



## Analysis I: 4D Modeling in Preconstruction

### Introduction

The construction industry is moving at an incredible rate and the technology that goes with construction can't seem to keep up. Within the past century of construction there have been many advances in how a building is designed, planned and even built. Building these buildings has become some big business, many companies trying to out bid one another in within the last hours a bid is due. People trying to prove the best way to compose their estimates, prove their schedule is the most efficient and produce a building that will be used for years to come.

With all of this competition in the market there is something bound to come of it. It is well known that competition breeds innovation, and the construction industry is starting to switch its gears to produce better ways to manage and construct what they do best. The construction industry has become to complex to do things the old fashioned way. The complication of higher standards, LEED design, pre-fabrication, and more efficient systems are all factors leading to this cause. This is causing too much confusion on all fronts with the laborers, owners and even some of the construction managers themselves. With the competition, there is the complexity of this industry, both being the major drivers to make their jobs easier and to even give others an edge in making their own projects that much better than the other guy.



4D modeling is one of the hot topics that is abuzz the construction industry. Last year in October a PACE (Partnership for Achieving Construction Excellence) seminar was held in Penn State. At least 60 members of the construction industry came to hear and discuss major issues in construction. Issues covered at the PACE seminar were LEED construction, prefabrication, safety and technology. The technology discussion focused on 4D modeling and animation and how it is and is not being used in construction. 4D modeling seemed to be the biggest taboo in construction as well.

4D modeling is one of the most discussed taboos in construction. 4D modeling is not some futuristic tool; it is a lot less complex than it sounds. Construction companies commonly use CPM schedules to design how a build will go together. These schedules can be hard to read due to the fact they only show the activity and the duration of that activity. Only people that have been in the business can effectively read these schedules and pick out areas of the project that will eventually have issues. Though this is even hard to see from the most experienced of schedulers. The schedules never actually show the complexities of the project as a whole. Interpreting the schedule with only 2D prints gives the reader a very broad aspect of what is actually going on. It's tough enough as it is to visualize how to put something together with out being able to actually see how it should look overall. Reviewing the hundreds of activities of a schedule can also be a drain on anyone trying to find mistakes or logical explanations of how the building should be built. (Koo, Fischer) The use of Gantt charts are another method of visually understanding what activities are going on within a building. With those charts one can at



least see what activities are occurring at the same time as well as what activities precede them.

“The combination of the graphic potential of 3D CAD with the construction project schedule is known as 4D CAD”(Webb, Smallwood, Haupt) With construction companies always needing to make deadlines and make quick decisions and keep that all within the standards of construction, there has to be a more efficient way to review the schedule. With the advances in computer technology and programming there is an efficient way to review building schedules and that is through these models. Being able to view what activities are going on in a building at any given time will ease the frustrations of the entire construction community, an issue that has been a thorn in the side of many for years.



### **How To Make A 4D Model**

Making a 4D model work is a very simple process. A 3 dimensional model is developed depending on the level of detail that will need to be used or will be presented. It's pointless to completely design a building in 3 dimensions when only the skin of the building will be analyzed. Granted having a complete model would be preferred to any owner that is having a building built for them, it is not always necessary. The model can be designed in a variety of programs most of which are AutoDesk applications. AutoCAD is one of the most popular programs out on the market for design and drafting. Other programs such as Autodesk VIZ and RevIT are 3 dimensional drawing programs. This cuts out the annoying process of extruding 2D plans into a 3D model in AutoCAD. RevIT can draw in 2 dimensions and have it automatically extrude to the heights that are needed based upon what the user inputs. What makes modeling in RevIT or VIZ so incredibly useful is the ability to name 3 dimensional objects individually or in groups. When a 3D model is made in AutoCAD there are no features outside of color of objects within the model. The other programs allow the option of naming and grouping of objects. This can prove useful when naming mass quantities of similar objects, like footings or light fixtures. The reason this is so helpful is when the 4D model has the schedule applied to it, finding the pieces of the building that the schedule is referring to is incredibly easy and efficient.



