Teaching Students to Use Event Based Modeling to Evaluate Schedule Risk

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Abstract

The ability to create accurate estimates and build project schedules is an essential engineering management skill. The accuracy of initial project estimates has an impact on one's ability to manage risk to cost, schedule and performance of a project. The problem with estimation accuracy is that we don't always have perfect information during the planning stages and we have to base estimates on the best information at hand, using assumptions to cover the grey areas. As the project progresses we tend to learn additional information that allows us to revise estimates and strengthen planning. Projects bring risks, and subsequent cost, schedule and performance issues that are compounded by less than accurate estimates. Project estimating and scheduling is taught as part of The Citadel's undergraduate and graduate technical project management courses. However, test results and end of course feedback reflected that while the students were learning the mechanics of scheduling and estimating they did not necessarily have a full grasp of learning outcomes or how a well-developed schedule's utility and information contributes to management decision making. It became clear that leaving students with a solid knowledge of scheduling and estimating concepts requires a deeper understanding of the process and how estimate and schedule elements work together to aid decision making. To improve mastery of course learning outcomes an event based spreadsheet simulation model was developed and introduced to the course which allows students to analyze the linkage between estimate and schedule elements and gain a fuller understanding of the estimating concepts as they relate to scheduling risk.

Keywords

Simulation, Spreadsheets, Schedule Risk.

Introduction

Project scheduling provides the who and when for the sequencing of activities to be performed to carry out the plan [1]. The ability to create estimates and build project schedules is an essential multi-disciplinary management tool and the importance of engineering practitioners and managers having a working knowledge continues to rise [2]. The accuracy of initial project estimates have an impact on one's ability to manage cost, schedule and performance of a project. Many factors can appear and challenge project success over the project's life cycle, and an accurate estimation process can be the difference between a successful project and a failed one. Estimation, however, is easier said than done. Accurate estimation and planning requires sound information. The problem with estimation accuracy lies with the fact that we don't always know everything we would like during the planning stages and estimates have to be based on the best information at hand, using assumptions to cover the grey areas. As the project progresses we tend to learn additional information that allows us to revise estimate and strengthen planning. Projects bring risks, and risks bring cost, schedule and performance issues.

Project schedule development and control is taught as part of The Citdel's undergraduate and graduate project management courses which explore the principles and applications of project scope, project requirements and work breakdown structures (WBS); development and control of schedules, risk management, project execution and closeout. Course content includes realistic projects, case studies, and technology tools. The students are introduced to the schedule as a management tool for recognizing the sequence of project activities, identifying critical activities, planning efficient use of resources and completion of the work scope to manage risk. They are taught why accurate scheduling contributes to effective project management and how schedules are produced and used. The curriculum encompass the basics of scheduling with specific emphasis on the inputs to the process, tools & techniques for analysis and the outputs. The specific course learning outcomes include:

1. Developing:
    a. Schedule Management Plan
    b. Activity List with Attributes and Milestone List
    c. Project Schedule Network Diagrams
    d. Activity Resource Requirements and Resource Breakdown Structure
    e. Project Schedule with Model Data and Schedule Baseline
    f. Activity Cost Estimates with Activity Cost Supporting Detail
2. Creating, updating, and analyzing project schedules to determine integrity and validity.
3. Applying resource management techniques to identify resource requirements and to level resources in order to meet project objectives.

However, test results and end of course feedback reflected that while the students were learning the mechanics of creating a schedule, they did not necessarily have a full grasp of a well-developed schedule's utility in management decision making. In response the faculty brainstormed on ideas they could incorporate into the instruction to better teach students to evaluate the impact of schedule changes and their risk impact in order to provide manager's information needed to better manage the project.

While the schedule is typically viewed as a tool that represents sequencing and phasing of individual activities required to complete the work faculty wanted to show students how scheduling provides answers as to how schedule estimates flow into the critical management information that enable project managers to:

- predict the project completion date
- control and effectively communicate project progress
- manage money by predicting cash flows
- determine the "time window" of an activity
- coordinate and expose conflicts among activities
- predict resource demand and improve resource allocation
- create an as-built record

An instructional goal was to show students how a project schedule can be used to evaluate the risk impact of changes and how they can be modeled to prove or disprove time-based claims. In general, faculty attempted to show students how the schedule is used to provide information needed to better manage the project. Event based simulation modeling provides a method to analyze the variables that are driving the project schedule and gain a fuller understanding of the related risk of schedule variations and their impact on project success. Event based modeling enables us to assess the project work-effort to efficiently use project resources. Because project schedules focus on time-phased resource needs, it is important to schedule those resources accurately. It is a common mistake to prepare estimates to meet the objectives of the customer instead of preparing them to evaluate objectives [3].

