

How Lifelong Learning Has Shaped My Career

Making 50+ Years of Scheduling Calculus Obsolete

GUI PONCE DE LEON PhD, PE, PMP, LEED AP

As Published



Tishman Distinguished Lecture

Human history teaches us. . .that economic growth springs from better recipes, not just from more cooking.

(Paul Romer, 2008)



Romer, Paul M. "Economic Growth." In *The Concise Encyclopedia of Economics*, edited by David Henderson. Library of Economics and Liberty. Article published August 2008. <http://www.econlib.org/library/Enc/EconomicGrowth.html#>



IN REMEMBRANCE OF TWO DISTINGUISHED ENGINEERS

PROF. ROBERT B. HARRIS



*“Why not be a teacher?
You’d be a fine teacher,
perhaps a great one.”*

“If I was, who knows it?”

*“You, your pupils, your
friends, God. Not a bad
public, that.”*

~ Sir Thomas More

CURTIS “BILL” BOTTUM JR.



Every once in a while, a leader appears in society who is totally dedicated to applying and living out the teachings of a great wisdom tradition in the everyday affairs of the world. Sometimes, depending on the particulars and circumstances, he or she becomes an agent of change, helping to transform society into one that increasingly works for the benefit of all. While these individuals can show up most anytime and anywhere, the following is about a contemporary of ours—Curtis Edward Bottum Jr. (pronounced “Boat-um”)—who showed up in his community and the world of business. Even though his parents had already named him Curtis, upon first seeing him his father declared, “He looks like a Bill to me.” So, he became a Curtis called Bill.

A *TWIST* ON THE MEANING OF LIFELONG LEARNING

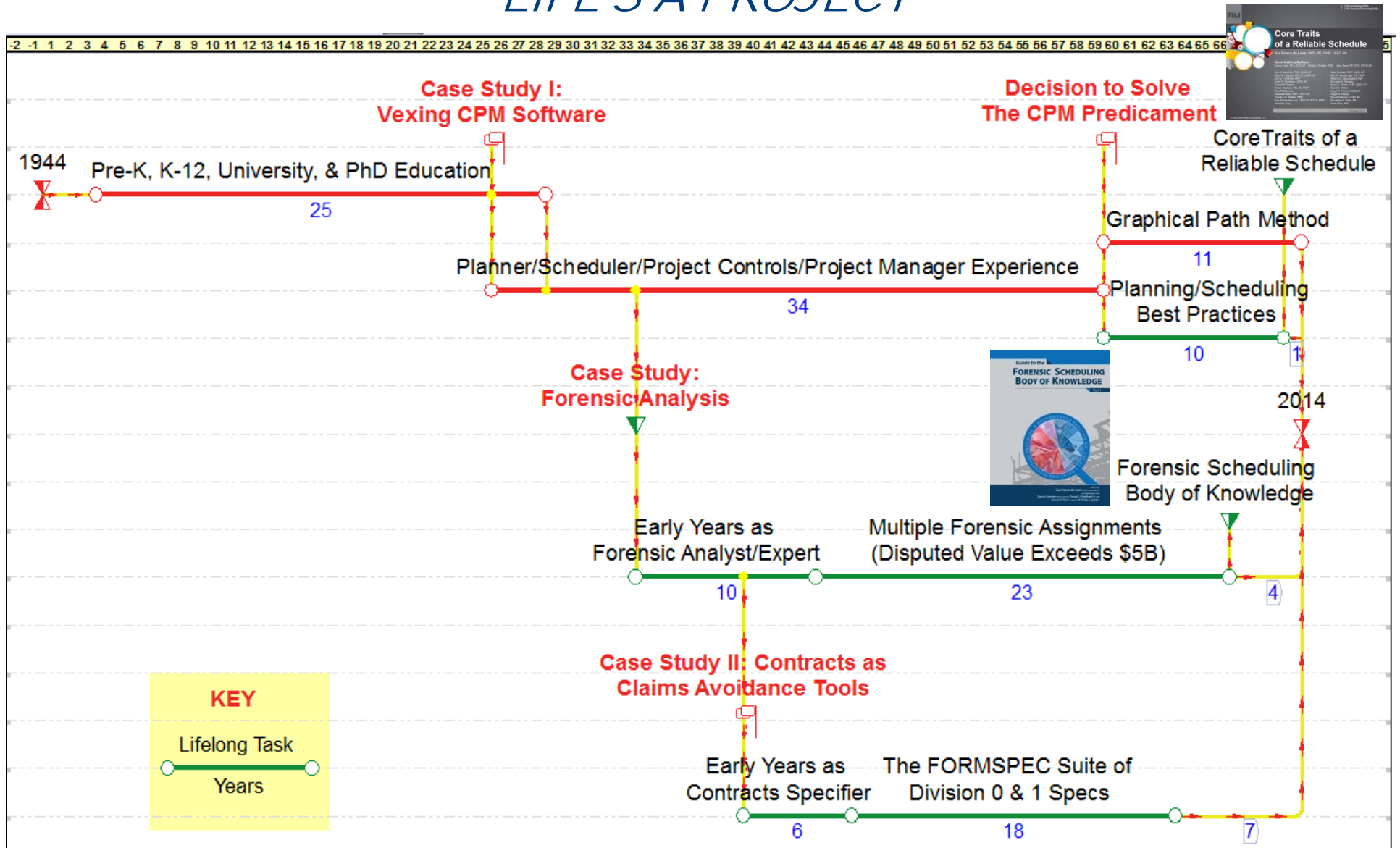
 **Conventionally speaking, lifelong learning is the pursuit of knowledge throughout life for personal or professional reasons**

As used in this lecture, it is a mindset where a professional acts as *both* teacher *and* student throughout one's career for the purpose of:

- ✓ Performing the next assignment just a bit better than the previous one
- ✓ Incrementally improving a knowledge where the opportunity arises
- ✓ Taking on a knowledge hurdle seemingly unsurmountable to others



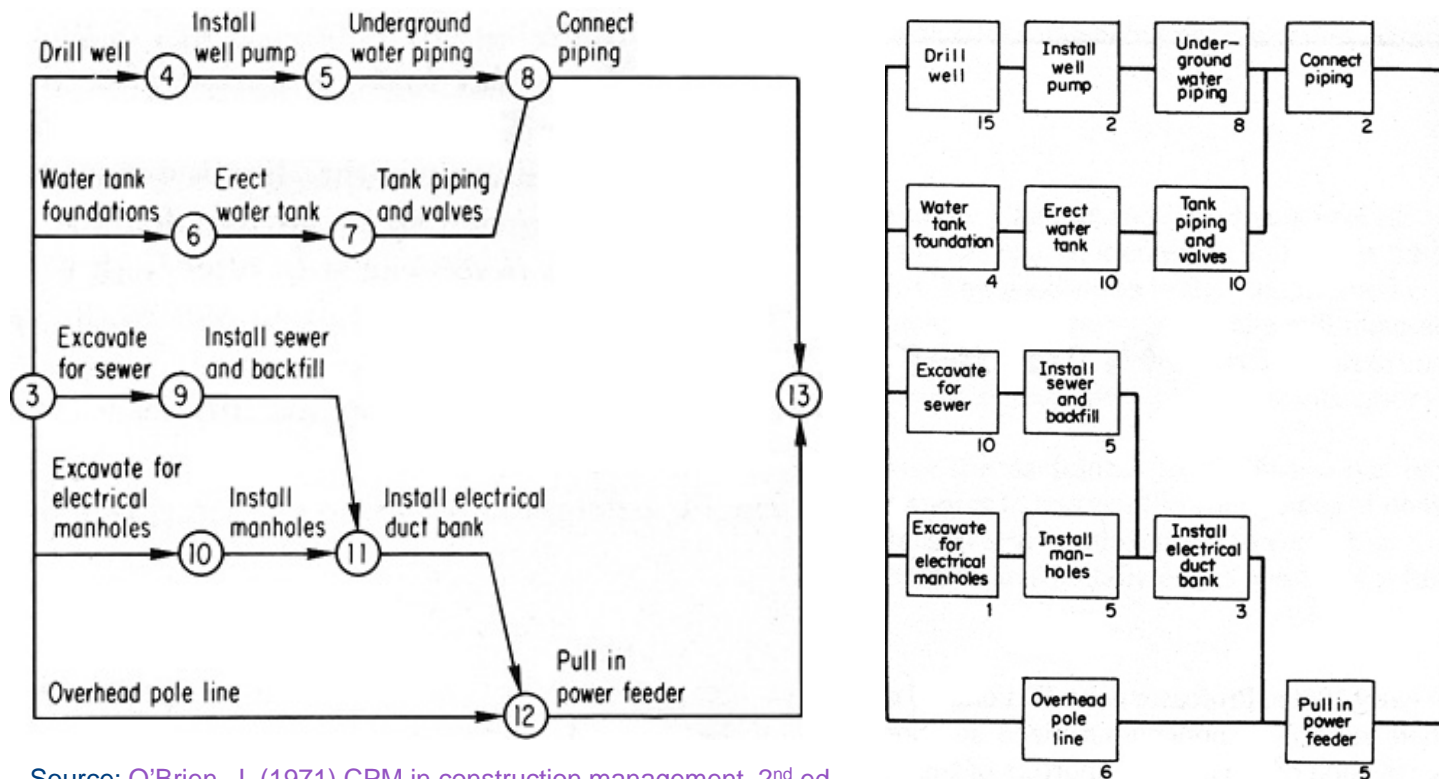
LIFE'S A PROJECT®



CASE STUDY I: SOLVING THE VEXING CPM SOFTWARE

Situation: In the spring of 1969, the largest contractor in Michigan cannot make head nor tail of newly purchased CPM software

Their schedules were limited to finish-to-start logic, in the late 1960s, a limitation in both arrow diagrams and the Fondahl activity-on-node diagram



Source: O'Brien, J. (1971) *CPM in construction management*, 2nd ed.



SOLVING THE VEXING CPM SOFTWARE

Paradox: While the network notation resembled the Fondahl *precedence* notation, the mathematics were upside down

The network was true precedence network diagramming (PDM) as we know it in that it allowed start-to-start and finish-to-finish logic

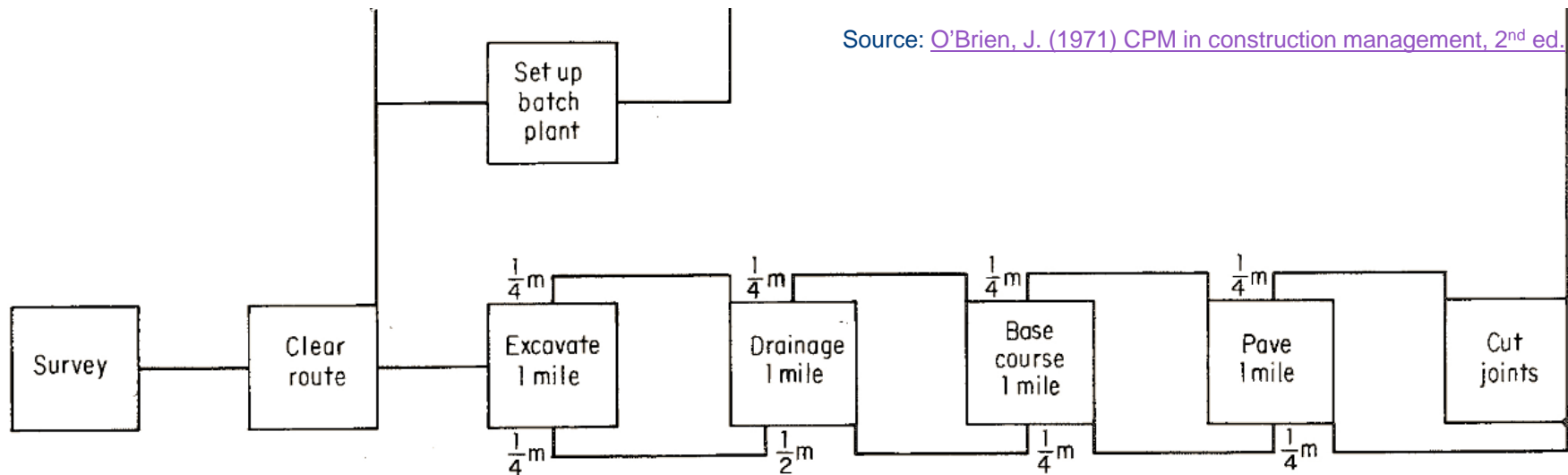
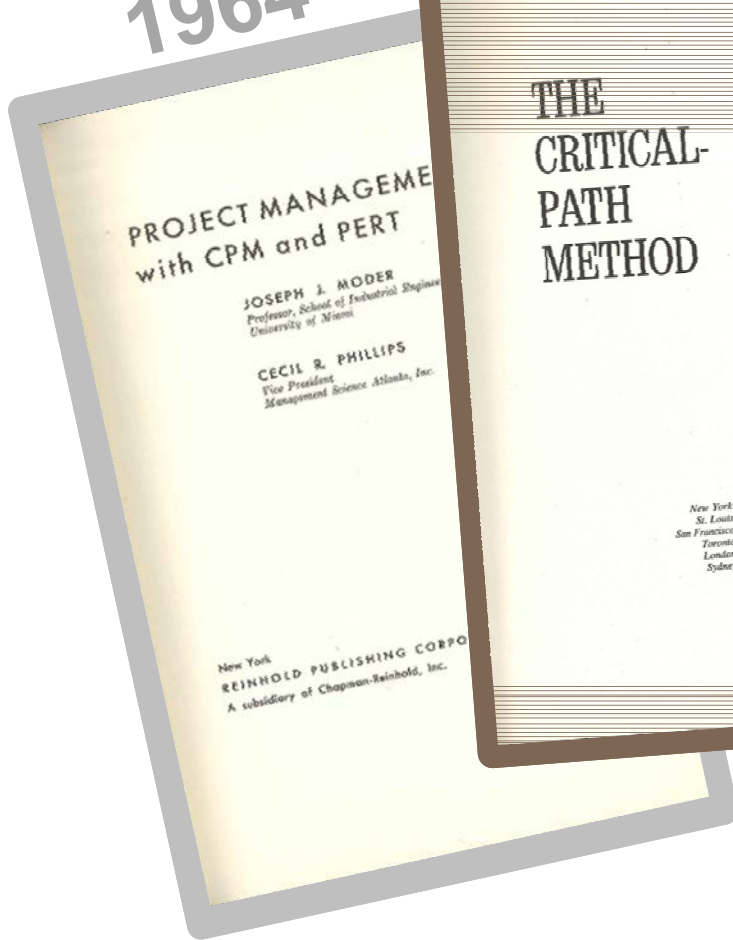


Figure 10.1.5 PDM version of network for 1-mile highway.

