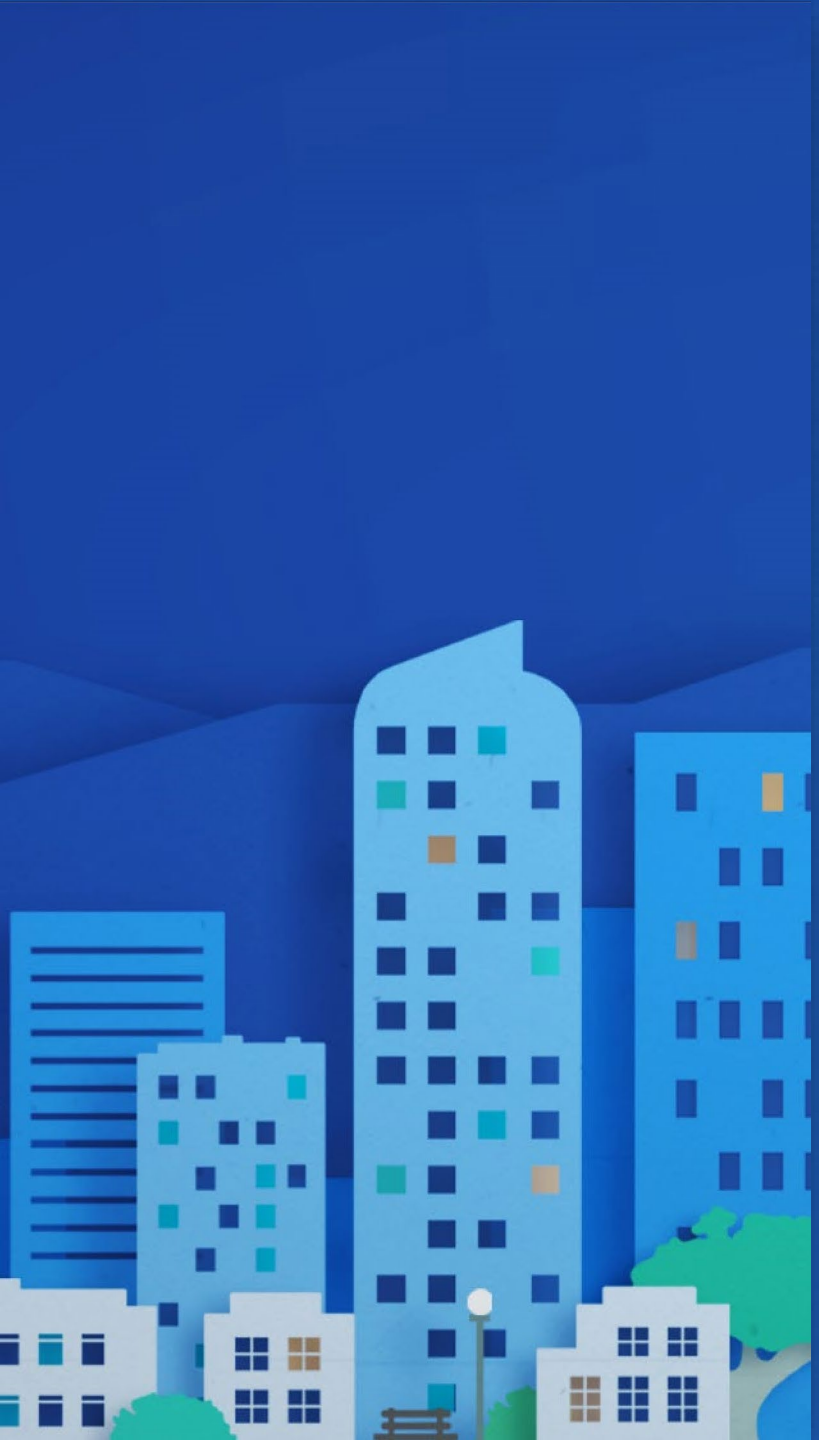



# Early *and* Late "P80" Dates

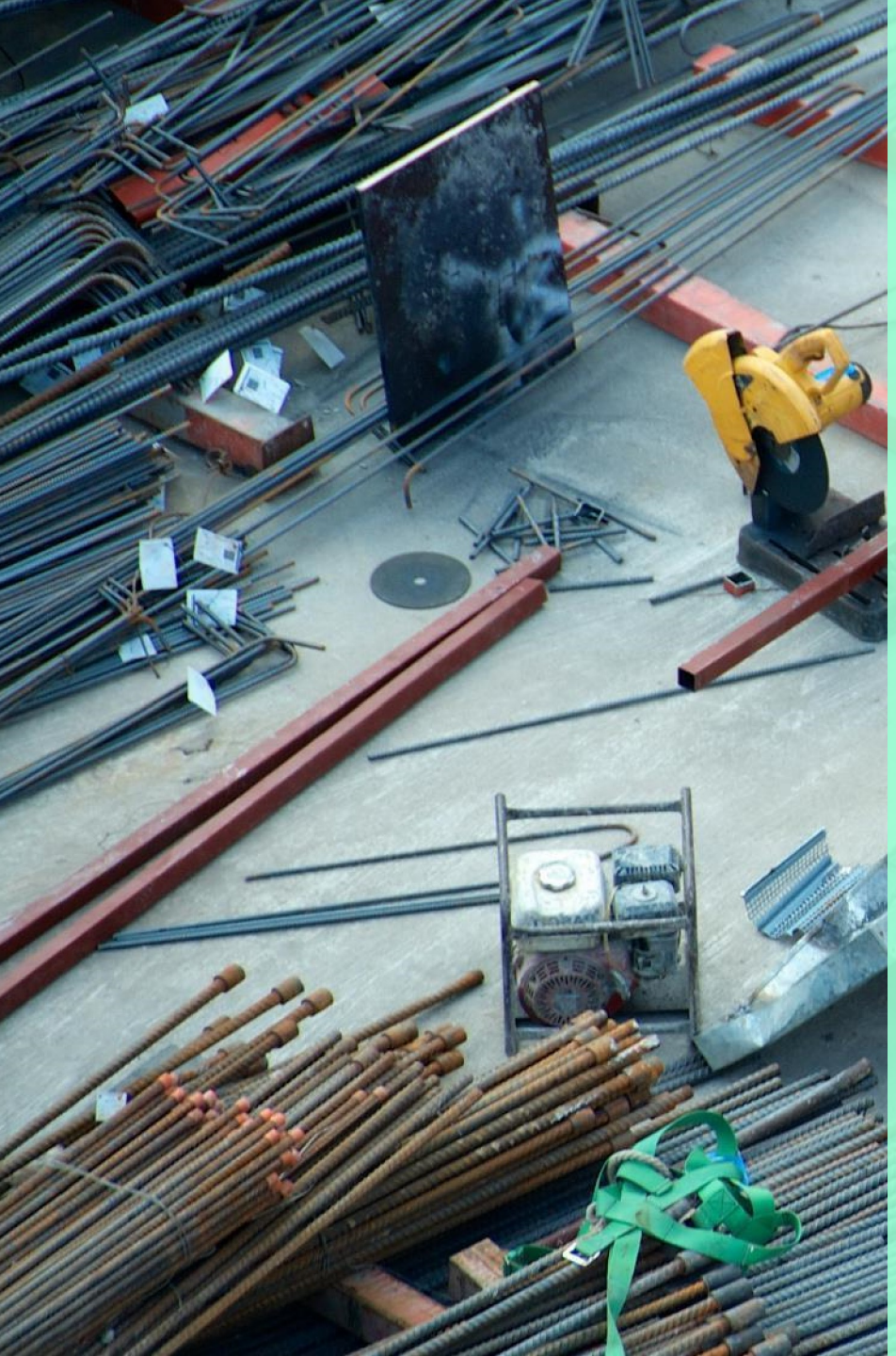
Presented by:
Gui Ponce de Leon, PhD, PE, PMP, LEED AP