Creating Initial Estimates

When developing initial estimates we are often hampered by insufficient information regarding specific activities or tasks and the thought that assumptions allow us to improve our estimates at some point in the future. Herein lies the paradox between the time needed to create accurate initial estimates and the expediency of using assumptions to cover gaps in information needed to develop accurate estimates. Another common cause of variances between estimates and actual work execution are problems whose severity of their impact were not seen or known[3]. Fortunately the insight gained from simulation can help to identify events whose accuracy have the greatest impact on the outcome.

Description

Event based simulation modeling can be an invaluable tool for anticipating and managing project risk due to uncertainties. Accurate project estimates help identify cost and schedule requirements with relative precision, and reduce the risk of running out of time, resources, and budget during a project. But even with years of experience, project managers can struggle with creating accurate project estimates. One of the key benefits of using simulation is that we can develop the "planned" baseline schedule using "best information at hand". Then by modeling changes to the estimate we can identify the potential impact of these changes. The model can be set up to estimate tasks in a best-case to worst-case range, using either single-point estimates or ranges such as those used in the PERT method [4]. But most importantly, modeling allows us to capture and visualize the inherent uncertainty in a given activity. Ranged estimates are also an ideal way

to prompt the student to consider the factors that will sway a task towards best-case estimate or the worst-case estimate and their impact on project completion dates.

Using the Model

Modeling with spreadsheet applications have an advantage over other software programs in that most students already have spreadsheet programs on their computers. Spreadsheets are also an attractive technology because students are likely to use spreadsheets in future projects, careers and in personal life. Spreadsheet programs are flexible, familiar, and relatively easy to use [5]. The specific simulation model we will discuss in this paper was developed using standard functions available in Excel 2016 and Microsoft Project which are used to introduce students to the concepts of event-based modeling using a simple project schedule involving the relocation of a work facility. The schedule shown in Table 1 consists of the nine activities, their task duration and precedence relationships which are used to calculate the start and end dates for each task.

Table 1. Facility Relocation Activities.

Planned	Project Start Date	1/2/2020	P1	P2	P3	P4	Max	
Activity	Task	Working Days	Predecessors				Start date	End date
S	Start	1					1/2/2020	1/3/2020
A	Locate Facility	8	S	S	S		1/2/2020	1/14/2020
B	Order Furniture	9	A	A	A		1/15/2020	1/29/2020
C	Interview	10	S	S	S		1/2/2020	1/16/2020
D	Hire & Train	12	C	C	C		1/17/2020	2/5/2020
E	Remodel	8	A	A	A		1/15/2020	1/28/2020
F	Furniture Setup	8	B	B	B		1/30/2020	2/11/2020
G	Inspect	8	D	E	F		2/12/2020	2/25/2020
H	Occupy	8	G	G	G		2/26/2020	3/9/2020
I	Start Operations	1	H	H	H		3/10/2020	3/11/2020

Students were provided the work scope statement with a complete by date and tasked with identifying the activities, determining precedence relationships and coming up with a duration estimate for each activity. The goal was to develop a baseline schedule displayed as a Gantt chart. Each exercise problem set required students to analyze, comprehend, and synthesis the lecture topics. The intention was to expose students to an assortment of related quantitative management techniques and topics which build a foundation from which to conduct effective decision making. Students were assigned in teams to come up with a reasonable plan for sequencing activities and estimating a duration for each. Students began by creating a single point duration estimate for each of the activities to form the baseline schedule estimate, in later exercise three-point estimates were used. Students gained insight as they determined if some activities could be done concurrently and if some required that predecessor activities be completed before an activity could start. The spreadsheet model can accept up to four predecessor tasks for each activity, with each activity taking up non-zero time. A sample baseline Gantt schedule is shown in Figure 1.