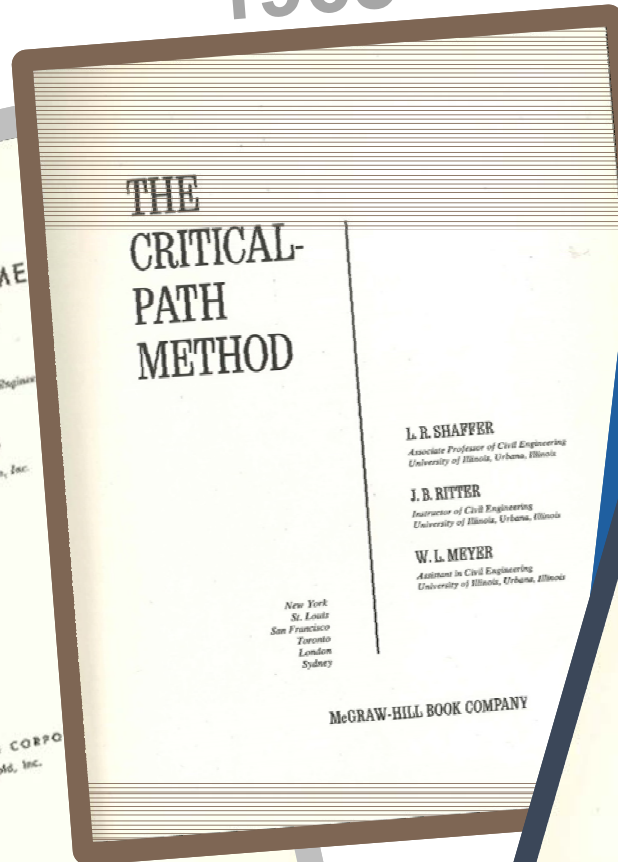
Even though PDM research at the H.D. Zachry Company culminated in 1962 and in 1963 IBM joint ventured with Zachry to develop software based on the method, PDM was largely MIA in the CPM literature

IN 1969, PDM WAS THE ELEPHANT IN THE ROOM

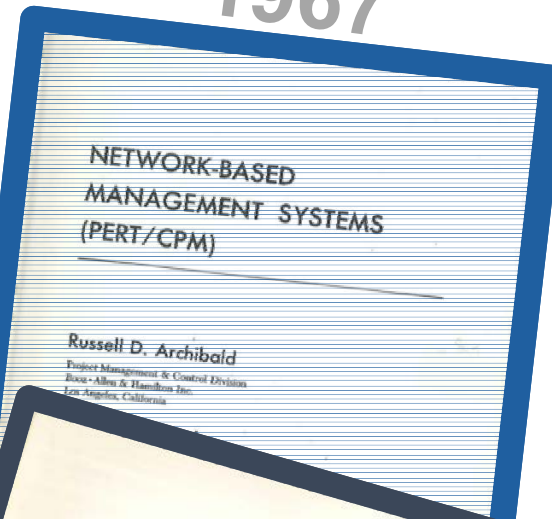
1964



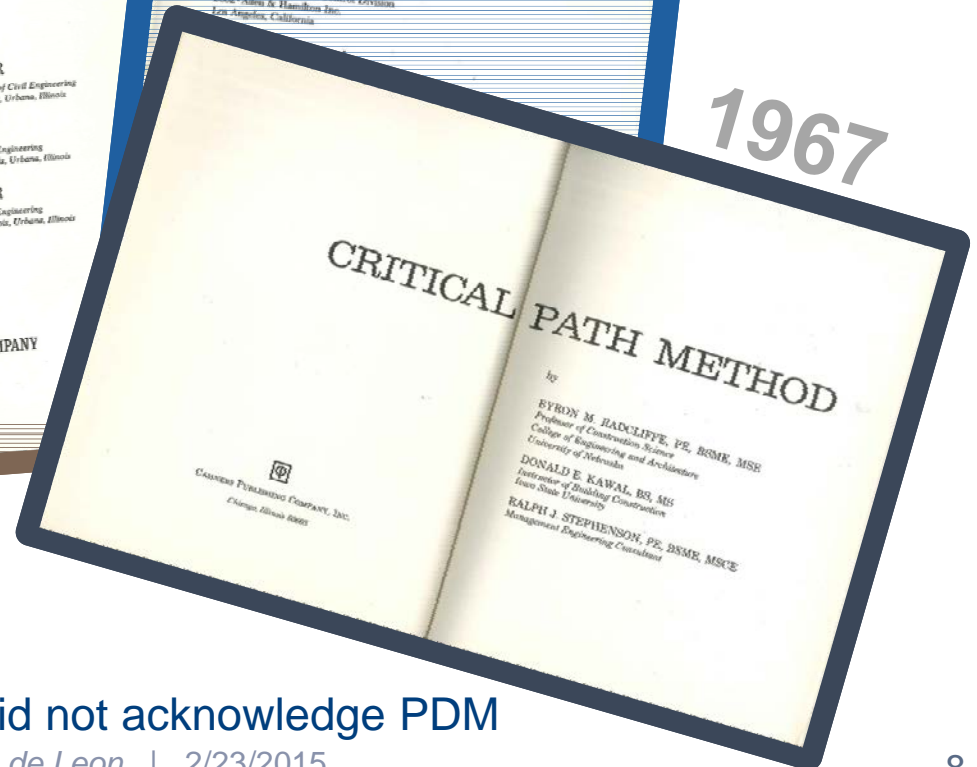
1965



1967



1967

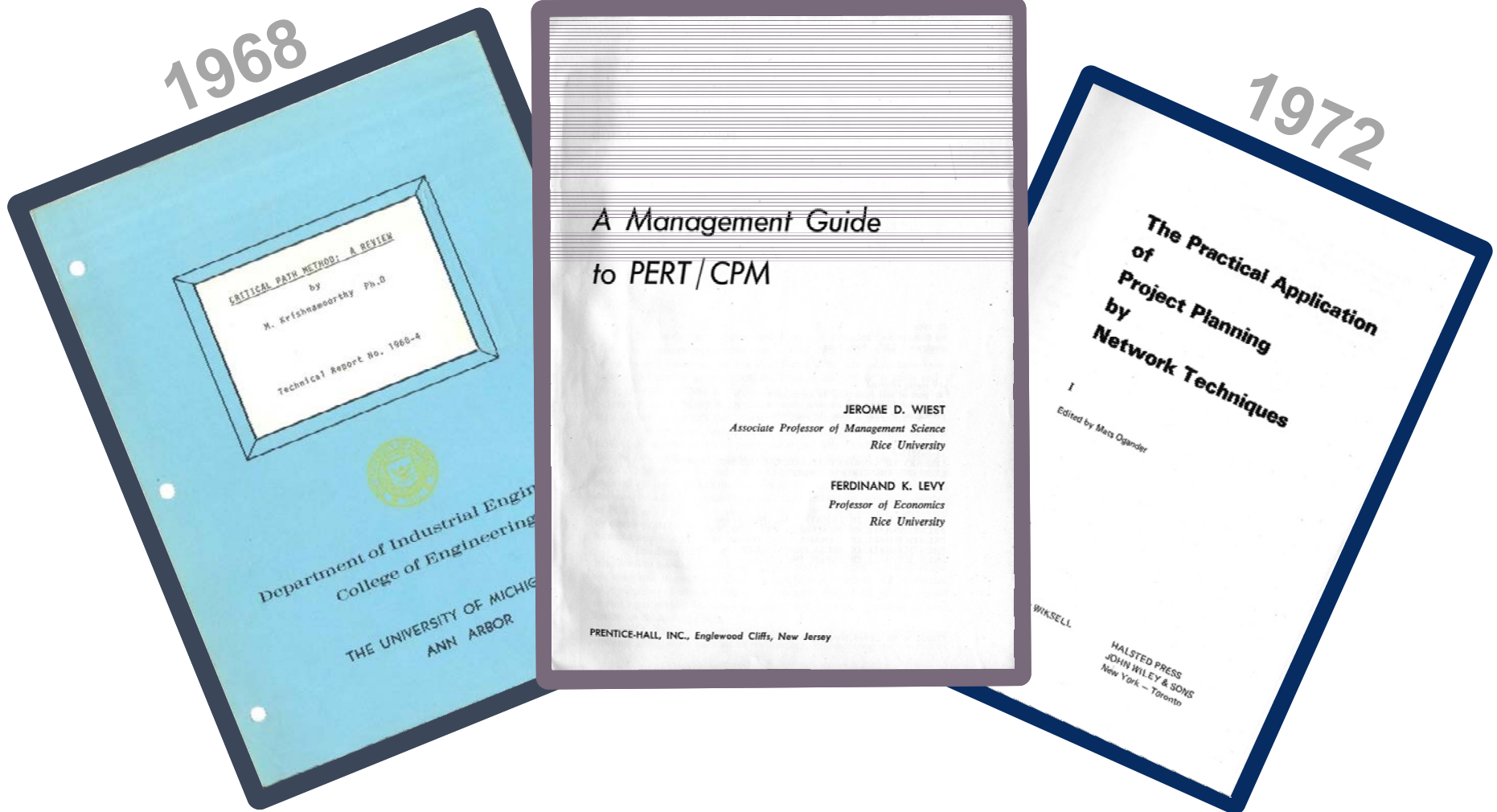


Texts published after 1963 that did not acknowledge PDM



OTHER TEXTS WITH NARY A MENTION OF PDM

1969



CREDIT GOES TO JIM O'BRIEN FOR TAKING PDM PUBLIC



SOLVING THE VEXING CPM SOFTWARE

Solution: Learn the network technique used by the software, work out the mathematics from scratch, and reconcile the results with the mathematics of CPM network schedules based on conventional arrow diagrams and on Prof. Fondahl's network model aka circle diagram

Lessons Learned:

1. Not uncommon for business innovation to outpace academia
2. Don't buy into a new method without first verifying it

Upshot: Take the copious research published in the first 10 years of CPM and apply it to the emerging precedence diagramming method



CASE STUDY II: **CONTRACTS AS CLAIMS AVOIDANCE TOOLS**

Situation: In the spring of 1983, Washtenaw County was completing a \$120M wastewater treatment plant project program that was mired in litigation and the County wanted to avoid history repeating itself on a subsequent \$13M project

Paradox: While the Division 0 Specifications provided by the County's engineer were proven specifications from legal and technical standpoints, they were largely silent relative to the types of schedule-related and change order pricing claims that had become the norm on projects completing in the late 1970s and early 1980s

Solution: Draft supplementary conditions and scheduling specifications to prospectively deal with—and hopefully altogether avoid—what had become endemic delay and extra cost claims



CONTRACTS AS CLAIMS AVOIDANCE TOOLS

Lessons Learned:

1. Contractors and their sureties abhor contract specifications that are not the industry standard
2. Newly drafted contract specifications, provided fair and balanced and supported by owners, eventually become the norm and operate to reduce the risk of delay and extra-work pricing disputes

Upshot: The 1983 supplementary conditions assignment led to development of the FORMSPEC[®] suite of construction industry contracts, used on projects amounting to billions of dollars, which were completed with no or negligible litigation—including the \$14.7B *Big Dig* Project in Boston, which reached substantial completion in 2004