"There are lies, there are damned lies, and then there are *deterministic* schedules"

Attributed to **Dr. VivekPuri**

*PMA's resident simulation guru*



# AGENDA

1. ***CPM Early-Only***
   **P80 Dates**

2. **GPM *Early <u>and</u> Late***
   **P80 Dates**

3. **Take-Aways**



# CPM *Early-Only* P80 Dates

1

# Conventional CPM Scheduling

## *Circa 1957-1959*

### Basic CPM Planning

1. Every activity is assigned an *estimated* duration and network logic ties convey activity dependencies
2. In creating activities and logic, the planner assumes that adequate resources are available to perform the network as diagrammed

### Basic CPM Scheduling

1. Forward pass calculates activity early dates and
2.

### Advanced CPM Scheduling

1. Time/cost trade-off algorithm extends and/or shortens project

d

## Conventional

# CPM Scheduling

## *Limitations*

### Optimistic Project Completion

completion date–
durations to yield the
leastof unknown likelihood
due cost schedule
to duration variability

. Resource heuristics shift

2

### The CPM *Total Float Handicap*

B pass calculates activities within free or total activity *bounding*
a late float to either remove all or dates, from which total
c much of over-commitments or floats are derived other
k resource conflicts
w
a
r

1. Using the longest path 1. algorithm with one activity duration–out of the many probable–underestimates the true project duration

2. Thus, it is advised to add 5% - 15% total float reserve (to finish early) to the CPM completion date for a more realistic completion date

Floating activities between early & late dates requires no-earlier-than constraints which reduce total float

2. Once actuald ates are introduced, neither total floats nor the actual (asbuilt) critical path can be algorithmically calculated left of the data date

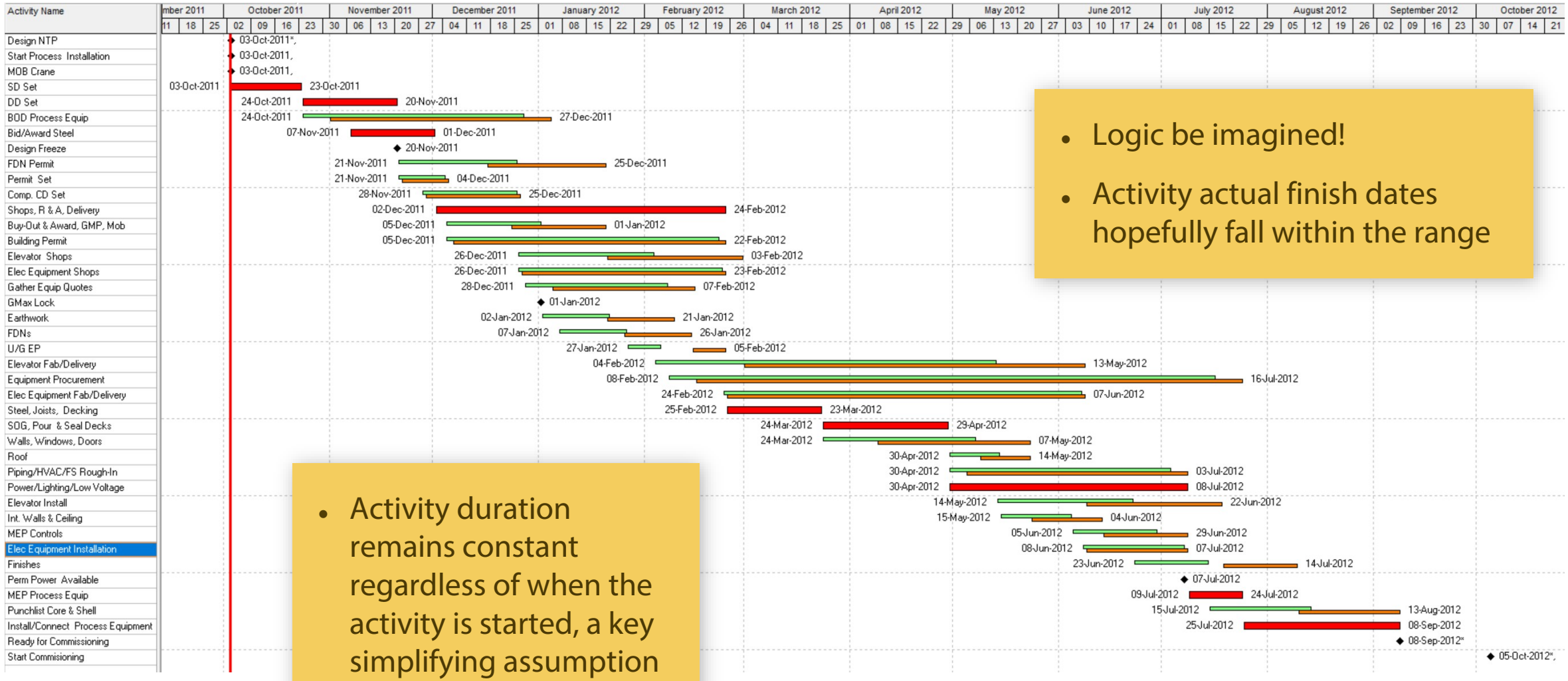
## Demise of the Logic Diagram

1. In the 1980s, bar charts which had been replaced by logic diagrams, reappear as schedule graphic surrogate

2. Collaborative planning on a time-scaled CPM network is compromised until PMA introduces the logic diagram method (LDM) networking technique in 2008

