Industry-based learning experiences in Project Planning and Scheduling

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Abstract

Guest speakers are notorious in bringing value to classroom through current and updated information and best practices implemented in companies they are working for. Sharing knowledge this way benefits everyone. However, going out in the field and investigating collaboratively all the pertaining issues regarding these practices motivates students to go into deeper understanding of all related class topics because they are transposed into real scenarios. Also, exchanging communication with Superintendents (SI) and Project Managers (PM) will clarify certain topics or questions if they are having difficulties understanding the materials presented in Planning and Scheduling classes – options that weren't really available in the past without the help of industry video materials. The complementary live industry-based educational model is intended to validate the concepts learned in class. Through a series of interview questions performed by students, SI and PM are imparting knowledge about major topics learned in class: project description and details of activities with their durations, development of initial schedule, maintaining and updating the schedules during the project, schedule changes and their effects, technology usage in the respective company setting. Using a reversed model (industry-based) will enable students to account effectively for the challenges and duties they will face in the future jobs, therefore becoming more marketable for a difficult job market. This is evidenced by detailed description and analysis of two case studies collected by team of students assigned to work on real case issues that dealt with scheduling the respective projects.

Introduction and literature review

The course of Planning and Scheduling is presenting fundamentals and techniques for understanding construction projects. Topics include bar charts, critical path method (CPM) using arrow and node activity networks, precedence diagrams, cost-time trade-offs, PERT, resource leveling and management, updating schedules during construction, introduction to project controls and computerized scheduling in Primavera P6. Various network methods of project scheduling, such as AOA, AON, PERT, bar-charting and line-of-balance techniques are presented. Computers assignments used for scheduling, resource allocation, and time/cost analysis are carried out throughout the semester. Simulation modeling may be used in predicting the productivity of construction operations and the performance of project schedules, concept proved by Lee et. al[4] in a study performed few years ago.

In particular, a planning and scheduling case study (group project) is assigned to teams of students. They work on a study of the planning and scheduling process on a real project. Each team is identifying with the instructor of the class a current project to study in the area or surroundings. The specifics of assignment are posted in the Learning Management System (LMS) available within University system and they are discussed in class to intimate details.

Since technology usage is a major part of this class project, the proposed reversed model will bring to the students industry specific experiences using technology and applications they may or may not have been exposed to in the previous classes. This particular educational model is novel because it studies the application of technology into planning and scheduling of projects in real case scenarios. Therefore, students will leave college with the necessary computer skills and collaboration ability that are crucial in our economy. Practical approach preferred by industry and the more hands-on experience working collaboratively with others (including

industry individuals) will benefit students in understanding project scheduling. Through the industry project-based educational model, students spend their time learning material from experiential case studies brought to the class in small-size groups. After collecting and analyzing quantitative and qualitative data about real projects selected in the University's region, they are preparing the findings to be exposed in class through presentations and small hands-on demos. These accumulate into a capstone project with all knowledge gained for deeper understanding of a scheduler's job. Their pragmatic preparation would be orientated to success if they test the current business practices and/or direct applications of the subject matters in the construction jobsite. Early in the nineties, Benjamin et. al.[1] created a knowledge-based prototype for improving scheduling productivity; the results confirm the system's effectiveness and support the further development of knowledge-based systems as tools for improving the productivity of the construction industry.

Real-world learning based on industry project-specific context and best business practices may make students a lot more marketable to industry. Every student from each group is sharing comments, opinions, concerns and experiences, field trip notes, and later these are compiled into an overall assessment tool of the teamwork. These factors continuously determine the instructor to maintain an industry-oriented course to impart knowledge about the skills that employers are looking for and implement their requirements directly in the classroom. Further scholarship can be sought from industry practices applied directly to student education based on findings of these projects. In a comparative study, Galloway [2] found that lack of uniformity in the instruction of CPM scheduling, the knowledge base of those graduating and then applying CPM scheduling to construction projects vastly varies, thus serving as a root cause for misunderstandings among the parties relative to what is required by the contract, how the tool is used for monitoring and controlling a project, and how the CPM tool can be used for determining delay and resolving disputes both during and after the completion of a project. The understanding of the CPM scheduling and its correct application to construction projects may be better learnt in the field by witnessing techniques that are directly implemented by project managers to a project plan.

