An Algorithmic and Functional Dissection of Graphical Path Method (GPM®) Float, Drift, and Total Float in Comparison to CPM Total Float

Timothy Deane Mather, PMP, CTO, Managing Principal, PMA Consultants LLC
Dr. Liang Liu, Associate Professor & William E. O'Neil Faculty Scholar, Department of Civil and Environmental Engineering at the University of Illinois at Urbana-Champaign
John Zann, P.E, LEED AP, Principal, PMA Consultants LLC

Abstract

With the advent of a novel network scheduling technique, graphical path method, new paradigms are created which, when fully understood, offer planners and schedulers insights into and flexibility around designing and optimizing networks of activities. This paper will analyze GPM float, drift, and total float in comparison to CPM total float. Algorithms for both networking methods will be described and explained along with graphical explanatory figures detailing the comparative evaluation between CPM and GPM. This paper demonstrates how GPM provides planners with additional flexibility in network development and allows planners to solve previously intractable resource optimization problems.

The evolution of CPM and the advent of GPM

The Critical Path Method (CPM) was originally developed by Kelly & Walker in 1956.[i] At the time of its creation, CPM was envisioned as a tool for schedule optimization. In the early days of CPM the planning process involved developing a network of activities in a logical sequence and then calculating the schedule to determine activity dates, total floats, and the critical path. As CPM calculations migrated to personal computers (in lieu of hand calculations) planners were able to develop schedules with significantly more activities. Today, detailed construction schedules can contain more than 50,000 activities. This increase in the size of schedules has shifted the focus from the planning process to the scheduling process. It is now common practice to enter information directly into a CPM software tool without first planning the project. However, some organizations use a full wall planning session prior to scheduling the project to ensure that the planning step is not lost. This often involves several hundred sticky notes and a long sheet of plotter paper with a printed time scale. Once the activities have been planned they are then entered into a CPM scheduling tool for calculation. The Graphical Path Method (GPM) was developed, in part, to re-instill planning into the scheduling process.

Harris defines total float in CPM as “that time span in which the completion of an activity may occur and not delay the termination of the project”. Total float is calculated as the late date minus the early date for an activity. To calculate the early and late dates, a forward and backward pass must be performed. [ii]

Total float in GPM has the same meaning as total float in CPM but is derived differently. In order to properly describe total float in GPM we have to first define the constituent parts of total float. GPM Gap is link-specific and measures, for two related activities, days the predecessor may be delayed without delaying the successor. GPM Float measures days an object (activity, etc.) may slip from and/or extend beyond planned dates without necessarily causing an overrun of a pertinent contract time. While analogous to CPM total float, GPM float differs in that it is measured from planned dates rather than early dates. Drift measures days an activity may backslide and/or extend to an earlier position without necessarily forcing an earlier project start or earlier interim release date. Drift plus float is a constant, and equals total float.[iii]

GPM uses LDM a novel network diagramming method which combines elements of ADM and PDM

The Graphical Path Method uses the Logical Diagramming Method (LDM) in order to graphically represent the network. Figure 1 offers an annotated LDM diagram.