# Common CPM Schedule Picture

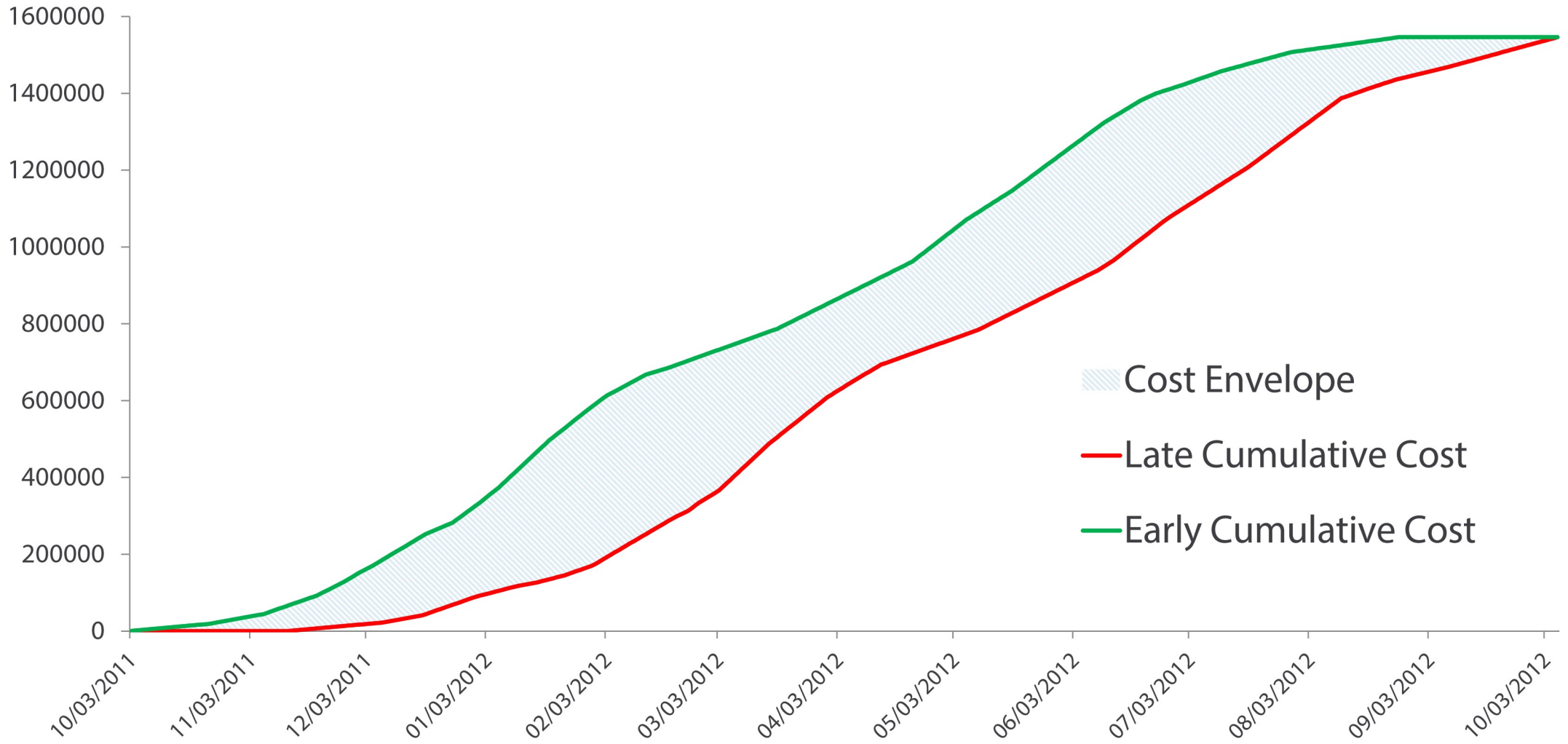
## Early and Late Dates *and* ***Base-Case*** Project Completion Date




- Logic be imagined!
- Activity actual finish dates hopefully fall within the range

- Activity duration remains constant regardless of when the activity is started, a key simplifying assumption

# CPM Early and Late
# *Bounding* Cost Distribution Curves



# Scheduling Under Uncertainty with PERT *Also Circa 1957*

## Typical Sources of Activity Duration Variability

- Learning curve
- Construction detail difference
- Slow testing or inspection delay
- Material shortage or damaged

- Duration may depend on the season when the activity starts, in-place congestion, level, etc.
- Subcontractor “B” crew

## Program Evaluation and Review Technique (PERT)

- Three-point duration estimates with simplified Beta distribution
- PERT defaults to mean duration for the activities

and runs forward and backward pass

- Project duration assumed to follow a normal distribution
- PERT calculates mean and variance for project duration

## PERT Limitations

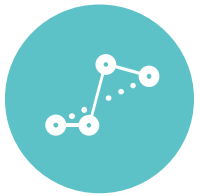
- Activity duration mean and variance simplifications
- Undervalues project duration mean due to *merge bias* that arises when activity duration variability is reduced to mean
- Activity criticality is reduced to a deterministic measure of total float & a critical path/s