Wilkes-Barre/Scranton International Airport

Avoca, PA

Name	Add into existing CAD package	Stand-alone package	Manual linking of product process	Formalized PBS-WBS linking	Type of CAD data required	IFC compliant	Planning software supported	Visualization medium	Web enabled	Real time updates of task 3D model	3D product object grouping	Real time navigation of 3D environment
Bentley Schedule Simulator Common Point 4D	No	Yes	Yes	No	Microstation	No	Primavera	Internal Bentley 3D Format	No	No	Manual	No
	No	Yes	Yes	No	AutoCAD, VRML	Yes	MS Project Primavera	VRML, 3D Studio, Macromedia Shockwave, AutoCAD dwg format	No	Yes	Manual	Yes
SmartPlant Review Project Navigator FourDviz	No	Yes	Yes	No	VR 3D objects (VRML)	No	MS Project Primavera	Internal 3D Format VRML	No	Yes	Manual	No
	No - Add in to Web Browser	Yes	Yes	No	3D VR Objects (VRML)	No	None	VRML	Yes	No	Manual	Yes
	No	Yes	Yes	No	3D CAD data (DXF)	No	None	Internal 3D Format OpenGL	No	Yes	Manual	Yes
Visual Project Scheduler	No	Yes	Yes	No	DXF	No	None	OpenGL	No	No	Manual	Yes

<sup>1</sup> Now the building model has been designed, and all the objects have been named, the next step of the process is importing the tagged building model into a 4D modeling program. There are many 4D modeling programs on the market and each one can do their job effectively. The table above describes some of the programs and their data input methods and resources. Some of the major programs that are on the market today and are being used actively are Graphisoft's Constructor and NavisWorks' JetStream<sup>2</sup>. The model is imported into the 4D modeling program and there the user can review the model with an assortment of tools varying to fly through, walking and orbital review. The schedule is then imported from generally a Microsoft Project file. After the schedule has been imported the program will have to build a list of all the tasks that stem from the schedule, this is where the 3D objects will be assigned to the schedule tasks.

Assigning building objects to schedule tasks is as simple as three clicks of the mouse. The first step here is selecting the 3D object or objects, then go to the task on the schedule that the objects correspond to. Select that task and right click on it and select the

<sup>1</sup> The graph is used from Heesom and Mahdjoubi Trends of 4D CAD Applications

<sup>2</sup> Navisworks Jet Stream is used as the basis of the "how to."



“assign selected objects” option in the drop down menu and, viola, the first task has been assigned. Continue this process for all the objects in the building and be sure to match up the objects to the proper part of the schedule, otherwise the 4D model will not make any sense. There are also specific functions the schedule can assign depending on the type of work and how the objects appear in the 4D model.

Upon completion of assigning all the tasks in the schedule to the building, the user can see the fruits of their effort in the animation of the model. Click on the play button and view how the building is put together, after that the user can return to the schedule in NavisWorks and critique how and when objects appear. The user can specify how the object appear or disappear throughout the construction schedule. Objects can start out as invisible, appear in a transparent form while under construction, and appear as a solid when construction is complete. This can also work in reverse if demolition is required in building. Where the objects and show up as solid and then fade away over the duration of the demolition. Colors can be assigned to show from task to task, such as finishes, a room can be built, then have a color code define what stage the room is in. The possibilities are endless with how to display what the 4D model will look like and how it will perform.





### **Real World Application**

With the application of today's modern technology, jobs can become easier; that is bearing in mind that technology is properly used. With the rise of 4D modeling in the construction industry it is inevitable that change will come, and it will come fast. David Epps said, "There's a wave coming, and it's gonna be sink or swim." Mr. Epps is part of Holder Construction and is a BIM Specialist there. Holder construction have made many 4D models, this comes to no surprise since Holder's specialty is constructing data centers. The centers have an incredible amount of coordination with their mechanical system with keeping the server rooms at a cool temperature as well as keeping the air quality in those rooms very clean.

