

We used a 4D scheduling package to link a Primavera schedule to 3D CAD model to create the 4D schedule. Currently design information is generally available in 2D CAD. In some cases 3D CAD may be available. However a 3D CAD 'drawing' or rendering is not sufficient for preparing a 4D schedule. A 3D model is required for preparing a 4D schedule. A 3D CAD will be a collection of points, lines and faces which convey no meaning. The 3D model on the other hand is made up of elements that have meaning in construction such as columns, beams, floors and walls etc. In current practice, where 2D drawings are the norm, the effort to prepare the 3D model is not trivial and takes substantial effort.

In the case discussed in this article, we prepared the 3D models of buildings and site works from 3D renderings and 2D CAD information.

The process of preparing a 4D schedule is shown in figure 1.

Figure 2 illustrates how a 4D software assembles a 4D schedule.

DRIVERS AND ENABLERS FOR 4D SCHEDULE

In general, owners are driving the adoption of BIM. The General Services Administration (GSA) has mandated BIM and related initiatives such as 4D scheduling for all its projects starting in 2007. The Construction Users Roundtable (CURT) a group of owners of large facilities is also pushing its members to take an aggressive role in implementing BIM and associated technologies.

General Motors is one such large owner who has taken the decision to use BIM for all its new projects. GM and other first users have reported big successes from their projects both in terms of savings in cost as well as in schedule.

There are two important enablers which make it easier to use 4D scheduling. The first is the generally increasing acceptance and usage of 3D CAD and modeling. The major software vendors are focused on delivering 3D functionality.

The second big factor in enabling 4D schedules is the availability of off-the-shelf software which can combine a schedule from a scheduling package and a 3D CAD model prepared with a standard CAD package and links them together. These 4D packages are platform 'neutral' which means that they will accept scheduling and CAD information from most of the leading packages in their classes.

WHERE 4D SCHEDULING IS BEING USED

Reports of the use of 4D scheduling indicate certain areas of focus for the current use of 4D. Some examples of the areas of application and what they sought to achieve are given below:

Visualization—In the case study covered in this article, the initial and primary motivation for developing the 4D schedule was to enable non-technical senior stakeholders, who would approve the project, understand what the scope of the project was, when they could expect finished buildings to open and how their current operations would be impacted by the construction.

Communications—A corollary of the visualization effort is communication. The model was also used to communicate the intent of the program to a larger audience as a community relations initiative.

Preconstruction planning—A complex renovation of large occupied building which had to be done in phases and by moving around the occupants was first planned out using a 4D model. It was claimed that this