# PERT

## Merge Bias

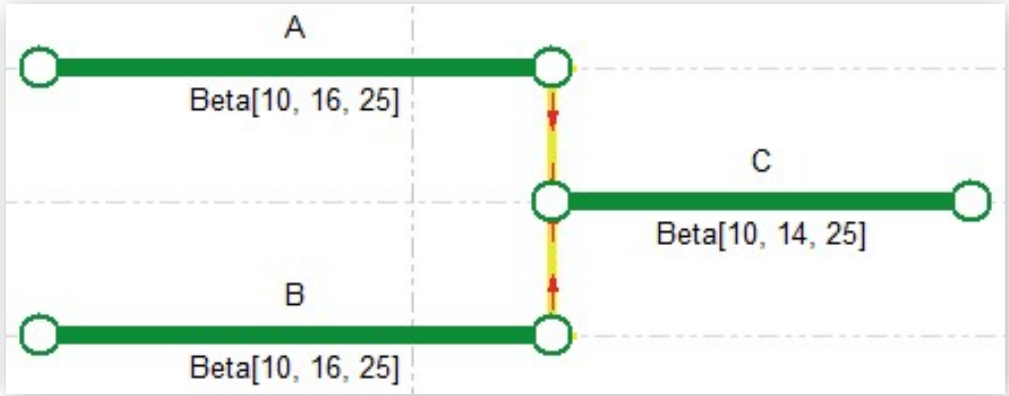


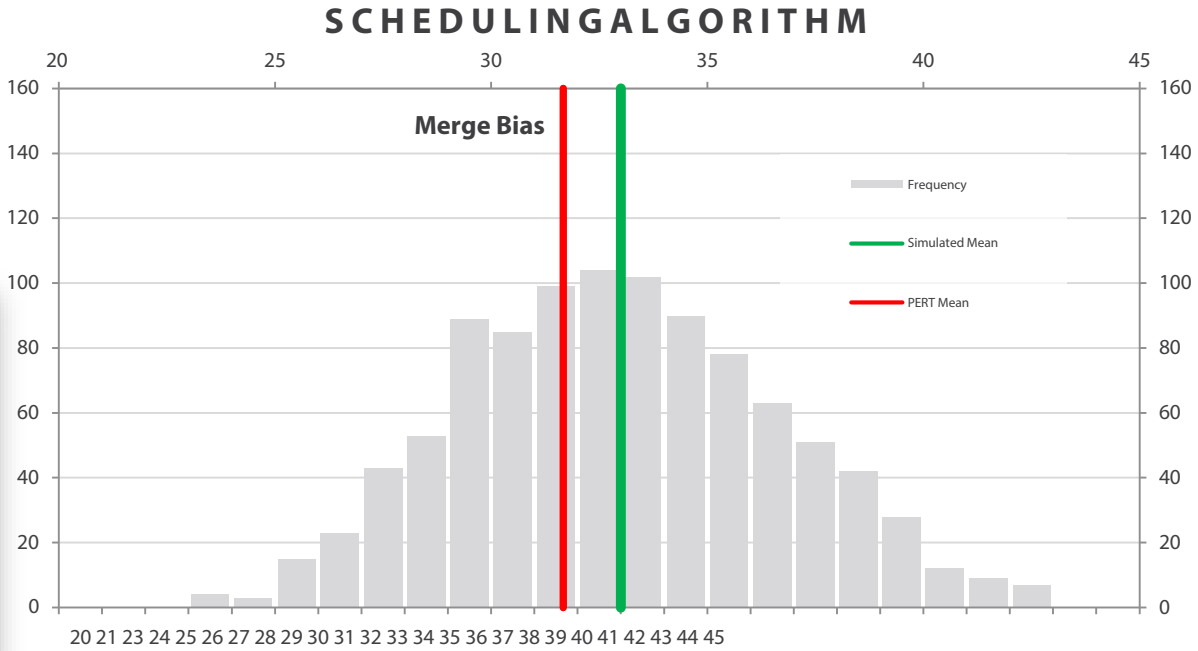
Runs longest path algorithm aka forward pass using mean activity durations to calculate ***mean event dates*** when paths merge



Using the longest path algorithm with mean activity durations ***underestimates*** the true stochastic longest path/project duration mean

More merging paths increase merge bias, that is, increase the spread between the PERT and the true stochastic mean project duration