Methodology for the project scheduling study – a teamwork study

The study of real-world projects has an ultimate objective – to learn about planning and scheduling process and challenges for real construction projects. Each team is identifying a project to study and examine how planning and scheduling is performed and conducted on the respective project, implementation and management of schedules being carefully analyzed. Deliverable requirements for each team projects are two-fold: a minimum of ten pages written report (that may include real schedules, attachments, appendices of interview transcripts and photos) and a presentation with multimedia for in-class presentation at the end of the semester. The report and the in-class presentation will address the following:

1. *Project Description*: information about type of building, size, type of construction, project duration (if ahead/behind the schedule), information about the project budget (if under/over the budget); project participants (owner, designer, GC, key contractors and subcontractors)
2. *Development of Initial Schedule*: participation in the development of the schedule, subcontractors' participation in planning of the project, details about it; level of detail the

schedule was developed, how did the planner(s) breakdown the work to activities; how did the planner(s) decided the sequence of the work (sequence of activities and work flow). Also, students are instructed to find if other alternative sequences were considered in the development of initial schedule, and why was the particular sequence selected. The core questions the team needs to answer is how the contractor assigned activity durations, what information did the planner(s) have to gather to develop the schedule and how was this information gathered.

3. Maintaining and updating the schedule during the project: the teams will need to address the problem of how is the schedule communicated to other parties (owner, subs, etc.) and what are the different schedules used (with the respective level of details). Also, on this part they would need to report on the frequency of updating and reason about this frequency.

4. Schedule changes: in order to understand the effects of changes on schedules and to see how these are influencing the updates, teams are required to identify what changes in the schedule took place since the project started and describe them in writing. Also, they need reporting the reason(s) these took place. In the short analysis they are instructed to conduct an investigation about what planning information (if available) at initial planning could have avoided these changes and later schedule updates. In a previous study, Mokhtar et. al.[5] presented a computer-assisted methodology that helps design managers in planning and scheduling changes with interrelated effects on the design information.

5. Technology usage: the student teams are given a guided battery of questions to help them understand how technology usage is helping in the planning and scheduling process. Below are the major questions they need to address based on the company specifics:

- What is the software used to help with scheduling: MS Project, Primavera (report on the version), MS Excel spreadsheets, and/or others?
- Does the company use Building Information Modeling (BIM) software (Autodesk Revit, Navisworks, Bentley Navigator, Graphisoft ArchiCAD, Synchro, others)?
- Is any modeling software used in conjunction with scheduling software for better coordination on and/or off-site?
- Does the company provide any sort of communication devices to employees such as smartphones or tablets? If positive, provide the brand and model.
- Has currently BIM software enhances the Cost estimating and Scheduling in your current or past projects? How? Please explain.
- Does your company encounter any issues when apply your BIM software to your project(s)? Please describe and explain with details.

The learning and analysis of technology usage in a construction project is important because in a past research study, Kang et. al.[3] found that teams using 4D models detected logical errors more frequently, faster, with fewer mistakes, and with less team communication, than teams using 2D drawings and bar charts for scheduling purposes. These findings show industry practitioners empirical evidence that Web-based 4D construction visualization can improve team collaboration on construction planning and scheduling. In this sense, students are exposed in a distinctive setting to value the contribution of technology on real projects for a better schedule control.

Case studies of student group projects and their peculiarity

Case 1: Stadium expansion granularity schedule-overview and general findings

In addition to assigning dates to project activities, project scheduling is intended to match the resources of equipment, materials and labor with project work tasks over time. Good scheduling can eliminate problems due to production bottlenecks, facilitate the timely procurement of necessary materials, and otherwise insure the completion of a project as soon as possible. In contrast, poor scheduling can result in considerable waste as laborers and equipment wait for the availability of needed resources or the completion of preceding tasks. Delays in the completion of an entire project due to poor scheduling can also create havoc for owners who are eager to start using the constructed facilities.