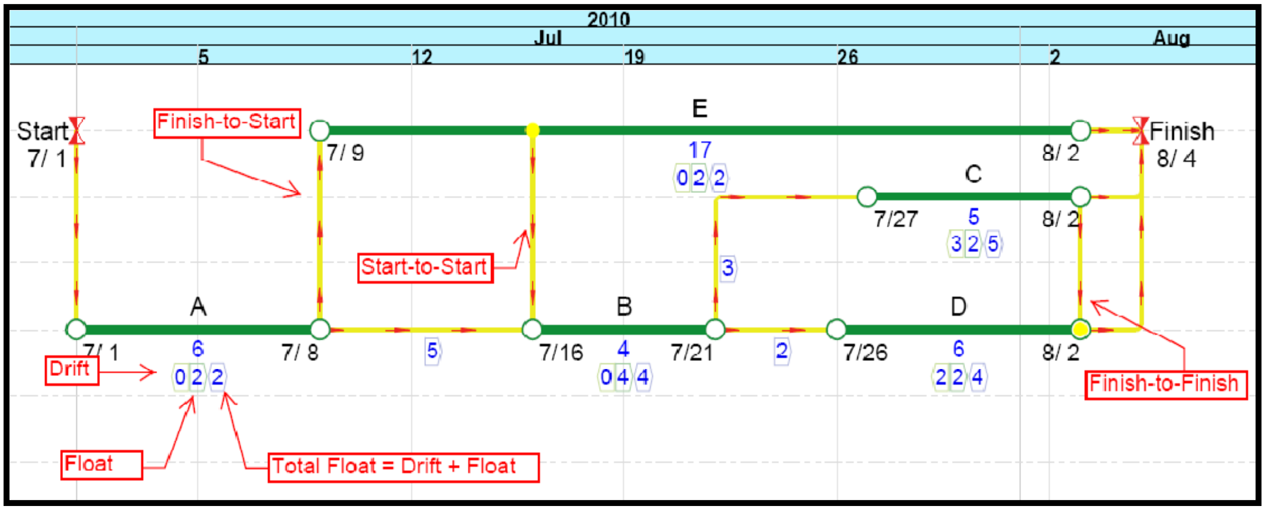

Figure 1 – Annotated LDM Diagram

Analyzing float calculations in CPM and GPM

In GPM, float is calculated as $Float_I = \min [Float_J + Gap_{I,J}]$, for all J Activities that are successors to Activity I. $Drift_I = \min [Drift_H + Gap_{H,I}]$, for all H Activities that are predecessors to Activity I. Total $Float_I = Drift_I + Float_I$.[iv]