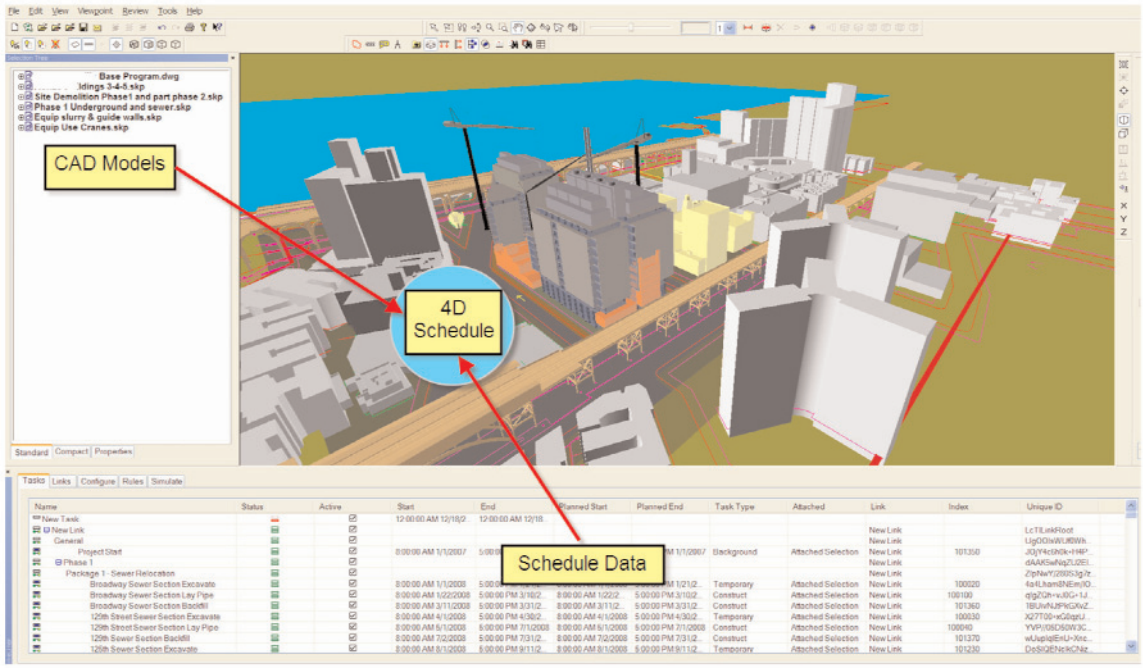

Figure 2—Using a 4D Scheduling Package

project could not be done without the initial detailed planning and buy-in using the 4D model.

The need to visualize and communicate drove one of the earliest initiatives in 4D scheduling for the Walt Disney Concert Hall in LA1. The job was so complex that it overwhelmed the sub-contractors. The contractor was driven to specially build a complete 4D model for the most complex part of the job. According to the report the contractor "used the model to comprehend, confirm, communicate, coordinate and troubleshoot. The tool helped find logic busts in the schedule while there was still time to adjust. It verified constructability and checked work flow, access and hoisting. And it helped educate the team. But primarily, it was shown at monthly coordination meetings to preview the next 90 days of work."

Collaboration, Planning, Scheduling and Constructability—The biggest payoff in cost and schedule reduction has been in the areas of collaboration, clash detection and coordination, planning and scheduling including logistics planning. There are a number of reports of successful use. The Denver Art Museum project, the first public project to use these high tech tools, is a success story and has been a proving ground for BIM and 4D scheduling [2]. According to the report "use of the 3D digital model, prevented 1200 collision of steel elements and sped steel erection to the finish line three months early. The contractor then gave nearly $400,000 back to the owner."

General Motors has committed all new projects to 3D modeling [3]. According to GM "The approach has proven itself by helping the company build faster, better and safer with less cost and risk."

Claims and Dispute Resolution—Supporting claims with visual demonstration of impact on schedule and cost is reportedly another area where 3D modeling and 4D Scheduling is finding use.

BENEFITS OF 4D SCHEDULING

It appears that the benefits of 4D Scheduling that are driving the use of 4D scheduling and 3D modeling are in both tangible and intangible categories. While the savings in cost and schedule, risk reduction, improved quality, reduction of RFIs and claims are tangible, an important intangible gain seems to be in using the models to communicate project parameters to non technical stakeholders and get their buy-in.

HOW 4D SCHEDULING DIFFERS FROM CONVENTIONAL SCHEDULING

4D scheduling quickly challenges and changes many of the practices of conventional scheduling. 4D scheduling is not simply taking a conventional schedule and attaching CAD elements to activities. It forces the scheduler to think differently and adjust the way schedules are developed. Some of the considerations are as follows.

Ring side seat—A 4D schedule provides the scheduler with a ring side seat to the construction site. The scheduler is quickly able to move around, look outside, inside and under the building or site and verify the sequences he is planning. The constant visual feedback forces the scheduler to plan at greater depth and