FORMSPEC® SPECIFICATIONS—25-YEAR TRACK RECORD

1980

1985

1990

1995

2000

2005

- ◆ **1983** Brief supplementary conditions incorporated into the contract documents on a \$13M project
- ◆ **1984** Supplementary conditions incorporated into the contract documents on a \$220M program
- ◆ **1987** Complete Division 0 Specifications (FORMDOC™) developed for the \$6.2B Boston Harbor Cleanup Project
- ◆ **1989** Complete Division 0 FORMSPEC® specifications developed for the City of Phoenix

Milestone Model Specifications

1990-1993 Complete Division 0 **MICHSPEC** Specifications developed for State of Michigan (still currently in use)

1991-2006 Complete Division 0 FORMSPEC Specifications developed for and used by the Detroit Water Board, including Design-Build and Construction Management at Risk (CMAR)

1991-1993 Big Dig project specifications developed by merging the legacy Mass Highway Department Division 1 Specs & FORMSPEC

2001-2007 CMAR version of FORMSPEC Division 0 Specifications used on the \$272M Visteon Village Project and on the \$150M+ JW Marriott Project

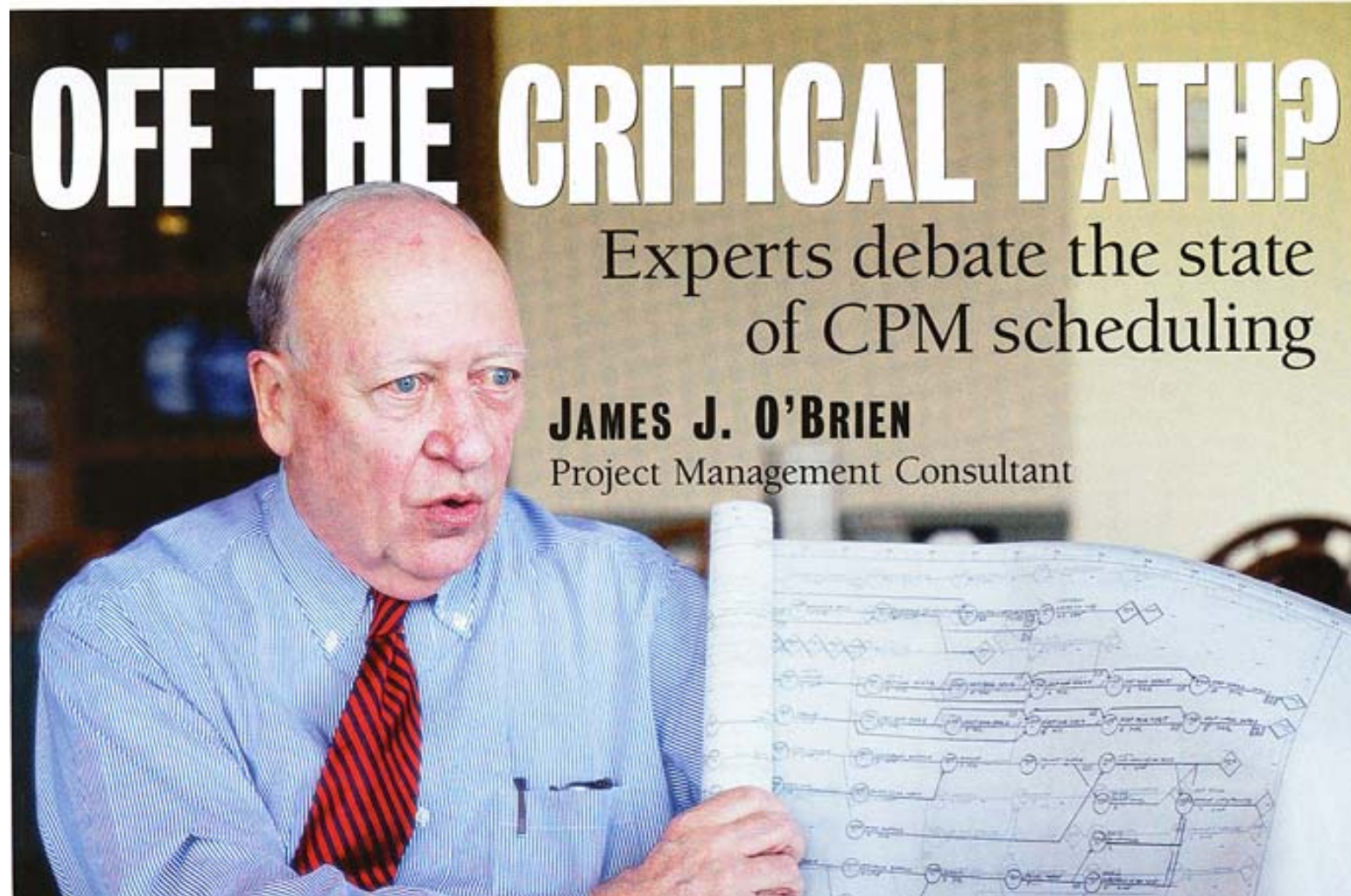


MAKING 50+ YEARS OF CPM CALCULUS OBSOLETE

enr.com

The McGraw-Hill Companies

May 26, 2003 \$5



SNIPPETS OF HOW CPM WENT OFF THE RAILS

“What is described as a CPM schedule these days sometimes is not one at all”

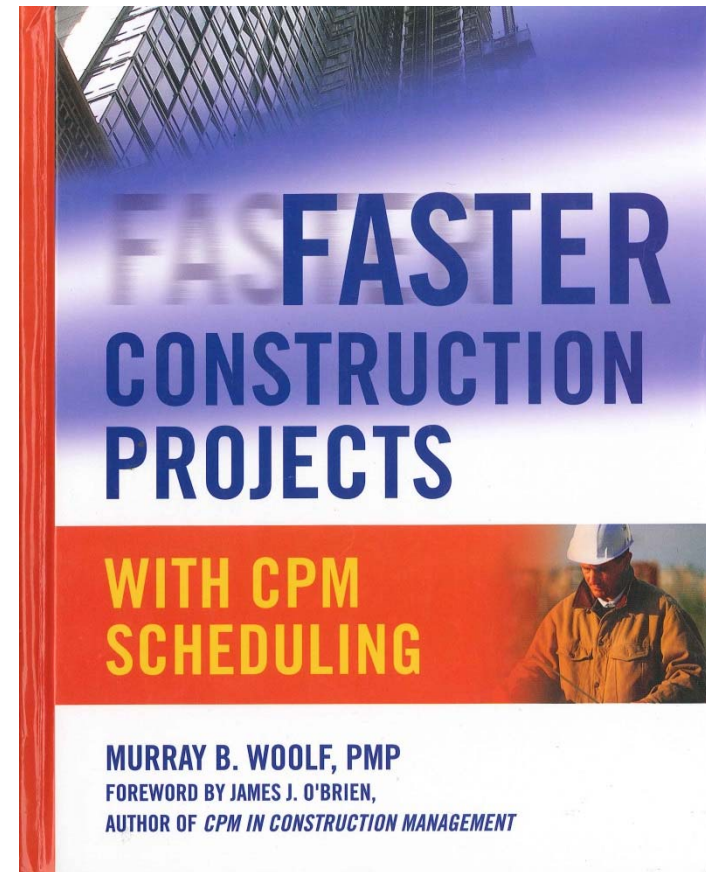
“They say they see widespread abuses of powerful software to produce badly flawed or deliberately deceptive schedules that look good but lack mathematical coherence or common sense about how the industry works”



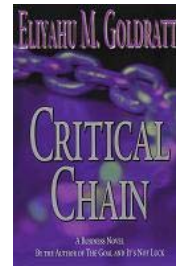
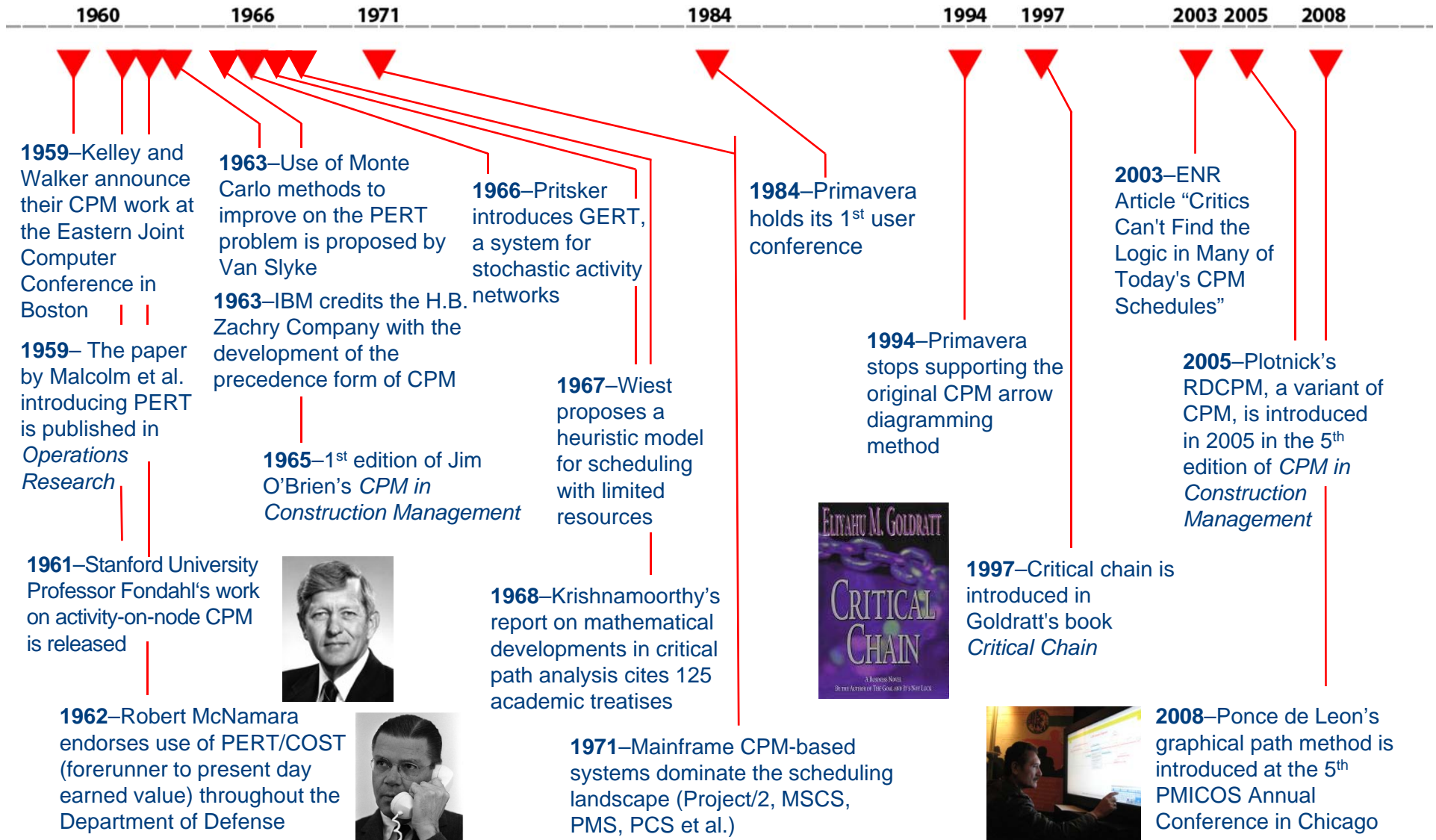
SNIPPETS OF HOW CPM WENT OFF THE RAILS *(cont'd)*

“we have collectively evolved the profession to where planning is no longer the essential first step in the scheduling process”

“Among the young guys, computers have made it easy to slap together something that looks right, but there is a thought process that must be involved, and it is hard to tell in many contemporary schedules if the thinking happened or not”



GPM WAS BORNE ALOFT ON CPM'S GIGANTIC 50 YEARS



THE CPM STATE OF AFFAIRS IN 2003

2003

2004

2005


2006

2007

- CPM had become schedule-centric, and “planning” the casualty
- CPM networks had been largely supplanted by logic Gantt charts
- Schedulers had become obsessed with overly detailed schedules
- Stakeholders had disengaged but planned their work just the same
- *A dates rule, logic serves* ethos had turned planning upside down
- Mathematically flawed schedules were the norm due to overuse of constraints and preferential logic
- Building a network on a computer on the fly had disabled *pull* planning, making CPM impractical for lean construction planners
- With the CPM algorithm non-functional left of the data date, there was no incentive to accurately record actual dates
- Resource leveling had fallen by the wayside, because black box, automated resource leveling produced unrealistic results
- Spreadsheets were becoming de rigueur tools for capital planning



TWO RECENT INSTANCES OF DISCONTENT WITH CPM



Eric Lamb, in “How to Fix a Broken Scheduling System”

“Schedules with an exhaustive level of detail in a CPM network try to predict day-to-day activities years in advance and are inherently flawed”

“For an industry striving to be more productive, the current state of scheduling practices is wasteful”

