# Interpreting Logic Paths in Multi-Calendar Project Schedules

Examining Multiple Float Path Calculation in Oracle Primavera P6

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## 1.0 INTRODUCTION

Logical sequencing of work is at the heart of successful planning and scheduling of projects. In capital-intensive industries, project schedules for all but the simplest investment projects are developed using logic-sequencing techniques commonly referred to as the critical path method (CPM).[1] Within a traditionally-constructed CPM schedule, certain activities can be labeled *critical* because any delay among them leads directly to a delay of the project completion. The sequence of these activities is the *critical path* (*CP*). The critical path and its activities are traditionally characterized by the following attributes:

1. Any delay of a CP activity leads to project delay (i.e. *critical*);
2. CP activities have total float=0;
3. CP has the greatest sum of durations (i.e. longest path);
4. CP determines the early project completion date (i.e. driving path to project completion);
5. Day-for-day transmission of delay (from CP activity to project completion).

Of these five attributes, the second (TF=0) has been the easiest to confirm by computation, so *zero total float* is often used interchangeably with *critical*. In such cases, the other four attributes of the critical path are typically presumed. Unlike critical-path activities, non-critical activities can be delayed by some finite amount (their total float, or *TF*) without affecting the project completion. Those activities with only small values of total float are labeled *near-critical* since only a small slip in the activity could be allowed before further slip would delay the project completion. The logical sequences of these activities are *near-critical paths.*

For managers of complex projects, the schedule is a logic-driven model of the execution plan – a tool for coordinating resources, avoiding conflicts, analyzing risks, and forecasting potential outcomes. In these projects, the definition, analysis, and communication of critical- and near-critical paths is a basic contributor to project success. In the absence of various complications – i.e. for the traditionally-constructed CPM schedule – critical and near-critical paths can be illustrated using a bar chart that is organized by total float and sorted by date. Thus, in Figure 1, the critical path is comprised of those activities with total float = 0.00d: i.e. the start and finish milestones and the activities A, B, C, E, J, K between them.

[1] The *precedence diagramming method* (PDM) – a revised and expanded form of CPM that is generally implemented in modern scheduling software – is also commonly referred to as CPM.

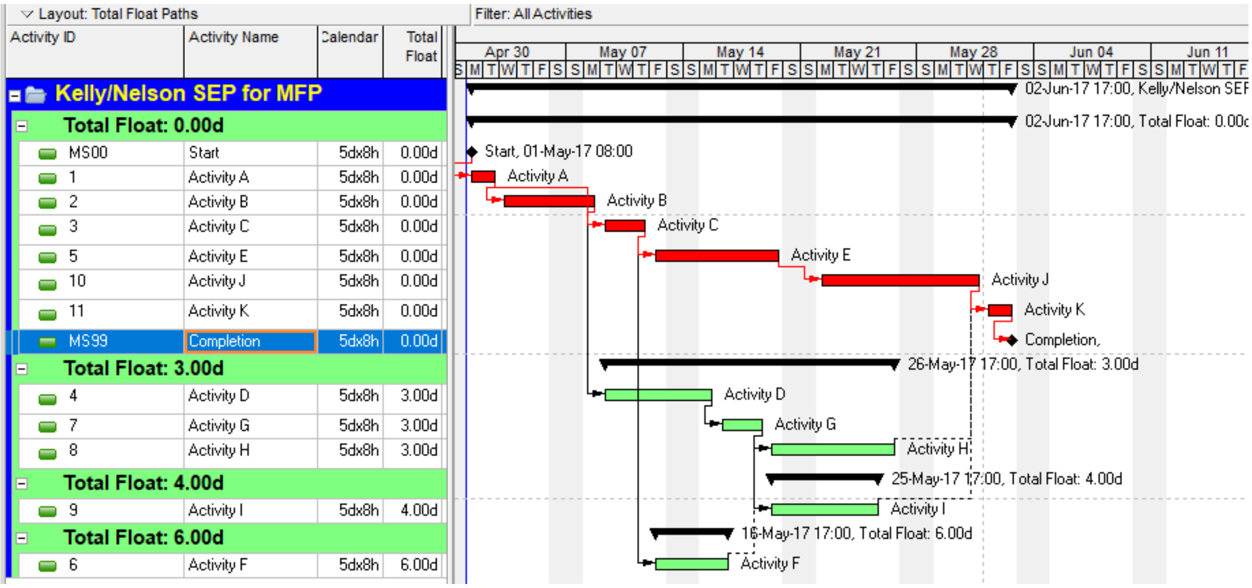

**Figure 1: K/N SEP. Classic Float Paths: Single-Calendar, Unconstrained, Org by TF (Crit~TF≤0)**

The first near-critical path is comprised of activities D, G, and H, with total float = 3 days (d). It is common to collectively refer to this sequence of activities as the *3-day float path*. Similarly, there is a 4-day float path and a 6-day float path. In fact, float path is formally defined as:

> *a theoretical sequence of activities that share the same float and thus act as a unit when considering project completion. The concept of float paths allows for summarization and simplification of work packages by allowing management or other stakeholders to visualize larger work packages than those used at the base work level. [1, p.54]*[2]

Even when it appears valid for determination of the critical and near-critical paths, total float and its corresponding float paths do not provide adequate information for management of complex project schedules. In particular, they do not support the differentiation of parallel/concurrent logic paths, even when they are critical or near-critical. Moreover, they are not useful for management of activity sequences that, though far from the critical path for the final project delivery, may be particularly risky or costly in terms of the coordination required. For these purposes, it has always been necessary to analyze and communicate *driving schedule logic*. [2, p. 507]

The *multiple float path* (MFP) calculation option provides methods for analyzing driving schedule logic in Oracle Primavera P6 (P6)[3]. Figure 1 was modeled after the simple example project of authors Kelly and Nelson, who previously explored aspects of MFP calculation in single-calendar project schedules. [3, p. 18] The present study was carried out to clarify the basis of MFP analysis and to identify areas of concern when interpreting MFP results

[2] The phrase "and thus act as a unit" presumes that two independent activity sequences can never share the same total float value, which may be unrealistic for large projects.

[3] Oracle® and Primavera® are registered trademarks of Oracle Corporation and/or its affiliates. Other names may be trademarks of their respective owners. Unless noted otherwise, the graphic and tabular calculations attributed to P6 have been generated using Primavera P6 Professional 18 Release 18.8.10 (Build 23448), with retained logic specified.

in projects with multiple calendars.

## 2.0 LOGIC PATHS AND DRIVING RELATIONSHIPS

In project scheduling, a network (logic) path is *"*any continuous series of connected activities in a project network diagram.*"* [1, p.80] Since any two selected activities within a schedule network may define the two ends of several distinct logic paths, the number of such paths can become exponentially greater than the number of activities in the project. Most mathematically-derived paths are trivial segments of longer paths, but some are important – like the critical path, near-critical paths, and float paths mentioned earlier. In particular, each of these important paths are governed by <u>driving logic relationships</u> from the first activity to the last activity in the path.

A driving relationship is "A relationship between two activities in which the start or completion of the predecessor activity determines the early dates for the successor activity with multiple predecessors. See also: Free Float." [1, p.45] Alternately, "A driving relationship is one that controls the start or finish of a successor activity."[4, p.297]

For practical purposes, a driving relationship is a <u>predecessor relationship</u> that prevents a successor activity's <u>early</u> start or <u>early</u> finish from being scheduled any sooner than it is. Since only early dates are relevant, it is possible to identify driving logic during the forward pass of the CPM analysis – as was done in P3.[4] [5, p. 31] It is also possible to identify driving relationships by evaluating the time intervals between the early dates of the related tasks, with zero-valued time intervals indicating driving relationships. These time intervals were originally described as "link lags" by Fondahl for FS relationships (~1962) and were subsequently established as "link gaps" by Ponce de Leon for other relationship types. [6, pp.4-5] In 2002, author Ron Winter introduced an alternate name, "slack", for the same intervals that he computed using add-in software for P3. [7, p. 6]

In P6, these intervals are called *relationship free float* (*RFF* or *Rel. FF*), and P6 uses them to identify driving relationships. Specifically, Oracle's documentation defines driving relationships using the general rule: "Rel. FF = Difference between internal dates and Driving flag is 'Y' if Free Float is 0, 'N' if it is not." [8, p. 1]. (The "Free Float" here must refer to the relationship, not the activity, so it is the same as Rel. FF, i.e. RFF.)

In the absence of any calendar reference to the contrary, the user would be expected to conclude that the RFF being referred to is the same-named parameter found in the relationship tables for each activity, but this is not correct. As shown in Figure 2 – where the weekend interval between the two activities contains no working time on the successor's (5-day) calendar and two days of working time on the predecessor's (7-day) calendar – P6 computes RFF according to the <u>predecessor</u> calendar.

[4] Primavera Project Planner™ ("P3") was P6's precursor in the market, though the latter was developed independently. Primavera® is a registered trademark of Oracle Corporation and/or its affiliates. Other names may be trademarks of their respective owners.

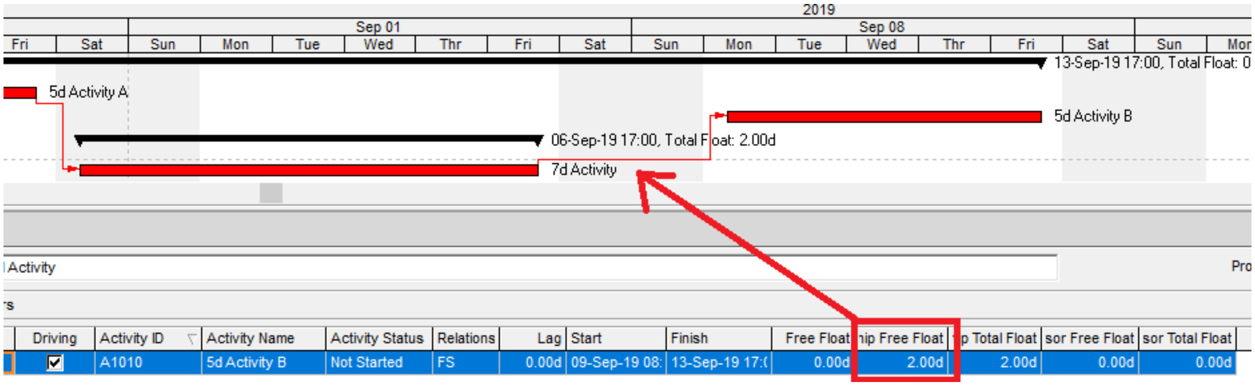


**Figure 2: Relationship FF Computed w/ Predecessor Calendar (Successor table shown)**

In fact, the definition of a driving relationship demands that there is no working time in the <u>successor's</u> calendar between the (early) scheduled predecessor and successor conditions (i.e. the "difference between internal dates" above.) In P6, this parameter is called *relationship successor free float (RSFF)*. Thus, in P6, the *driving* flag of a relationship directly correlates to RSFF=0, not RFF=0. The correlation is easily seen by examining predecessors and successors with different calendars as displayed in Figure 3. Unfortunately, it is easy to be misled by the existing Oracle documentation.

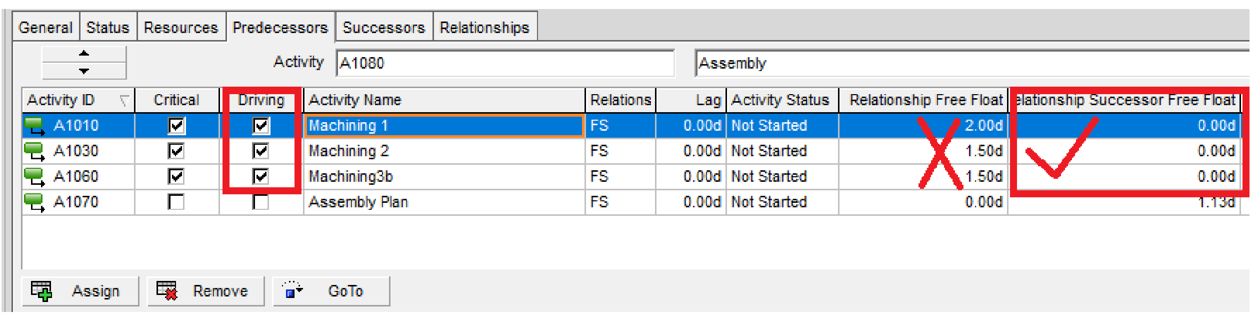


**Figure 3: P6 Relationship Floats and Driving Flags[5]**

Every incomplete activity in a properly constructed project schedule possesses its own driving logic path(s). Each such driving path begins with the data date (or with the constrained start of a driving path predecessor), and it extends to the activity's early finish date. The path for the last activity in the project represents a special case – the driving path(s) to project completion.

Finally, it is worth re-stating that driving logic can be defined – both by general convention and within the P6 application – solely by the forward pass and accompanying early dates. Total float and other consequences of the backward pass are not necessary for its definition. This is especially important when the meaning of total float is complicated by other factors.

## 3.0 TOTAL FLOAT COMPLICATIONS AND THE LONGEST PATH

In most modern project schedules, the identification of critical and near-critical paths using total float can be

[5] This figure presents data taken from the shop work example presented later in the paper.

confused by certain complicating factors (multiple calendars, late constraints, reported progress, etc.), which are well documented [9, pp. 3-7]. In Figure 4 for example, Activities B and D of the example schedule are re-assigned from a 5-day calendar to a 7-day calendar.