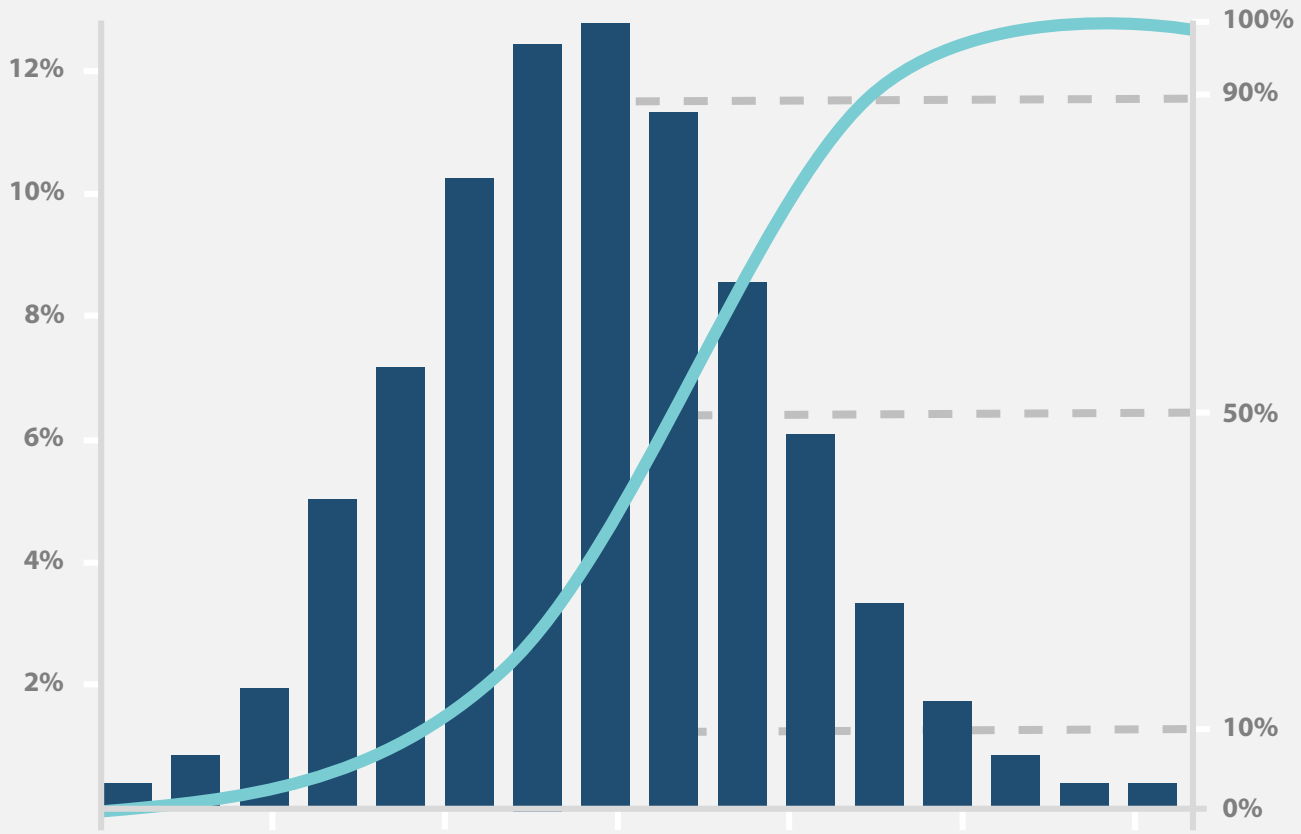


# CPM

## Schedule Simulation

*Introduced in 1963 by Richard M. Van Slyke–**56 years ago!***




## Improvements over PERT

- Uses generic duration distributions
- Avoids merge bias by running many iterations rather than one forward pass
- Each iteration runs forward pass with sampled duration set and finds *one instance* of the project completion
- Tabulates results from simulation to calculate project mean and variance
- Introduces “criticality index,” a random measure of activity criticality

# *Early-Dates-Only*

# Bias

## in CPM Schedule Simulation

### Van Slyke CPM Simulation Algorithm

- In every iteration, every activity starts strictly on the early start date
- Backward pass only used to determine total floats; impact of random float use on project completion is

### *Early-Only* Iteration Completion Dates

- Each iteration generates one instance of the early schedule rather than the as-built schedule
- Impact on completion of duration risk assumes that no activity is delayed from its early start date

03

# Early-Only Project Completion Risk

not modeled in any way

- By generating multiple iterations of the early schedule only, CPM schedule simulation, then and now, merely

generates *the early* project completion distribution function

# Case Study

## Design-Build Contract to Rebuild a Food Processing Facility

- Executed in 2012
- Simulated using CPM Schedule Risk Analysis Algorithm

**Assumptions for Simplicity**

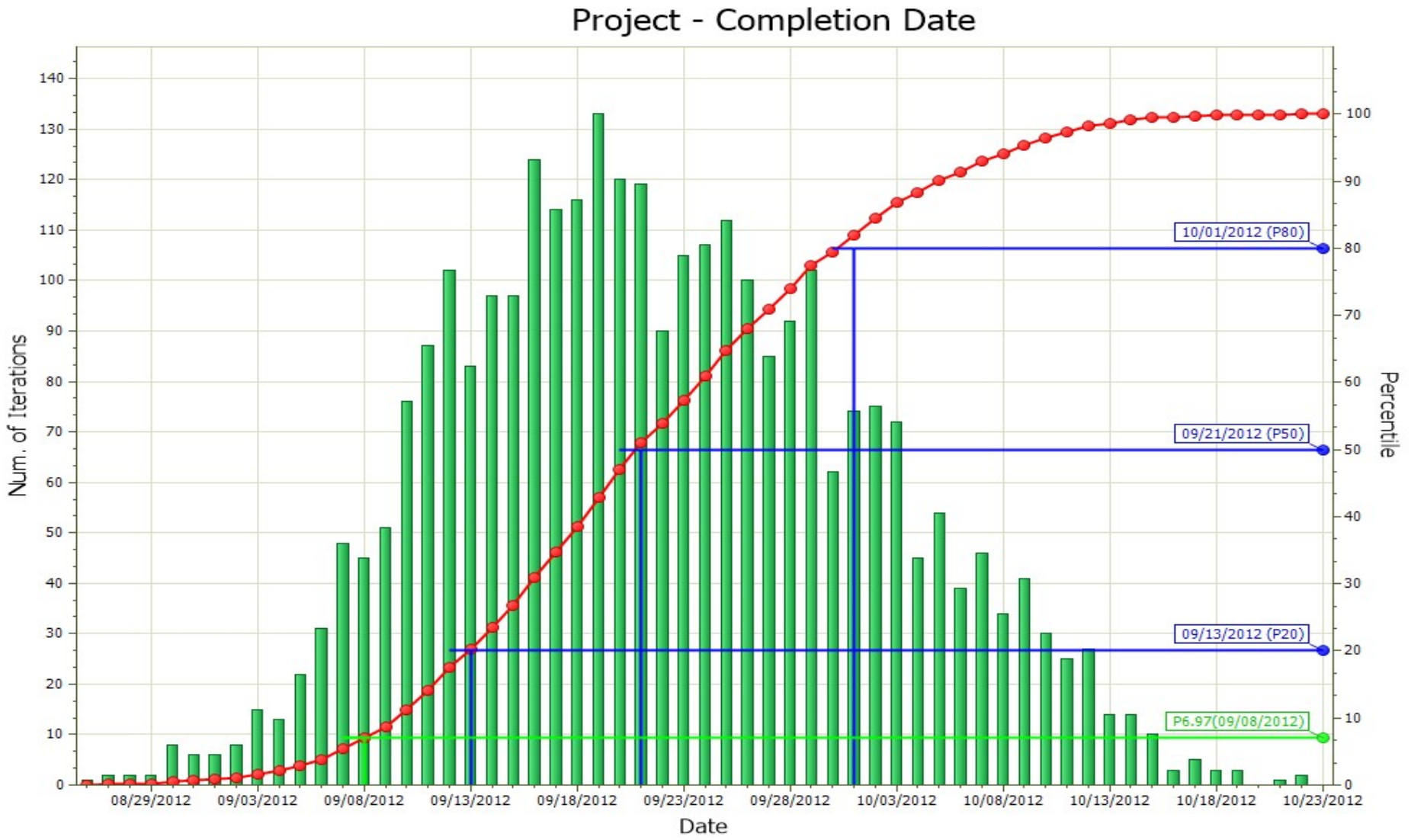
- 3-point duration estimates follow triangular distribution
- All uncertainty modeled using duration variability and no other risks

## Project Ready for Commissioning

- **Required by 10/03/2012**
- **Early planned completion by 09/08/2012**
- **Duration: 341 calendar days**
- Early completion total float: **27** days **(7.9%)**