“Simply, we have created a monster”

Stu Ockman, in “Dearth of Scheduling Software Expertise Still Bedevils Many Legal Cases,” alluding to a 2,900-activity schedule that had *928 constraints*, lamented that



“The multiple constraints made finding the critical path for the project’s start and end dates impossible, not to mention the nearly 83 workdays of negative float they yielded. Lawsuits followed the project”



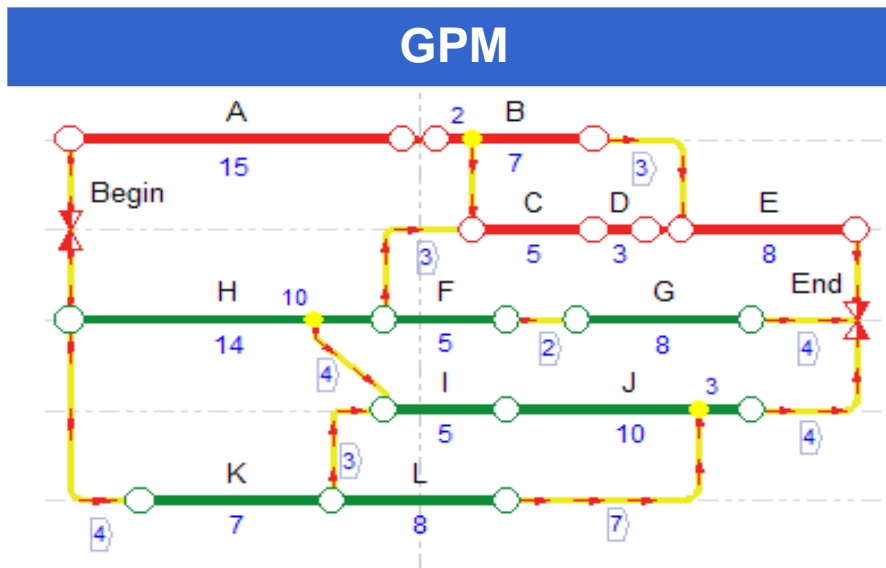
THE METHOD AS APPLIED IN PLANNING/SCHEDULING



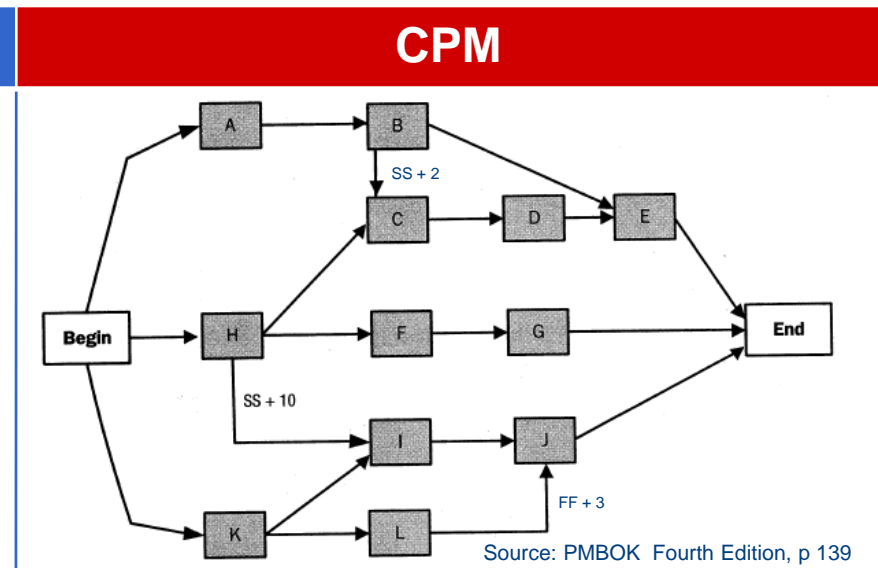
The *engine* behind digital graphical and visualization tools that kinetically calculate and display the schedule as stakeholders physically manipulate activities, milestones, and benchmarks

- ✓ Visualization is enabled by a new time-scaled logic diagramming method (LDM) that combines the strengths of arrow diagrams & precedence diagrams
- ✓ As an activity is manipulated, GPM self-healing and GPM scheduling algorithms kinetically reposition impacted activities without invoking the CPM forward or backward pass
- ✓ Activities may be on planned dates without resorting to date constraints or preferential logic
- ✓ Both *forward* planning and *backward* planning are allowed
- ✓ An activity on planned dates can *drift* back (to the early start) and may *float* forward (to the late finish)
- ✓ Total floats left of the data date are calculated, which allows algorithmic identification of the *then-existing* as-built critical path

GPM RELIES ON THE LDM NETWORK NOTATION



**Logic Diagramming Method (LDM)
(rheonomic activity flow graph)**



**Precedence Diagramming Method (PDM)
(scleronomic activity flow graph)**

Source: PMBOK Fourth Edition, p 139

LDM AND PDM CONTRASTED

GPM/LDM

Activity-on-Link, with PDM Logic Constructs

Essentially Equal Logic Tie Capability—Modeling of FS/SS/FF/SF Logic Allowed

An Embedded Node aka *Embed* Is Used for PDM Logic

In LDM, Embedded Node Offset Equates to Lag in PDM

Stakeholders and the Software May Control Network Layout

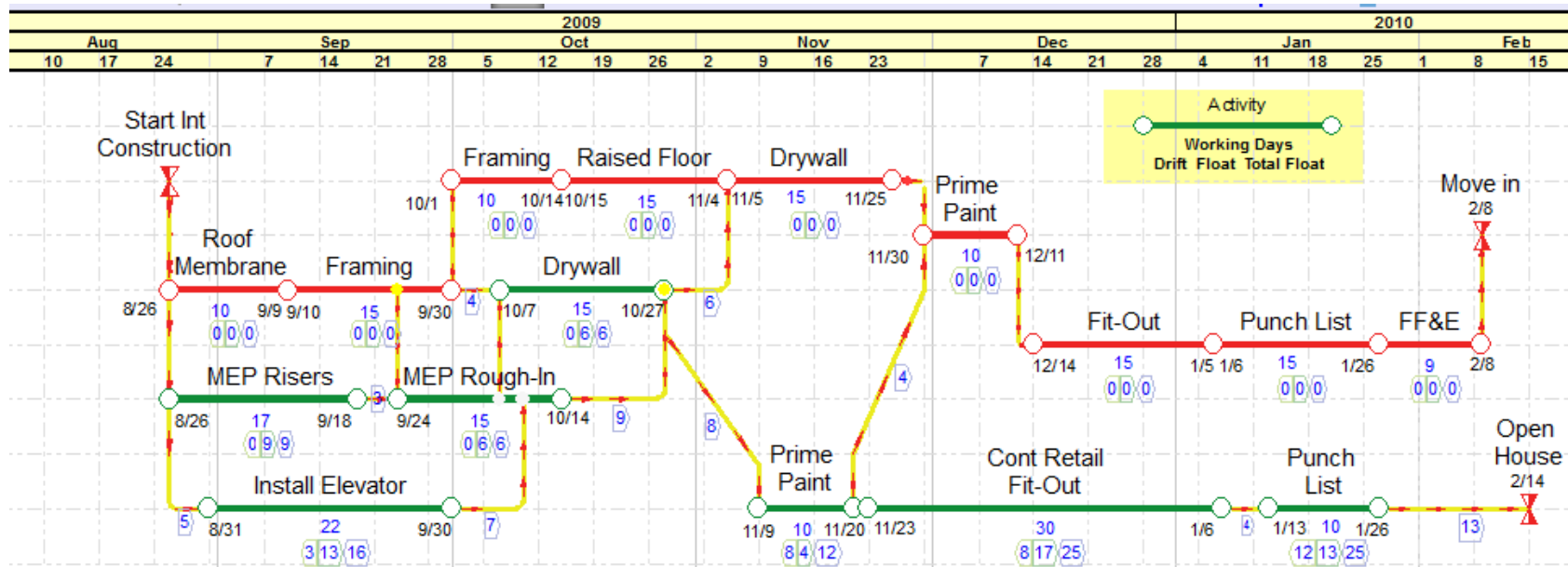
CPM/PDM

Activity-on-Node, with PDM Logic Labels on the Links

Links Labeled as SS, FF, SF Are Used for PDM Logic

Software Dictates Schedule Layout, e.g., Gantt Chart

Unlike ADM and PDM, which Are both Commonly Built Schematically, LDM Is a Time-Scaled Diagram



THE GPM PLANNING/SCHEDULING ETHOS

1. Graphical, visual, and sufficiently simple schedules are a priority
2. Emphasis is on collaborative planning vs. schedule machinations
3. Stakeholder consensus is more important than fictive precision
4. Collaboration improves where level of detail stimulates participation
5. Time-scaled networks with PDM logic are superior to Gantt charts with logic ties
6. The network is built forward or backward or using both planning approaches
7. Stakeholders, not the scheduling algorithm, drive key activity dates
8. Stakeholder strategies in context drive resource leveling
9. Building a schedule is done by physical object manipulation rather than by data entry
10. Level 1 and level 2 schedules are developed independently as opposed to by merely hammocking level 3 schedules

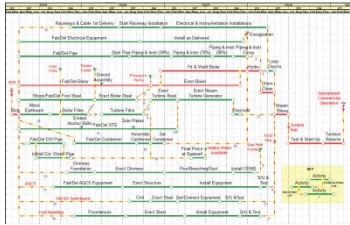


THE POWER OF THE GPM *SCHEDULING* ALGORITHMS

1. Date constraints are not needed to start activities on planned dates
2. Planned dates do not supersede early dates, which create drift (i.e., reverse float)
3. If planned start > algorithmic early start, *drift* exists
4. If planned start < algorithmic late start, *float* exists
5. For every activity & milestone, drift + float = total float
6. PDM logic is modeled through embedded nodes vs. link labels
7. Gap, a relationship attribute, measures logic tie/link leeway
8. Total float is derived from gaps as opposed to subtracting early dates from late dates
9. Total floats are algorithmically calculated left of the data date, and the as-built critical path is identified left of the data date
10. The kinetic nature of the algorithmic GPM engine provides a more cognitively responsive environment for both schedulers and non-schedulers alike



GPM TOPICS SELECTED FOR FURTHER DISCUSSION



Sufficiently simple schedule presentations

II. THE ISSUE WITH ALL-EARLY-DATE SCHEDULES

Problem: A schedule chock-full of early dates that neglects making use of total floats is seemingly unrealistic to non-scheduling stakeholders responsible for delivering the project

Attempting to move realistic working schedules, stakeholders resort to bar charts, often disconnected from the CPM schedule

Solution: Stakeholders are afforded the option to manually schedule selected activities between early and late dates without overriding the algorithmic early dates

The issue with all-early-date schedules

Tishman Distinguished Lecture | Dr. Gui Ponce de Leon | 2/23/15 | 30

III. THE CPM 40-YEAR RESOURCE LEVELING SOLUTION

Starting with the early schedule, through opaque heuristics, CPM software calculates alternate activity start dates by delaying activities, if the early dates cause overruns in resource limits

A black-box operation that involves entering leveling criteria and pushing a button, followed by calculations and activity rescheduling on the whole, in one fell swoop. Very complex interface with lots of different options and toggles to check

Dystopia rather than Utopia **Upshot**

Black-box, automated solutions are not context-specific and produce unrealistic and usually very inefficient results

It wasn't too long before software-driven resource leveling fell by the wayside

CPM vs. GPM resource leveling

Tishman Distinguished Lecture | Dr. Gui Ponce de Leon | 2/23/15 | 31

IV. GPM RISK CORRECTS FOR THE CPM "OPTIMISM BIAS"

The early-dates bias in CPM schedules is magnified in CPM schedule simulation aka CPM schedule risk analysis

- In every realization, every activity is scheduled on early dates
- Neither floating nor pacing, realities in the real world, are possible

Floating: event that occurs randomly and that involves

- Delaying the start of an eligible activity
- Within its float from existing when the activity is scheduled