Attitudes toward the formal scheduling of projects are often extreme. Many owners require detailed construction schedules to be submitted by contractors as a means of monitoring the work progress. The actual work performed is commonly compared to the schedule to determine if construction is proceeding satisfactorily. After the completion of construction, similar comparisons between the planned schedule and the actual accomplishments may be performed to allocate the liability for project delays due to changes requested by the owner, worker strikes or other unforeseen circumstances.

Formal scheduling procedures have become much more common with the advent of personal computers on construction sites and easy-to-use software programs. Sharing schedule information via Internet has also provided greater incentive to use formal scheduling methods. Savvy construction supervisors often carry schedule and budget information around with wearable or handheld computers. As a result, continued development of easy to use computer programs and improved methods of presenting schedules have overcome the practical problems associated with formal scheduling mechanisms. But problems with the use of scheduling techniques will continue until managers understand their proper use and limitations.

Project Overview

The Paulson Stadium Expansion project will be in construction midst of an active football season. The plan will consist of an increase in the stadium's capacity from 7,070 seats to approximately 12,690 seats. The new construction will provide over 5,000 extra seats within the stadium. There will be additions of on-grade seating, a club level, and an elevated deck with seating. The plan also includes a concession building and two restroom buildings to help accommodate the upgraded capacity. The project is a 58,000 sq. ft. General Contractor awarded to work on this project, as the second project on the University's campus, reported an earlier successful project consisted of a Biology Building with full ADA compliant labs and classrooms. The GC is one of the largest privately held construction firms in the nation. Its success is the result of a strong work ethic and industry knowledge combined with innovation and collaboration. The GC in cause is a recognized builder of one of the world's largest aquarium, which is a model of project efficiency, superior quality, and exceptional service from start to finish. The calculated stadium expansion project duration is approximate to 10 months. This Stadium Expansion Project includes many key players. The University's Athletic Foundation is the owner of the project. There are also two major subcontractors handling concrete work and structure pertaining to development of stadium expansion.

Development of Initial Schedule

The project schedule development is handled by their Project Manager and their Superintendent. A general schedule is then configured and discussed with the subcontractors. Subcontractors are then allowed and urged to put in their suggestions about the schedule. The project schedule is a fairly detailed schedule for project of this size. Due to changes occurring and unforeseen weather the schedule fluctuated and changed. The project schedule is divided into seven subparts consisting of General Detail, Club Level, Mid Deck, Lower Bolt, Toilet East, Toilet West, and Concession. When the project starts the actual detail will be broken down into more specific activities. Each Building will then have a very detailed schedule and time constraints on different activities.

Students assigned to this team reported that planners were then able to breakdown each of the work activities after knowing and understanding what important parts are and key to the completion dates. The concrete work is vital within this project and there was a lot of sequencing of the cast-in-place and precast concrete. Project planners were able to sequence all of the work. A project of this size takes a lot of studying the drawing plans in-and-out. The project manager identified all activities and how to tackle all challenges to the project. Activity durations were assigned with production rates and the known subcontractors' experience. Subcontractors were able to give their input on their work output to prepare the schedule. The project planners took on a huge role of gathering and analyzing all schedule information gathered. They were negotiating activity durations with all the subcontractors and Superintendents. Communicating and maintaining the schedule was a huge success for GC. The company emailed the schedule persistently each week to allow for total understanding of it for various crews. GC also allotted a meeting each week with the foremen to discuss the schedule. The schedule was shifted around periodically due to unforeseen weather. This project had received over 46 inches of rainwater, much more than usual weather on the respective period of time.

Maintaining and updating schedules

"Three hard dates equal three soft schedules", reported the Project Manager for this site. When working with any schedule it is hard to know what to plan initially, but if one could avoid these problems it would be easier for the scheduler; students reported the Project Manager on site "not having parties involved in creating schedules and maintaining them accurate", and "many reasons for subcontractors to not provide input." Also there are sometimes unforeseen factors such as crowded working conditions and inclement weather days causing delays.