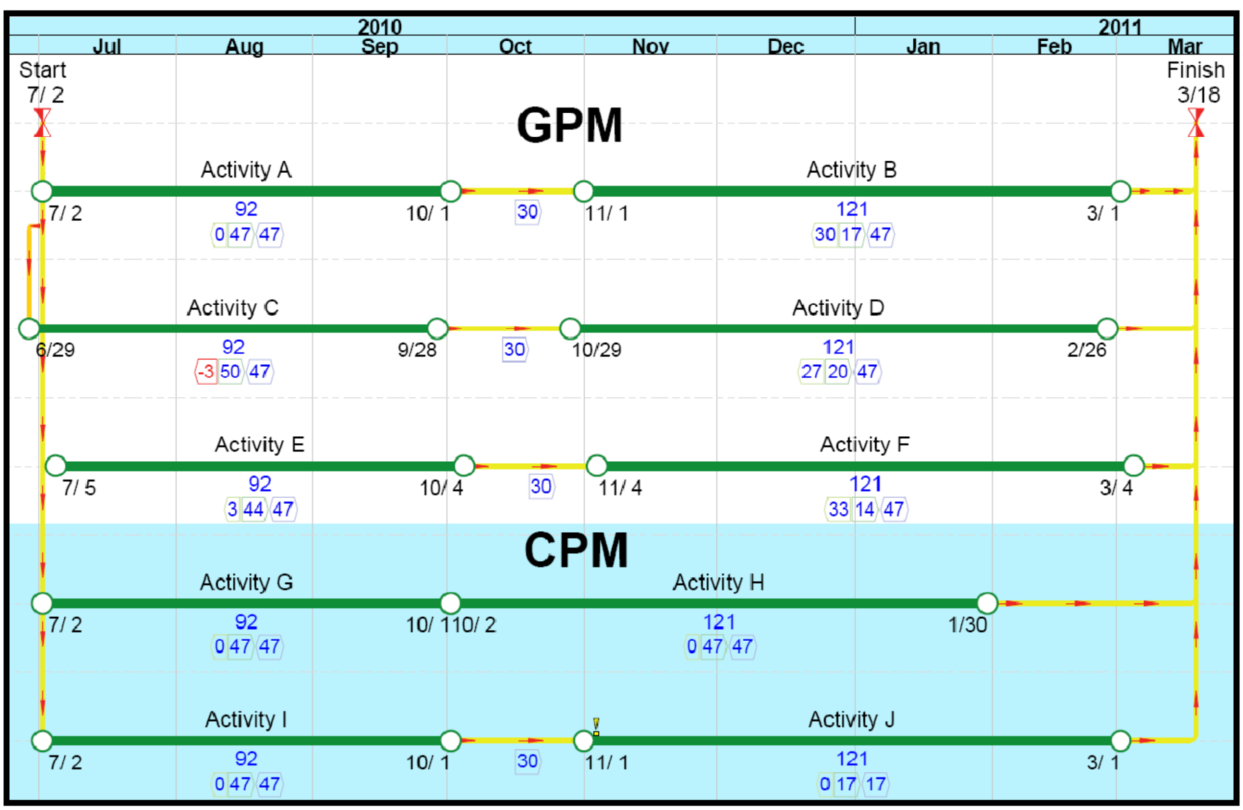

Figure 2 - Comparing GPM and CPM Float

In the example above, Activity A has a planned start date of 7/2 which coincides with the project start date. Activity B has a planned start date of 11/1, or 30 days after completion of Activity A. This 30 days difference is known as the gap. Activity B has a planned finish date of 3/1 which is 17 days prior to the project completion date. The powerfully simple mathematics of GPM tell us that:

$Drift_I$ = min [$Drift_H$ + $Gap_{H,I}$], for all H Activities that are predecessors to Activity I.
Drift Activity A = min[0 + 0] = 0: Drift Activity B = min[0+30] = 30
Drift Activity C = min[-3 + 0] = -3: Drift Activity D = min[-3+30] = 27
Drift Activity E = min[3 + 0] = 3: Drift Activity F = min[3+30] = 33

Total $Float_I$ = $Drift_I$ + $Float_I$
Total Float Activity A = 0 + 47 = 47: Total Float Activity B = 30 + 17 = 47
Total Float Activity C = -3 + 50 = 47: Total Float Activity D = 27 + 20 = 47
Total Float Activity E = 3 + 44 = 47: Total Float Activity F = 33 + 14 = 47

The CPM calculations involve a simple forward and backward pass to develop the early and late starts. Total Float is then calculated as $TF_{ij} = LFD_{ij} – EFD_{ij.}$ The results of these calculations are summarized below in Table 1.

Activity	ES	EF	LS	LF	Total Float
G	7/2/10	10/1/10	8/18/10	11/17/10	47
H	10/2/10	1/30/11	11/18/10	3/18/11	47
I	7/2/10	10/1/10	8/18/10	11/17/10	47
J	11/1/10	3/1/11	11/18/10	3/18/11	17

Table 1 – CPM Float

Both activities G and H have a total float of 47. However, the total float for J is only 17. This result occurs because CPM is predicated on calculated early start dates rather than planned dates. Because CPM is predicated on calculated early start dates there is no concept of drift in CPM. In a cascading conundrum of consequences: forcing an early start date later by setting a no earlier than (NET) constraint results in a loss of total float. Not that the planner has any less true flexibility in CPM than in GPM, after all, the planner that creates the constraint can also take the constraint away. While this works well in small demonstrative examples, in the real world with hundreds or thousands of activities in a network path, the altered float calculations downstream of the constraint can be difficult if not impossible to detect. The following section further highlights the paradox of the CPM's total float calculation using a small network example.