Pacing: event that occurs randomly and that involves

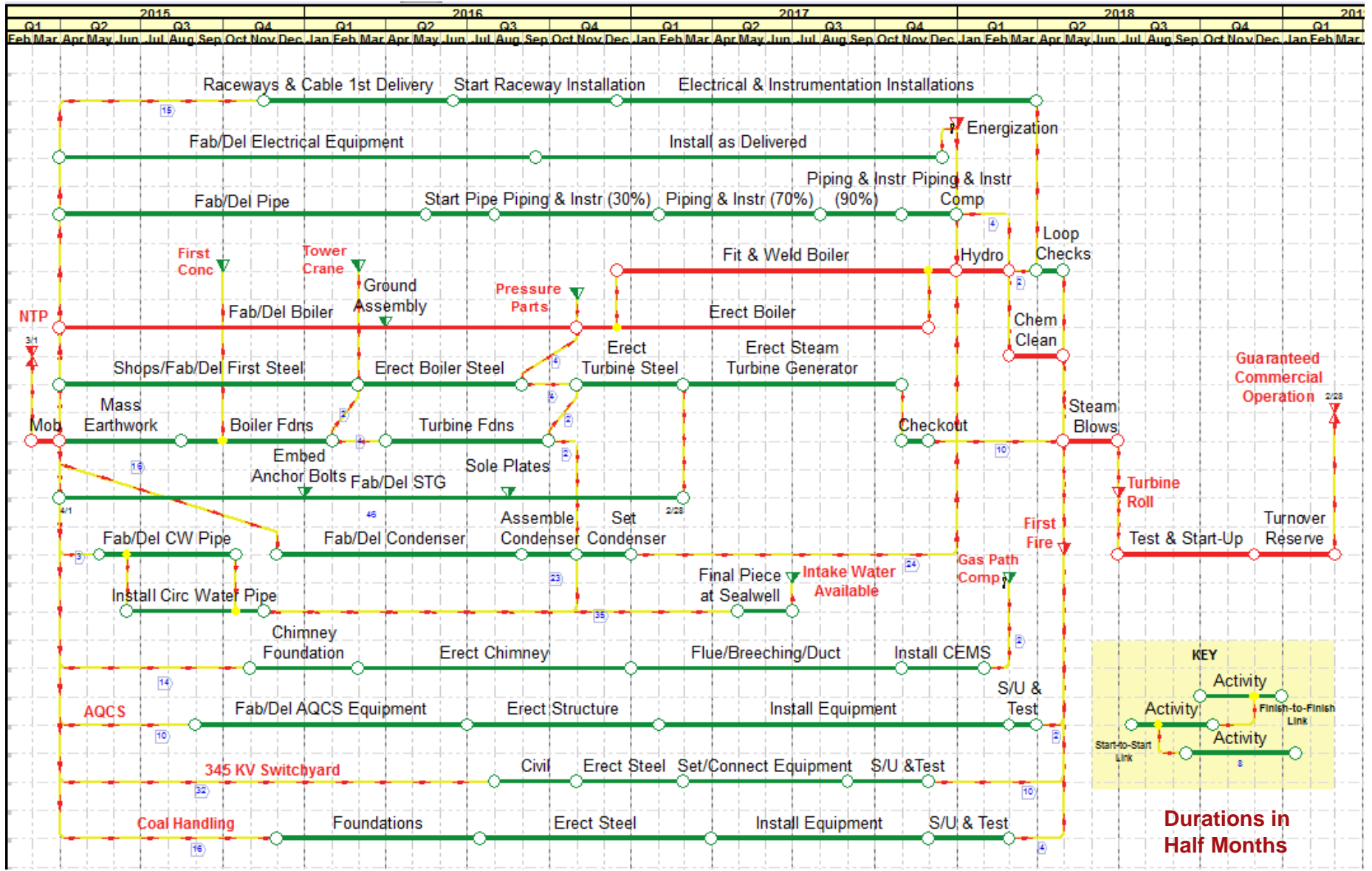
- Delaying the start of a pacing-eligible activity
- Within its float from existing when the activity is scheduled, provided the ratio of the then-existing float to the deterministic float exceeds a specified threshold

GPM risk corrects for the CPM "Optimism Bias"

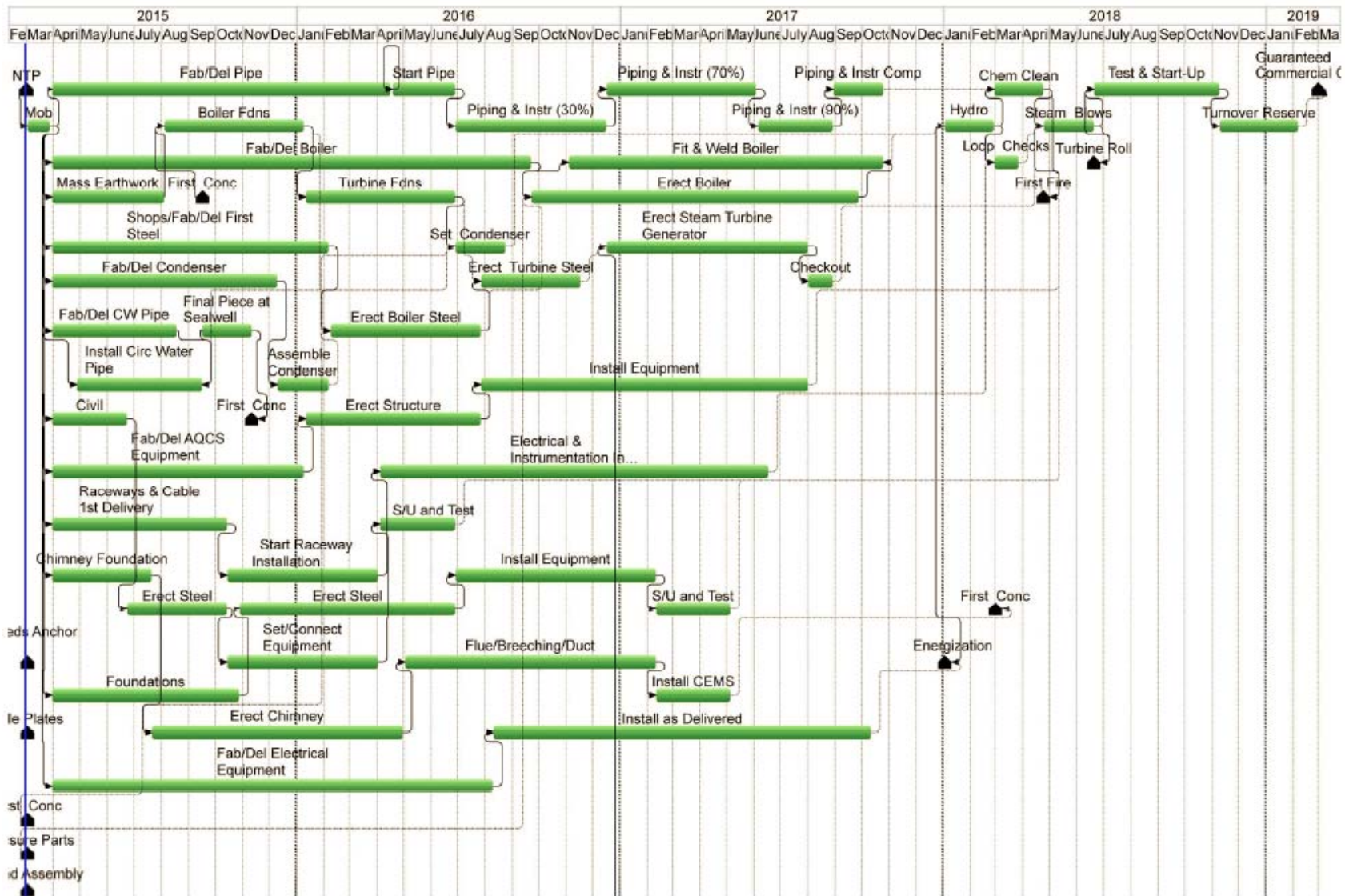
Tishman Distinguished Lecture | Dr. Gui Ponce de Leon | 2/23/15 | 32



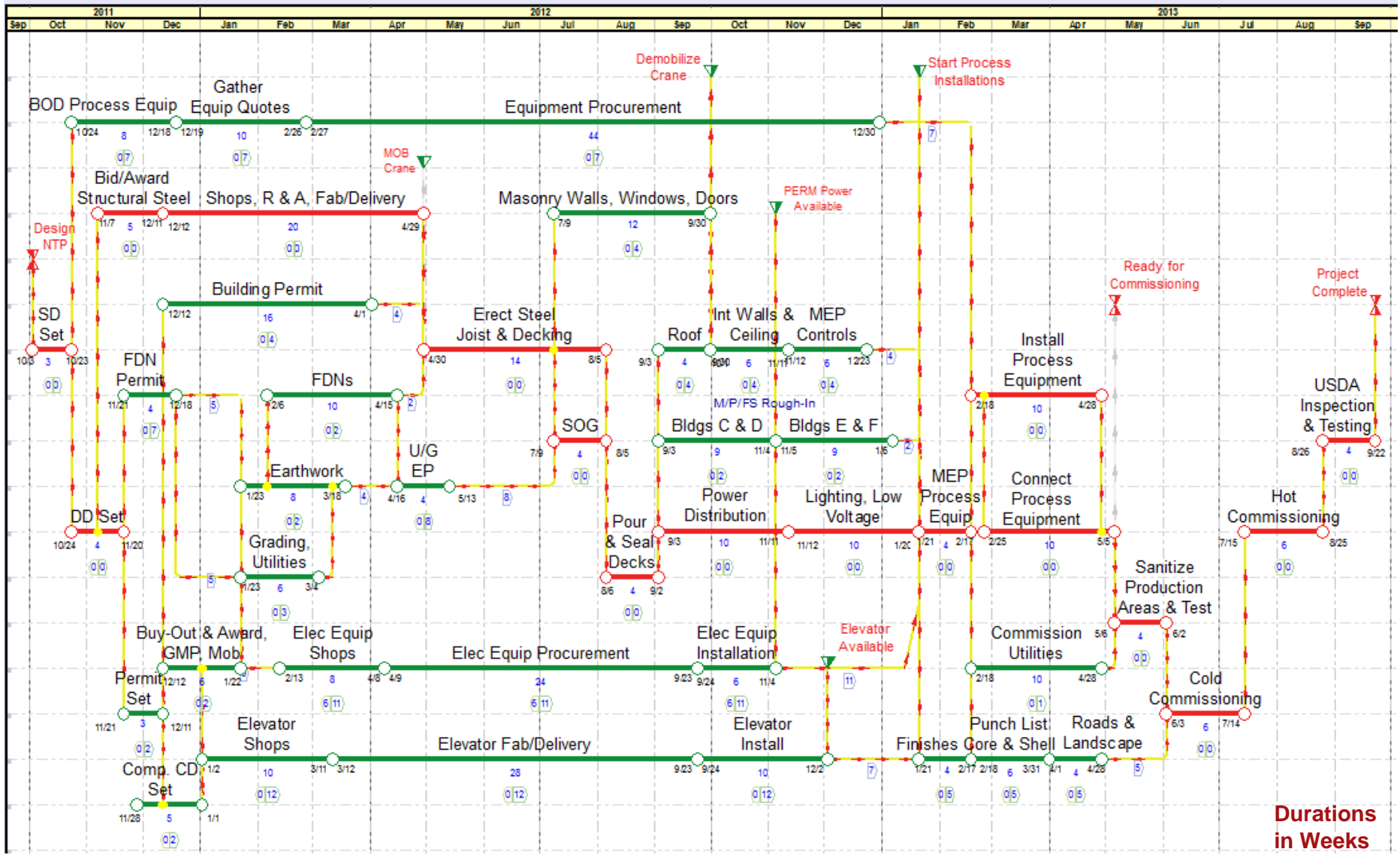
I. A SUFFICIENTLY SIMPLE SCHEDULE PRESENTATION



A SCHEDULE ONLY A TRAINED EYE CAN FOLLOW



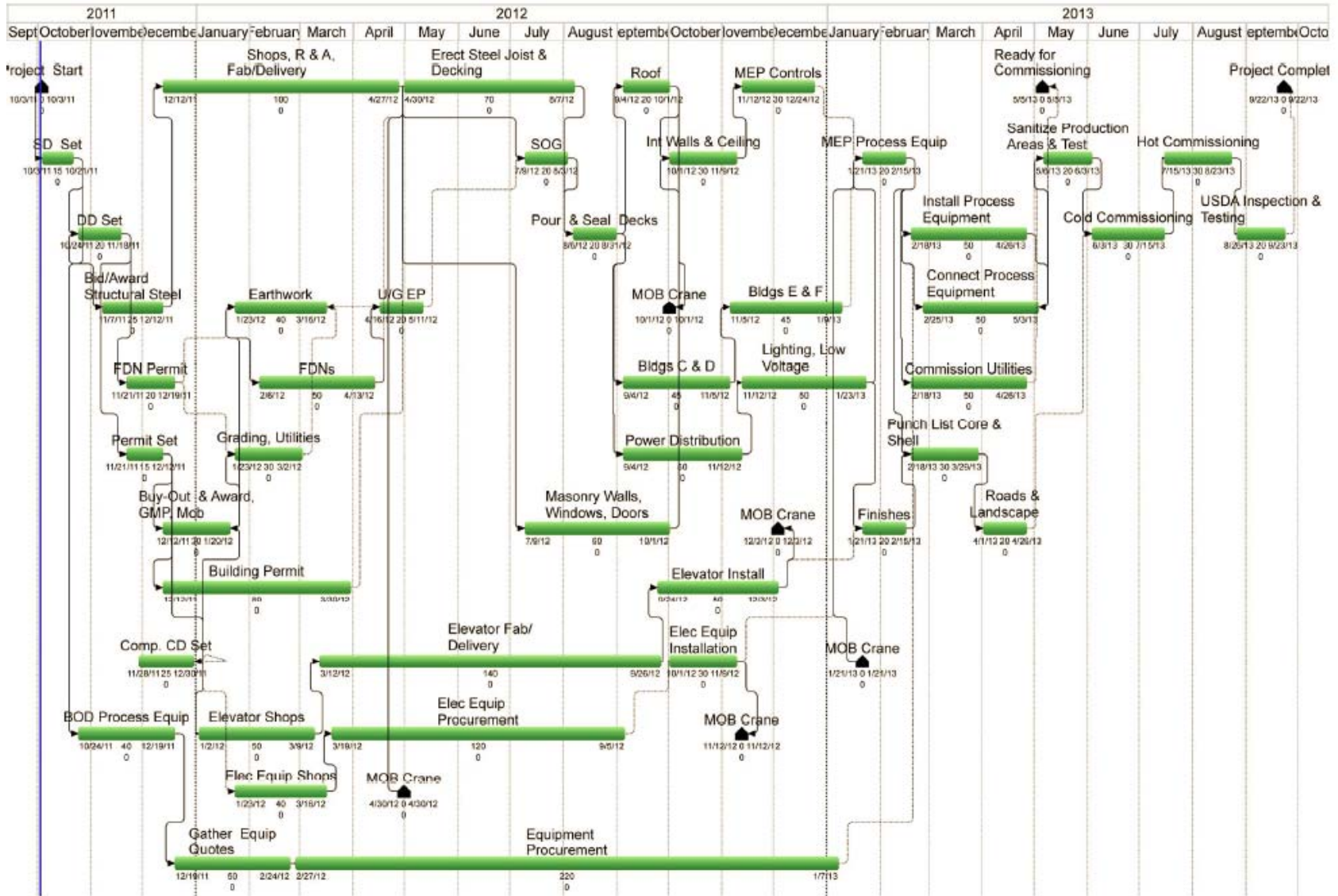
ANOTHER SUFFICIENTLY SIMPLE SCHEDULE DISPLAY