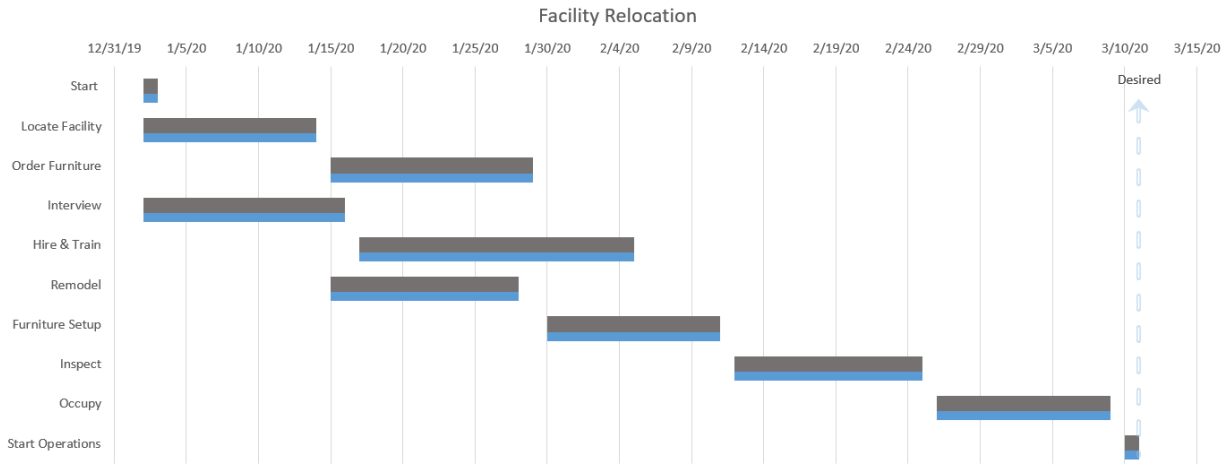

Figure 1. Planned Schedule of Activities.

The blue bars represent the planned task durations and the grey bars represent actual durations. For the initial planned schedule planned durations and actual durations are equal. Once the "planned" baseline schedule was developed we introduced changes to the planned activity durations by entering adjusted activity times in the actual working days section of the spreadsheet shown in Table 2 and asked the students to evaluate the impact on the schedule.

Table 2. Planned and Actual Activity Durations.

	Project Start Date	1/2/2020	P1	P2	P3	P4	Max		1/2/2020	Max		
Activity	Task	Planned Working Days	Predecessors				Start date	End date	Actual Working Days	Start date	End date	% Complete
S	Start	1					1/2/20	1/3/2020	1	1/2/2020	1/3/2020	100%
A	Locate Facility	8	S	S	S		1/2/2020	1/14/2020	10	1/2/2020	1/16/2020	100%
B	Order Furniture	9	A	A	A		1/15/2020	1/29/2020	8	1/17/2020	1/30/2020	100%
C	Interview	10	S	S	S		1/2/2020	1/16/2020	10	1/2/2020	1/16/2020	65%
D	Hire & Train	12	C	C	C		1/17/2020	2/5/2020	13	1/17/2020	2/6/2020	85%
E	Remodel	8	A	A	A		1/15/2020	1/28/2020	8	1/17/2020	1/30/2020	0%
F	Furniture Setup	8	B	B	B		1/30/2020	2/11/2020	8	1/31/2020	2/12/2020	0%
G	Inspect	8	D	E	F		2/12/2020	2/25/2020	8	2/13/2020	2/26/2020	0%
H	Occupy	8	G	G	G		2/26/2020	3/9/2020	8	2/27/2020	3/10/2020	0%
I	Start Operations	1	H	H	H		3/10/2020	3/11/2020	1	3/11/2020	3/12/2020	0%

Results of changing activity durations are shown in the Gantt schedule displayed in Figure 2. The blue bars depict the planned activity durations, the grey bars depict the actual activity durations and the green bars reflect the activity completion %. The differences in the planned and actual activity durations and the impact on schedule are apparent. Figure 2 depicts the shift in activity start and end dates, duration, and that the project completion date has now surpassed the desired completion date.