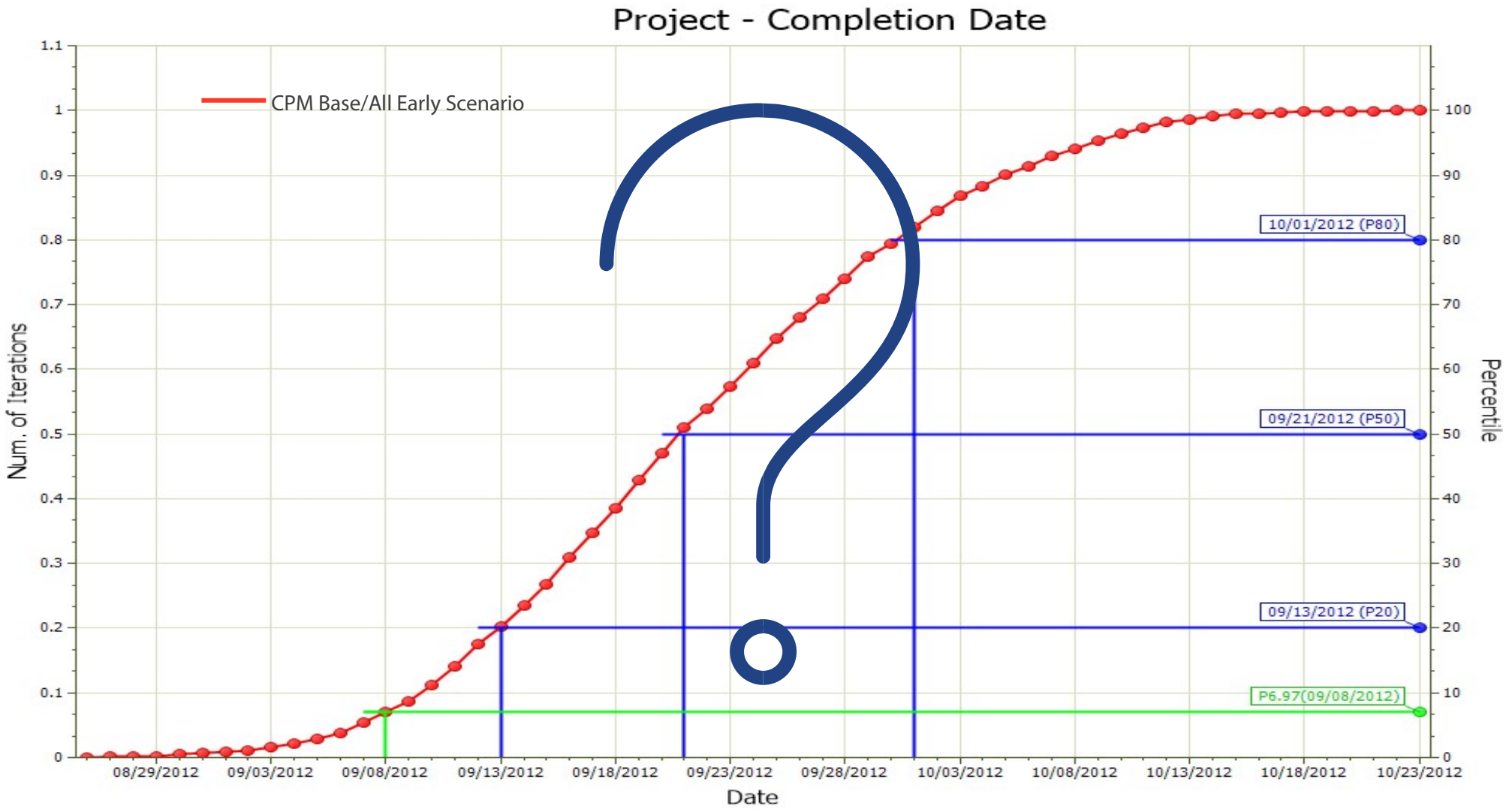
# All-Early-Dates

## CPM Simulation Project Completion Risk Distribution ***Lower Bound***



CPM Schedule Simulation

# *Is there NO bounding* late completion risk curve?


Project - Completion Date
CPM Base/All Early Scenario
10/01/2012 (P80)
09/21/2012 (P50)
09/13/2012 (P20)
P6.97(09/08/2012)
Num. of Iterations
Percentile
Date
08/29/2012
09/03/2012
09/08/2012
09/13/2012
09/18/2012
09/23/2012
09/28/2012
10/03/2012
10/08/2012
10/13/2012
10/18/2012
10/23/2012



# GPM *Early and Late* P80 Dates

## 2

## *Graphical* Path Method

# Planning/Scheduling *Circa 2007-2009*

### *Planned* Start Between Early and Late Start Dates

An activity with total float may be ***floated*** to planned dates without constraints, while retaining the option to ***drift*** back, as float + drift = total float. G***ap*** is calculated for logic ties *aka* links

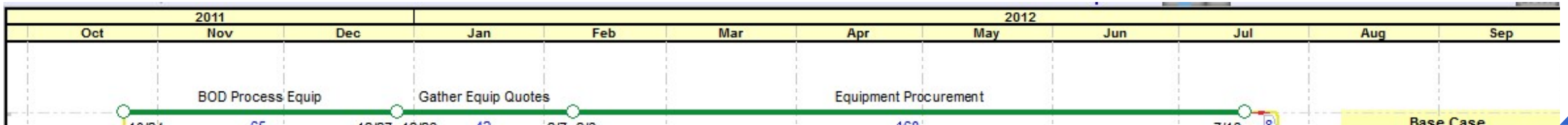
### GPM Scheduling Algorithms (NO forward/backward pass)

Self-healing and gap-driven algorithms that kinetically refresh the schedule only where impacted as the user adds/deletes/revises/shifts activities, links, milestones, weather days, etc.