Durations in Weeks

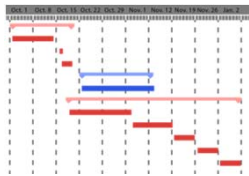


AN EQUIVALENT TIME-SCALED PRECEDENCE DIAGRAM



II. THE ISSUE WITH ALL-EARLY-DATE SCHEDULES

Problem: A schedule chock-full of early dates that neglects making use of total floats is seemingly unrealistic to non-scheduling stakeholders responsible for delivering the project



Aspiring to more realistic working schedules, stakeholders resort to bar charts, often disconnected from the CPM schedule



The GPM Solution: Stakeholders are afforded the option to manually schedule selected activities between early and late dates *without overriding* the algorithmic early dates

THE *GPM PLANNED* DATES PRECEPT IN SCHEDULING

The scheduler may manually override activity dates

Activities placed between early and late dates are on GPM planned dates; the GPM algorithm retains the algorithmic early dates

Because planned dates do not override early dates, GPM detects that an activity retains the ability to *drift back* without forcing an earlier project start and to float forward as much as the late dates permit

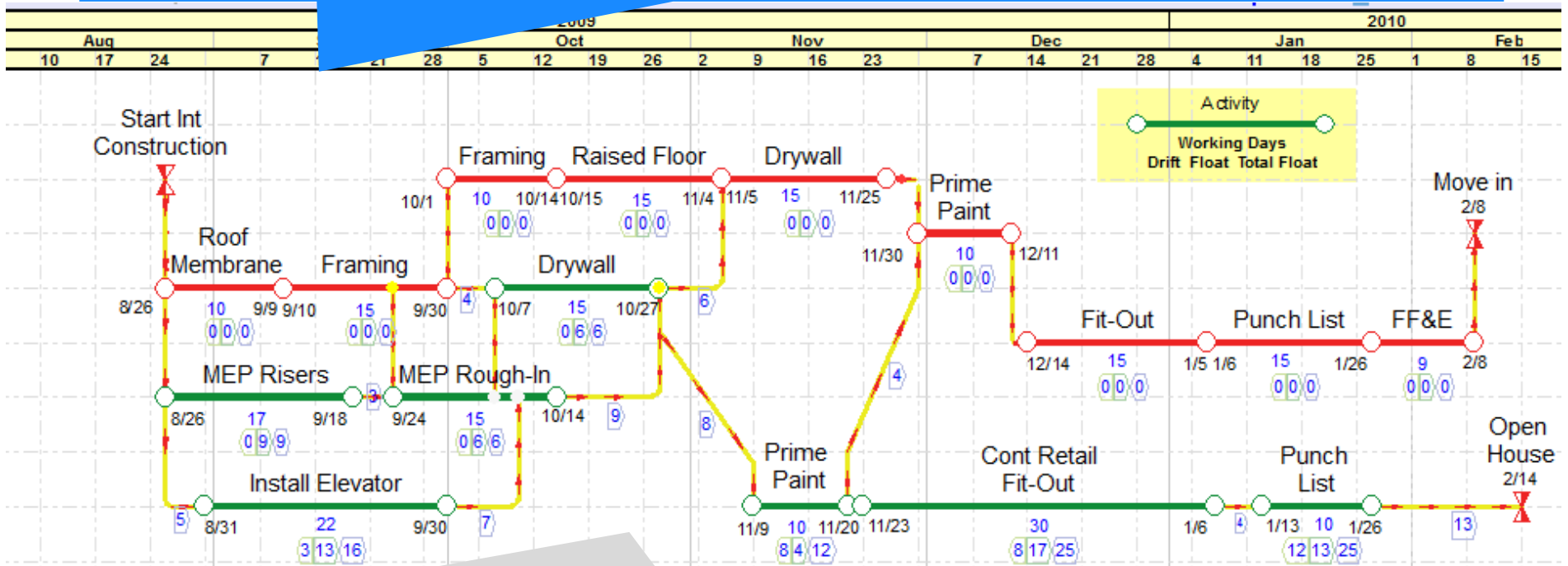
The combination of planned dates/drift/float represents a paradigm shift from the CPM early-date bias, one-directional float protocol

$$\text{DRIFT} + \text{FLOAT} = \text{TOTAL FLOAT}$$



THE PLANNED DATES/DRIFT/FLOAT/TOTAL FLOAT PRECEPT

When an activity is on early dates, drift = 0 and float = total float; conversely, when on late dates, drift = total float and float = 0



As an activity shifts to later dates, drift increases, float decreases, and total float is a constant; if the activity shifts back to earlier dates, drift decreases, float increases, and total float remains constant

III. THE CPM 40-YEAR RESOURCE LEVELING SOLUTION

Starting with the early schedule, through opaque heuristics, CPM software calculates alternate activity start dates by delaying activities, if the early dates cause overruns in resource limits

A black-box operation that involves entering leveling criteria and pushing a button, followed by calculations and activity rescheduling on the whole, in one fell swoop. Very complex interface with lots of different options and toggles to check

> Dystopia rather than Utopia **> Upshot**

Black-box, automated solutions are not context-specific and produce unrealistic and usually very inefficient results

It wasn't too long before software-driven resource leveling fell by the wayside

THE CPM RESOURCE LEVELING PREDICAMENT



MURRAY WOOLF

Author of [Faster Construction Projects with CPM Scheduling](#)

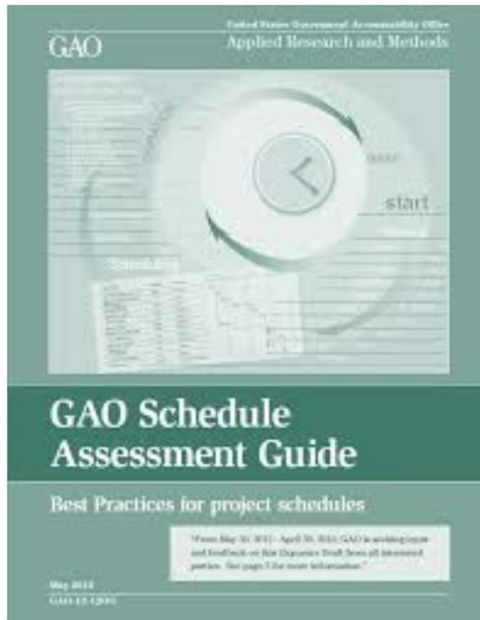
“In general, I discourage the use of any button that, once pushed, takes the decision-making out of the minds of those who are charged with managing the project and instead delegates it to a softly hissing microchip”

“...If you give this power to the computer (software), no human will thereafter be able to (easily) identify or understand the total-float of activities because it obscures the various paths and, hence, one will not be able to exploit activities according to available total-float. Do you really want to surrender such power to the computer?”

➤ So, what's a stakeholder to do?



THE CPM RESOURCE LEVELING PREDICAMENT *(cont'd)*



Woolf's views are echoed in the [GAO Schedule Assessment Guide](#):

“Automated leveling may produce inefficient output, such as delaying activities if resources are partially available and, thus, prevent activities from being partially accomplished while the project waits for the full complement of resources to become available”

The GAO guide further posits that:

“Resource leveling can be performed automatically with scheduling software or *manually by management and planners* or both”
(italics mine)

➤ **So, what's a stakeholder to do?**

SYNERGIZING STAKEHOLDER/MACHINE INTERACTION



GPM resource-constrained scheduling is a *transparent, hybrid, stakeholder-driven/software-aided* process that amalgamates schedule context and stakeholders' judgment

To improve a resource histogram profile, stakeholders, utilizing float and drift, may in every possible way (manually or by conceding to the software), shift a selected activity, crash or extend the activity, split the activity, and/or push UNDO to return to any prior state

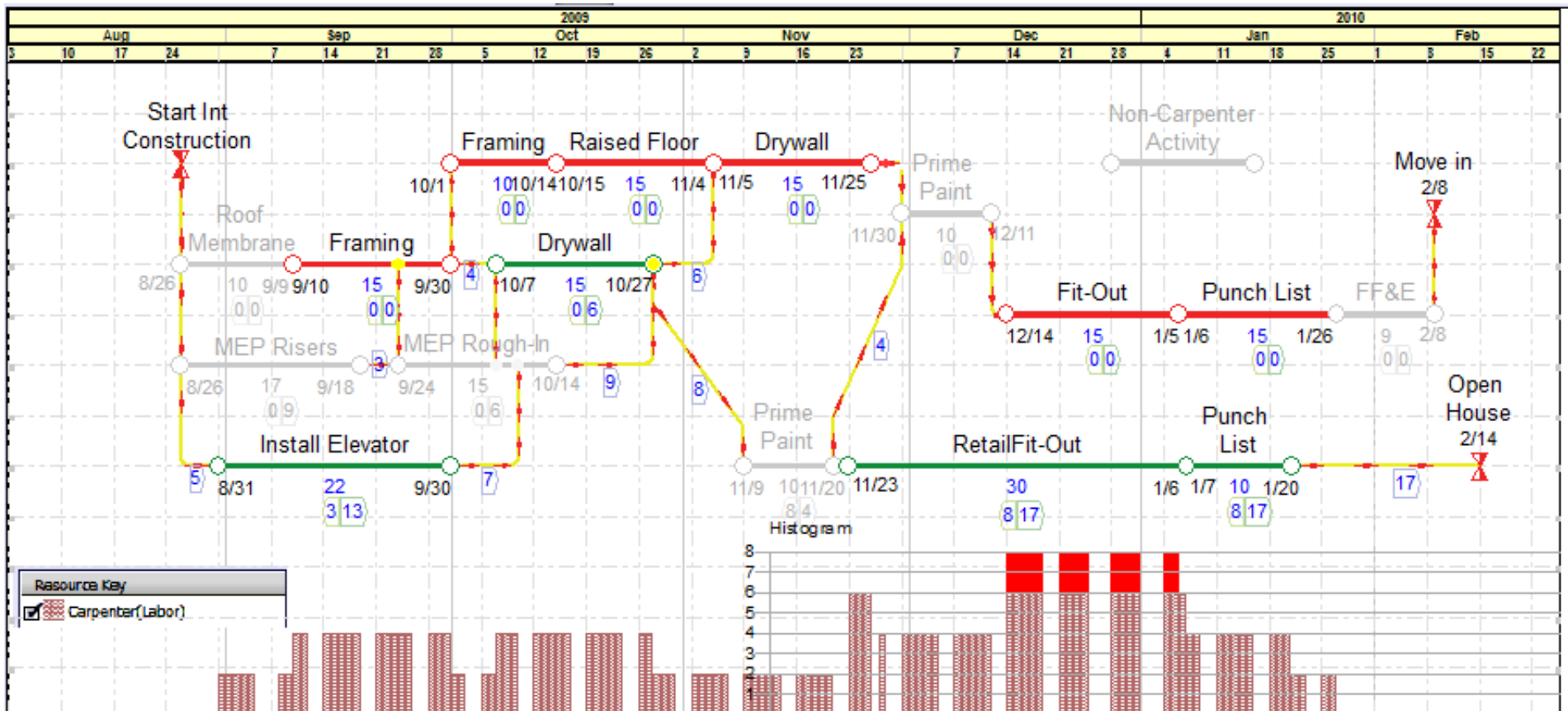
- ✓ *As an activity is manually or digitally manipulated, other preceding and/or succeeding activities that are impacted based on logic are simultaneously repositioned along the time scale*
- ✓ *The GPM algorithms also kinetically refresh the evolving resource histograms*



