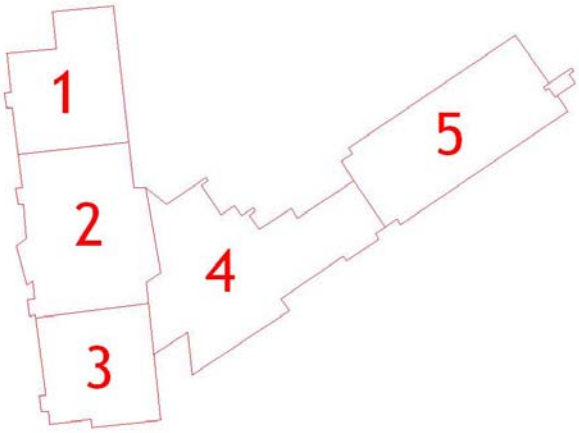
Analysis II: Application of 4D modeling

Introduction

The use of 4D technology is pervasive in the college learning atmosphere. Where else can students be exposed to the newest trends in all forms of technology with no bias? Through out the Penn State curriculum students are exposed to these technologies and are shown how to use them on an introductory level. Through the PACE seminar that took place in October 2005 many ideas were discussed and 4D modeling was one of the topics discussed in depth. With the use in the construction industry as well as what has been learned in class, modeling is the trend of the future of construction.



The Wilkes-Barre/ Scranton International Airport is a prime candidate to use as a part of an in depth analysis of 4D modeling. The airport has been sectioned into 5 major sections and the building was supposed to be erected in the order of the sections that have been labeled. The scheduled activities have been lumped into broad categories, but overall the building is split into five sections. The building is in the shape of a T, and the top of the T is split into three sections, the base of the T in two.

The original plan was to work on building the top of the T first, and then continue along with the base. Section one of the building has a basement, so a great deal of

excavation had to be done as well as the sub grade areas found areas two and four. The sub-grade levels in area one are actually accessible via truck ramp which also doubles as a cargo transfer yard for freight. After the basement excavation of section one was completed, excavation for the rest of the grade-level structures would begin. The phasing of the sublevel with grade-level sections provides a good way to mark specific finishing points and milestones between each section of the building. But these outlines are all theoretical, and the job was completed in an entirely different manner, due to loading of the project and money issues.

The 3 dimensional model was created from the 2 dimensional floor plans of the airport. The model was originally created in AutoCAD, the model was drawn to scale and the floor plan was extruded from this plan. This is the typical method of making 3D models and is one of the most tedious of methods as well. The model depicts the structural elements of the building. The foundations as well as the structural steel are what have been modeled. This brings up the point of the detail of the models used in 4D modeling, since only the structural elements are under analysis a model that contains everything dealing with the building structure, thus making the model easier as well as simple to understand.

After the building was extruded and properly put together the 3D CAD model was imported to AutoDesk VIZ. To save time on modeling and representation of the model the floor and roof beams were represented by a single 4” plane. This plane would also represent other phases of construction including the metal floor decking as well as

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pouring the slab on deck. Using this method saved time on modeling the building as well as representing stages of the model.

After the model was created the model was then imported to VIZ and the building objects were labeled appropriately. The building pieces were mainly grouped together as similar tasks such as grade beams or columns. Each group included parts of the building that corresponded to the schedule specifics. Area one has low and high foundation elements and is grouped together as such. The schedules used in this analysis are derived from the as-built schedule received from Turner Construction. Assigning the tasks of the building to the erection schedule was quite simple. With the building objects named in groups the same as the activities, matching the schedule to the model was easier than expected.


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Schedule Review

The as-built schedule of the Wilkes-Barre/ Scranton International Airport is very unique in how the building was actually built. As planned the building was supposed to be build sections 1 through 5 in that order and not deviate from that pattern. Unfortunately the steel erector had a different plan in mind. With the way Turner had the schedule laid out; the steel erector would be dealing with a layout plan that had a low steady cash flow. The cash flow was apparently not sufficient enough for the erector and decided to erect the steel in a way that cash flow would be higher in the early stages of construction.

The plan that steel erector planned out erected the steel in order that follows: Section 1, Section 2, Section 5, Section 4, Section 3. Erecting the steel in this manner would give the contractor more work to do up front and that means more money up front as well. But due to the sequence that occurred a 3 month gap in steel erection occurred. The erector had to stop due to financial reasons of their own and stopped erecting steel. This caused some major headaches on the job and would eventually push the planned schedule back by two months. Due to this delay in erection the curtain wall of the building was placed in the winter months, which made for very unfavorable working conditions at the airport.

If the steel erector just followed the schedule and did their job, the building would have been on track and even the steel erector would not have run into the financial problems that pulled them off the job. But hind sight is always 20/20 which makes for an


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excellent analysis of what could have been done instead. The schedule can be reviewed in the appendices under "As-Built Schedule"

SIPS Scheduling

SIPS is an industry acronym for Short Interval Production Schedule. These schedules are commonly used on high rise building with many repetitive activities. The key to making a sips schedule work efficiently is the coordination of the schedule to overlap activities. Typically with SIPS schedule there is a specific process to determine the best way to complete the schedule. Starting out with the building plans and dividing it into manageable areas of work is the first step. Identifying the activities that are contained within each section and the duration of each of those activities would be next to come. From there the development of the activity sequence occurs and is followed by planning the work involved and review with the project foremen and superintendents will tie the schedule together. After the schedule has been reviewed by the foremen communicating the plan is where people can be creative.