## *Algorithmic* As-Built Critical Path

Total floats (and critical paths) are algorithmically calculated (and identified) left of the data date and refresh, when impacted, the instant the schedule changes right of the data date

# GPM Schedule Graph–*Base-Case Completion*


2011
2012
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
BOD Process Equip
Gather Equip Quotes
Equipment Procurement
Base Case

# Float Use Impact

## on Project Completion Under Uncertainty

### Common to delay non-critical work using total float

- Level resources
- Pace progress
- Shift in priorities
- Design holds
- Competing projects
- Other strategic reasons

### Float use impact with schedule uncertainty

- Floating activities alters risk on the (early-dates merge bias)
- Floating an activity–before it is cause an overrun of actual duration planned project completion subject to float duration variability

### Early-dates merge bias

- High-total-float paths do not path affect merge bias until the slippage is significant started–may
- Low-total-float paths have the late date if the high probability to impact sufficiently exceeds the duration plus remaining total

# GPM Float Use Modeling
## In Schedule Simulation

### Floating
**in GPM Simulation**

- Delayed start of activity to use *then-available* float before sampled duration is considered (i.e., before simulated activity performance)
- Modeled as a random decision if simulating a version of the as-built other than the pessimistic 100%-use-of-total-float case

### Pacing
**in GPM Simulation**

- Delayed start of activity to use *then-available* float (in the iteration) that is larger than the deterministic, base-case float due to float use and durations sampled on other paths
- Decision based on threshold of then-available float to base-case float (in the deterministic scenario)

# NetRisk™ Case Study

## Design-Build Contract to Rebuild a Food Processing Facility

- Executed in 2012
- Modeled and simulated using NetPoint® and NetRisk™

**Assumptions for Simplicity**

- 3-point duration estimates follow triangular distribution
- All uncertainty modeled using duration variability and no other risks

## Project Ready for Commissioning

- Required by 10/03/2012
- Early planned completion by 09/08/2012
- Duration: 341 calendar days
- Early completion total float: 27 days (7.9%)

# Early and Late P80 Dates

## Modeling Bounding Completion Risk Envelope with GPM and NetRisk

CPM algorithm generates ***optimistic bound*** **(Slide 23)**

- In each iteration of the simulation, project completion is generated based strictly on the early schedule
- Use of float is not simulated; 56 years hence, there is no CPM schedule simulation algorithm other than the CPM forward/backward pass

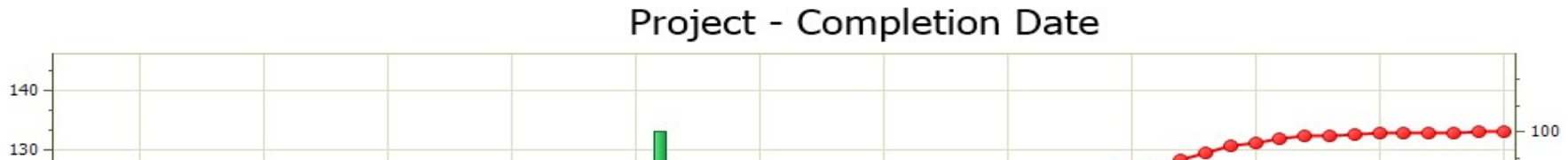
GPM algorithm generates ***pessimistic bound*** **(Slide 24)**

- Each iteration in a GPM simulation is a simulated instance of the as-built schedule: every activity is dealt with based on logic, floated if allowed, and simulated using its sampled duration