The Paradox of CPM's Total Float Calculation for Planned Activity Dates

(no application in the figures just LDM)

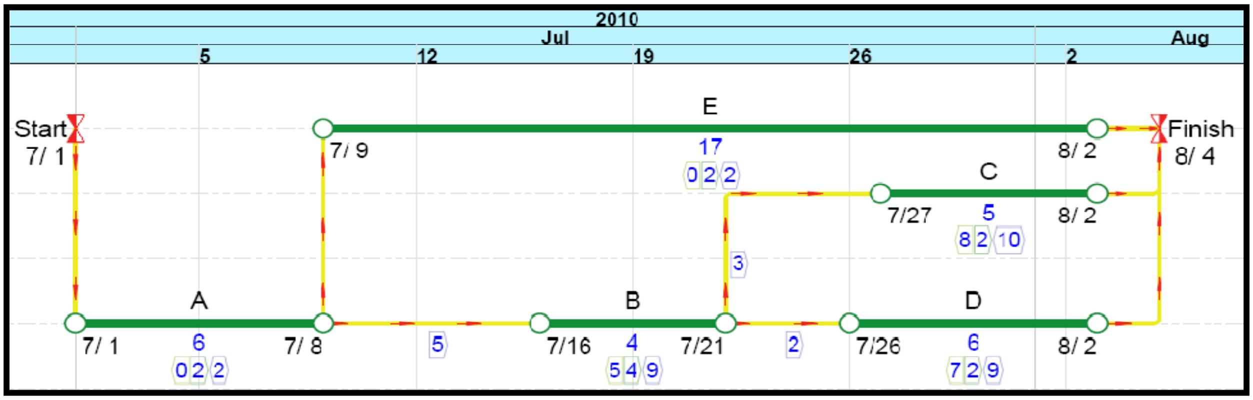

Figure 3 – GPM Example

Many experienced planners regularly place an activity between the early and late start dates. This allows planners to optimize resources and to tradeoff between time and cost without impacting the project completion. This practice, however, is often handicapped by the way CPM calculates the total floats. CPM calculates total floats based on backward and forward pass and ignores the network potential of GPM's Drift, or the time that an activity or a chain of activities could have gained by shifting predecessor activities early or moving predecessor activities in tandem.

In a network example shown in Figure 3, activities E, C, D all carry the same total floats of only 2 days according to the CPM calculation. Looking carefully, a seasoned planner will recognize that, in fact, activities C and D have a lot more flexibility to move around without impacting the completion of the project - as much as 5 days for C (2 days between 8/2 and the project completion date of 8/4 plus 3 days between activities B and C) and 4 days for activity D (2 days between 8/2 and the project completion date of 8/4 plus 2 days between activities B and D), assuming activity B's start and end dates remain fixed. A further investigation will reveal that there is a gap of 5 days between A and its successor B, which literally increases the actual total floats of activity C to 10 days, D to 9 days, and B to 9 days. This set of "real" total floats represents the true flexibility that planners should consider, rather than the mere 2 days reported by the traditional CPM float calculation. Note that the durations and total floats shown in Figure 3 are working days. For example, there are 5 working (7 calendar) days between the end of Activity A (July 8) and the start of Activity B (July 16).

GPM capitalizes on Drift and compensates for the error of CPM's total float calculation. In fact, the sum of drift and float is the real total float of an activity, drift is the amount that an activity can move to the left (towards the project beginning) and float is the amount that an activity can move to the right (towards the project end) without impacting the beginning and ending of the project. The calculated drift, float and total float, as shown in the three boxes below each activity in Figure 3, provide planners with accurate information which enables the optimization of resource utilization and leveling.

Resource Leveling Using Accurate (GPM) Total Float Inclusive of Drift

When drift is used in calculating the accurate total floats for activities, project managers can explore creative ways of balancing and leveling resource utilization of a project. Let's use the schedule in Figure 3 as an example and assume the following numbers of welders are needed for each activity.