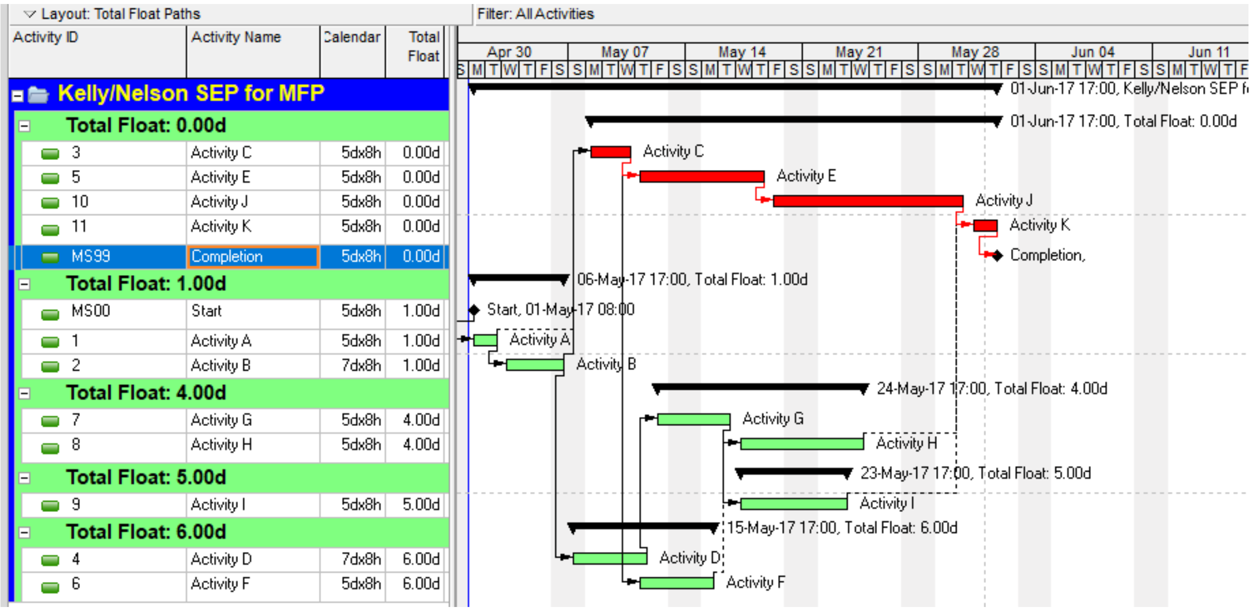


**Figure 4: K/N SEP. Two-Calendars, Unconstrained, Org by TF (Crit~TF≤0)**

Among other consequences, Activity B and its predecessors gain 1 day of total float – they could be allowed to slip 1 day with no impact on the Completion date. Moreover, the *critical* float path defined by TF=0 does not extend over the full duration of the project.

Next, Figure 5 demonstrates what happens when a late finish constraint is applied to Activity F, introducing negative float. A continuous *path* of critical activities now seems to exist, but it is no longer correlated to a single value of total float. In addition, the negative float on Activity F suggests a high degree of criticality, though it could still be substantially delayed without affecting the Completion date.

As shown, the complications introduced by these modern scheduling features lead to unresolvable conflicts among the traditional attributes of the critical path definition from the original CPM theory, which were listed earlier.

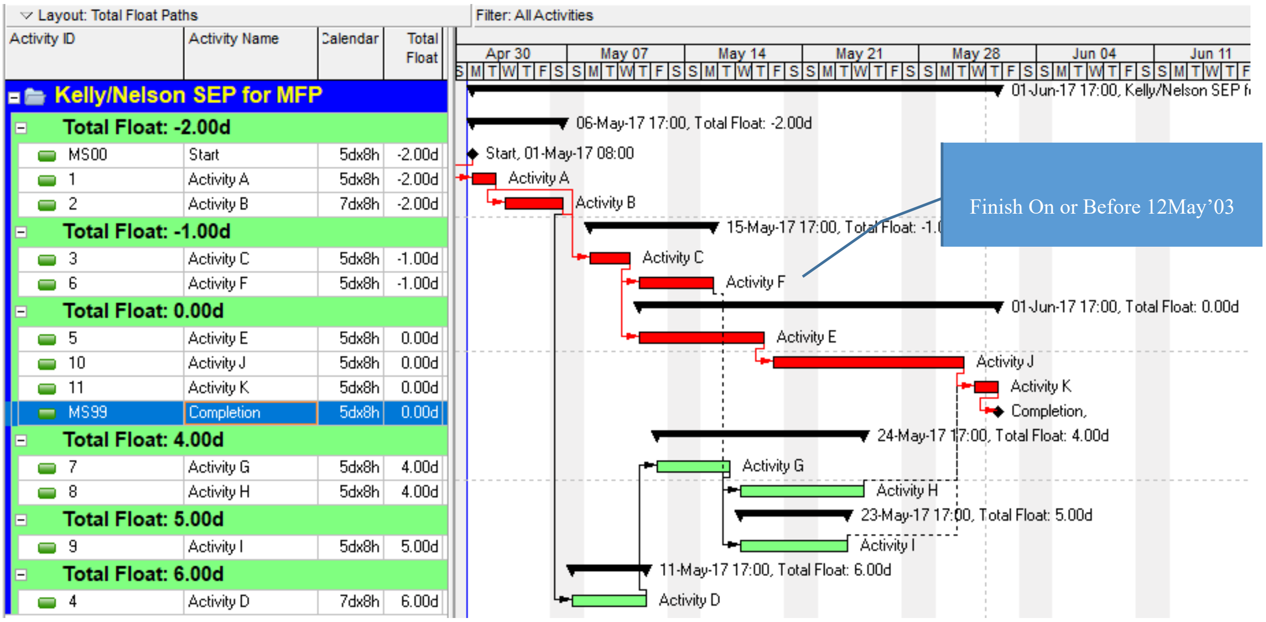


**Figure 5: K/N SEP. Two-Calendars, Constraint (Act f), Org by TF (Crit~TF≤0)**

P6's *Longest Path* (LP) method aims to bypass these conflicts by preserving only the fourth (NOT the third) of the five listed CP attributes, namely:

4. CP determines the early project completion date (i.e. driving path to project completion).[6]

The LP method traces driving logic during the backward pass, flagging all activities on the driving path to project completion as *critical*, regardless of their total float values. [10, p. 1] As shown in Figure 6, the method is effective in identifying the activities that determine the early completion date of the project, overcoming the complications of multiple calendars and late constraints. Unfortunately, its reliance on the binary *driving* flag means that *nearness* to the critical/Longest/driving path is not quantified. It therefore fails to identify near-critical paths.

Moreover, the Longest Path often includes activities that possess positive total float. Since these activities could be allowed to slip without delaying the project, they can give rise to substantial disputes when contract terms (or legal precedent) presume a different definition of criticality. Finally, the LP method is similar to the traditional total float-based methods in being unable to differentiate between parallel/concurrent critical paths or to readily identify driving logic paths that are not critical.

[6] Consistent with recommended practice, this paper uses "Longest Path" (with initial capitalization) when referring to the specific Primavera software feature – and the path identified by this feature – and uses "longest path" (lower case) when referring to the classical theory. [9, p3]

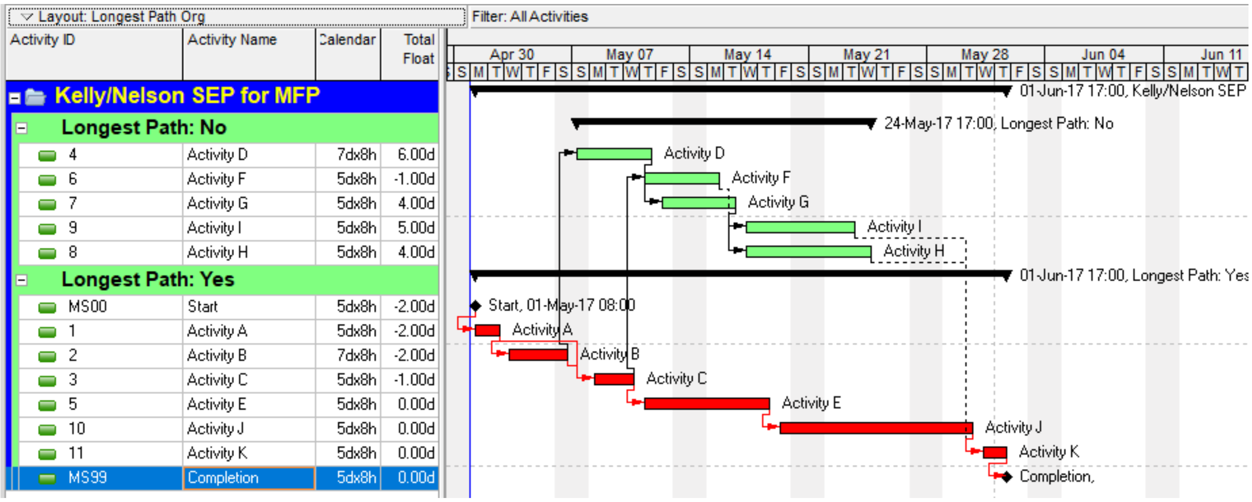

**Figure 6: K/N SEP. Two-Calendars, Constraint (Act f), Org by LP (Crit~LP)**

## 4.0 ENHANCED PDM: LOGIC-BASED CODING OF SCHEDULE ACTIVITIES

Beginning in the late 1990s, engineering firm Black & Veatch developed its *Enhanced* PDM (EPDM) algorithm for post-processing of P3 schedules, later working together with Primavera Systems to implement the new algorithm in P6. Author Scott Herold's foundational paper introduced several new relationship parameters into the CPM calculation [11, p. 5]:

- relationship early start (RES)
- relationship early finish (REF)
- relationship late start (RLS)
- relationship late finish (RLF)
- relationship total float (RTF).

The stated objective of Herold's paper was to illustrate the organization of CPM schedules into "as-scheduled critical float paths." This was needed to overcome the shortcomings of both the traditional (TF-based) float paths and the Primavera Longest Path algorithm in complex projects with parallel/concurrent logic paths, multiple calendars, and other complications.

In contrast to the LP approach, EPDM seemed intended to restore the preeminence of total float as the basis of *criticality* in multi-calendar projects. At the same time, the methodology could clearly differentiate paths of driving logic (i.e. activity sequences) using relationship metrics that compensated for the effects of multiple calendars on total float. Thus, multiple independent driving logic paths with the same total float value – whether a result of parallel/concurrent logic or of multiple late date constraints – could be easily differentiated. Conversely, a single driving logic path with multiple values of total float (due to calendar switching) could be easily consolidated.

The EPDM output that Herold proposed is summarized in Figure 7, where float path 0001 includes five activities with three different values of total float (due to calendar switching), and float path 2 constitutes a parallel logic branch of equal criticality.

| Act ID | Rem Dur | Cal ID | Early Start | Early Finish | Late Start | Late Finish | Total Float | RANK |
|---|---|---|---|---|---|---|---|---|
| 0001 | | | | | | | | |
| A-002 | 15 | 1 | 23JUN03 | 11JUL03 | 09JUN03 | 27JUN03 | -10 | 0001 |
| A-005 | 10 | 1 | 16JUN03A | 25JUL03 | 16JUN03A | 11JUL03 | -10 | 0002 |
| A-006 | 14 | 3 | 26JUL03 | 08AUG03 | 12JUL03 | 25JUL03 | -14 | 0003 |
| A-007 | 12 | 2 | 09AUG03 | 22AUG03 | 26JUL03 | 08AUG03 | -12 | 0004 |
| A-011 | 6 | 2 | 23AUG03 | 29AUG03 | 09AUG03 | 15AUG03* | -12 | 0005 |
| 0002 | | | | | | | | |
| A-012 | 0 | 3 | 01JUN03A | 14JUN03A | 01JUN03A | 14JUN03A | | 0001 |
| A-013 | 24 | 2 | 26JUL03 | 22AUG03 | 12JUL03 | 08AUG03 | -12 | 0002 |
| 0003 | | | | | | | | |
| A-009 | 21 | 3 | 26JUL03 | 15AUG03 | 14JUL03 | 03AUG03 | -12 | 0001 |
| A-010 | 12 | 3 | 16AUG03 | 27AUG03 | 04AUG03 | 15AUG03 | -12 | 0002 |
| 0004 | | | | | | | | |
| A-008 | 7 | 3 | 02AUG03 | 08AUG03 | 30JUL03 | 05AUG03* | -3 | 0001 |
| 0005 | | | | | | | | |
| A-004 | 5 | 1 | 09JUL03* | 15JUL03 | 07JUL03 | 11JUL03 | -2 | 0001 |
| 0006 | | | | | | | | |
| A-001 | 0 | 1 | 09JUN03A | 13JUN03A | 09JUN03A | 13JUN03A | | 0001 |
| A-003 | 5 | 1 | 30JUN03 | 04JUL03 | 07JUL03 | 11JUL03 | 5 | 0002 |

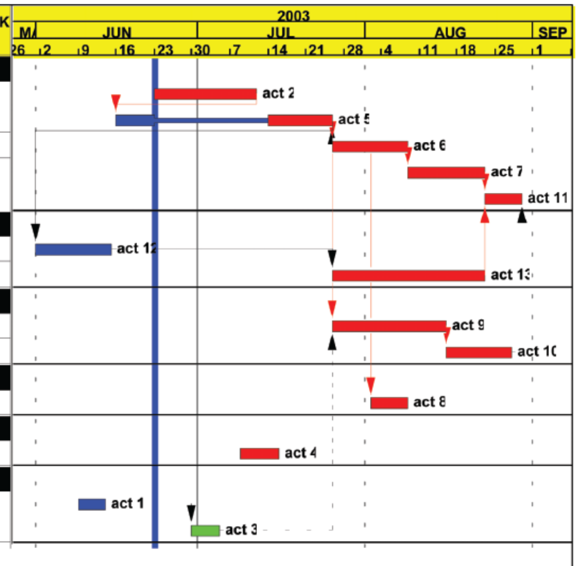


**Figure 7: EPDM Fig 3 – {P3} Grouped by "Path" and Sorted by "Rank" (Crit~ TF≤0)**

It is interesting to note that the lowest relationship total float found along each of these two paths is -14. In general, less-critical activities would always have higher-numbered float paths than more-critical activities, but the inverse was not necessarily true. A higher float path number would NOT indicate lower criticality when the two logic paths were parallel/concurrent.