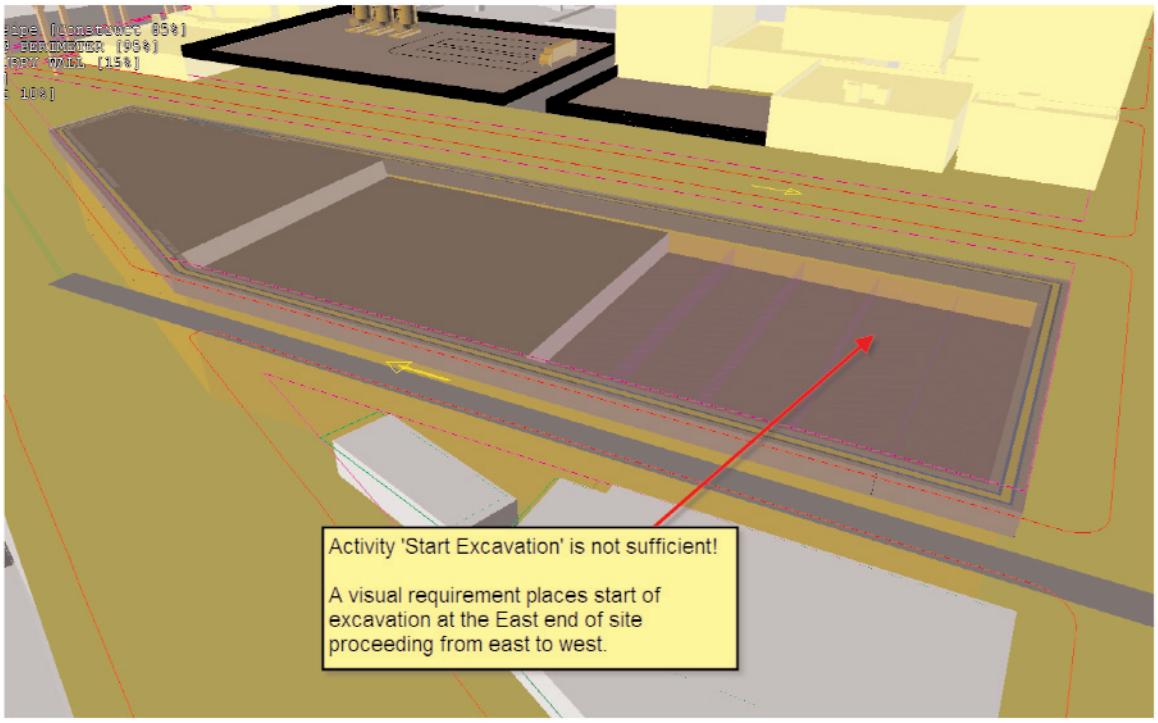

Figure 3—'Start Excavation' Must Choose a Side

refine logic to avoid visual incongruities in the representation.

Management of Detail—There may be issues of too little or too much detail depending on the stage of project definition and the granularity of the 4D representation desired. During early phases, with only sketchy intent or schematic drawings available, these may not be sufficient for generating 4D schedules. The necessary component details would need to be developed separately. At the other end, a finished construction model will likely show every element of construction. This may be too much for the scheduler who works at a certain higher level of abstraction.

Even a "fully developed" 3D model from the A/E will require additional work for the scheduler. For example, the model from the A/E will likely show a continuous floor slab in its model. The scheduler on the other hand may require the 3D model to be further detailed in order to show the sequence of concrete pours and may need to use his or her own 3D modeling resources to develop these details.

Management of hard and soft logic—The visual connection to the schedule discourages generalizations. Long duration activities with overlapping relationships (SS, FF) sometimes create impressions of out of sequence logic busts. Finish to Start (FS) relationships are likely to gain in respectability while using of negative lags will get a reality check.

The scheduler now has to make some choices earlier based on more refined decisions. It is no longer enough to have the activity 'Start excavation' – a particular area has to be chosen to start and another to end to make sense visually. Figure 3 illustrates such a point.

Similarly, soft logic connections will also require greater planning and be less arbitrary to withstand challenges using visual common sense. Logic busts are easily detectable as shown in figure 4 below.

Impact of Logistics—A ringside seat for the scheduler will force him or her to factor in impact of logistics on the schedule right from the beginning. The availability of access, lay-down areas, and equipment sequences cannot be ignored.

Managing what is not on A/E drawings—This is a completely new challenge to the scheduler at many levels. First the scheduler has to find information which is generally not found in Construction Document (CD) packages. The CDs are prepared by the A/E while site information such as logistics etc is prepared by the CM or GC. Secondly the scheduler must get this information in a compatible 3D CAD package.

WHAT 4D SCHEDULING DOES NOT DO

While 4D scheduling adds an exciting new dimension to scheduling, it also does not currently support many important facets of current scheduling practice. The important current scheduling practices not supported are discussed below:

Procurement and Offsite Activities: Because of its nature, 4D models do not support offsite activities such as the submittal – approval and the procurement cycles, offsite work such as fabrication or activities like coordination etc. These important and often critical activities must be carried in the conventional schedule but cannot be displayed visually.