Activity A: 10 welders
Activity B: 9 welders
Activity C: 8 welders
Activity D: 7 welders
Activity E: 6 welders

If we plot the resource profile, it will look like the one shown in Figure 3(a) with the highest daily resource demand of 21 welders to complete the tasks by 8/2 due to the concurrent resource demand of activities C (8 welders), D (7 welders) and E (6 welders). If only 15 welders were available per day, then the resource demands in Figure 3(a) would exceed the supply, as shown in red in the resource histogram. CPM-based algorithms will determine that the resource demand exceeds the available resources and, on the basis of the inaccurate total floats of 2 days for activities C, D, and E, these algorithms will erroneously extend the project completion date beyond 8/2 to keep the resource demand within the limit of 15 welders.

This miscalculation could have been avoided had the total floats for activities C and D been accurately calculated, which should be 10 and 9 days respectively due to the drifts of activities B, C, and D. With the correct total float information, planners can move activities B, C, and D simultaneously as shown in Figure 3(b) to level the peak resource demand to only 14 welders and still can complete the project on time on 8/2.

This example illustrates the importance of drift and the impact of accurate total float calculation. Planners need accurate total float information to fully utilize it in planning projects realistically such as resources and cost. Some may argue that experienced planners can spot such opportunities to shift activities despite the inaccurate total floats calculated by CPM algorithms; however, when the size of activities increases, most planners cannot find such information readily. The above illustrative examples were created using NetPoint™, a GPM® based planning system, which accurately calculates total floats inclusive of drifts and provides real-time interactive graphics for planners to experiment with what-if scenarios on resource leveling and optimization.