Technology Usage

The GC's managers used Microsoft Project (versus Primavera) and Microsoft Excel in their planning stages due to its more user-friendly qualities. They also use Sure Track - earlier version of Primavera P6 with critical path determination capability. The other technology component the GC reported through students is BIM (Building Information Modeling) software, but this particular GC only had around the jobsite three full time employees. GC reported usage of BIM mainly on large projects. Also, subcontractors use BIM to make shop drawings and clash detections possible to be analyzed. With all the benefits that BIM has, some subcontractors do

not use it or have decided to not acquire the technology yet. Also when scheduling the stadium expansion project the construction manager decided against any BIM or scheduling software in conjunction with each other. The devices that GC uses on the project site were iPhones and iPad's. IPhones and iPad's were very useful devices in the field because of the portability and easy to use programs wirelessly. The foremen can work in the field and able to check through these devices on the activities' progress they perform.

Students in this team conveyed that some planning information during the initial planning was lacking parties involved in creating the master schedule. One reason for not having all subcontractors within the planning stage was because they might not fully understand the scope of work and different construction phases. Also, there were many factors for changes including very crowded site conditions. Another important factor was weather as an impact on all trades schedules. The weather affected all early starts, early finishes, late starts, and late finishes of trades' activities.

Finally, students assigned to investigate this project believed P6 software would have been more beneficial if used during the project interval. They witnessed P6 software in-class as being a very powerful tool when creating and managing construction projects. Although BIM is used on overhead coordination on larger jobs, the subcontractors created shop drawing with BIM software and for clash detections analysis. Other subcontractors did not use or had the knowledge to use BIM software. On this particular project, GC did not use BIM or scheduling software combined because it was considered to be a smaller-size project. However the company does provide computers, I-Phones, and I-Pads to their project managers/superintendents. The company has not used BIM software to schedule and compute construction costs data. The main reason for not using BIM is because in the past architects and engineers did not apply BIM knowledge correctly. It has been reported some difficulties in coordination of trades and one main problem GC reported was getting useful information across stakeholders in an efficient manner with help of BIM knowledge.

Case 2: Hotel renovation directed change on a day –to-day schedule

This group project for Planning/Scheduling course consisted of interviewing and investigating a construction company's detailed schedule and planning activities for a very particular project involving an old hotel renovation, restoration and modernization. Initially, the team did research partially on the project which included visiting the jobsite, taking pictures, meeting with the general contractor, and asking some pertinent questions. The hotel was sold to a Californian based investment company who purchased recently. The hotel has a storied past, built at the turn of the 20th century as a Coca Cola bottling plant. It was later converted into Mulberry Inn and has served as a boutique hotel up until just recently. One GC in the area won the bid for the renovation of this hotel.

<u>Project Description, Overview and General Findings</u>

Under new ownership, a very unique project was presented because the old structure of the hotel is dated and required a great deal of support and innovation to bring it up to current building codes. The old hotel is to be completely gutted and renovated into a spectacular new

hotel consisting of almost 30,000 square feet of construction and renovation, and spanning three stories. The 1st floor is made up of a lobby and the kitchen, while the other two floors made up of hotel rooms for guests. The original building was constructed from masonry veneer, and metal and wood studs (see figure 1.)

Figure 1. Hotel renovation and restoration

The initial project schedule and duration was determined to be six and half months, but as described later in this paper, another month was added to this timeline as the owner initiated changes at the beginning of construction. From the contractor's point of view, the project was on schedule and on budget. The additions the owner had made pushed the budget to an additional $375,000 and one extra month of work. Outside of this change in schedule and budget, the job was in the process of being completed right on schedule. The general contractor in charge of this renovation won the bid after hand selected three other companies to compete for the job. GC's extensive experience in commercial renovation and quality driven attitude won the bid. This particular student team interviewed the Director of Construction for GC. He was the leader's team in organizing and planning along with three project managers and one superintendent. The major subcontractors working on the job included the Mechanical, Electrical, and Plumbing companies. These three key subcontractors were in charge of all the MEP work being done throughout the hotel. This includes the constructing and re-routing all new mechanical, electrical, and plumbing to the old existing portions throughout the newly renovated hotel.