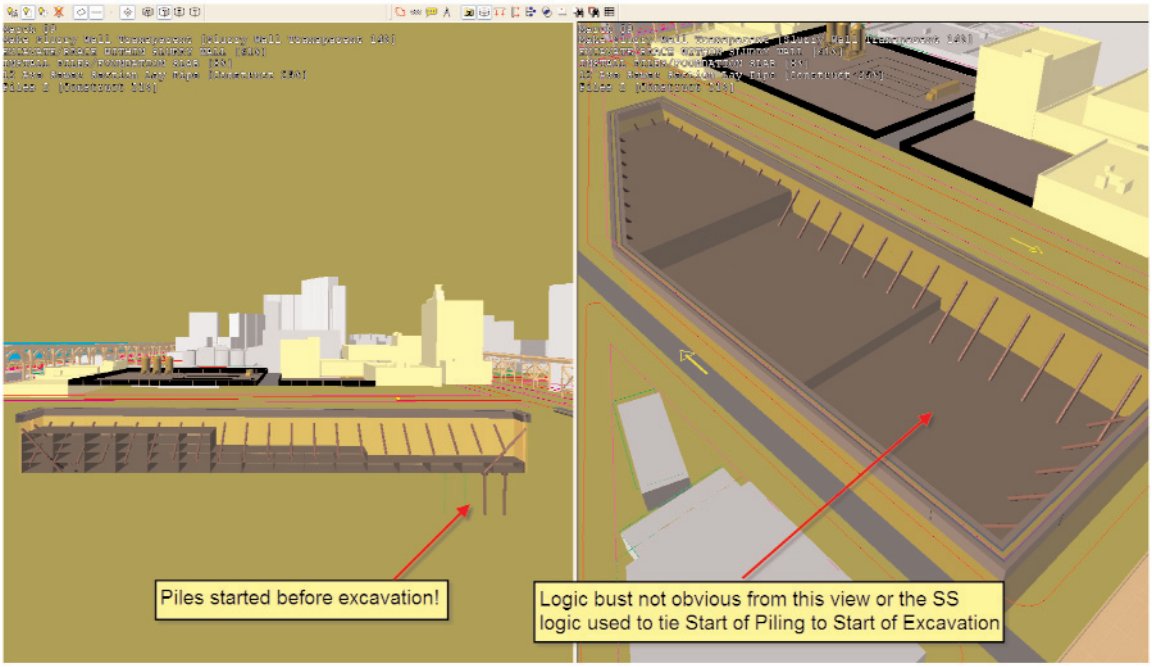

Figure 4—Visual Indication of Logic Busts

Critical Path, Late Dates and Float—Currently there are no built in features in the 4D package which facilitates showing the critical path and other data like total float and late dates. While showing critical path in a different color will make visual sense, it is not clear what value there may be in showing total float or late dates visually.

Cost, Resources and Earned Value—Currently 4D modeling does not support any advanced features of scheduling such as cost and resource loading, cash-flow analysis and earned value analysis. It is not clear whether these features need to be supported in the 4D model or remain a part of the existing scheduling practice.

LEARNING CURVE BARRIERS TO 4D SCHEDULING

While 4D scheduling certainly seems to be proving its worth and is being funded more frequently both by owners and by construction managers (Ultimately by the owner), the steep learning curve to using 4D technology remains a significant barrier to its use at this point of time (early 2007). Some of the learning curve barriers are as follows.

Learning CAD and 3D Modeling—The scheduler will generally be quite an expert in reading and interpreting construction drawings. However these are generally in paper copies of 2D representation. Now the scheduler will need to learn how to navigate through a 3D CAD environment. This is one more thing to learn. It is not a trivial task and must be in addition to many facets of knowledge and training the schedulers need in the field of scheduling.

Learning a 4D Package—The 4D software packages offer substantial functionality in taking 3D CAD Model information and CPM scheduling information and linking them to produce a 4D schedule. Like any advanced software it takes training and many hours of hands-on use to get to an acceptable level of productivity.

Need CAD Partner—Currently the drawings and models available are generally not suitable for use in 4D schedules. The A/E practice is not generally aligned with the needs of BIM and 3D modeling. Current A/E practice produces 2D drawings or at best 3D CAD drawings which are renderings. The drawings are a collection of lines and points and do not make up elements like columns, beams and walls which can be used for a 4D schedule. A 4D scheduler needs a CAD partner who will bridge the gap between the drawings that are being produced and the 3D CAD model suitable for use in the 4D schedule. This may be a little or lot of work depending on the quality of the drawings.

More Thorough Understanding of Scheduling—4D has added another level of difficulty to scheduling. The scheduler must consider more factors and have more interaction with the field to create the schedule. It not only places more responsibility on the scheduler but also calls for more active participation in the project execution.