- Pessimistic completion is generated by always using 100% of available float

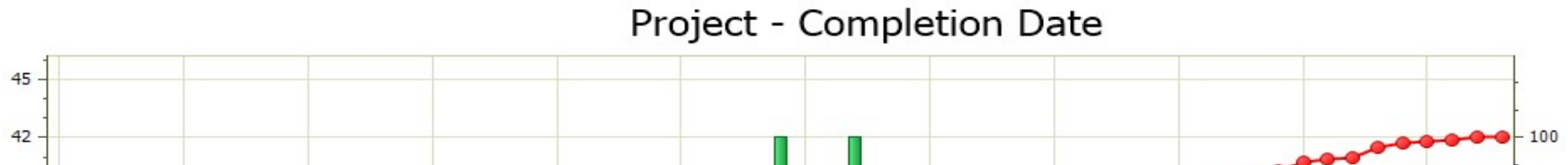
# All-Early-Dates

## CPM Simulation Project Completion Risk Distribution ***Lower Bound***


Project - Completion Date
140
130
100

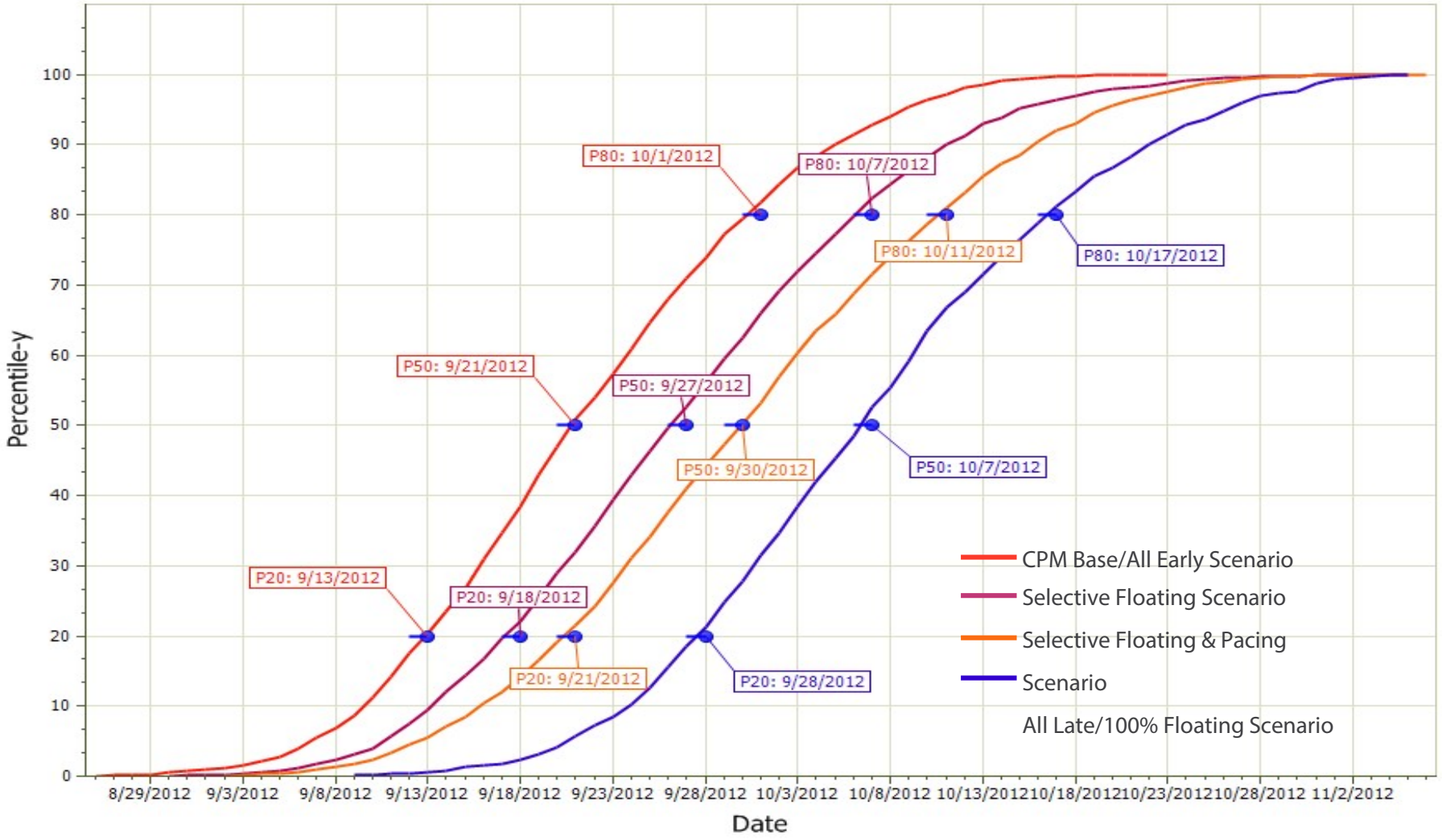
# All-Floating-Dates

## GPM Simulation Project Completion Risk Distribution ***Upper Bound***


Project - Completion Date
45
42
100

# GPM Simulation Yields *Early and Late* "P" Dates

## NetRisk Bounding Completion Distribution/Risk Envelope





# Take-Aways

3

# Take-Aways

1. Van Slyke's CPM schedule simulation corrects for the PERT merge bias but does not model the risk of float use

2. By generating ***only*** multiple versions of the early schedule, CPM schedule simulation merely yields the ***early*** project completion distribution curve

3. GPM simulation, by modeling random use of total float, generates multiple instances of the as-built schedule as well as the ***pessimistic*** as-built schedule

4. In GPM simulation, 100%-*then-available float* use in every iteration is a practical late bound for the project completion risk

5. GPM simulation corrects for the CPM early bias; **NetRisk** *bounding envelope* yields *CPM optimistic* P dates (no-float-use risk) and *GPM pessimistic* P dates (100%-float-use risk)

6. GPM algorithms also calculate ***safe-float:*** the extent an activity with total float can be floated without any significant impact on the likelihood of meeting the project completion date

# Bibliography



# Bibliography


AACE International. “AACE International Recommended Practice No. 57R-09: Integrated Cost and Schedule Risk Analysis Using Monte Carlo Simulation of a CPM Model.” Morgantown: Author, 2011.

AACE International. “AACE International Recommended Practice No. 64R-11: CPM Schedule Risk Modeling and Analysis: Special Considerations.” Morgantown: Author, 2012.

Archibald, R. D. and Villoria, R. L. *Network-Based Management Systems: PERT/CPM*. New York: Wiley & Sons, 1968.

Fondahl, J. W. *A Non-Computer Approach to the Critical Path Method for the Construction Industry*, 2nd ed. Stanford: Department of Civil Engineering, Stanford University, 1962.

Ford Jr., L. R. and Fulkerson, D. R. *Flows in Networks*. Princeton: Princeton University Press, 1962.

Gong, D. & Rowings Jr., J. E. “Calculation of Safe Float Use in Risk-Analysis-Oriented Network Scheduling.” *International Journal of Project Management* 13, no. 3 (1995): 187-194.

Gumbel, E. J. *Statistics of Extremes*. New York: Columbia University Press, 1958.

Harris, R. B. *Precedence and Arrow Networking Techniques for Construction*. New York: Wiley & Sons, 1978.

# Bibliography


Hulett, D. *Practical Schedule Risk Analysis*. Burlington: Gower Publishing Company, 2009.

Kahneman, D. *Thinking, Fast and Slow*. New York: Farrar, Straus & Giroux, 2011.

Kelley Jr., J. E. "Critical-Path Planning and Scheduling: Mathematical Basis." *Operations Research* 9, no. 3 (1961): 296-320.

Kelley Jr., J. E. and Walker, M. R. "Critical-Path Planning and Scheduling." *Proceedings of the Eastern Joint Computer Conference* 16 (1959): 160-172.

Kelley Jr., J. E., Walker, M. R., and Sayer, J. S. "The Origins of CPM: A Personal History." *PM Network* 3, no. 2, (1989): 7-22.

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

MacCrimmon K. R. and Ryavec, C. A. "An Analytical Study of the PERT Assumptions." *Operations Research* 12, no. 1 (1964): 16-37.

Malcolm, D. G., Roseboom, J. H., Clark, C. E., and Fazar, W. "Application of a Technique for Research and Development Program Evaluation." *Operations Research* 7, no. 5 (1959): 646-669.

# Bibliography


Moder, J. J. and Phillips, C. R. *Project Management with CPM and PERT*. New York: Reinhold Publication Corp., 1964.

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

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

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

Ponce de Leon, G. "Project Planning Using the Logic Diagramming Method." *AACE International Transactions*. Atlanta, GA, May 2008.

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

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

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

# Bibliography


Ponce de Leon, G. and Puri, V. “Removing the Early-Dates Bias in CPM Risk Analysis.” *AACE International Transactions*, 2016.

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

Stockhausen, M. "Examining Probabilities of Completion to Time/Cost Tradeoff: A Critical Analysis of PERT/CPM Procedures.” *Proceedings of University of Montana-Missoula National Conference on Undergraduate Research* (2010): 179-189.

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

Van Slyke, R. M. *Uses of Monte Carlo in PERT*. Memorandum RM-3367-PR. Santa Monica: RAND Corporation, 1963.

Weaver, P. “Why Critical Path Scheduling Is Wildly Optimistic!” Presented at PMI College of Scheduling 8th Annual Conference, San Francisco, CA, May 2011.

Wiest, J. D. and Levy, F. K. *A Management Guide to PERT/CPM*. Englewood Cliffs: Prentice-Hall, 1969.

# Bibliography

Williams, T. “Criticality in Stochastic Networks.” *Journal of the Operational Research Society* 43, no. 4 (1992): 353-357.

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

“A budget reserve is to contractors as red meat is to lions, and they will devour it.”

Attributed to **Bent Flyvbjerg** by **Kahneman** in *Thinking, Fast and Slow*