Development of Initial Schedule

The GC developed the hotel renovation schedule. The project team and the director of construction came up with a schedule that would be efficient, productive and also meet the strict deadline imposed by new owner. Because of such a time constraint, they decided to conduct two separate, ten hour shifts. Therefore, the use of labor resources allows for twenty hours of work time in a twenty-four hour period. Their reasoning behind this concept was to utilize all possible hours without wasting any productive construction time. The GC constructed a schedule that was

day-to-day based. Instead of doing a schedule by weeks and months, they were able to know what needed to be completed every day to make sure the project stays on track. They also have scheduled the day-to-day activities at least a month in advance. They explained their reasoning behind scheduling a month in advance, so they were able to make adjustments and compensate for possible time constraints arise. Another reason mentioned was the fact they were able to break down the project as much as possible which in return, makes the project more manageable. The company also used a bar chart to visually track progress as it occurred in the look ahead schedule and later visualize how much time was remaining for activities in the look ahead schedule.

The first phase of the hotel renovation began with the demolition process. GC had three different contractors that underwent the demolition and completed it within a month. General Contractor had the project broken down into three main areas of focus, which consisted of Mechanical, Electrical, and Plumbing retrofitting.

Next, the planners needed to come up with a workflow and assign tasks in a way that the scope of the project was clear, understandable and also efficient. They first wanted to approach the renovations in a staggered design, meaning the renovations were to begin at the bottom and progressively move up. But as more thought went into it, they decided that they were going to proceed with a descending concept. This new idea would mean starting on the third story, and work their way down. The reasoning behind this approach was due to the fact that workers constantly have to walk over finished product as work continues, it could possibly cost more money to complete the project. The other idea was to disperse the subcontractors throughout the building and working on it at the same time. However, this idea did not last because it was considered to be more efficient working on one level at a time, rather than disperse the man power throughout the hotel in the same time. GC was able to assign the activity durations based on previous experience and prior project expertise. This fact played a critical role in being awarded the bid to complete the renovations. Prior to the project being awarded to a construction company, the owner made it very clear that the hotel renovations needed to be completed and ready for operation on a certain day. Because the GC has had the experience, they were able to take the deadline and calculate if the time frame was reasonable and possible. This allowed them to “construct” a schedule that would fit the time constraint the project had established. The owner gave the project just little over seven and a half months, starting on the first of September and finishing in the middle of April. This duration consists of all activities from the start of mobilization to punch list and walkthroughs.

Maintaining and updating the schedule during the project

All factors in the project needed to be taken into consideration: labor, materials and equipment. One might also have to consider the role of the subcontractors, as they affect the sequencing of the activities. In measuring the factors, the project manager must keep track of the productivity of his labor field, measuring the progress over a given period of time. From these results, the project manager can then make a comparison against the project estimate, and against the objectives to meet the expected time lines, milestones and goals. These techniques have been utilized during the entire process of GC’s renovation of the hotel. Because they work from a basic Primavera schedule with a limited number of activities, it is important that their leadership

be very hands-on and communicates with all parties. A weekly conference call was conducted each Wednesday with the owner in order to convey the progress. Prior to each of these conference calls, he meets with his superintendent to ensure all critical activities are progressing as planned. This also gives him an opportunity to hold everyone accountable for the work completed.

Next, the owner of the project and all stakeholders had to be contacted with the new changes and justifications on why these changes came up (what problems and setback caused changes to the schedule) and how the new schedule will make up lost time, add to the time, or subtract from the time originally thought was needed to complete the project. And of course any new costs that have risen up were communicated to the owner and all concerned. Then a document had created to show the financial impact to the project: use of time, which parts of the schedule are affected, the involvement and the costs effects that have come up with these additional working hours needed to make up time for the unexpected changes. Going through all these steps in the project updates with the students, the GC had the chance to expose them well into learning process of their specific case of updating and managing labor, material and equipment of a work-in-progress schedule.

Schedule changes

In this particular project, the project manager and his team had to deal with changes imposed by owner deciding lately to use a new and more complex Information Technology (IT) system throughout the hotel. This system was not initially a part of the plans when the original scheduling was drawn. At the time of the owner's implementation of this system, some of the construction had already begun. This caused a problem with the current MEP systems, and added a month to the project duration. This schedule change has been handled very well because of the great leadership and decision making process of the GC. Because the change came after initial plans and being requested by owner, it is understood by all parties that the budget and duration would increase. Students reported that these types of changes are quite common in any construction project and must be handled with the utmost efficiency to keep owners happy.

