How to Befuddle a College Professor
(without Really Trying)
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Forward: The following was published in the Association for the Advancement of Cost Engineering's (AACEi) monthly journal, "Cost Engineering" in the October 2003 edition (Volume 47, No. 10).

A funny thing happened on the way to writing a review on a textbook on CPM (Critical Path Method;) the world tilted. When it finally rightened, I was left with 50+ emails from friends and strangers, excited people talking about their recollections of the beginnings of CPM theory, a reference list of textbooks as long as my arm, a slightly confused college professor, and newly-found knowledge about my favorite subject; namely CPM Scheduling using Precedence Diagramming Method (PDM.)

It all started when I began reviewing a textbook titled, "Construction Scheduling with Primavera Project Planner, Second Edition" by Leslie Feigenbaum. I was reading the section where Mr Feigenbaum explains how to compute a CPM manually. I shook my head (this is when the tilting began,) re-read the section a second and then a third time. Was I losing my mind, or did this college professor just compute the CPM incorrectly?

As a sanity check, I discussed this issue with the members of the AACE Planning and Scheduling Committee. They could not believe this either! There was a definite consensus of the group that the method used in this textbook was inconsistent with the correct method of computing a CPM for a PDM network, and thus was incorrect.

Cloaked with this mantel of virtue and armed with the knowledge that I was correct, I contacted the book's author, Mr Feigenbaum by email. I explained in my letter who I was and that I was reviewing his textbook. My appreciation of many of the features to be found in his textbook (see my review of this book) was conveyed. Then, I 'dropped the bomb.' I said,

> *"Unless I am mistaken, your method of computing a CPM is completely non-standard and (I am afraid) does not produce the same results as the 'standard' approach in all cases. At the very least, your workday calculations do not match those produced by P3."*

I finished my email by suggesting that Mr. Feigenbaum contact me to discuss the issue.

The very next day, a very polite but guarded Mr. Feigenbaum called me and we had a long discussion. Did I understand that this book was internally reviewed by experts in the scheduling field and then submitted to the publishers who also had their experts review the textbook for correctness? "Yes," I said. Did I understand that this very popular and widely-distributed textbook has been sold world-wide for five years and is on its second edition? "Yes," I said. Did I understand that a great many other textbooks compute the CPM in the exact manner as they do here at Texas A&M? "Err, no," I said. "What books?"

Over the course of the next couple of days, Mr. Feigenbaum was able to locate and list the following list of textbooks that showed the same method as that used at Texas A&M. This list is included below,

"Scheduling Construction Projects" by, Edward C Willis,
"A Management Guide to PERT / CPM with GERT / PDM / DCPM and other
    Networks", 2nd Edition, 1977, Prentice-Hall, by Jerome D. Wiest &
    Ferndinand K. Levy,
"Construction Planning & Scheduling", 2nd Printing, 1994, AGC of
    America, by Paul J. Stella & Thomas E. Glavinich,
"Critical Path Methods in Construction Practice", 4th Edition, 1990,
    John Wiley & Sons, by James M. Antill & Ronald W. Woodhead,
"Jelen's Cost & Optimization Engineering", 3rd Edition, McGraw Hill,
    by Kenneth K. Humphreys,
"CPM in Construction Management", 5th Edition, McGraw Hill, by James
    J. O'Brien & Fredric L. Plotnick,
"The Civil engineering Handbook", 1995, CRC Press, Edited by W. F.
    Chen,
"Project Management with CPM, PERT and Precedence Diagramming", 3rd
    Edition, 1983, Van Nostrand Reinhold Co., by Joseph J. Moder, Cecil R.
    Phillips & Edward W. Davis,
"Project Management: A Systems Approach to Planning, Scheduling and
    Controlling", 5th Edition, 1995, Van Nostrand Reinhold Co., by Harold
    Kerzner,
"Project Management: A Managerial Approach", 2nd Edition, Wiley, by
    Jack R. Meredith & Samuel J. Mantel, Jr.

This got me to doubting my own basis of knowledge, so I went through my library only to find that my references did not show how to calculate a PDM CPM network. I then asked my AACE P&S Committee peers for such references and this is the list that we came up with,

"Skills & Knowledge of Cost Engineering", 4th Edition, AACEI, Edited
    by Richard E. Larew,
"Primavera Training Guide, Course 601" by Primavera, inc. ,

"Project Planning Using SureTrak for Windows Version 2.0/Version 3.0," Paul E Harris ISBN 0-6463795-9 , ISBN 0-95-777830-9, ISBN 0-95-777831-7, ISBN 0-95-777832-5,

"Planning and Scheduling Using Microsoft Project 2000," Paul E Harris, ISBN 0-95-777833-3, ISBN 0-95-777834-1, ISBN 0-95-777835-X, ISBN 0-95-777836-8.

The PMI Body Of Knowledge (PMBOC) in their "Time Management" section does not offer to show how any CPM network is calculated, much less a PDM network.

So it appears that the version of calculation used by Mr. Feigenbaum at the Texas A&M University, College of Architecture, Department of Construction appears to be better supported by references that the method used by the AACE.

Along the way, we stopped describing the methods of computing a PDM CPM with such long descriptions and starting calling them, "The Aggie Method" (for Mr. Feigenbaum's university) and "The AACE Method" to denote the method that is adopted by the AACEi in body.   As it appears that there are definitely two methods available to compute a PDM CPM and that both apparently give the same answers, an explanation of the two methods is in order.