SIMPLE GPM RESOURCE ALLOCATION DEMONSTRATIVE



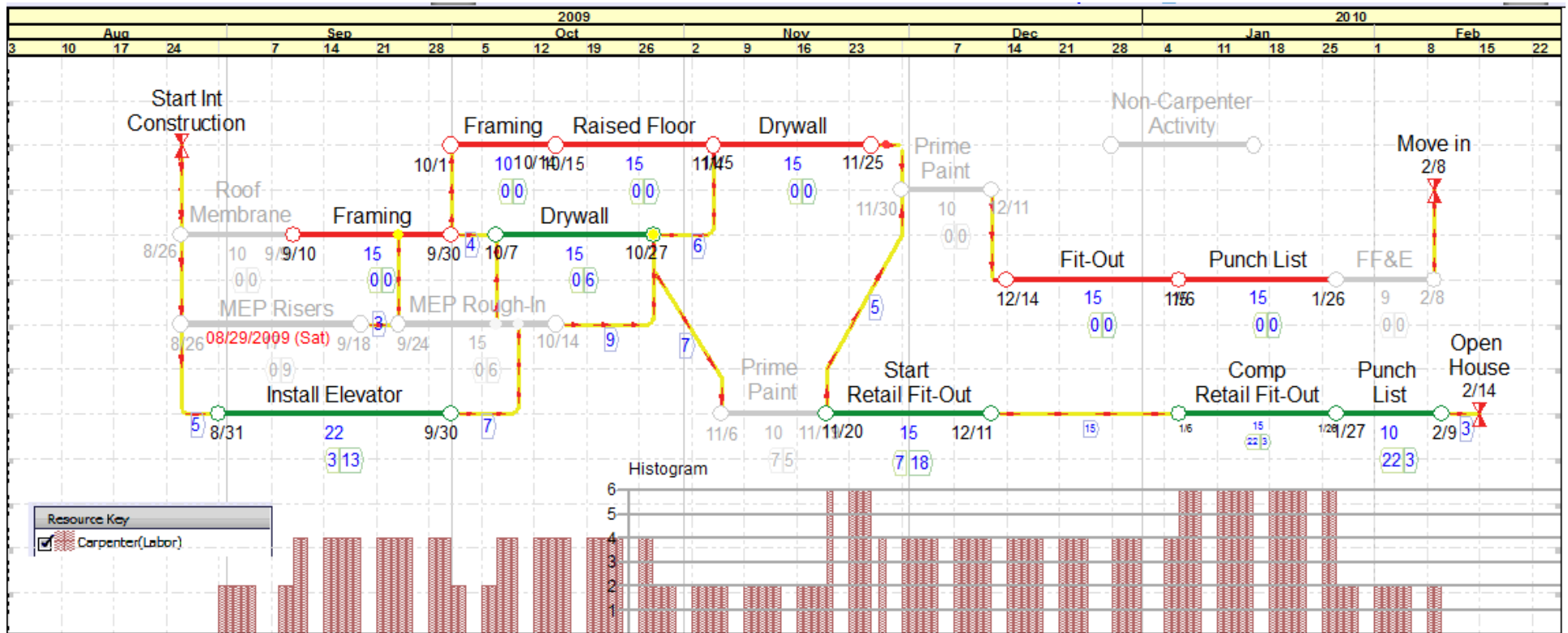
The objective is to eliminate the carpenter limit (6 carpenters) overrun between Dec 14 & Jan 5; the selected activity is Retail Fit-Out because it contributes to the overrun, is noncritical, and uses carpenters



FIRST 3-STEP SEQUENCE IN LEVELING DEMONSTRATIVE



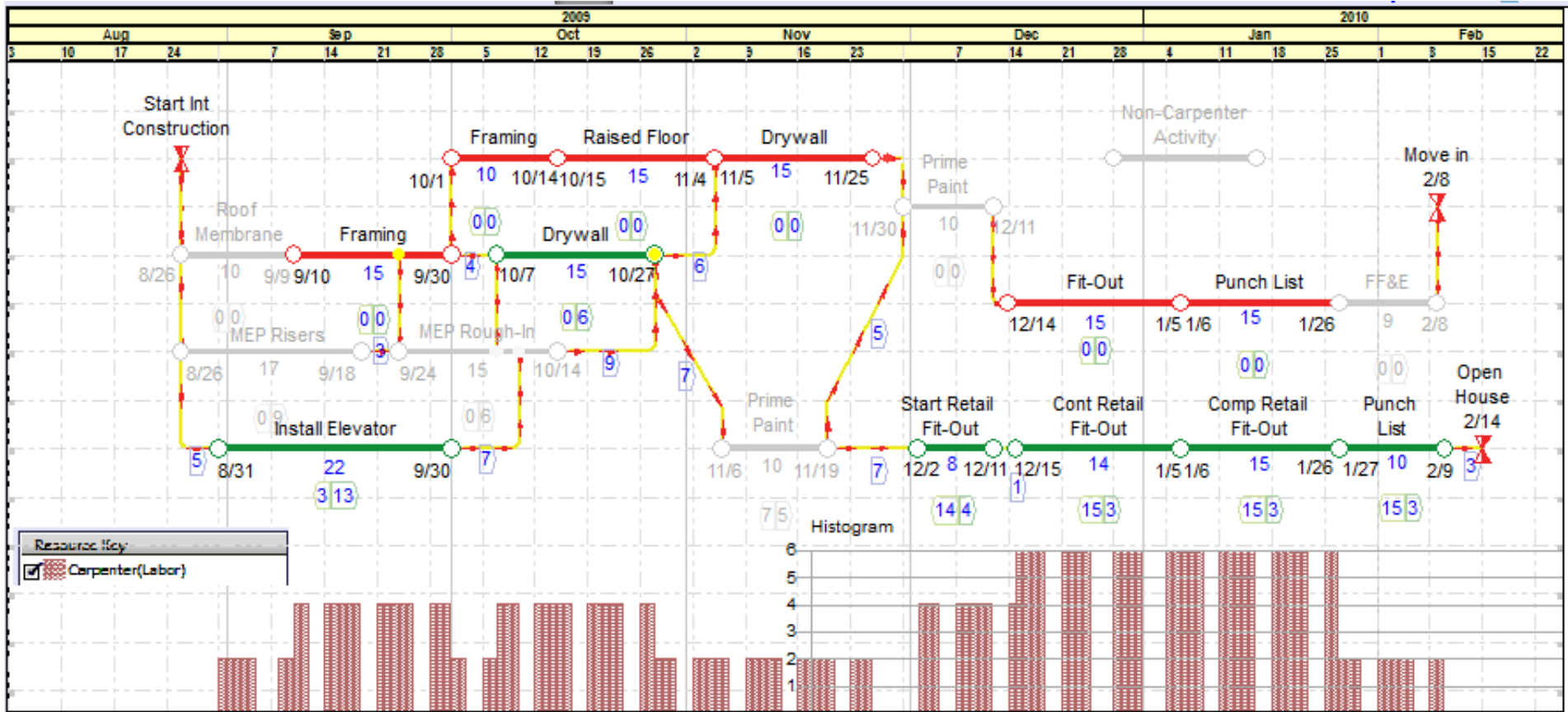
- Step 1: Retail Fit-Out is split (on 14 Dec 09) into two 15-day activities
- Step 2: Comp Retail Fit-Out floats by 14 days (gap reduces to 3 days)
- Step 3: Start Retail Fit-Out drifts back 1 day (drift reduces to 7 days)



THE NEXT 3 STEPS IN THE LEVELING DEMONSTRATIVE



- Step 4: Extend 'Start Retail' to 30 days; crew reduces to 2 carpenters
- Step 5: Split 'Start Retail' (on 14 Dec 09) into 14-day and 16-day activities
- Step 6: Turn "Logic" off, crash 'Start Retail' to 8 days from its start node, crew doubles to 4 carpenters; drift 'Start' Retail' by 1 day and turn logic back on



The 6 steps involved in this demonstrative are further detailed in the presentation [Logic Gantt Chart RIP](#)



IV. GPM RISK CORRECTS FOR THE CPM “OPTIMISM BIAS”

➤ The early-dates bias in CPM scheduling is magnified in CPM schedule simulation aka CPM schedule risk analysis

- In every realization, every activity is scheduled on early dates
- Neither *floating* nor *pacing*, realities in the real world, are possible

Floating: real-world event that occurs often and involves

- *Delaying the start of an eligible activity within its float then-existing when the activity is started*

Pacing: real-world event that involves

- *A decision to delay an activity because of a float-generating unrelated delay that originated before the pacing decision*

➤ In the real world, floating and pacing decisions rely on anticipated vs. as-built durations



FLOAT CONSUMPTION RISKS IN SCHEDULE SIMULATION

➤ In GPM risk, whether an eligible activity floats or paces in a realization is modeled by defining a likelihood factor

- A floating or pacing critical path delay occurs whenever an activity that floated or paced and that falls on the longest path would not otherwise have been critical but for the floating or pacing decision

➤ Relative to CPM, researches have proposed off-simulation approaches to quantify the influence of float use on the mean of the project completion probability distribution

- Sakka & El-Sayegh propose activity-by-activity regression relationships
- Gong proposes activity-by-activity time disturbance analyses



DEMONSTRATING THE CPM EARLY-DATES BIAS

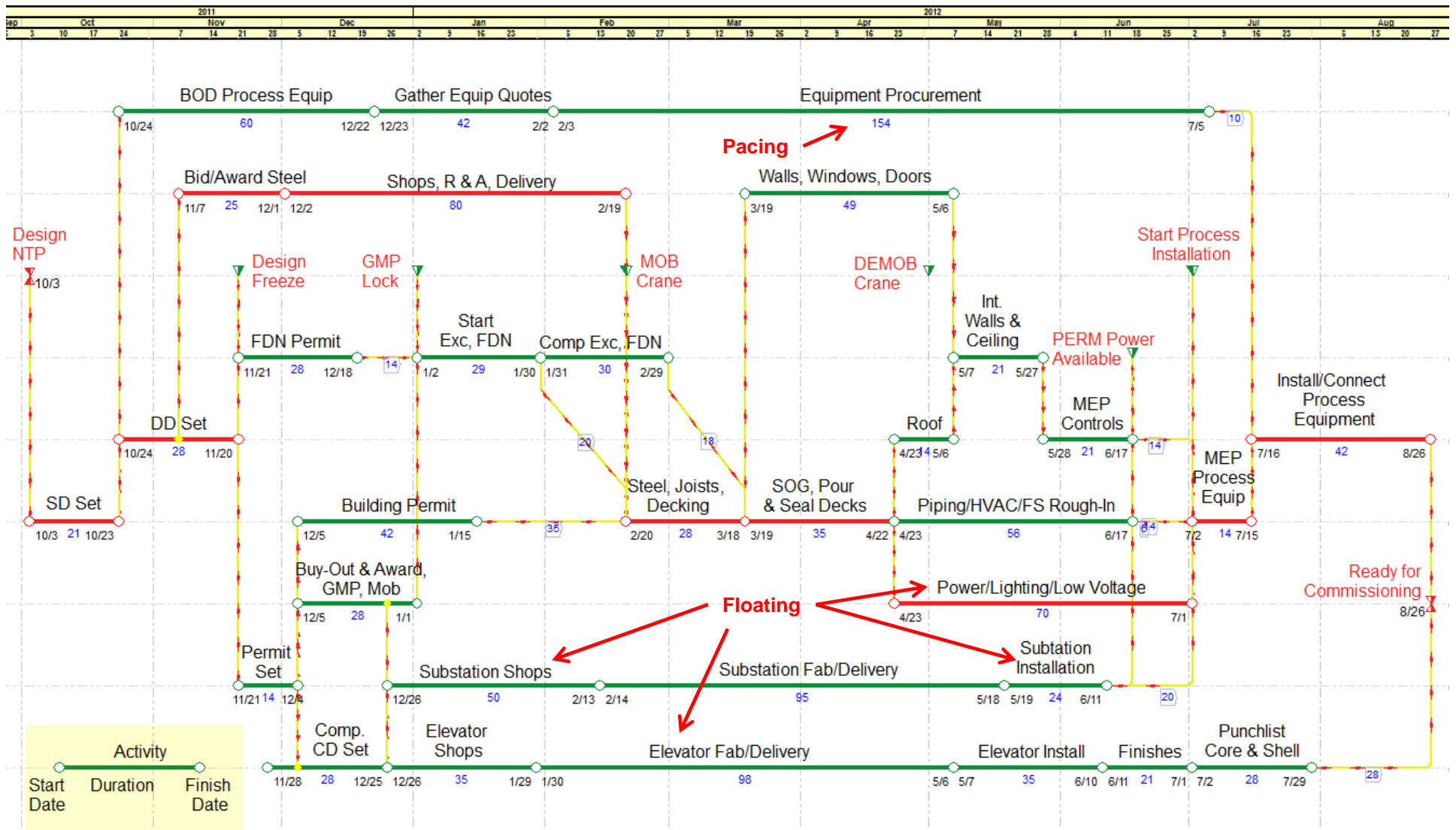
➤ **In the case study that follows, a deterministic schedule for a project is assessed for risk by ranging activity durations based on three-point estimates**