Finally, the schedule summarized by Figure 7 includes two late constraints that cannot be met. The result is extensive negative total float, so ten of the eleven incomplete activities have been flagged as critical. Within this negative-float regime, the figure in the EPDM paper identified five float paths for critical activities. It is therefore not surprising that the terms *multiple critical float paths* and *multiple critical paths* – though not mentioned in the paper – became associated with the EPDM algorithm.[7]

## 5.0 EPDM IN P6: "CALCULATE MULTIPLE FLOAT PATHS" (MFP)

While publicly endorsing Black & Veatch's EPDM algorithm to "unravel the complexities of multiple critical paths" [12, p. 1], Primavera Systems integrated the *multiple critical path* advanced calculation option in P6 Version 5 (2005). [5, p. 32] The feature was subsequently renamed *multiple critical float paths* and then *multiple float paths* as seen in current versions of the software.

In general, MFP calculation options have been well-received among scheduling professionals. The authors of one construction-industry reference book declare, "For the project management team using multiple calendars, this one feature of Oracle Primavera P6 series software is alone worth the price of converting to this product." [2, p. 294]

[7] Other authors have referenced a (presumably similar) version of Herold's paper presented two months earlier, at the PMI College of Scheduling 2004 Annual Conference. That paper – alternately titled "Enhanced PDM" and "Multiple Critical Paths" in various references – has not been located for review, though the emphasis suggested by the latter title is clear.

A key recommended practice of AACE International also lists MFP analysis (using both of its earlier names) as one of three potential methods for identifying near-critical paths in project schedules. In particular:

> *Calculating multiple paths using the "free float" setting will result in a primary critical path that is identical to the critical path displayed when critical activities are defined as the longest path. All subsequent float paths will be increasingly distant float paths from the longest path. The amount of difference between float paths (or measure of near-criticality) is not presented but may be inferred using total float.* [9, p. 10]

In the most recent study, authors Kelly and Nelson performed a detailed review and analysis of MFP applications in single-calendar projects, demonstrating the consequences of the various user options and examining the calculations in detail. [3, pages 14-22] The analysis was supported by extensive reference to detailed support documentation and help files from Oracle. In general, the authors made the following key observations:

- In large, real-world projects, it is common to identify multiple, parallel branches of the Longest Path, which MFP analysis (either Total-Float or Free-Float option) differentiates into sequentially-numbered float paths. Existing Oracle documentation – and a casual reading of other authoritative documents that are based on it – suggest that only the first of these paths is truly ("the most") critical and that all the rest are incrementally less critical than the first. This is often incorrect; the float path numbering in such cases may be considered essentially arbitrary with respect to the potential impact on project completion.
- When the *total float* option is used, float path assignments are affected by late date constraints. As a result, some LP activities may be relegated to high-numbered paths, and some non-LP activities may be found on low-numbered paths. Thus, the *total float* option does not define a single critical path for a project with late date constraints.
- Activities with a*s-late-as-possible* (ALAP) constraints routinely appear as driving predecessors in P6. Consequently, ALAP-constrained activities can be over-represented in the lower numbered (i.e. *more critical*) float paths, displacing other activities to higher-numbered paths. (Applying filters to hide ALAP-constrained activities in float path layouts is a common, if imperfect, response to this issue.)
- The Oracle-documented tie-breaking rules for path tracing and path numbering in Free-Float analyses could be verified in a standard example project.

The authors concluded that MFP analysis is a useful tool for analyzing and understanding the logic of the schedule, but the repeated Oracle references to a single "most-critical" path and multiple "sub-critical" paths are incorrect. Such references permeate the documents and have been repeated by other respected authors. [3, 22] The authors further concluded, "(T)he longest path remains the correct definition of critical path, and total float values in a network without finish constraints remains the best way to gauge an activity's proximity to the critical path. While the float path values do provide useful information about the CPM network to analysts and schedulers alike, those values do not represent a ranked order of criticality."

## 6.0 MULTIPLE FLOAT PATH CALCULATION

The mathematical algorithm for calculating multiple critical paths is proprietary, and Oracle resources – including online help files and other technical documents available to users – provide minimal and sometimes contradictory information. Nevertheless, the following key points of understanding are evident from the available information, complemented by detailed evaluation of calculation results.

## *MFP Terms*

P6's MFP calculation treats logic relationships similarly to activities, but with their durations equal to the specified lags, and with all finish-to-start links. Consequently, early and late dates for each relationship can be calculated during the forward and backward passes. For relationships without lags, P6 uses the predecessor activity's calendar to compute early dates (RES, REF) during the forward pass, and it uses the successor's calendar to compute late dates (RLS, RLF) during the backward pass.[8] The calculations also incorporate the effects of the lag calendar (from P6's calculation options) when non-zero lags are introduced. With the relationship early and late dates established during the network calculations, float values can be computed.

As noted during the earlier discussion of driving logic, the interpretation of relationship float values is substantially affected by the calendar used in the float computations. P6 therefore computes relationship floats using both predecessor and successor calendars. In addition to early and late dates, each relationship possesses the following float values:

- relationship total float (RTF) = RLS - RES [using the predecessor's calendar][9]
- relationship successor total float (RSTF) = RLF - REF [using the successor's calendar][10]
- relationship free float (RFF) = (successor activity ES/EF) - REF [using predecessor's calendar]
- relationship successor free float (RSFF) = (successor activity ES/EF) - REF [using successor's calendar]

As implied by their common preface, all of these terms are properties of specific relationships, NOT of the two associated schedule activities. In general, activities can be associated with multiple relationships – and thus, multiple values of relationship floats. Consequently, a reference to an <u>activity</u> having or possessing a particular relationship float value is ambiguous.[11]

Since relationship float values are closely related to driving logic in project schedules, P6 uses them to identify and trace the driving logic float paths in the MFP calculation. The key difference between their usage is that the free floats (RFF and RSFF) are associated with driving logic to early dates only, while the total floats (RTF and RSTF) reflect less-conventional bi-directional driving logic; i.e. to both early and late dates, as spelled out by Herold in the

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[8] Oracle defines RES, REF, RLS, and RLF with reference to "the relationship calendar" – a term that is not otherwise defined. [13, p. 3] In practice, the dates for zero-lag relationships behave as described here. For positive-lag relationships, then only REF and RLS are constrained by the "relationship lag calendar" schedule option.

[9] Oracle defines relationship total float as, "The Total Float on the relationship. Calculated as Relationship Late Start – Relationship Early Start on the successor's calendar...." [13, p. 3] The last part appears incorrect. As easily inferred from Figure 2, RTF is computed using the predecessor's calendar, not the successor's.

[10] Oracle documentation states, "The relationship successor Total Float is the total float of the potential successor activity if that specific relationship was the driving relationship, using the successor's calendar..." [13, pp. 3-4] – though how this would be calculated for non-driving relationships is not clear. Harold's paper derived and used a similar term, "resulting successor TF" (RSTF), for the same purpose. Essentially, Harold's RSTF = RLF - REF [using the successor's calendar].

[11] E.g. "…the module determines which predecessor activity has the most critical Relationship Total Float on the backward pass." [13, p. 2]

EPDM paper. [11, pp. 5-6] Adapting Herold's description to P6 terminology, a relationship is bi-directionally driving when:

- RTF = $TF_{(predecessor\ activity)}$ (Backward driving, i.e. predecessor's late dates are driven by the relationship), AND
- RSTF = $TF_{(successor\ activity)}$ (Forward driving, i.e. successor's early dates are driven by the relationship. As noted earlier, such relationships also have RSFF=0).

The actual application of the terms in identifying and tracing multiple float paths in P6 depends on the options selected by the user.

### *Float Path Numbering*

The primary artifact of the MFP calculation is the assignment of individual activities (and some relationships) to specific numbered float paths. Each float path is calculated in two steps. First, the float path is initiated by a starting (or *seed*) relationship. Then the rest of the float path is defined by tracing driving logic backward (and sometimes forward) from the seed relationship, assigning the traced activities and relationships to the numbered float path. The trace ends (in a given direction) when the activity being examined has no driving relationships with any unassigned activities.

P6 calculates these numbered float paths sequentially and without overlap, such that the calculation of float path 2 cannot commence until float path 1 has been completely defined. Unlike recursive logic tracing algorithms used in other tools, MFP does not explicitly address the logic junctions between paths. When an activity with multiple driving relationships is encountered during a float path trace, only one of the relationships is included in the trace. The others are relegated to compete for seeding subsequent float paths. This approach makes MFP computations very efficient. It also leads to ambiguous float path definitions under certain (typically multi-calendar) conditions, to be discussed later in this paper.

### *Float Path Order*

A secondary artifact of the MFP calculation is the unique sequence-numbering of the individual activities in each float path. P6 calls this sequence numbering the *float path order* of the activity. For each path, the single activity with no unassigned driving predecessors is the first activity in the logical sequence; it has a float path order of 1. The single activity with no unassigned successors is the last activity in the logical sequence; it has the highest float path order, which equals the total number of activities in the path. Float path orders for the intervening activities are assigned accordingly. Since P6 reserves *float path order* to the sequence of tasks within a particular float path, any use of the same or similar term in reference to the sequential numbering of float paths would be ambiguous.[12]

[12] E.g. "**When Using the Total Float Option:** There are new key fields used to determine *multiple float path order*…." [13, pp. 2-3] Although the language of this document is vague, this section's two references to "float path order" appear to address path seeding (i.e. *float path* sequential values), not tracing.

### *Display of MFP Results*

The following display techniques – typically saved as a single layout in P6 – are generally useful for interpretation and communication of MFP results in multi-calendar project schedules:

- Within a *Gantt chart* top view, activities are grouped by *project* and then by *float path*. Then within each float path the activities are sorted by *float path order*.
- With the activity *details* shown on the bottom pane, the columns of the predecessor and successor tables are customized to include all of the *multiple float path* fields. (The float fields are most useful.) Right-justification facilitates condensing the columns while still distinguishing the necessary information.
- Often for production reports, a filter is applied to display only activities with *float paths* assigned or with *float paths* below a specified value. (For clarity, no such filters are applied here.)

## 7.0 MFP CALCULATION OPTIONS

As shown in Figure 8, multiple float paths may be calculated using *total float* or *free float* options, and a key ending activity may be specified (or omitted) for each option. These combinations lead to four basic calculation methods. (Only the first of these – total float with no ending activity – was demonstrated in the EPDM paper.)

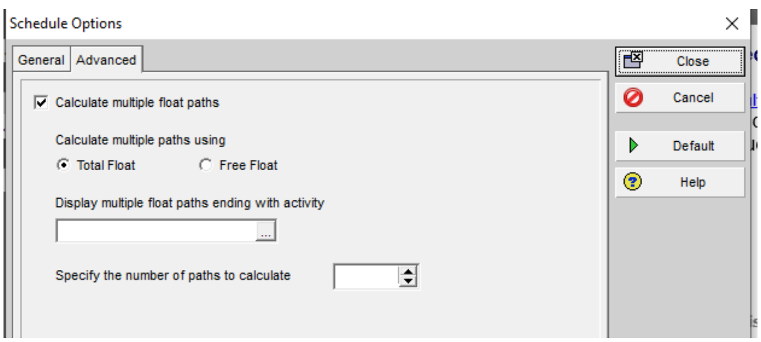


**Figure 8: MFP Options Dialog**

### *Number of Paths to Calculate*

The four calculation methods may each be truncated by specifying a limit on the number of paths to calculate. This number has no impact on the seeding or tracing of individual float paths at or below the limit. Activities that would normally be assigned to float paths above the limit simply have no float path assigned.

Since float path assignments can be ambiguous, any entry here increases the risk that important float paths may be missed or overlooked. Unless the schedule is so large that truncating the analysis is necessary to provide reasonable computation time (a situation never encountered by the authors), it is better to leave this option blank, and use appropriate filtering to de-clutter the output.

### *Ending Activity*

When an *ending with* activity is specified, then the entire MFP analysis including float path assignment is restricted to activities and relationships that are path-predecessors of the specified activity. (These can be flagged during the backward pass). This option can be useful for validating the logical consistency of the schedule. E.g., specifying one of the project's key completion milestones as the ending activity (with no limit on the number of paths) quickly identifies those activities *with no float path* that:

- Have no successors at all; or
- Have successors but have been logically disconnected from the completion plan for the milestone.

The fact that any of these activities could be allowed to slip indefinitely without delaying the key completion milestone often indicates inadequate logic. Further interpretation of the ending activity depends on whether the *total float* or *free float* option is selected.

### *Total Float Option*

*Choose this option to identify critical paths based on the total float of activity relationships…. [14, p.1]*

The *total float* option reflects P6's implementation of the Enhanced PDM algorithm outlined in Herold's paper. It is characterized by the following key attributes:

- Total float is accepted as the sole indicator of an activity or relationship's logical importance, or criticality.
- Any driving logic path whose activities have different values of total float due to calendar switching is consolidated into a single float path.
- Parallel logic paths – with or without calendar-switching effects – are segregated into separate float paths.
- Float path 1 is seeded by the logic relationship with the lowest relationship total float in the project. (As a pre-qualifier, this relationship must be a path-predecessor of the specified ending activity, and some other tie-breakers apply.)
- Each successive *float path* is seeded by a pre-qualified relationship with the lowest relationship total float. (Some tie-breakers apply.)
- Once seeded, each *float path* is defined by tracing bi-directionally driving logic backward AND forward from the seed relationship.
- When grouped and sorted as suggested earlier, total float values generally increase as float path numbers increase. Logical connections between float paths do not follow a predictable pattern, however, especially in the presence of multiple calendars and intersecting logic.
- The primary impact of specifying an ending activity is the exclusion of activities and relationships that are not path predecessors of the specified activity. Float path 1 (and adjacent concurrent float paths) may reliably reflect the driving path to the specified activity only when that activity controls the late dates of all its predecessors (i.e. there are no intersecting logic paths or late constraints.)