As a means of improving communication in the following explanations, I will refer to "Days" and "Day Numbers" when I actually mean "Time Units." We all recognize that a CPM schedule can be computed in minutes, hours, days, weeks, months, or years. As most construction projects are scheduled in days, we are all familiar with the reference to "days."

The AACE Method

It is possible that AACE adopted this technique sometime after the software Primavera Project Planner (P3) was released in 1985. The technique describes the method that P3 uses to compute a PDM network. I learned this technique well before becoming involved with AACE and believed that it was the only way to correctly calculate the CPM. All of my scheduling associates also use this technique and were unaware of another technique.

Rule 1. Day numbers for a CPM network begin with Day 1.

Rule 2. For each activity without any unresolved predecessor relationships, you first compute the start and finish day numbers. Given a particular Early Start day number (ES) and the Activity Duration (Duration,) you compute the Early Finish day number (EF) using the following rule,

$$EF = ES + Duration - 1.$$

Rule 3. Once the ES and EF day number have been computed, you compute the ES for a finish-to-start (FS) relationship to the successor activity using the following formula,

$$ES_{(successor)} = EF_{(predecessor)} + Lag + 1.$$

The other three relationships are calculated as 'normal' without the "+ 1" adjustment.

Rule 4.   Activities are starused as having begun in the morning before work begins and having ended in the evening after work has ended.

Rule 5. Once day numbers are computed, they are converted into dates using the work calendar for that activity without any further modification.

The Aggie Method

It is possible that this technique is older than the AACE Method. This appears to be the technique used by Microsoft Project to compute a PDM network.   This PDM method is very similar to the method used in ADM calculations. The Aggie Method is a widely taught method and its practitioners also seem to be unaware that another technique exists.

Rule 1. Day numbers for a CPM network begin with Day 0.

Rule 2. For each activity without any unresolved predecessor relationships, you first compute the start and finish day numbers. Given a particular ES and the Duration, you compute its EF using the following rule,

$$EF = ES + Duration.$$

Rule 3. Once the ES and EF day numbers have been computed, you compute the ES for a FS relationship to the successor activity using the following formula,

$$ES_{(successor)} = EF_{(predecessor)} + Lag.$$

The other three relationships are calculated using the same formula, only adjusting the start and end points of the relationship as required.

Rule 4.   Activities are starused as having begun and end in the evening after work has ended.

Rule 5. Since the day starts at the end of the day, you must adjust all start day numbers by first adding 1 work day and then converting them to dates using a work day calendar. Finish dates are converted directly without adjustment.

Conclusion

So which method is right for you? Well if you plan to take the upcoming AACEi Scheduling Certification test, you had better know and use the AACE Method. People using the Aggie Method will be marked incorrect and will probably not pass the certification exam. Those using P3 to compute their CPM should also use the AACE Method if they wish to understand how the underlying calculations made.

If you are a slightly-worried, Senior Lecturer at the Texas A&M University, College of Architecture, Department of Construction, and you have a very popular textbook using the Aggie Method, I would suggest that you keep on using the Aggie Method. Mr. Feigenbaum, I would like to take this opportunity to apologize for ruining your weekend in early August of this year.

Either way, I think that from now on, we all should first preference our discussion of how to compute a PDM CPM network by first saying which method we are employing.

Summary

It appears that for the past 15+ years, there have been two, formalized and competing methods for computing a PDM CPM. The really interesting thing about this fact is that apparently no one knew this. The chart below will summarize the two methods,

CPM Calculation Rules Summary	
AACE Method	Aggie Method
Begin with Time Period 1	Begin with Time Period 0
For Activities: Early Finish = Early Start + Duration - 1	*For Activities:* Early Finish = Early Start + Duration
For Relationships: FS rel.: $ES = EF_{(Predecessor)} + Lag + 1$ All others.: $ES = ES/EF_{(Predecessor)} + Lag$	*For Relationships:* All rels.: $ES = ES/EF_{(Predecessor)} + Lag$
Statusing: Activities begin at the start of the day and finish at the end of the work period.	*Statusing:* Activities start and finish at the end of the work period.
Changing work time units into dates: Convert time units directly into Dates	*Changing work time units into dates:* Add one to each Start Time Unit and then convert to dates. Convert Finish time units directly to dates.

If we were to use both methods on the same five, 1-day activities in a serial chain of FS relationships, the following would summarize both calculations,

CPM Calculation Example: A Chain of 5 1-Day Activities with FS Relationships:		
AACE Method Day #'s	Both Methods Calendar Date	'Aggie' Method Day #'s
Act 1 ES = Day # 1	ES = 05AUG03	Act 1 ES = Day # 0
Act 1 EF = Day # 1	EF = 05AUG03	Act 1 EF = Day # 1
Act 2 ES = Day # 2	ES = 06AUG03	Act 2 ES = Day # 1
Act 2 EF = Day # 2	EF = 06AUG03	Act 2 EF = Day # 2
Act 3 ES = Day # 3	ES = 07AUG03	Act 3 ES = Day # 2
Act 3 EF = Day # 3	EF = 07AUG03	Act 3 EF = Day # 3
Act 4 ES = Day # 4	ES = 08AUG03	Act 4 ES = Day # 3
Act 4 EF = Day # 4	EF = 08AUG03	Act 4 EF = Day # 4
Act 5 ES = Day # 5	ES = 11AUG03	Act 5 ES = Day # 4
Act 5 EF = Day # 5	EF = 11AUG03	Act 5 EF = Day # 5

One may proceed down the left or the right side of the table above. Each method produces the same calendar dates as shown in the center column.