Currently the majority of 4D modeling applications are used as an explanative and communication tool (Heesom ,Mahdjoubi) The explanation can be used functionally as well as marketing tool. 4D models are used mainly in weekly foramen's meetings to describe where work is in process and where they should continue to work. 50 percent of the time is spent in this manner. With the marketing also a large part of this, 4D modeling can provide a "medium" between all the parties involved in the project. The owner can visualize how the building layout will work best; contractors can see how complex a job will be as well as construction managers. Jim McAllister has the same idea about 4D modeling. Jim sees 4D modeling as a tool for CMs or architects to help their clients make the decision of why to select them over anyone else. The 4D simulations help the visual aspect of construction. "Each party receives project information including a project schedule, 2D drawings and 3D product model and from this builds a mental 4D model of



how the building will be built. It is often these are not the same, which leads to communication difficulties.” (Heesom, Mahdjoubi) This brings up a very good point of why the construction industry is only using this as a tool for visualization. As of right now, the industry is at a turning point, many of the members are people that have worked their way up through the ranks. Many of these members aren't computer savvy and keeping this technology to a visual aid is very helpful and can improve the effectiveness of the work.

With all this focus on providing 4D modeling as strictly a visual aid there is so much more potential than just that. The potential to using 4D models for in-depth analysis and even prediction of what will happen on a job site is a huge eye opener. The best example of using 4D modeling for deep analysis is with Charlie Yetter of Trammel Crowe Company. Charlie was working on the Shirlington Condos and encountered a major set back in their schedule. While 20 percent of the way through their overall construction Charlie found the project to be lagging by 6 weeks. A schedule was developed to bring the activities up to speed, but the complexity of this schedule left many scratching their heads. This is where the visualization is important; transferring that schedule to a 3D model of the condos explained what tasks had to be done where and when. Now this visualization was conducted after construction had begun. This makes the case of analysis of the current building construction and what was holding the schedule back. After that the visualizations were used in the meeting to push what areas had to have the most attention and focus on construction. When this schedule was implemented the project regained the six weeks that was lagging the job and set them

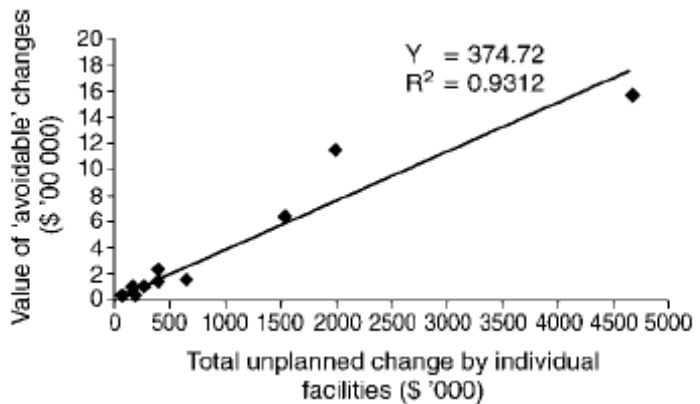




back on track. This is where 4D modeling can be used to assess the logic of the schedules and feasibility of overlapping tasks.

Mera has a similar situation with the use of 4D modeling on some of Jacob's projects. As soon as the modeling was completed and implemented on the job, she noticed an immediate change in the rate of construction that took place. The schedule got back on track and even was ahead of itself in some areas. Using 4D modeling a tool to analyze the logic of a schedule is where the real application can be applied. While schedules are made by good old fashioned logic, sometimes that is not enough. With the thousands upon thousands of activities that occur within a schedule, it is 100 percent likely that something will go wrong during construction and will set the schedule back. This is inevitable on any job. Nothing is

perfect, but with the use of 4D in the preconstruction stage to analyze the schedule for validity before anything is even built can save thousands upon thousands of dollars as well as weeks in lost work.