Overall, the *total float* option seems most useful for two very different use cases:

- Prioritizing competing workflows in extremely complex schedules involving multiple calendars, intersecting logic paths, and multiple constrained milestones of equal value. Such projects are relatively rare.

- Defining near-critical paths in complex schedules with multiple calendars and intersecting logic paths, but with only a single constrained completion milestone. Such schedules are common in simple construction projects. In P6, the critical path of such projects is typically defined by Longest Path.

### *Free Float Option*

*Choose this option to define critical float paths based on longest path…. [14, p.1]*

Like P6's Longest Path criterion for criticality, the *free float* option defines float paths by backward-tracing through driving relationships. It is characterized by the following key attributes:

- *Relationship free float* and *relationship successor free float* are accepted as the primary indicators of an activity or relationship's logical importance, or criticality. Total float is generally ignored.
- As for the previous option, any driving logic path is consolidated into a single float path regardless of total float values.
- As for the previous option, parallel driving logic paths are segregated into separate float paths.
- If an ending activity is specified, then float path 1 is seeded by the specified activity. If no ending activity is specified, then float path 1 is seeded by the open-ended activity with the lowest free float.[13]
- Each successive float path is seeded by a pre-qualified relationship with the lowest relationship free float (RFF).[14] (Some tie-breakers apply.)
- Once seeded, each float path is defined by tracing traditional driving (i.e. early-dates) logic backward from the seed relationship. Such driving logic is defined by relationship successor free float (RSFF=0).[15]
- When grouped and sorted as suggested earlier, each float path typically appears as a branch extending backward from one of the paths above it.
- As a result of the differing criteria for seeding (RFF) versus tracing (RSFF) driving logic paths, the parallel branches of driving paths in projects with multiple atypical calendars can be separated and relegated to much higher-numbered float paths than expected.
- The primary impact of specifying an ending activity is the explicit definition of the end-point of the driving and near-driving logic paths being traced. Then float path 1 (and concurrent float paths) reliably reflect the driving path to the specified activity under most practical conditions.

Overall, the *free float* option can provide clear, well-supported results in most cases, and it seems to be preferred by most users. Its use seems particularly valid for the following cases:

- Identifying the driving and near-driving logic paths to a primary ending-with activity – e.g. a Substantial Completion milestone – that defines the project's performance period but *is not* the final activity in the schedule.
- Identifying the driving and near-driving logic paths to intermediate project milestones or other important activities.
- Together with Longest Path, identifying the distinct, parallel logic branches that drive the project's completion date.

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[13] Or more correctly – in both cases – an imaginary successor relationship following the activity.

[14] In the absence of an ending-with activity, then the imaginary successor relationship following each open-ended activity competes to seed the successive float paths.

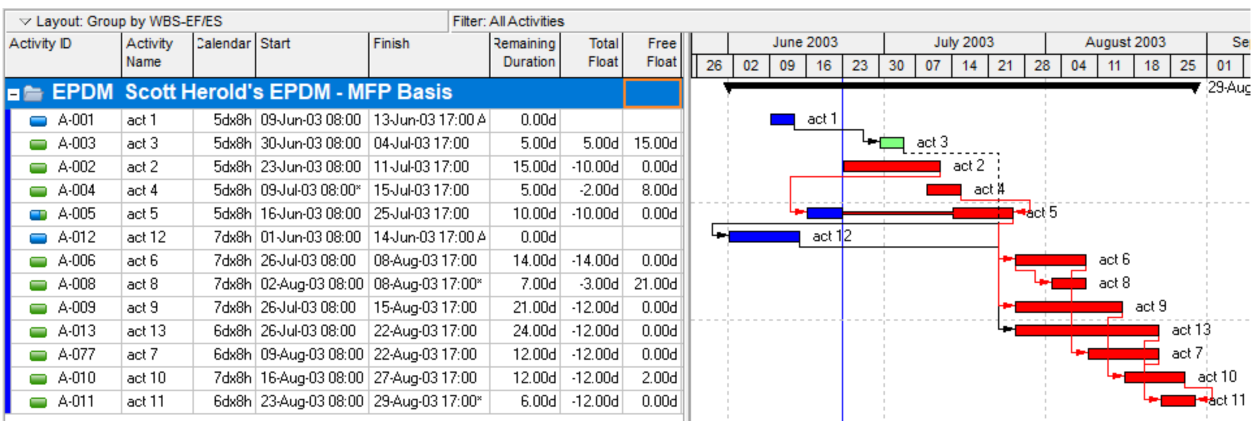
[15] A different procedure is described in the documentation: "1. Free Float is calculated on the activity 2. Next it will look at the predecessor activities to see if FF and RSFF match 3. Once it finds a predecessor where the RSFF and FF are different the first path ends there 4. Once that path is determined it looks at the next activity with the least FF and starts again." [13, p. 3] This is unreliable, as P6 behavior in the shop test example below does not match.

- Together with Longest Path, identifying critical and near-critical paths (to a key completion milestone) in complex schedules with multiple calendars, intersecting logic paths, AND multiple late constraints. Unlike the previous option, the *nearness* to the critical path is not readily defined by total float. Manual reference to the relationship free floats of selected relationships is necessary.

## 8.0 SUMMARY OF MFP EXAMPLES AND INTERPRETATIONS

### *EPDM Example, From Herold*

The original EPDM example of Figure 7 – re-created in Figure 9 using P6 – is useful in that it illustrates a number of the difficulties that EPDM and P6's MFP calculation were designed to address. It depicts a project schedule with multiple calendars, intersecting logic paths, a single unmet late date constraint, and out-of-sequence progress. With critical activities flagged according to TF≤0, virtually all remaining work is *critical*. With the three different activity calendars, two weeks of negative float could correspond to -10 days, -12 days, or -14 days, depending on the activity's calendar. Thus, an activity with -10 days of total float on a 5-days/week calendar is just as critical as another activity with -14 days of float on a 7-day calendar. Another activity with -12 days of total float might be more or less critical than either of the first two depending on its calendar. As such, the use of total float to indicate either membership on or nearness to the critical path is not particularly useful.


Layout: Group by WBS-EF/ES — Filter: All Activities

| Activity ID | Activity Name | Calendar | Start | Finish | Remaining Duration | Total Float | Free Float |
|---|---|---|---|---|---|---|---|
| EPDM | Scott Herold's EPDM - MFP Basis | | | | | | |
| A-001 | act 1 | 5dx8h | 09-Jun-03 08:00 | 13-Jun-03 17:00 A | 0.00d | | |
| A-003 | act 3 | 5dx8h | 30-Jun-03 08:00 | 04-Jul-03 17:00 | 5.00d | 5.00d | 15.00d |
| A-002 | act 2 | 5dx8h | 23-Jun-03 08:00 | 11-Jul-03 17:00 | 15.00d | -10.00d | 0.00d |
| A-004 | act 4 | 5dx8h | 09-Jul-03 08:00* | 15-Jul-03 17:00 | 5.00d | -2.00d | 8.00d |
| A-005 | act 5 | 5dx8h | 16-Jun-03 08:00 | 25-Jul-03 17:00 | 10.00d | -10.00d | 0.00d |
| A-012 | act 12 | 7dx8h | 01-Jun-03 08:00 | 14-Jun-03 17:00 A | 0.00d | | |
| A-006 | act 6 | 7dx8h | 26-Jul-03 08:00 | 08-Aug-03 17:00 | 14.00d | -14.00d | 0.00d |
| A-008 | act 8 | 7dx8h | 02-Aug-03 08:00 | 08-Aug-03 17:00* | 7.00d | -3.00d | 21.00d |
| A-009 | act 9 | 7dx8h | 26-Jul-03 08:00 | 15-Aug-03 17:00 | 21.00d | -12.00d | 0.00d |
| A-013 | act 13 | 6dx8h | 26-Jul-03 08:00 | 22-Aug-03 17:00 | 24.00d | -12.00d | 0.00d |
| A-077 | act 7 | 6dx8h | 09-Aug-03 08:00 | 22-Aug-03 17:00 | 12.00d | -12.00d | 0.00d |
| A-010 | act 10 | 7dx8h | 16-Aug-03 08:00 | 27-Aug-03 17:00 | 12.00d | -12.00d | 2.00d |
| A-011 | act 11 | 6dx8h | 23-Aug-03 08:00 | 29-Aug-03 17:00* | 6.00d | -12.00d | 0.00d |



**Figure 9: EPDM – EF/ES Organization, Constraint (act 11) (Crit~TF≤0)**

The schedule was analyzed using P6's MFP calculation in both the free float mode and the total float mode. The results, discussed in more detail in the Appendix, show the use and limitations of these options, along with some possible interpretations of the data. Each calculation mode identifies six unique float paths in the schedule, including two parallel branches of the critical (Longest) path. While the driving relationships along each float path generally agree in both modes, the distribution of parallel/concurrent activities between float paths do not. Moreover, the relative sequencing of non-critical float paths is different. These differences can be attributed to the alternate rules for seeding and tracing new float paths, as illustrated in the Appendix.

The MFP calculation under the *total float* option is nearly identical to the *pure float method* EPDM output of Figure 7, suggesting that the two algorithms are at least similar. One notable exception is that the MFP analysis <u>excludes</u> completed activities, whereas the analysis from the EPDM paper (which used P3) included them. It is also important to note that, when an ending-with activity is specified, then the MFP calculation completely excludes all activities and relationships that cannot be traced backward from that activity. If, as is the case with this example, the total float values of activities and relationships are controlled by a constraint that is not applied to the ending-with activity, it is difficult to discern a relationship between the total float values and the driving relationships. The result demonstrates why the *total float* option with an ending activity is rarely useful and can be misleading.

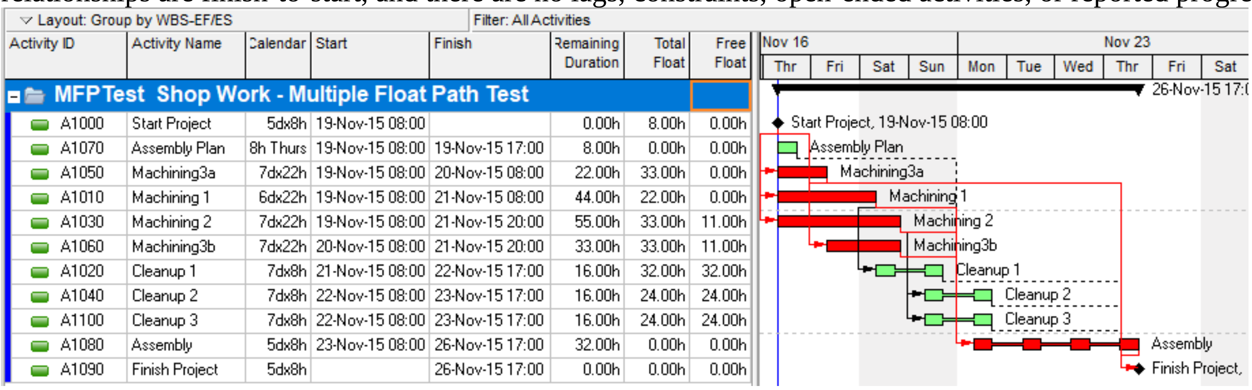
This example demonstrates that both calculation modes can be useful for clarifying critical and near-critical logic paths in a schedule that is complicated by multiple calendars, negative float, and out-of-sequence progress. In some cases, total float may be controlled by a small number of rigidly enforced late date constraints, and violation of any single constraint is equally unacceptable to the project team. In these cases, MFP analysis using the *total float* option and NO ending-with activity may be most useful for prioritizing the remaining work. With or without an ending activity, however, the *total float* option is not useful for defining the driving/controlling logic for activities away from the critical path. In contrast, the *free float* option is generally preferred for defining the driving logic to a specific ending activity, especially one that is far from critical.

Finally, it is confirmed that the suggestion of a single *most critical* path followed by a number of *sub-critical* paths is not supported in general, even in the project example that seems to have originated this particular terminology. For both calculation options, it is important to remember that the detailed seeding and tracing of float paths are governed primarily by relationship floats, NOT activity floats. As a result, inspection of activity total float and free float fields in a typical MFP output plot may sometimes be misleading. Reference to the detailed relationship parameters, though tedious, is absolutely necessary to determine whether one float path is in fact *more critical* than the next.

### *Unaligned Calendars – Shop Work*

Although it provides a good demonstration of the MFP calculation in a project with simple and well-aligned calendars, the EPDM example does not reflect the full gamut of calendar variations observed in modern project schedules. In particular, the consequences of calendar switching among the 5-day, 6-day, and 7-day calendars used in the EPDM example are manifested almost exclusively in total float (rather than free float) values. Other calendar types in construction include 24-hour/curing; weather/rain (both distributed and lumped); day/night shift; calendars with annual/seasonal shutdowns for social or environmental restrictions; and calendars with specific black-out times for external events. In other industries, resource-driven activities are used to incorporate the planned holidays and vacations times of individual resources; and calendars for rare, periodic work periods like board meetings are used to accurately model the potential schedule impact of missing such approval windows. Such calendars are often not well-aligned with the typical work-week calendar, and there is a greater chance of non-intuitive float-switching along driving logic paths. Consequently, the depiction of parallel/concurrent driving logic paths can be confused.