GSA 4D INITIATIVE

The General Services Administration (GSA) is actively encouraging BIM and 4D Phasing [4]. The GSA website has published their intent as follows:

"4D Phasing - The Office of the Chief Architect (OCA) is currently encouraging, documenting, and evaluating 3D, 4D, and building information modeling (BIM) technologies on a project-by-project need basis.

GSA is supporting the understanding project phasing through the use of 4D models. 4D models, which combine a 3D model with time, allow A/Es, contractors, and GSA associates to communicate the proposed project phasing to all stakeholders. With 4D modeling, these stakeholders are able to better understand how the project affects them (e.g., - where the construction zones will be, where and when tenants will have to move to swing space, etc.). GSA is also able to use 4D models to understand projected construction schedules for funding purposes."

SHAPING THE FUTURE

The GSA has a modest goal for using 4D modeling. 4D scheduling has already proved its worth in complex construction scenarios in improving collaboration and communication and returning tangible benefits in cost savings and schedule reduction. The GSA initiative is a formal recognition of the role schedulers have to play in the paradigm shift toward a BIM world. This is an opportunity for schedulers and AACE International to pursue 4D projects and provide feedback to the standards setting bodies. Some of the issues which we need to tackle in shaping evolving technology and emerging standards of practice are as follows:

Preserve CPM Scheduling Values—While benefiting from the added level of detail that 3D models bring, we have to work hard to ensure that schedulers do not lose sight of the real values conventional scheduling provides in critical path and float analysis, earned value analysis, cost and resource loading studies etc.

Understand Process Changes—BIM and 4D scheduling are not only improving schedule by improving coordination and eliminating delays because of errors; they are also changing processes and work sequences and durations. Schedulers must stay abreast of these developments and use them in developing project plans and schedules in the future.

Align BIM model to scheduler needs: Currently there is a big gap between where 2D/3D CADS are and 3D models need to be. As standards of architectural practice evolve to meet BIM needs, schedulers must participate to ensure that the model elements that they need to develop 4D schedules are part of the 3D CAD model deliverables and are incorporated in the emerging BIM standards.

Align Naming Conventions of Models—Similar to the disconnect between how estimators and schedulers measure and aggregate quantities, a disconnect exists between how architects and schedulers 'view' a job. How layers and components get named and used by the architect can make life easy or difficult for the downstream 4D scheduler.

Align 4D software—The 4D software are evolving with usage. The more schedulers use the software and provide feedback and enhancement requests the better the software will become.

Influence technology development—BIM provides the framework for software vendors to develop analysis software that help planners, architects and engineers do their jobs. Examples are programs that can calculate usable space, do energy analysis or simulate the patterns and time it takes for crowds to exit a building etc. Schedulers should actively encourage vendors that develop tools and utilities which will help them. These tools and aids could be simple such as 3D models of equipment and structures or complex such analysis of truck movement during excavation. For example, software that matches site photos to the model and calculates progress would greatly ease schedule updating and earned value measurement.

4D scheduling is moving from being a buzzword to reality. Its value in saving cost and time has been confirmed with field data. This presents an additional opportunity to schedulers for enhancing their value to the project team. 4D scheduling and BIM also offers new challenges for proactively shaping the tools and improving usability and productivity and establish standards of practice. Schedulers and AACE International must actively promote its use and seek out opportunities to influence the technology, the tools and the practice standards.

ACKNOWLEDGMENTS

I gratefully acknowledge the help and knowledge that Dr. Arie Schinnar, a scholar, a teacher and a private practitioner of CAD and architecture has provided in this initiative. Dr. Schinnar is the CAD partner without whose participation, insights and help this project could not have been completed.

REFERENCES

1. Movie of Job that Defies Description is Worth More Than A Million Words. ENR 4/8/2002
2. Sharing High-Tech Tools Creates Rocky Mountain High. ENR 5/15/2006
3. Automotive Giant Commits New Projects to 3D Modeling. ENR 7/10/2006
4. 4D Scheduling, GSA.gov: Home > Buildings > Public Buildings > Design and Construction > 3D-4D Building Information Modeling > 4D Phasing

Abhimanyu Basu, PE PSP
Basu Technology, Inc.
26 Manor House Drive
Cherry Hill, NJ 08003, US
Phone: +1.856.245.9082
Email: abhibasu@basutech.com