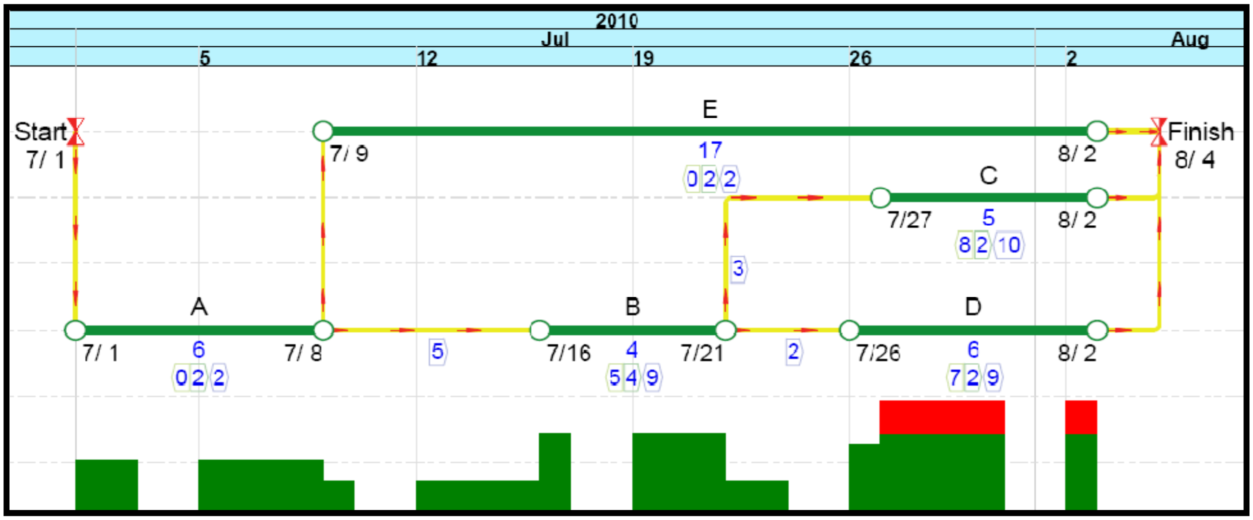

Figure 3(a) Original Resource Profile

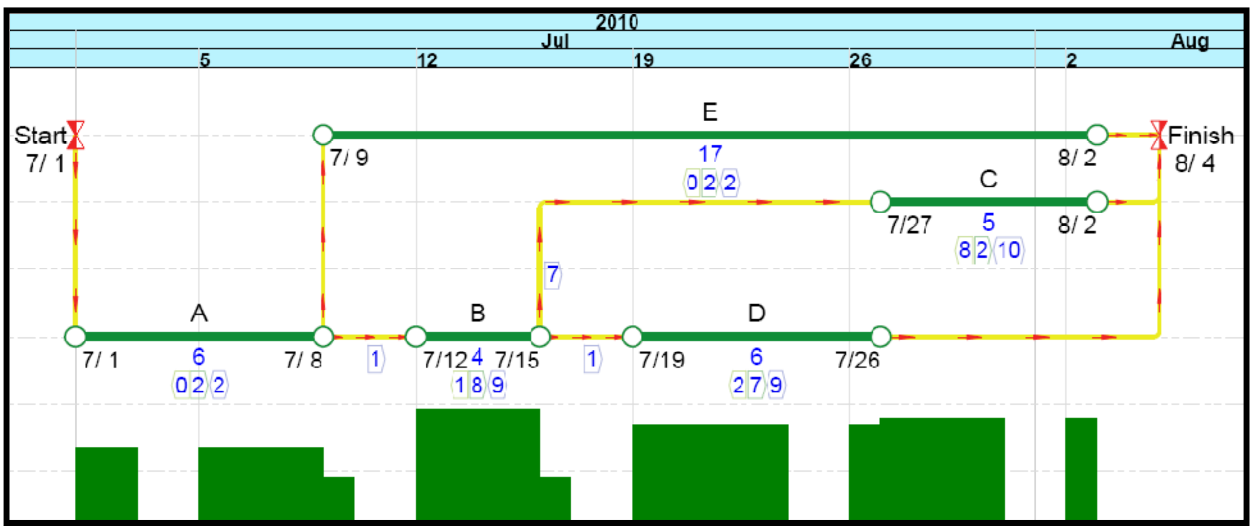

Figure 3(b) Adjusted (Leveled) Resource Profile Using Drift

Advantages to the planner of GPM and GPM enabled software

GPM provides additional flexibility in the planning process by accurately calculating and displaying drift and by accurately calculating total float as the sum of drift and float. This additional flexibility allows planners the ability to optimize network design reflecting the best possible choices for placement of activities related to the distribution of resources in time cost tradeoffs. GPM enables real time calculation of the entire network because GPM does not rely on a forward/backward pass in order to calculate floats and criticality. A further benefit of the GPM algorithms is the ability to calculate float and criticality left of the data date, as described in “The Forensic Scheduling Body of Knowledge Part I”.[v]

By using NetPoint to develop a GPM plan the planner gains the additional benefit of real time network updates. The NetPoint system is developed as an event/object driven tool. All current CPM software features an architecture which has three separate components; a database engine, a CPM engine, and a graphical display engine. Changes in the database are processed through the CPM engine and are then rendered through the graphics engine in order to update the network graphic. NetPoint does not use a database and invests control of the network in the actual graphical objects on the screen. Events, such as changes in logic or duration, cause each of the objects on the screen to react, in real time, to any changes which impact them, according to the rules of GPM. With GPM the planner is in complete control of a mathematically and algorithmically grounded graphical representation of their network model.

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[i] O'Brien, James Jerome, and Fredric L. Plotnick. "Chapter 1." *CPM in Construction Management*. New York: McGraw-Hill, 2006. 9-10.

[ii] Harris, Robert B. Precedence and Arrow Networking Techniques for Construction. New York: Wiley, 1978. 74-75.

[iii] Ponce de Leon, Gui, Forensic Scheduling Body of Knowledge *Part I, Ann Arbor Mi 2010*

[iv] Transactions PMI Global Congress 2010 Dr. Gui Ponce de Leon GPM® and Forensic Total Float
Nominated by the Scheduling Community of Practice
Session RSC04

[v] Ponce de Leon, Gui, Forensic Scheduling Body of Knowledge *Part I, Ann Arbor Mi 2010*