Figure 10 presents the complexities of such unaligned calendars, using a simple Shop Work example. The core work of this project involves three parallel machining operations followed by a simple assembly operation. All relationships are finish-to-start, and there are no lags, constraints, open-ended activities, or reported progress.




| Activity ID | Activity Name | Calendar | Start | Finish | Remaining Duration | Total Float | Free Float |
|---|---|---|---|---|---|---|---|
| MFPTest Shop Work - Multiple Float Path Test | | | | | | | |
| A1000 | Start Project | 5dx8h | 19-Nov-15 08:00 | | 0.00h | 8.00h | 0.00h |
| A1070 | Assembly Plan | 8h Thurs | 19-Nov-15 08:00 | 19-Nov-15 17:00 | 8.00h | 0.00h | 0.00h |
| A1050 | Machining3a | 7dx22h | 19-Nov-15 08:00 | 20-Nov-15 08:00 | 22.00h | 33.00h | 0.00h |
| A1010 | Machining 1 | 6dx22h | 19-Nov-15 08:00 | 21-Nov-15 08:00 | 44.00h | 22.00h | 0.00h |
| A1030 | Machining 2 | 7dx22h | 19-Nov-15 08:00 | 21-Nov-15 20:00 | 55.00h | 33.00h | 11.00h |
| A1060 | Machining3b | 7dx22h | 20-Nov-15 08:00 | 21-Nov-15 20:00 | 33.00h | 33.00h | 11.00h |
| A1020 | Cleanup 1 | 7dx8h | 21-Nov-15 08:00 | 22-Nov-15 17:00 | 16.00h | 32.00h | 32.00h |
| A1040 | Cleanup 2 | 7dx8h | 22-Nov-15 08:00 | 23-Nov-15 17:00 | 16.00h | 24.00h | 24.00h |
| A1100 | Cleanup 3 | 7dx8h | 22-Nov-15 08:00 | 23-Nov-15 17:00 | 16.00h | 24.00h | 24.00h |
| A1080 | Assembly | 5dx8h | 23-Nov-15 08:00 | 26-Nov-15 17:00 | 32.00h | 0.00h | 0.00h |
| A1090 | Finish Project | 5dx8h | | 26-Nov-15 17:00 | 0.00h | 0.00h | 0.00h |

**Figure 10: Shop Work – EF/ES Organization, No Constraint (Crit~LP)**

The primary complication is that the eleven activities employ five different calendars. The final assembly and sign off of the finished product are performed by resources working a normal 5-day work week, but the planning, machining, and cleanup activities are all performed according to calendars whose available working hours – especially spanning the weekend – are substantially more or less than the standard. For example, all four machining activities finish at various times over the weekend; they are all included on the Longest Path because each of them is a driving predecessor of the subsequent assembly activity. The assembly planning activity is not on the Longest Path, but one day of delay – according to its own calendar – could delay the project for a week. The figure demonstrates no clear correlation between activity float values and membership on the Longest Path. A simple construction example demonstrating similar issues might involve mixed concrete and asphalt construction spanning a winter paving shutdown period – perhaps with monthly meetings of a change-review board added into the mix.

As detailed in the Appendix, six or seven float paths were identified from this schedule using the free float and total float modes, respectively. The majority of the float paths were comprised of only a single activity each. Most importantly, in both modes non-critical activities have displaced several parallel branches of the critical (Longest) Path to higher-numbered float paths. Consistent with prior conclusions, the float paths are not correlated with activity float values, so reference to relationship floats is needed to characterize the basis for and relative *criticality* of each float path.

The Appendix shows the detailed tracing of each of the float paths and demonstrates how the various *tie breakers* are applied to assign float path numbers based on, for example, the Activity ID's sorted alphanumerically. For the *total float* option in particular, the resulting float path assignments are confused and fragmented. The detailed analysis also confirms the previously-noted limitations on the use of an ending-with activity with the *total float* option; it is rarely useful and can be misleading.

This example demonstrates that P6's proprietary algorithms for seeding and tracing float paths are more nuanced than might be suggested by the initial (EPDM) paper or by the user documentation. In particular, the rules for preferring or pre-qualifying specific activities and relationships prior to tie-breaker testing – when parallel driving logic is most likely – remain unclear.

More importantly, the example demonstrates the fragmentation and dispersal of the Longest Path – with some parallel branches relegated to float paths much higher than expected – when multiple calendars are not perfectly aligned. The fragmentation is the result of conflicts between the criteria for driving path tracing (which depend partly or wholly on successor calendars) and the criteria for path seeding (which depend primarily on predecessor calendars). This phenomenon exists with both *total float* and *free float* options, and it provides the primary argument against specifying any limit on the number of float paths to be analyzed. Unfortunately, the observation of such fragmentation – whether on the Longest Path, the float-defined critical path, or on the driving path to some other ending activity – means that the entire float path sequence resulting from the MFP analysis may be essentially unreliable.

The shop work example is not representative of typical construction or fabrication projects, and it was developed explicitly to explore the behavior of P6's MFP analysis in schedules with multiple, unaligned calendars. While some limits to the validity of MFP analysis are evident, these appear to exist primarily in *edge-case* conditions like those of the example.

## 9.0 OVERALL CONCLUSIONS

The interpretation of driving schedule logic in modern project schedules, including the associated critical- and near-critical paths, is often complicated by multiple calendars and other factors. P6's *multiple float path* analysis option was developed to provide the needed clarity when these conditions are present.

The primary value of MFP analysis is in providing an intuitive graphical arrangement of schedule logic, revealing driving and near driving paths that are otherwise obscured, namely:

- Separate and distinct *float paths* that share the same value of total float;
- Single *float paths* with multiple values of total float.

These are of primary importance to forward-looking managers of complex projects.

The *free float* option is useful for general-purpose identification and tracing of driving and near-driving logic paths to a specified project completion activity, to specified intermediate project milestones, or to any other important activities in the schedule. Like P6's Longest Path, it evaluates early dates only, ignoring late constraints and total float. This option is more likely to provide understandable results when an ending activity is specified.

The *total float* option is primarily useful – especially together with Longest Path – for defining critical and near-critical paths in unconstrained projects with multiple calendars. It is also useful for prioritizing workflows in overly-constrained project schedules with multiple calendars. In either case, no ending activity should be specified.

Although the bi-directional driving logic calculations of this option are nominally more restrictive than the conventional driving logic calculations of the *free float* option, the observed results appear no more valid (nor less arbitrary) in the examples studied. Because its results can be confusing or misleading under many conditions, the *total float* option is less preferred for general-purpose use.

Our observations have confirmed the main conclusion of the earlier study. Namely, *float path* number alone is not a reliable indicator of the *criticality* of any particular activity or path. Although some overall patterns can be observed, conclusions of relative criticality require detailed and nuanced review of the underlying relationship data. For multi-calendar projects in particular, parallel branches of driving logic paths can become fragmented and widely separated. Under such conditions, members of the Longest Path (i.e. driving activities to project completion) can be displaced to much higher float paths by non-Longest Path activities with different calendars. When such displacements are observed, then the overall validity of the analysis should be questioned.[16]

As an accessory feature, MFP analysis also provides the most expedient method to filter schedule activities based on a common path-successor. Such filters are necessary to confirm the vertical and horizontal integration of complex schedules. For example, if an activity is included within a particular branch of the work breakdown structure (WBS) but is excluded from the float paths leading to the corresponding WBS completion milestone, then the activity is likely missing some important successor logic.

Finally, our study revealed instances where the existing Oracle documentation may require revision. Most importantly, Oracle documentation repeatedly refers to float path 1 as the *most critical* path and to all higher-numbered float paths as *sub-critical* paths. Clearly this fails to account for the parallel logic branches that are common in project schedules – and which were even present in the foundational EPDM paper that introduced the method. In other places, "most critical" seems to have been substituted for more precise language (e.g. "lowest relationship total float equaling the predecessor activity total float") in a number of user-facing documents. While such simplifications may be useful for introducing elementary concepts, they do not foster understanding of the underlying methods.

In addition, we have identified a number of cases (generally in footnotes) where the core documentation of the MFP analysis is either imprecise, is directly at odds with known good practice, or is not supported by the observed behavior of the software. Even though the underlying methods are proprietary, it seems reasonable to expect some improvement in the consistency of the documents.

[16] Displacement of Longest Path activities to higher-numbered float paths can also be the result when the activities are wrongly included on the Longest Path due to malformed level-of-effort activities. (MFP analysis correctly excludes such activities from the driving path to project completion.)

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## 11.0 APPENDIX – DETAILS OF MFP EXAMPLES AND INTERPRETATIONS

## DETAILS OF MFP EXAMPLES AND INTERPRETATIONS

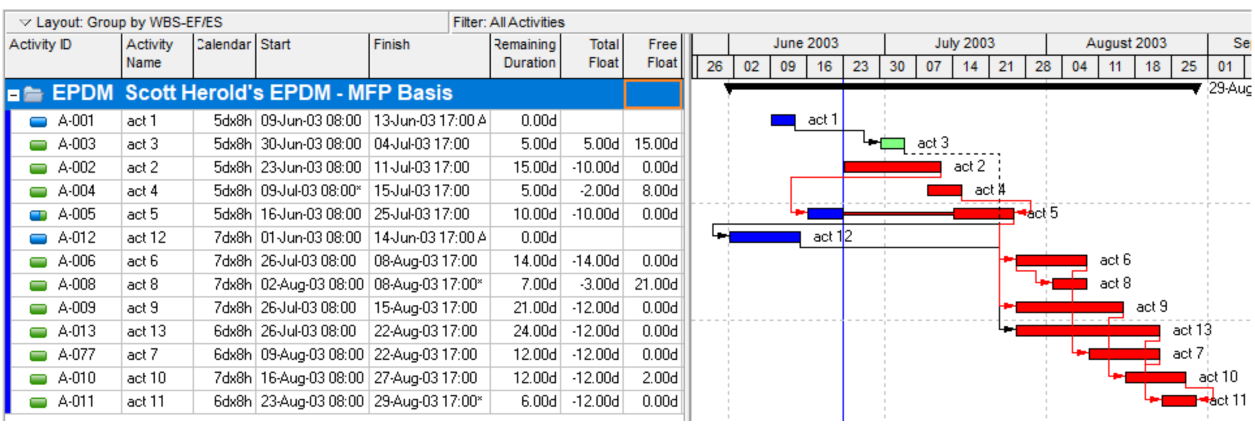
### Appendix Table of Contents

## INTRODUCTION

As a supplement to the primary report, this document provides detailed descriptions, observations, and potential interpretations of *multiple float path* (MFP) calculations in two simplified project schedule examples.

## EPDM EXAMPLE, FROM HEROLD

Figure A- 1– re-created after the original EPDM example of the Herold paper – demonstrates the quandary that EPDM and P6's MFP calculations were developed to address. It depicts a project schedule with multiple calendars, intersecting logic paths, a single unmet late date constraint, and out-of-sequence progress. With critical activities flagged according to TF≤0, virtually all remaining work is *critical*. With the three different activity calendars, two weeks of negative float could correspond to -10 days, -12 days, or -14 days, depending on the activity's calendar. Thus, an activity with -10 days of total float on a 5-days/week calendar is just as critical as another activity with -14 days of float on a 7-day calendar. Another activity with -12 days of total float might be more or less critical than either of the first two depending on its calendar. The traditional use of total float to indicate either membership on or nearness to the critical path is not valid under such conditions.



Layout: Group by WBS-EF/ES — Filter: All Activities

| Activity ID | Activity Name | Calendar | Start | Finish | Remaining Duration | Total Float | Free Float |
|---|---|---|---|---|---|---|---|
| EPDM | Scott Herold's EPDM - MFP Basis | | | | | | |
| A-001 | act 1 | 5dx8h | 09-Jun-03 08:00 | 13-Jun-03 17:00 A | 0.00d | | |
| A-003 | act 3 | 5dx8h | 30-Jun-03 08:00 | 04-Jul-03 17:00 | 5.00d | 5.00d | 15.00d |
| A-002 | act 2 | 5dx8h | 23-Jun-03 08:00 | 11-Jul-03 17:00 | 15.00d | -10.00d | 0.00d |
| A-004 | act 4 | 5dx8h | 09-Jul-03 08:00* | 15-Jul-03 17:00 | 5.00d | -2.00d | 8.00d |
| A-005 | act 5 | 5dx8h | 16-Jun-03 08:00 | 25-Jul-03 17:00 | 10.00d | -10.00d | 0.00d |
| A-012 | act 12 | 7dx8h | 01-Jun-03 08:00 | 14-Jun-03 17:00 A | 0.00d | | |
| A-006 | act 6 | 7dx8h | 26-Jul-03 08:00 | 08-Aug-03 17:00 | 14.00d | -14.00d | 0.00d |
| A-008 | act 8 | 7dx8h | 02-Aug-03 08:00 | 08-Aug-03 17:00* | 7.00d | -3.00d | 21.00d |
| A-009 | act 9 | 7dx8h | 26-Jul-03 08:00 | 15-Aug-03 17:00 | 21.00d | -12.00d | 0.00d |
| A-013 | act 13 | 6dx8h | 26-Jul-03 08:00 | 22-Aug-03 17:00 | 24.00d | -12.00d | 0.00d |
| A-077 | act 7 | 6dx8h | 09-Aug-03 08:00 | 22-Aug-03 17:00 | 12.00d | -12.00d | 0.00d |
| A-010 | act 10 | 7dx8h | 16-Aug-03 08:00 | 27-Aug-03 17:00 | 12.00d | -12.00d | 2.00d |
| A-011 | act 11 | 6dx8h | 23-Aug-03 08:00 | 29-Aug-03 17:00* | 6.00d | -12.00d | 0.00d |



**Figure A- 1: EPDM – EF/ES Organization, Constraint (act 11) (Crit~TF≤0)**

### *EPDM Example – Free Float Option*

P6's LP algorithm may correctly identify the Longest/critical path for the project (Figure A- 2), but parallel driving and near-driving logic paths – critical or not – are not readily differentiated.