Sub contractors or site superintendents would generally communicate the plan through the plans that are hand. Others would use maybe a power point focusing on the areas that need to be worked on. Why use these primitive forms of communication when there is 4D modeling to fully visualize the process. Applying a SIPS schedule to a 4D model is a double whammy, using advanced scheduling and applying that to advanced communication is the most effective way to get the job done. There would be no questions about what the schedule is trying to show.


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With the Wilkes-Barre/Scranton International airport a SIPS schedule will be developed and analyzed for the effectiveness of using it on the building. The building is already broken down into 5 sections of construction. The durations of each activity can be utilized from the original schedule and applied to the schedule. The activities of the building can be sorted into 10 different activities:

- Footings
- Grade Beams
- Slab On Grade
- Column erection
- Floor Beams
- Floor Decking
- Cable Trusses
- Roof Beams
- Roof Decking
- Slab On Deck

Each activity is basic and many of the activities such as curing, backfill and trim out have been either assimilated into the duration of the activity or would occur at the same time as another activity. Focusing on the steel erection is what is important to this analysis. The foundations of the building had to be taken into account because the columns wouldn't stand without the foundations and also the erection of the steel is ultimately determined by when the concrete is finished.

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The plan to build the building is working from the inside out. A major issue is that the old airport still stands next to the one that is under construction and the road that is used runs along areas 1, 2 and 3. The site limits are tight on two sides and working away from the current airport would be most logical. Starting with section 3 is the best way to start this process. To continue with trades, sections 2 and 4 would be next and then finish up with section 5 and 1. As soon as one activity in an area, that activity will move to the next section of the building. One drawback to this plan is that the mechanical room for the building is in the basement of area 1. Area 1 is the only area that has a basement and areas 2 and 4 have sub grade walls and foundations. This is a major issue when designing the schedule for the new erection sequence. One of the critical activities is making sure the mechanical equipment is in place and is covered from the elements. With that in mind, section one has to be started first. Instead of building the building by sections, the building will have to have the sub grade foundations constructed first, and then the rest of the building as planned. Constructing areas 1, 2 and 4 will set the building on the same plane and construction can take off from there. The use of an extra crane during the erection of the building will also contribute to the overall speed of the erection of the steel.

As the foundations are being completed the footings in area 3 will start and thus start the rest of the scheduled plan. The schedule will follow the activity sequence as detailed in the previous page. The detailed schedule can be viewed in the appendices under SIPS schedule.


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Comparing Schedules

After completing the SIPS schedule, it was immediately applied to the 4D model created for the as-build schedule. Upon review of the schedule, the plan looked good on paper and in logic but didn't work out the way it was expected to run. The schedule saved a month over all with overlapping of trades and some activity compression by adding more crews. The key that made the building work well is the use of two cranes on the project working simultaneously. The major problem with the model was no matter how the activities were sequenced or added extra crews, area 4 could not finish as planned. Granted the schedule saved a month of time, but the sequencing of the project just didn't look like it would be easy to work on. As a student, viewing the model it was easy to spot simple mistakes that were made during the assigning of tasks. On top of all of that it really made the logic used to plan out the building look like a joke. The building jumped from area to area so much that the crane operators would go crazy through the erection. The use of an extra crane on the SIPS schedule is what mainly pushed the envelope of construction. Trying to keep the building crews and durations to what was originally planned made coordination difficult of the SIPS schedule, but in the long run two months was saved. The costs of having an extra crane would make an additional cost of $132,000. This is according to RSMeans, but the actual costs of having the crane on site wouldn't cost a penny since the GC (Sordoni) owned the crane. The only costs would be paying the crane operator and that would be around $81,000. The duration of the activities did not change dramatically nor did the amount of workers, so the additional

costs would actually only be $81,000. Not bad for cutting 2 months of work out of the schedule.

Conclusion

Scheduling is most definitely an art form in itself. There's lots of art out there, but that doesn't mean its good. The logistics behind developing a schedule for the steel erection sequencing takes phenomenal amounts coordination and long term thinking. This is a skill that is acquired over years of experience and learning.

Overall the SIPS schedule that was developed saved 6 weeks in construction time which by any standard is a considerable amount of time. Charlie Yetter was amazed at how the 4D model developed with the recovery schedule regained 6 weeks of work on his job, the 4D model for the airport advanced building by 6 weeks from the as-built schedule. Unfortunately the flow of work did not go as planned. Working from the inside moving outward as described in the schedule is a very logical idea. This is not always how it works. When making the schedule everything was falling into place and two months were removed from the schedule in overall build time, but do to the duration of some of the activities, the actual sequence that occurred was not as smooth. Section 4 was the main reason behind this due to its size and volume. Areas 1 through 3 do not have a second floor that is the same size as it's first. Construction for the sections of the second floor took much less time than the first. With area 4 the area involved with the second floor and the erection of the beams took an awfully long time to erect. Area 5, though having a second floor of the same size as its first, wasn't as large as area 4 and thus it's completion before the rest of the building.


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When the SIPS schedule was first developed it looked like it would work, but as soon as it was applied to a 4D model, some of the flaws were much more pronounced than on paper. After viewing the animation changes in the sequence were made to make activities run more smoothly. Granted this did increase the amount of work done overall it still could not be arranged that the sections were to be built as planned. The only way to bring the schedule to up to the speed that was in theory was to add 2.5 more crews to the activities that were affecting the duration of area 4. Trying to keep costs down and workers not crowed in their workspace, this was not an option to consider.

What did make the difference in the two months less of construction time is the use of an extra crane. As mentioned before two fewer months of work for $81,000 is not a bad amount to pay at all.