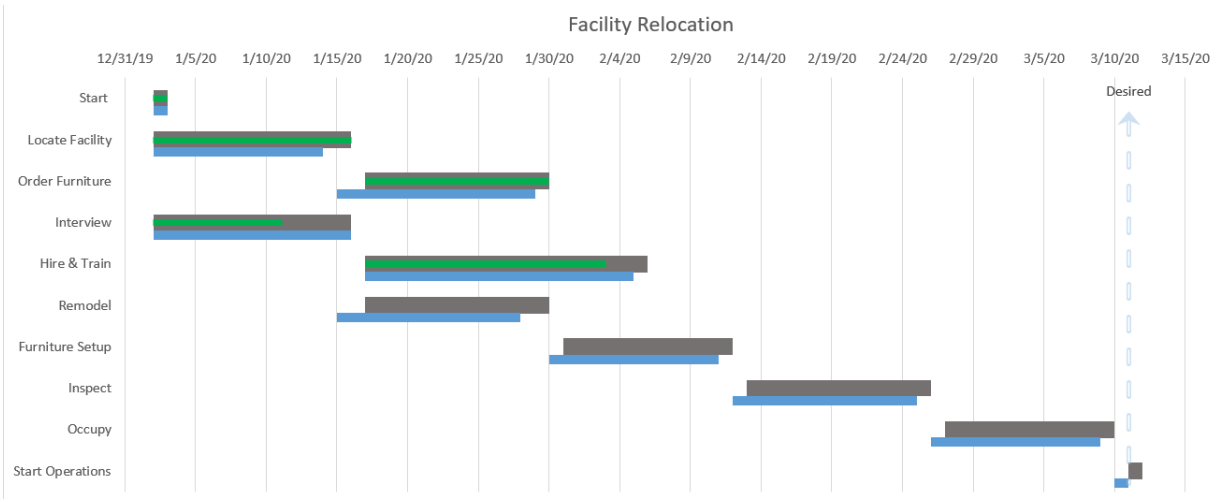

Figure 2. Planned Versus Actual Schedule of Activities and Completion %.

A real benefit of using the simulation model is that it visually provides the students with the effects of activity duration changes which they can analyze and discuss with the class. It is important for students to understand that not all projects finish on time and/or within budget. Delays and changes occur that impact the schedule, consequently impact on the project completion. If something that happened results in some meaningful changes to the schedule activities, it is called an event. Event based modeling can easily be used to identify the downstream effects of activity delay or change on a project schedule. Although not all activity changes from the planned schedule of work will result in a schedule impact, event based modeling emphasizes how to assess potential schedule impacts, as well as how to determine what, if any effect they have on the project completion date.

Assessing the impact of activity changes to the schedule completion is described by:

(Planned Schedule) + (Activity Duration Change Impact) = (Schedule Impact Liability)

Decisions play a crucial role in the management of every organization. Understanding the impact of schedule changes helps students, project managers and the organizations they work for to reduce risks and make important decisions. Having a good knowledge of event-based modeling techniques can play an important role in the management and operations of technical projects. This introduction to event-based modeling provides students with the knowledge and practical application experience in building useful models using readily available excel software.

Conclusion

By focusing on the concepts of valid data collection, organization, analysis, interpretation, and presentation vice the mechanics of calculation students gained abilities and confidence needed to solve demand based problems using modeling methods. Using event based modeling allowed students to demonstrate the ability to organize data, conduct analysis, and to interpret results and report their conclusions. Students presented core learning concepts and used project management problem sets in the homework assignments to increase comprehension. Initially students showed a tendency to present modeling results with insufficient interpretation and explanation of what

the results mean. Providing students with a report template for homework helped them to organize their thoughts and by the end of the course few students expressed any resistance to the format. At the end of instruction students have the opportunity to fill out a class assessment survey and were asked "What did you like most about this class?" Responses included:

- "Very applicable information and skills."
- "Being exposed to modeling with Microsoft Excel really opened my eyes to sensitivity analysis."
- "The simulation exercises gave me a much better understanding of the importance of the schedule as a decision making tool."

A number of students stated that by the end of the class they had obtained a much greater appreciation for Excel's built in functions and ease of use. Students felt techniques learned in the class were definitely transportable to the job market. In the future, the professor's priority is to develop more practical application problems which involve the event-based modeling as a decision-making tool. A continued emphasis on introducing the students to modelling concepts will allow the faculty to concentrate on teaching valuable analytic techniques that have direct applicability for real world problem solving. This paper discussed development of an event based modeling class for project management and engineering students. Although the class is a new addition to the course content student response has been universally positive. Improvements to the design of the class will include incorporation of a wider set of scheduling problem sets and presentation of homework results.

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