Layout: Group by WBS-EF/ES — Filter: All Activities

| Activity ID | Activity Name | alendar | Start | Finish | Remaining Duration | Total Float | Free Float |
|---|---|---|---|---|---|---|---|
| **EPDM** | **Scott Herold's EPDM - MFP Basis** | | | | | | |
| A-001 | act 1 | 5dx8h | 09-Jun-03 08:00 A | 13-Jun-03 17:00 A | 0.00d | | |
| A-003 | act 3 | 5dx8h | 30-Jun-03 08:00 | 04-Jul-03 17:00 | 5.00d | 5.00d | 15.00d |
| A-002 | act 2 | 5dx8h | 23-Jun-03 08:00 | 11-Jul-03 17:00 | 15.00d | -10.00d | 0.00d |
| A-004 | act 4 | 5dx8h | 09-Jul-03 08:00* | 15-Jul-03 17:00 | 5.00d | -2.00d | 8.00d |
| A-005 | act 5 | 5dx8h | 16-Jun-03 08:00 A | 25-Jul-03 17:00 | 10.00d | -10.00d | 0.00d |
| A-012 | act 12 | 7dx8h | 01-Jun-03 08:00 A | 14-Jun-03 17:00 A | 0.00d | | |
| A-006 | act 6 | 7dx8h | 26-Jul-03 08:00 | 08-Aug-03 17:00 | 14.00d | -14.00d | 0.00d |
| A-008 | act 8 | 7dx8h | 02-Aug-03 08:00 | 08-Aug-03 17:00* | 7.00d | -3.00d | 21.00d |
| A-009 | act 9 | 7dx8h | 26-Jul-03 08:00 | 15-Aug-03 17:00 | 21.00d | -12.00d | 0.00d |
| A-013 | act 13 | 6dx8h | 26-Jul-03 08:00 | 22-Aug-03 17:00 | 24.00d | -12.00d | 0.00d |
| A-077 | act 7 | 6dx8h | 09-Aug-03 08:00 | 22-Aug-03 17:00 | 12.00d | -12.00d | 0.00d |
| A-010 | act 10 | 7dx8h | 16-Aug-03 08:00 | 27-Aug-03 17:00 | 12.00d | -12.00d | 2.00d |
| A-011 | act 11 | 6dx8h | 23-Aug-03 08:00 | 29-Aug-03 17:00* | 6.00d | -12.00d | 0.00d |

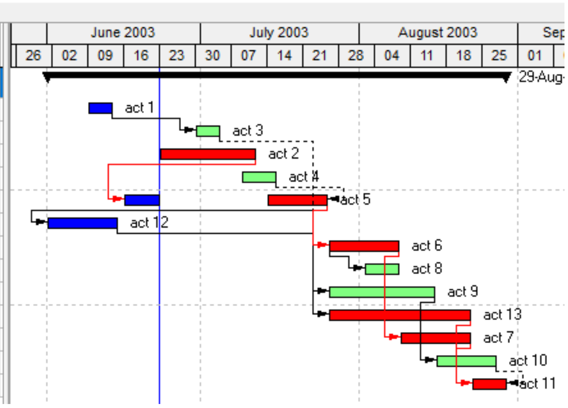



**Figure A- 2: EPDM – EF/ES Organization, Constraint (act 11) (Crit~LP)**

By combining the *free float* MFP option with the LP definition of the critical path, Figure A- 3 is able to clearly define the two parallel critical float paths for the project (float paths 1 and 2). [1]

Layout: MFP2 — Filter: All Activities

| Activity ID | Activity Name | Remaining Duration | Calendar | Total Float | Free Float |
|---|---|---|---|---|---|
| **Scott Herold's EPDM - MFP Basis** | | | | | |
| **Float Path: 1** | | | | | |
| A-002 | act 2 | 120.00h | 5dx8h | -80.00h | 0.00h |
| A-005 | act 5 | 80.00h | 5dx8h | -80.00h | 0.00h |
| A-012 | act 12 | 0.00h | 7dx8h | | |
| A-013 | act 13 | 192.00h | 6dx8h | -96.00h | 0.00h |
| A-011 | act 11 | 48.00h | 6dx8h | -96.00h | 0.00h |
| **Float Path: 2** | | | | | |
| A-006 | act 6 | 112.00h | 7dx8h | -112.00h | 0.00h |
| A-077 | act 7 | 96.00h | 6dx8h | -96.00h | 0.00h |
| **Float Path: 3** | | | | | |
| A-009 | act 9 | 168.00h | 7dx8h | -96.00h | 0.00h |
| A-010 | act 10 | 96.00h | 7dx8h | -96.00h | 16.00h |
| **Float Path: 4** | | | | | |
| A-004 | act 4 | 40.00h | 5dx8h | -16.00h | 64.00h |
| **Float Path: 5** | | | | | |
| A-003 | act 3 | 40.00h | 5dx8h | 40.00h | 120.00h |
| **Float Path: 6** | | | | | |
| A-008 | act 8 | 56.00h | 7dx8h | -24.00h | 168.00h |
| **No Float Path** | | | | | |
| A-001 | act 1 | 0.00h | 5dx8h | | |

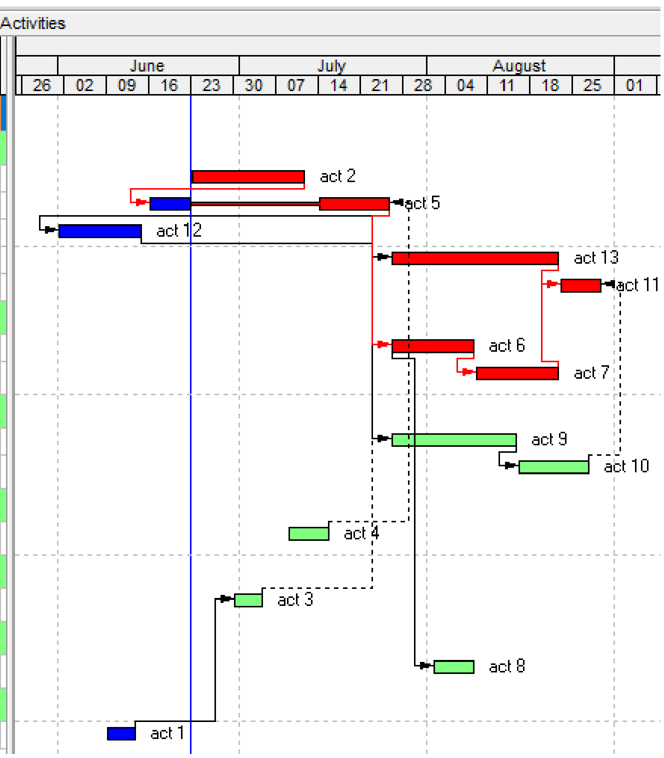



**Figure A- 3: EPDM – MFP-FF, Constraint, End @ Activity " ", Path Limit " " (Crit~LP)**

Using the relationship listing of Table 1, the seeding and tracing of these paths can be understood as follows: In the absence of an ending-with activity, float path 1 is seeded by the open-ended activity with the lowest free float, i.e. act 11. (Activity 8, with 21 days of free float, is the only other activity with no successors.) Two of act 11's three predecessor relationships have the same (zero) values for RFF and RSFF, and the corresponding predecessor activities (act 7 and act 13) have the same early finish date. Activity 13 is selected for float path 1 based on the next tie-breaker: its early start date is sooner. Activity 12, completed out of sequence, has a driving relationship

[1] In general, *day* is not a reliably stable duration unit in multi-calendar projects. Subsequent float tabulations are therefore shown in hours, which are used for internal calculations in P6.

(RSFF=0) with act 13 and is included here.[2] Similarly, driving logic is traced backward through act 12, act 5 and act 2, all based on RSFF=0. At that point, float path 1 has been fully traced.

| Pred_ID_Name | Pred_Task_ES | Pred_Task_EF | Succ_ID_Name | Succ_Task_ES | Succ_Task_EF | Pred_ID _FP-FPO | Succ_ID _FP-FPO | Pred-FF | Succ-FF | RFF | RSFF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A-001 act 1 | 23-Jun-03 00:00 | 23-Jun-03 00:00 | A-003 act 3 | 30-Jun-03 08:00 | 04-Jul-03 17:00 | No Path | 5.1 | | 120.00h | 0.00h | 0.00h |
| A-004 act 4 | 09-Jul-03 08:00 | 15-Jul-03 17:00 | A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | 4.1 | 1.2 | 64.00h | 0.00h | 64.00h | 64.00h |
| A-002 act 2 | 23-Jun-03 08:00 | 11-Jul-03 17:00 | A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | 1.1 | 1.2 | 0.00h | 0.00h | 0.00h | 0.00h |
| A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | A-012 act 12 | 25-Jul-03 17:00 | 25-Jul-03 17:00 | 1.2 | 1.3 | 0.00h | | 0.00h | 0.00h |
| A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | A-006 act 6 | 26-Jul-03 08:00 | 08-Aug-03 17:00 | 1.2 | 2.1 | 0.00h | 0.00h | 0.00h | 0.00h |
| A-006 act 6 | 26-Jul-03 08:00 | 08-Aug-03 17:00 | A-008 act 8 | 02-Aug-03 08:00 | 08-Aug-03 17:00 | 2.1 | 6.1 | 0.00h | 168.00h | 0.00h | 0.00h |
| A-003 act 3 | 30-Jun-03 08:00 | 04-Jul-03 17:00 | A-009 act 9 | 26-Jul-03 08:00 | 15-Aug-03 17:00 | 5.1 | 3.1 | 120.00h | 0.00h | 120.00h | 168.00h |
| A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | A-009 act 9 | 26-Jul-03 08:00 | 15-Aug-03 17:00 | 1.2 | 3.1 | 0.00h | 0.00h | 0.00h | 0.00h |
| A-012 act 12 | 25-Jul-03 17:00 | 25-Jul-03 17:00 | A-013 act 13 | 26-Jul-03 08:00 | 22-Aug-03 17:00 | 1.3 | 1.4 | | 0.00h | 0.00h | 0.00h |
| A-006 act 6 | 26-Jul-03 08:00 | 08-Aug-03 17:00 | A-077 act 7 | 09-Aug-03 08:00 | 22-Aug-03 17:00 | 2.1 | 2.2 | 0.00h | 0.00h | 0.00h | 0.00h |
| A-009 act 9 | 26-Jul-03 08:00 | 15-Aug-03 17:00 | A-010 act 10 | 16-Aug-03 08:00 | 27-Aug-03 17:00 | 3.1 | 3.2 | 0.00h | 16.00h | 0.00h | 0.00h |
| A-077 act 7 | 09-Aug-03 08:00 | 22-Aug-03 17:00 | A-011 act 11 | 23-Aug-03 08:00 | 29-Aug-03 17:00 | 2.2 | 1.5 | 0.00h | 0.00h | 0.00h | 0.00h |
| A-010 act 10 | 16-Aug-03 08:00 | 27-Aug-03 17:00 | A-011 act 11 | 23-Aug-03 08:00 | 29-Aug-03 17:00 | 3.2 | 1.5 | 16.00h | 0.00h | 16.00h | 16.00h |
| A-013 act 13 | 26-Jul-03 08:00 | 22-Aug-03 17:00 | A-011 act 11 | 23-Aug-03 08:00 | 29-Aug-03 17:00 | 1.4 | 1.5 | 0.00h | 0.00h | 0.00h | 0.00h |

**Table 1: EPDM – Relationship Listing for MFP-FF3**

Float path 2 is seeded by the act 7 – act 11 relationship. After definition of the previous path, this relationship has the lowest RFF value (0h) of the remaining candidate relationships. Starting from the seed relationship, the backward trace terminates with act 6 because it has no unassigned predecessors.

Float path 3 is seeded by the act 10 – act 11 relationship. This relationship has the lowest RFF value (16h) of the remaining candidate relationships. (Other candidate relationships are act 4 – act 5 and the previously-mentioned imaginary relationship after the open-ended activity.) Starting from the seed relationship, the backward trace terminates with act 9 because it has no unassigned predecessors.

Float path 4 is seeded by the act 4 – act 5 relationship. This relationship has the lowest RFF value (64h) of the candidate relationships. (Other candidate relationships are act 3 – act 9 and the previously-mentioned imaginary relationship.) Starting from the seed relationship, the backward trace terminates with act 4 because it has no unassigned predecessors.

Float path 5 is seeded by the act 3 – act 9 relationship. This relationship has the lowest RFF value (120h) of the remaining candidate relationships. (The only other candidate relationship is the imaginary one after act 8.) Starting from the seed relationship, the backward trace terminates with act 3 even though it has a driving predecessor (act 1, which is complete) that remains unassigned.

> **Hypothesis:** Activity 12 was completed out of sequence. Under retained logic it has an internal remaining early finish date that is later than the data date and is therefore included in float path 1. Activity 1 was completed prior to the data date and under retained logic has an internal remaining early finish that is equal to the data date. Because the completed act 1's internal remaining early finish date is NOT later than the data date, it has no logic impact on incomplete activities and is excluded from the logic trace.