“The graph<sup>3</sup> to the left illustrates the value of unplanned changes using 4D modeling. The cost incurred to a project through unplanned changes is reduced dramatically.” (Heesom, Mahdjoubi). That graph shows the amount of money that would

<sup>3</sup> The graph was used from (Heesom, Mahdjoubi) 4D CAD trends article.



have been spent in RFIs, DCs and other changes in the construction documents and schedule that could be avoided if 4D modeling was used.

Application	Attributes			
	Level of interactivity with 4D simulation	Level of graphical representation	Level of interactivity with 4D simulation	Level of dynamic capability of simulation
Product modelling and visualization	Low	High	Low	Low
Process modelling and analysis	High	Low	High	High
Collaboration and communication	High	Low	High	High/Low

<sup>4</sup>The chart above depicts what tasks best fit for 4D modeling. 4D modeling has had many other real world uses in complex projects. One of the most well noted projects being Frank Gehry's Disney concert Hall in Los Angeles. This concert hall would have tested the limits of the contractors as well as the CMs involved. With the help of 4D modeling the building went up a lot easier than expected. Mera Faddoul of Jacobs is currently using 4D modeling to reduce the need of making mock-ups. Jacobs has composed a detailed 3D model of a court room in a courthouse that is being built in Virginia. The model will be used in an immersive environment and presented to judges and other judicial members of the court. This eases the mid construction change orders of the owner by determining the faults right up front. This will also save thousands of dollars and time in the overall scheme of things. While this may not apply to 4D, the overall building can be modeled in the same manner of detail. The technology to make models of this scale is there, but is it that necessary? Jake Hawes of Clark construction asked the same question. Using 4D modeling as a visual aid will defiantly be a selling point to some, but to convey a basic concept it is not necessary to have that level of

<sup>4</sup> The chart is referenced from (Heesom, Mahdjoubi) 4D CAD trends.



detail. Depending on what the model will be used for will ultimately determine the level of detail. The used of a highly detailed model can still be used to analyze schedules as a basic model, it never hurts to have the detail around just incase.

### **Neglect of Use**

Old habits die hard, many people know that phrase and it couldn't be farther from the truth. With that mindset, the technology that is being developed for construction isn't catching on as quickly as expected. The issues that are the driving this lack of development stem from a variety of reasons such as the generation difference and money.

Through some of the interview made to gather details of 4D in the real world, the interviewees had a variety of reasons for using and not using 4D modeling. One of the most prominent reasons was due to the transition of people in the construction industry. A generation of young adults is graduating from college with a lifetime of computer usage under their belts. Working with computers comes as second nature, and the computers that they grew up with advanced a lot faster then the generation before that. These young professionals find it easy to grasp the technology and the logic behind using the technology. Granted many do not have the real world experience to realize that the simulations of a computer can not generally take into account typical errors of being a human involves. The generations before now have worked through the ranks and have seen and experienced a life time of knowledge of how the construction industry works. It has worked that way for their entire lives. The use of 4D modeling seems like a bad idea by many of the older construction workers. Its difficult gain the trust of something you know very little about let along a program that produced the logic for the schedule.



Convincing these workers is one of the biggest reasons that 4D isn't as popular as it is today. Slowly 4D is pushing its way into how the job gets done. Seth Glinsky of Forrester construction mentioned how Forrester is introducing new ideas and technology little by little in weekly update meetings. These meetings inform the staff of Forrester how this technology is used and educating them on how to use it. This is used in all fields and not just 4D.

That is where a lot of this boils down to, is educating the industry the full capabilities of what 4D modeling can do. The laborers may be open to viewing the model if it has been created by a CM or GC but to model one for them selves is not very common. A rising trend is a lot of larger contractors are taking this issue into their own hands and making 4D models for themselves, but mainly from the new hires that know how to use the software or are open to learning the software. Making these 4D models can be very labor intensive which just adds to the reasons of why it's so expensive to have made for a company, and also hard to train people to use as well.