Technology Usage

The company reported the fact that technology is moving companies forward and inevitably merging with smaller businesses to create increased income. (Figure 2)

In this particular project, there was technology usage for planning and scheduling purposes. Project manager from GC side primarily used Primavera P6 as well as MS Project to help with both planning and scheduling. He stated that many of the employees are undergoing training for basic use in Primavera P6. Unfortunately, this particular GC does not use much BIM software as their projects usually each average one to twelve million dollars, with their largest project to date upwards of sixty million dollars. Some BIM software was used by the architect to draw the plans, but that portion of the project was a separate entity that the contractor itself was not participating in. All GC employees were equipped with i-Phones and i-Pads. Company forms are loaded into a drop box via server and available for execution through a "sign and send" app. This includes subcontract agreements, timesheets, daily logs, etc.

Figure 2. I-pad usage for MEP systems coordination

The i-Phones and i-Pads are an exceptional help for efficient scheduling, subcontractor-owner communication and access to all construction documents while in the field. The project manager disclosed that Building Information Modeling software was overboard for many of the projects he performs such as the hotel restoration project. He stated that they are "not built to compete with the larger contractors who use BIM software", their successful zone is "in the six to twelve million dollar range." This statement shows how regional contractors think, build, and compete for jobs in a different manner than the national or international contractors.

Learning outcomes and conclusions on the case studies

After completing this course, students should be able to:

1. Understand the parameters affecting project planning, describe construction projects and processes using bar charts, network diagrams
2. Perform schedule computations to calculate project duration, activity early and late dates, total and free float and identify the critical path
3. Understand the effect of resources on the schedule, and be able to calculate the schedule under resource constraints
4. Update and evaluate project progress
5. Understand the relationship between project duration and cost when the schedule must be shortened
6. Understand the contractual provisions related to schedule, identify the sources and impact of changes and interruptions on the schedule
7. Compare and contrast the appropriateness of scheduling tools for varying construction operations
8. Use Primavera P6 to develop, monitor and update project schedules and understand how technology like BIM and/or mobile devices available on the jobsite can help with scheduling activities on daily operations

From a technology point of view, students came with real-world applications and conclusions referring to increased efficiencies and more productive teams. Communication devices helped

the flow of work on-and-off the construction site and leave employees with no question unanswered. Even though most of the participants on the construction site in this case were equipped with channel radios for communication between lead laborers to exchange project information as needed, more infusion of I-pads and iPhones was promoted. Most encounters that GC found by applying BIM to a project have been positive; the software being applied to a project has the potential to find quickly problems and early eliminate them. The main conclusion the group came is that using computerized technology helps planning for a schedule and a cost estimate that is much more accurate.

Overall, students working in groups for these assigned projects and interviewing project managers reported repetitively that they have learnt just how important scheduling is to any type of construction project. One of their important finding from case studies declares that if there is a problem with getting supplies or completing a certain CSI division on time - scheduling can be used as a tool to allow shifting some activities around so the project can be completed by the initial deadline yet. In the learning process, they appropriately realize the amount of effort and money a good baseline schedule can save to contractors. Students are now aware that poor scheduling can result in waste of time and money, the case when laborers and equipment sit around waiting for resources to be deployed or the preceding tasks/activities to be completed. Lessons learnt show a schedule success only when companies set schedules way before the project is started so that the employees start working on the project knowing exactly what they need to do and when they need to do it. Also students learnt that most schedules are done nowadays with computer-based software like Primavera or Microsoft Project programs. The computer-based systems allow for the schedules to be completed quicker and edited or updated easier at a later time when work is deployed and progresses. Through a series of interview questions performed by students, SI and PM are imparting knowledge complementing understanding of majors topics taught in class. Technology usage like BIM or BIM in conjunction with other software used for scheduling purposes enable students to better understand the main benefits of integrated BIM application for a construction contractor. Using a complementary model that is industry-based with technological applications for planning and scheduling enable students to account effectively for the challenges and duties they will face in future jobs, therefore making them more marketable for a tough job market. This is significant to the new body of knowledge that grows for planning and scheduling projects nowadays with infusion of new technologies. As educators, our responsibilities to construction students are to help them acquire the needed tools and knowledge of technology applications in order to successfully face the new construction industry challenges.

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