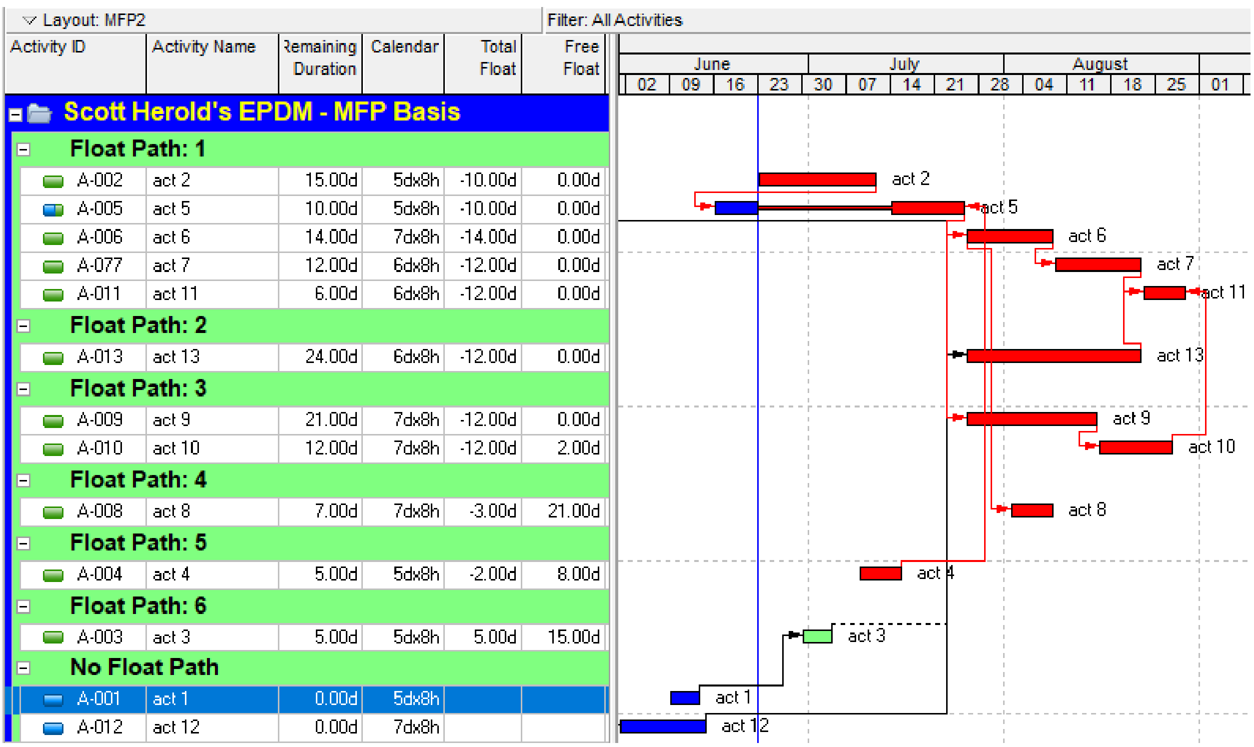
[2] The schedules in this paper are computed using the widely-recommended retained logic setting for out-of-sequence progress. This allows driving logic to flow from act 5 to act 13, through the completed act 12.

[3] The relationship lists included here were developed using an external spreadsheet program to manipulate and consolidate exported data. Such views are not available inside P6.

Finally, float path 6 is seeded by the imaginary relationship following the open-ended act 8 and inheriting its free float value of 168h. The backward trace then concludes with act 8 since it has no unassigned predecessors.

*EPDM Example – Total Float Option*

Figure A- 4 illustrates the result of MFP analysis using the *total float* option with no other restrictions. The output is nearly identical to the *pure float method* EPDM output of Figure 7 in the main paper, implying that the two algorithms are essentially similar. The key exception is that MFP analysis <u>excludes</u> completed activities like the out-of-sequence activity A-012; the analysis from the EPDM paper (in P3) included them.


Layout: MFP2 | Filter: All Activities

| Activity ID | Activity Name | Remaining Duration | Calendar | Total Float | Free Float |
|---|---|---|---|---|---|
| Scott Herold's EPDM - MFP Basis | | | | | |
| Float Path: 1 | | | | | |
| A-002 | act 2 | 15.00d | 5dx8h | -10.00d | 0.00d |
| A-005 | act 5 | 10.00d | 5dx8h | -10.00d | 0.00d |
| A-006 | act 6 | 14.00d | 7dx8h | -14.00d | 0.00d |
| A-077 | act 7 | 12.00d | 6dx8h | -12.00d | 0.00d |
| A-011 | act 11 | 6.00d | 6dx8h | -12.00d | 0.00d |
| Float Path: 2 | | | | | |
| A-013 | act 13 | 24.00d | 6dx8h | -12.00d | 0.00d |
| Float Path: 3 | | | | | |
| A-009 | act 9 | 21.00d | 7dx8h | -12.00d | 0.00d |
| A-010 | act 10 | 12.00d | 7dx8h | -12.00d | 2.00d |
| Float Path: 4 | | | | | |
| A-008 | act 8 | 7.00d | 7dx8h | -3.00d | 21.00d |
| Float Path: 5 | | | | | |
| A-004 | act 4 | 5.00d | 5dx8h | -2.00d | 8.00d |
| Float Path: 6 | | | | | |
| A-003 | act 3 | 5.00d | 5dx8h | 5.00d | 15.00d |
| No Float Path | | | | | |
| A-001 | act 1 | 0.00d | 5dx8h | | |
| A-012 | act 12 | 0.00d | 7dx8h | | |



**Figure A- 4: EPDM – MFP-TF, Constraint (act 11), End @ Activity " ", Path Limit " " (Crit~TF≤0)**

Like the *free float* option and the earlier EPDM analysis, the *total float* MFP analysis identifies six different float paths for this project. The float path definitions using the *total float* option are more or less the same as those of the *free float* option shown in Figure A- 3, with three key exceptions:

- Activity 13 and its parallel sequence – <u>act 6 - act 7</u> – trade places between float paths 1 and 2.
- Activity 12 – completed out of sequence and previously slotted between act 5 and act 13 according to retained logic – is now excluded.
- Activity 8 is *promoted* from float path 6 to float path 4.

Float path 1 depicts a *most critical* float path that is ultimately defined by the single lowest-float (-14d) relationship along with its contiguous chain of bi-directional driving and driven activities. These activities all have the equivalent of two weeks of negative total float – measured according to three different calendars. Float path 2 depicts a parallel path of equivalent calendar-adjusted float, though the equal criticality of the two paths is not readily apparent. Using the relationship listing of Table 2, the seeding and tracing of these paths can be understood as follows:

Float path 1 is seeded by the act 6 – act 7 relationship. This relationship has the lowest RTF value (-112h) of all candidate relationships, and its predecessor finishes later than that of the other relationship with the same RTF, act 12 – act 13. Driving logic is traced backward from this seed through act 6, act 5, and act 2 – based on [RTF = $TF_{(predecessor\ activity)}$]. With no predecessors, act 2 terminates the backward trace. Driving logic is traced forward – based on [RSTF = $TF_{(successor\ activity)}$] – from the seed through act 7 and act 11, which has no successors. At that point, float path 1 has been fully traced.

Float path 2 is seeded by the act 12 – act 13 relationship, which is the remaining one with lowest RTF (-112h). There is no backward trace because the predecessor, having been completed out of sequence, has no TF value and is excluded. The forward trace terminates with act 13 because it has no unassigned successors.

Float path 3 is seeded by the act 10 – act 11 relationship, which has the latest-finishing predecessor of the two remaining relationships with the lowest RTF (-96h). The backward trace takes in act 10 and act 9, stopping there because act 9's driving predecessor (act 5) is already assigned. There is no forward trace because the successor of the seed relationship (act 11) is already assigned.

The remaining three float paths in Figure A- 4 can be described similarly.

| Pred_ID_Name | Pred_Task_ES | Pred_Task_EF | Succ_ID_Name | Succ_Task_ES | Succ_Task_EF | Pred_ID_FP-FPO | Succ_ID_FP-FPO | Pred-TF | Succ-TF | RTF | RSTF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A-001 act 1 | 23-Jun-03 00:00 | 23-Jun-03 00:00 | A-003 act 3 | 30-Jun-03 08 | 04-Jul-03 17:00 | No Path | 6.1 | | 40.00h | 40.00h | 40.00h |
| A-004 act 4 | 09-Jul-03 08:00 | 15-Jul-03 17:00 | A-005 act 5 | 14-Jul-03 08 | 25-Jul-03 17:00 | 5.1 | 1.2 | -16.00h | -80.00h | -16.00h | -16.00h |
| A-002 act 2 | 23-Jun-03 08:00 | 11-Jul-03 17:00 | A-005 act 5 | 14-Jul-03 08 | 25-Jul-03 17:00 | 1.1 | 1.2 | -80.00h | -80.00h | -80.00h | -80.00h |
| A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | A-012 act 12 | 25-Jul-03 17 | 25-Jul-03 17:00 | 1.2 | No path | -80.00h | | -80.00h | -112.00h |
| A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | A-006 act 6 | 26-Jul-03 08 | 08-Aug-03 17:00 | 1.2 | 1.3 | -80.00h | -112.00h | -80.00h | -112.00h |
| A-006 act 6 | 26-Jul-03 08:00 | 08-Aug-03 17:00 | A-008 act 8 | 02-Aug-03 08 | 08-Aug-03 17:00 | 1.3 | 4.1 | -112.00h | -24.00h | -24.00h | -24.00h |
| A-003 act 3 | 30-Jun-03 08:00 | 04-Jul-03 17:00 | A-009 act 9 | 26-Jul-03 08 | 15-Aug-03 17:00 | 6.1 | 3.1 | 40.00h | -96.00h | 40.00h | 72.00h |
| A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | A-009 act 9 | 26-Jul-03 08 | 15-Aug-03 17:00 | 1.2 | 3.1 | -80.00h | -96.00h | -80.00h | -96.00h |
| A-012 act 12 | 25-Jul-03 17:00 | 25-Jul-03 17:00 | A-013 act 13 | 26-Jul-03 08 | 22-Aug-03 17:00 | No Path | 2.1 | | -96.00h | -112.00h | -96.00h |
| A-006 act 6 | 26-Jul-03 08:00 | 08-Aug-03 17:00 | A-077 act 7 | 09-Aug-03 08 | 22-Aug-03 17:00 | 1.3 | 1.4 | -112.00h | -96.00h | -112.00h | -96.00h |
| A-009 act 9 | 26-Jul-03 08:00 | 15-Aug-03 17:00 | A-010 act 10 | 16-Aug-03 08 | 27-Aug-03 17:00 | 3.1 | 3.2 | -96.00h | -96.00h | -96.00h | -96.00h |
| A-077 act 7 | 09-Aug-03 08:00 | 22-Aug-03 17:00 | A-011 act 11 | 23-Aug-03 08 | 29-Aug-03 17:00 | 1.4 | 1.5 | -96.00h | -96.00h | -96.00h | -96.00h |
| A-010 act 10 | 16-Aug-03 08:00 | 27-Aug-03 17:00 | A-011 act 11 | 23-Aug-03 08 | 29-Aug-03 17:00 | 3.2 | 1.5 | -96.00h | -96.00h | -96.00h | -80.00h |
| A-013 act 13 | 26-Jul-03 08:00 | 22-Aug-03 17:00 | A-011 act 11 | 23-Aug-03 08 | 29-Aug-03 17:00 | 2.1 | 1.5 | -96.00h | -96.00h | -96.00h | -96.00h |

**Table 2: EPDM – Relationship Listing for MFP-TF**

*EPDM Example – Ending-With Activity*

Without an ending-with activity, these MFP solutions are largely controlled by the last activity in the schedule (act 11), which is also the only activity with a late date constraint. If act 11 were specified as the ending-with activity for the analysis, the only difference in the results would be the omission of act 8 (the sole activity that is NOT a path predecessor of act 11) from the defined float paths.

In perhaps a better illustration of the calculation option, Figure A- 5 depicts the result of repeating the *total float* analysis after selecting act 8 as the ending-with activity. The primary impact of this selection is the pre-filtering of the activities (and relationships) to be analyzed, such that only act 8 and its path predecessors (activities 2, 4, 5, and 6), along with their intervening relationships, are included. The subsequent processes for seeding and tracing logic paths are unchanged, being based on RTF and RSTF. The result is the set of all path predecessors of act 8, arranged into float paths according to relationship total float. (The total float of -112h shown for act 6 is not relevant for the analysis; the lowest RTF value for seeding float path 1 is in fact -80h, as shown in Table 3.) Because total float of the activities and relationships is controlled by another constraint – NOT act 8 – these float paths have nothing to do with the driving logic for act 8. This result demonstrates why the *total float* option with an ending activity is rarely useful and can be misleading.