- **PERT solution:** conventional PERT technique where the three-point estimates are replaced by PERT mean values and the network is calculated using the standard critical path algorithm
- **CPM solution:** simulation technique where activity durations are random variables and neither floating nor pacing are allowed
- **GPM solution:** simulation technique where activity durations are random variables and both floating and pacing are allowed

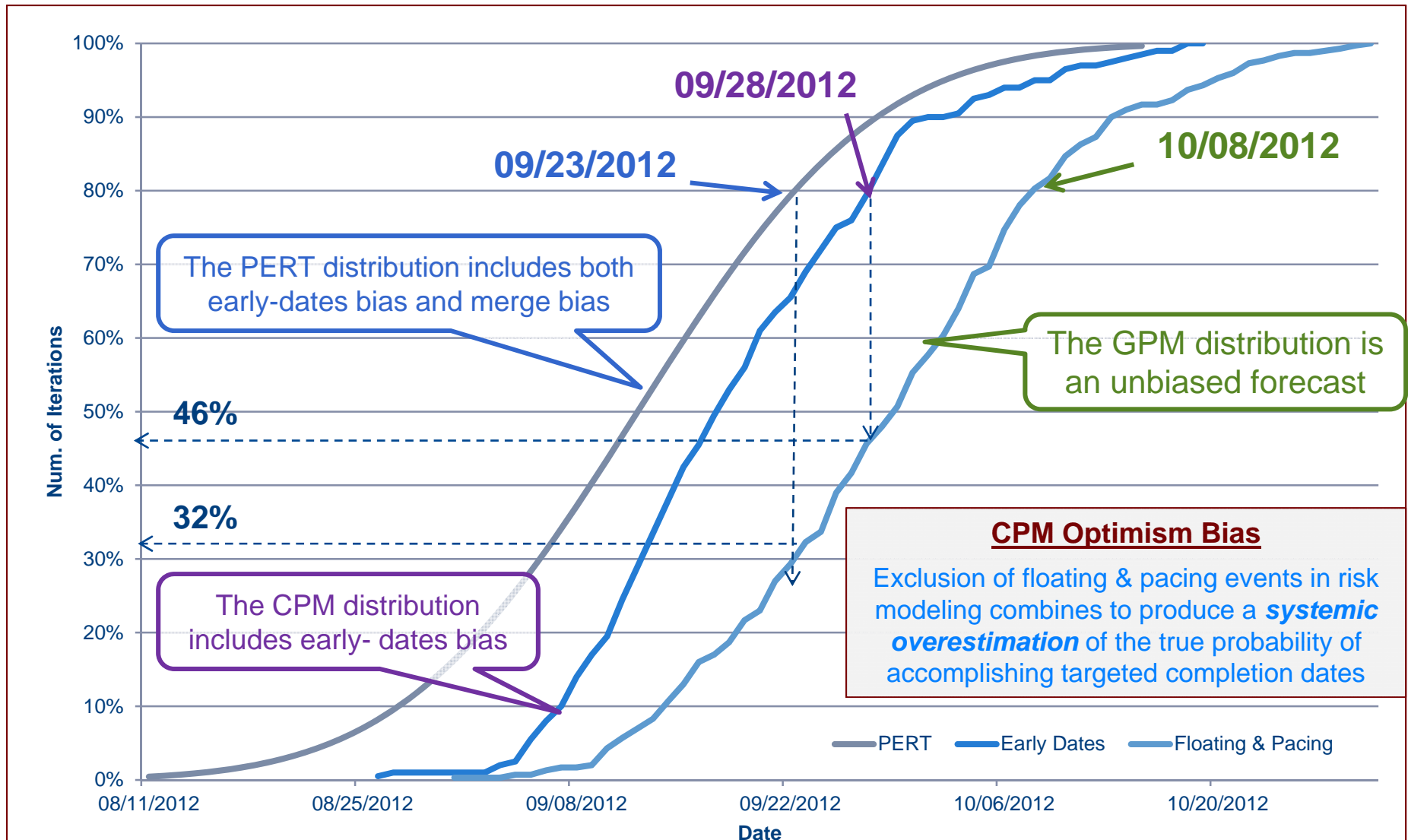
➤ **The objective is to determine the probability distribution function of the project completion date, and the completion date with an 80% likelihood of being met aka the P80 date**



PROJECT NETWORK USED IN THE CASE STUDY



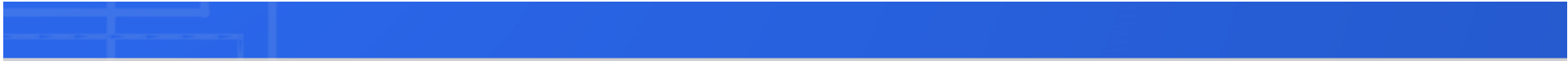
DEMONSTRATING THE CPM "OPTIMISM BIAS"



TAKE-AWAYS

- 1 Committing to lifelong learning makes for an exciting *life-is-a-project* career
- 2 Lifelong learning morphs into lifelong innovation where there is a mindset for never wasting a lesson learned, being opportunistic about improving the practice, and going for breakthrough innovation where warranted
- 3 GPM networks, due to their sufficiently simple visuals, are intuitive and more fluently processed by schedulers and non-scheduling stakeholders alike
- 4 GPM planned dates, which generate drift, not only render resource leveling practical, at last, but also preserve total float traceability
- 5 GPM is a method that allows collaboration between network planners and lean construction planners because it supports both *pull* and *push* planning
- 6 GPM resource leveling allows stakeholders to remain engaged and to direct resource leveling to proceed manually or digitally, activity by activity
- 7 GPM schedule risk more accurately predicts the probability of project completion by permitting modeling of floating and pacing risks in simulation





BIBLIOGRAPHY

- Archibald, R. & Villoria, R. *Network-Based Management Systems (PERT/CPM)*. New York: John Wiley & Sons, 1968.
- Ballard, G. *Last Planner™ System of Production Control*. UK: University of Birmingham, 2000.
- Fondahl, J. *A Non-Computer Approach to the Critical Path Method for the Construction Industry*, 2nd ed. Palo Alto: Stanford University, 1962.
- Goldratt, E. *Critical Chain*. Great Barrington: The North River Press Publishing Corporation, 1997.
- Gong, D. & Rowings, J. "Calculation of Safe Float Use in Risk-Analysis-Oriented Network Scheduling." *International Journal of Project Management* 13, no.3 (1995): 187-194.
- Gong, D. "Optimization of Float Use in Risk Analysis-Based Network Scheduling." *International Journal of Project Management* 15, no.3 (1997): 187-192.
- Harris, R. *Precedence and Arrow Networking Techniques for Construction*. New York: John Wiley & Sons, 1978.
- Hulett, D. *Practical Schedule Risk Analysis*. Burlington: Gower, 2009.
- IBM Corp., *Construction Project Management Control System at the H.B. Zachry Company*. IBM Application Brief. Armonk: Author, c. 1966.
- Joyce, E. "Dearth of Scheduling Software Still Bedevils Many Legal Cases." *Engineering News-Record*, April 30, 2013.
- Kelley, J. Jr. & Walker, M. "Critical Path Planning and Scheduling." *Proceedings of the Eastern Joint Computer Conference*. Boston: National Joint Computer Committee (1959): 160-173.
- Kelley, J. Jr. & Walker, M. "The Origins of CPM: A Personal History." *PM Network*. (1989)



BIBLIOGRAPHY *(cont'd)*

Korman, R. "Critics Can't find the Logic in Many of Today's CPM Schedules." *Engineering News-Record*, May 26, 2003.

Krishnamoorthy, M. *Critical Path Method: A Review*. Technical Report no. 1968-4. Ann Arbor: University of Michigan, 1968.

Lamb, E. "How to Fix a Broken Scheduling System." *Engineering News-Record*, September 30, 2013.

Malcolm, D. et al. "Application of a Technique for Research and Development Program Evaluation." *Operations Research* 7, no 5. (1959): 646-669.

Moder, J. & Phillips, C. *Project Management with CPM and PERT*. New York: Reinhold Publishing, 1964.

National Aeronautics and Space Administration. *PERT/COST Systems Design. DOD and NASA guide*. Washington, D.C.: Author, 1962.

O'Brien, J. *CPM in Construction Management*. New York: McGraw-Hill, 1965.

O'Brien, J. *Scheduling Handbook*. New York: McGraw-Hill, 1969.

O'Brien, J. *CPM in Construction Management, Project Management with CPM*, 2nd ed. New York: McGraw-Hill, 1971.

O'Brien, J. & Plotnick, F. *CPM in Construction Management*, 5th ed. New York: McGraw-Hill, 1999.

Ogander, M. *The Practical Application of Project Planning by Network Techniques*. New York: John Wiley & Sons, 1972.

PMA Consultants, LLC. [Guide to Specifiers for Bidding Requirements, Contract Forms and Conditions of the Contract and Progress Schedule Specification](#). Ann Arbor: Author, 2001.



BIBLIOGRAPHY *(cont'd)*

Ponce de Leon, G. "Graphical Planning Method: A New Network-Based Planning/Scheduling Paradigm." Presented at the PMI College of Scheduling 5th Annual Conference, Chicago, IL, May 4-7, 2008.

Ponce de Leon, G. "Project Planning Using Logic Diagramming Method." Presented at the AACE International 52nd Annual Meeting, Toronto, Ontario, Canada, June 29-July 2, 2008.

Ponce de Leon, G. "GPM: An Objectbase Project Networking Method." Presented at the 6th Annual PMI College of Scheduling Conference, Boston, MA, May 17-20, 2009.

Ponce de Leon, G. "GPM and Forensic Total Float." Presented at the 7th Annual PMI College of Scheduling Conference, Calgary, Alberta, Canada, May 2-5, 2010.

Ponce de Leon, G. et al. *Guide to the Forensic Scheduling Body of Knowledge*. Ann Arbor: PMA Consultants, LLC., 2010.

Ponce de Leon, G. ["CPM to GPM: Easing the Transition."](#) PMI Webcast, October 20, 2011.

Ponce de Leon, G. "Scheduling, Fast and Slow; Intuitions and Algorithms." Keynote presented at the 2nd Annual GPM & NetPoint User Conference, Orlando, FL, January 20, 2012.

Ponce de Leon, G. "Logic Gantt Chart Requiescat in Pace." Ann Arbor, MI: PMA Consultants, LLC., 2013.

Ponce de Leon, G. "Mitigating the Planning Fallacy." Keynote presented at the 3rd Annual GPM & NetPoint User Conference, New Orleans, LA, January 25-26, 2013.

Ponce de Leon, G. "Tweaking the Scheduling Paradigm." Keynote presented at the 4th Annual GPM & NetPoint User Conference, Orlando, FL, January 21, 2014.

Ponce de Leon, G. et al. *Core Traits of a Reliable Schedule*. Ann Arbor: PMA Consultants, LLC., 2014.



BIBLIOGRAPHY *(cont'd)*

Ponce de Leon, G. "Power to Stakeholders: The GPM Planners' Credo ." Keynote presented at the 5th Annual GPM & NetPoint User Conference, San Diego, CA, January 13-14, 2015.

Pritsker, A. *GERT: Graphical Evaluation and Review Technique*. Santa Monica: RAND Corporation, 1966.

Project Management Institute. *A Guide to the Project Management Body of Knowledge (PMBOK®)*, 4th ed. Newtown Square: Author, 2008.

Radcliffe, B., Kawal, D., & Stephenson, *Critical Path Method*. Chicago: Cahners Publishing Company, 1967.

Shaffer, L., Ritter, J., & Meyer, W. *The Critical Path Method*. New York: McGraw-Hill, 1965.

US Government Accountability Office. *GAO Schedule Assessment Guide*. Washington, D.C.: Author, 2012.

Van Slyke, R. "Monte Carlo Methods and the PERT Problem." *Operations Research* 11, no. 5. (1963): 839-860.

Weaver, P. "A Brief History of Scheduling – Back to the Future." *PM World Journal* III, issue VIII. (2014).

Wiest, J. "A Heuristic Model of Schedules for Large Projects with Limited Resources." *Management Science* 13 (1967): 359-377.

Wiest, J. & Levy, F. *A Management Guide to PERT / CPM*. Englewood Cliffs, NJ: Prentice Hall, 1969.

Wolf, M. *Faster Construction Projects with CPM Scheduling*. New York: McGraw-Hill, 2007.



THANK YOU!