Another issue that was found as another reason to not use 4D modeling is the costs. The costs are most likely the number one reason that some companies aren't using 4D modeling. Mark McGaughan of Facchina-McGaughan is adamant about their usage of 4D modeling. Their first reason being that it is not required by owners. Many owners are still looking for the best deal, and if you have an \$80,000 model as part of your bid package, and another company doesn't, that other company is 80,000 lower than you, and you lose the job. As soon as 4D is quantified then we might rethink our situation. The costs of modeling a building through a 3<sup>rd</sup> party company are also ludicrous. Jake Hawes



of Clark mentioned that they are using Graphisoft software for their models. Graphisoft can actually sub them selves out and be a modeler, but their focus is on the software. Jake is head of estimating for Clark and also pushing the start up of a stand alone department within Clark for 4D modeling. Clark was dependent on Graphisoft at first, but were trained to use the software so Clark could become self sufficient in making their own models. Over time Clark would need less and less support from Graphisoft and eventually be fully functional in their modeling. His main complaint is there needs to be more functional training of the program instead of just how to use the program verbatim.

To make 4D modeling more mainstream many professionals comment that the software need to be better designed. This design can swing in both directions of making it more or less sophisticated. Mera Faddoul mentioned that while designing some of their models she mentioned that NavisWorks was far too easy to operate. While being so easy that it actually caused some major frustrations throughout their process. Working in the 3D environment of only being able to visualize and not edit caused a few headaches. A simple fix of moving a wall required that the 3D model be opened up in whichever modeling program that was used to model the building, making the required fix or changes to the model and then importing that model back into NavisWorks. If there were more tools that could be used to edit the physical building that would make Mera and the rest of her team so much more at ease.

Charlie Yetter also thinks that these programs are still not being used to their full potential, he wants to see the dollar amount, or a “5<sup>th</sup> Dimension” introduced as part of the programs. Jake Hawes would agree with Charlie on this topic. While 5D modeling is



not to much different than 4D modeling, it takes on a whole new level of data and communication. There most definitely will be this technology in the near future. David Epps Jakes Hawes biggest complaint about Graphisoft is the complexity of the program in it's self. The files that are used in Graphisoft are very large files and loading them takes a significant amount of time. Graphisoft consequently also produces large files that can take up an unnecessary amount of hard drive space.

### **Conclusions**

4D modeling is undoubtedly the wave of the future and will eventually be used by everyone in the construction industry. The catch is making the industry use it. Construction seems to be in the midst of a technological renaissance and needs to embrace the fact that the opportunities to advance and provide a better service and make their jobs easier are good things and worth the risk in investing into.

The focus needs to be educating the industry on its potential and not through seminars either demonstrating everything that has been said in this paper thus far. Have more interactive learning session's sponsored by the construction company or software company. This is hands on learning as well, sitting there taking notes will only influence people so much. Sitting people down and actually going through tutorials will show these people the ease that is involved in making basic models and fundamentals. With the fact that college graduates that know about this technology should be tapped into as well and used in companies effort to start their own modeling departments. With all the potential colleges and universities are putting out on the construction market, companies should take the initiative, invest in the technology and hire these grads to manage or create 4D





models. The construction industry seems to stubborn to accept this technology and is waiting for the industry to change naturally and adapt to the new people that will eventually make it up. While some companies are taking the initiative and are using this technology on a daily basis, these are the ones that will be ahead of the game when 4D modeling becomes an industry standard. Other companies should follow suit and do the same.

The use of 4D modeling will also improve the overall communication and flow of data within construction parties involved on a job. If a model is developed and then sent out to all the sub contractors, all of the contractors would be on the same page, with little ambiguity involved in understanding the construction schedule. “Due to the fragmented nature of the construction industry, numerous contractors and subcontractors can be working on a construction site during any stage. A 4D model can assist in the communication between different contractors to best determine execution patterns and avoid conflicts between trades.” (Heesom, Mahdjoubi) With this in mind each company should take into consideration what the construction industry has to use, and embrace it.