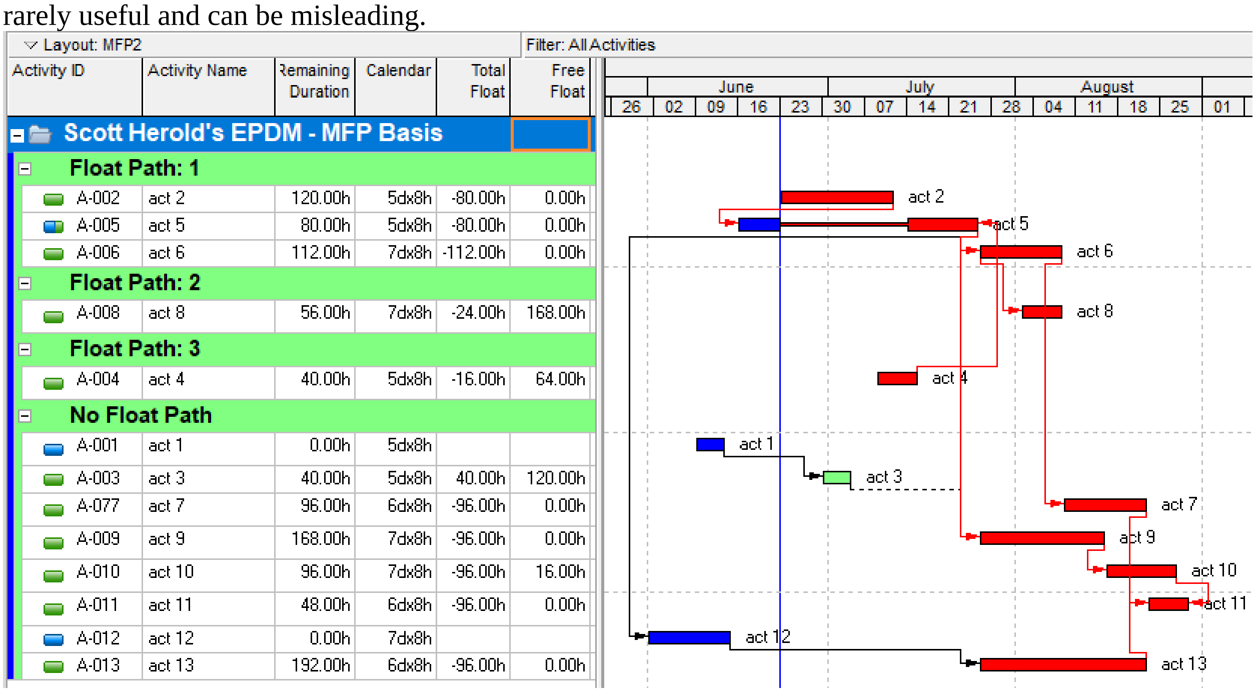
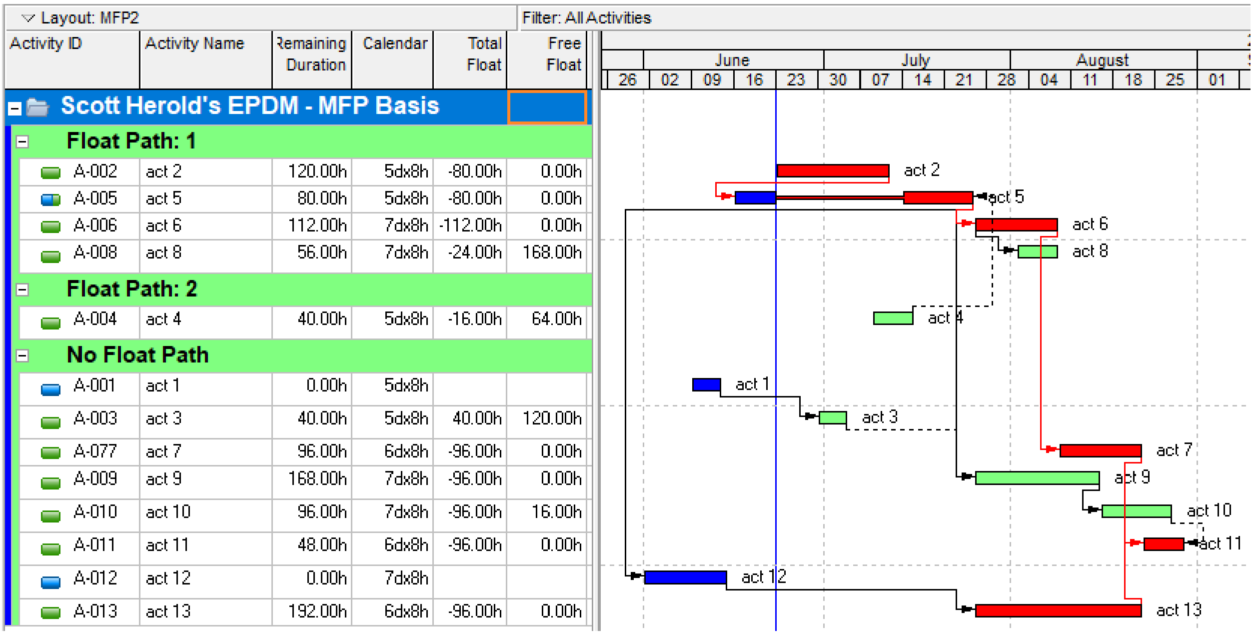



**Figure A- 5: EPDM – MFP-TF, Constraint (act 11), End @ Activity "act 8", Path Limit " " (Crit~TF≤0)**

| Pred_ID_Name | Pred_Task_ES | Pred_Task_EF | Succ_ID_Name | Succ_Task_ES | Succ_Task_EF | Pred_ID_FP-FPO | Succ_ID_FP-FPO | Pred-TF | Succ-TF | RTF | RSTF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A-004 act 4 | 09-Jul-03 08:00 | 15-Jul-03 17:00 | A-005 act 5 | 14-Jul-03 08 | 25-Jul-03 17:00 | 3.1 | 1.2 | -16.00h | -80.00h | -16.00h | -16.00h |
| A-002 act 2 | 23-Jun-03 08:00 | 11-Jul-03 17:00 | A-005 act 5 | 14-Jul-03 08 | 25-Jul-03 17:00 | 1.1 | 1.2 | -80.00h | -80.00h | -80.00h | -80.00h |
| A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | A-006 act 6 | 26-Jul-03 08 | 08-Aug-03 17:00 | 1.2 | 1.3 | -80.00h | -112.00h | -80.00h | -112.00h |
| A-006 act 6 | 26-Jul-03 08:00 | 08-Aug-03 17:00 | A-008 act 8 | 02-Aug-03 08 | 08-Aug-03 17:00 | 1.3 | 2.1 | -112.00h | -24.00h | -24.00h | -24.00h |

**Table 3: EPDM – Relationship Listing for MFP-TF, Ending with Act 8**

As shown in Figure A- 6, performing the *free float* MFP analysis ending with act 8 clearly illustrates the driving and near-driving logic paths to the ending activity. Moreover, the first row of Table 4 demonstrates that act 4 is 64h (8 days) away from driving act 5 and (through it) act 8. It should come as no surprise that since act 8 itself is not on the longest path, substantial portions of the longest path have no float path assigned.




| Activity ID | Activity Name | Remaining Duration | Calendar | Total Float | Free Float |
|---|---|---|---|---|---|
| Scott Herold's EPDM - MFP Basis | | | | | |
| Float Path: 1 | | | | | |
| A-002 | act 2 | 120.00h | 5dx8h | -80.00h | 0.00h |
| A-005 | act 5 | 80.00h | 5dx8h | -80.00h | 0.00h |
| A-006 | act 6 | 112.00h | 7dx8h | -112.00h | 0.00h |
| A-008 | act 8 | 56.00h | 7dx8h | -24.00h | 168.00h |
| Float Path: 2 | | | | | |
| A-004 | act 4 | 40.00h | 5dx8h | -16.00h | 64.00h |
| No Float Path | | | | | |
| A-001 | act 1 | 0.00h | 5dx8h | | |
| A-003 | act 3 | 40.00h | 5dx8h | 40.00h | 120.00h |
| A-077 | act 7 | 96.00h | 6dx8h | -96.00h | 0.00h |
| A-009 | act 9 | 168.00h | 7dx8h | -96.00h | 0.00h |
| A-010 | act 10 | 96.00h | 7dx8h | -96.00h | 16.00h |
| A-011 | act 11 | 48.00h | 6dx8h | -96.00h | 0.00h |
| A-012 | act 12 | 0.00h | 7dx8h | | |
| A-013 | act 13 | 192.00h | 6dx8h | -96.00h | 0.00h |

**Figure A- 6: EPDM – MFP-FF, Constraint, End @ Activity "act 8", Path Limit " " (Crit~LP)**

| Pred_ID_Name | Pred_Task_ES | Pred_Task_EF | Succ_ID_Name | Succ_Task_ES | Succ_Task_EF | Pred_ID _FP-FPO | Succ_ID _FP-FPO | Pred-FF | Succ-FF | RFF | RSFF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A-004 act 4 | 09-Jul-03 08:00 | 15-Jul-03 17:00 | A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | 2.1 | 1.2 | 64.00h | 0.00h | 64.00h | 64.00h |
| A-002 act 2 | 23-Jun-03 08:00 | 11-Jul-03 17:00 | A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | 1.1 | 1.2 | 0.00h | 0.00h | 0.00h | 0.00h |
| A-005 act 5 | 14-Jul-03 08:00 | 25-Jul-03 17:00 | A-006 act 6 | 26-Jul-03 08:00 | 08-Aug-03 17:00 | 1.2 | 1.3 | 0.00h | 0.00h | 0.00h | 0.00h |
| A-006 act 6 | 26-Jul-03 08:00 | 08-Aug-03 17:00 | A-008 act 8 | 02-Aug-03 08:00 | 08-Aug-03 17:00 | 1.3 | 1.4 | 0.00h | 168.00h | 0.00h | 0.00h |

**Table 4: EPDM – Relationship Listing for MFP-FF, Ending with Act 8**

*EPDM Example - Conclusions*

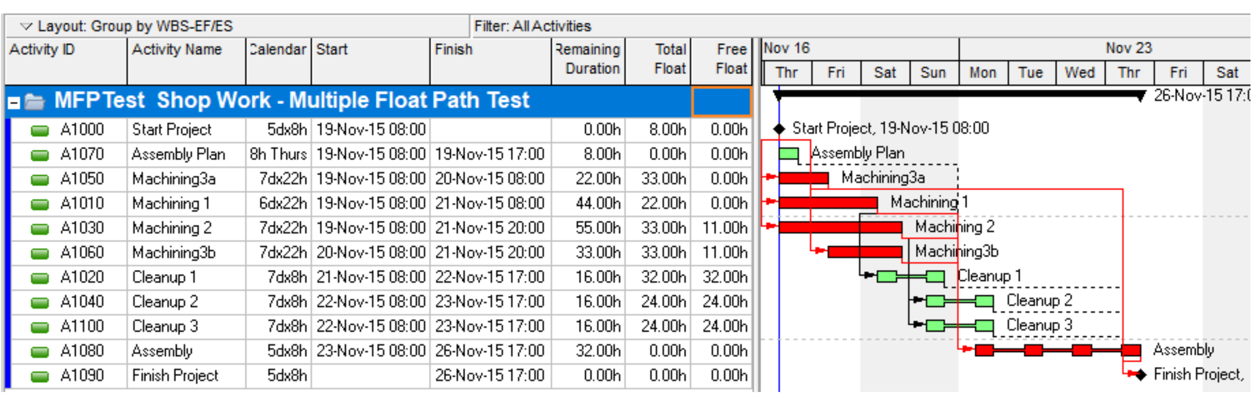
Both *flavors* of P6's MFP calculation can be useful for clarifying critical and near-critical logic paths in a schedule that is complicated by multiple calendars, negative float, and out-of-sequence progress. In some cases, total float may be controlled by a small number of rigidly enforced late date constraints, and violation of any single constraint is equally unacceptable to the project team. In these cases, MFP analysis using the *total float* option and NO ending-with activity may be most useful for prioritizing the remaining work. With or without an ending activity, however, the *total float* option is not useful for defining the driving/controlling logic for activities away from the critical path. On the other hand, the *free float* option is generally preferred for defining the driving logic to a specific ending activity, especially one that is far from critical.

Finally, it is confirmed that the suggestion of a single *most critical* path followed by a number of *sub-critical* paths is not supported in general, even in the project example that seems to have originated this particular terminology. For both calculation options, it is important to remember that the detailed seeding and tracing of float paths are governed primarily by relationship floats, NOT activity floats. As a result, inspection of activity total float and free float fields in a typical MFP output plot may sometimes be misleading. Reference to the detailed relationship parameters, though tedious, is absolutely necessary to determine whether one float path is in fact more *critical* than the next.

## UNALIGNED CALENDARS – SHOP WORK

Although it provides a good demonstration of the MFP calculation in a project with simple and well-aligned calendars, the EPDM example does not reflect the full gamut of calendar variations observed in modern project schedules. In particular, the consequences of calendar switching among the 5-day, 6-day, and 7-day calendars used in the EPDM example are manifested almost exclusively in total float (rather than free float) values. Other calendar types in construction include 24-hour/curing; weather/rain (both distributed and lumped); day/night shift; calendars with annual/seasonal shutdowns for social or environmental restrictions; and calendars with specific black-out times for external events. In other industries, resource-driven activities are used to incorporate the planned holidays and vacations times of individual resources; and calendars for rare, periodic work periods like board meetings are used to accurately model the potential schedule impact of missing such approval windows. Such calendars are often not well-aligned with the typical work-week calendar, and there is a greater chance of non-intuitive float-switching along driving logic paths. Consequently, the depiction of parallel/concurrent driving logic paths can be confused.

Figure A- 7 presents the complexities of such unaligned calendars in a simple *shop work* example. The core work of this project involves three parallel machining operations followed by a simple assembly operation. All relationships are finish-to-start, and there are no lags, constraints, open-ended activities, or reported progress. The primary complication is that the eleven activities employ five different calendars. The final assembly and sign off of the finished product are performed by resources working a normal 5-day work week, but the planning, machining, and cleanup activities are all performed according to calendars whose available working hours – especially spanning the weekend – are substantially more or less than the standard. For example, all four machining activities finish at various times over the weekend; they are all included on the Longest Path because each of them is a driving predecessor of the subsequent assembly activity. The assembly planning activity is not on the Longest Path, but one day of delay – according to its own calendar – could delay the project for a week. The figure demonstrates no clear correlation between activity float values and membership on the longest path. A simple construction example demonstrating similar issues might involve mixed concrete and asphalt construction spanning a winter paving shutdown period – perhaps with monthly meetings of a change-review board added into the mix.


Layout: Group by WBS-EF/ES | Filter: All Activities

MFPTest Shop Work - Multiple Float Path Test

| Activity ID | Activity Name | Calendar | Start | Finish | Remaining Duration | Total Float | Free Float |
|---|---|---|---|---|---|---|---|
| A1000 | Start Project | 5dx8h | 19-Nov-15 08:00 | | 0.00h | 8.00h | 0.00h |
| A1070 | Assembly Plan | 8h Thurs | 19-Nov-15 08:00 | 19-Nov-15 17:00 | 8.00h | 0.00h | 0.00h |
| A1050 | Machining3a | 7dx22h | 19-Nov-15 08:00 | 20-Nov-15 08:00 | 22.00h | 33.00h | 0.00h |
| A1010 | Machining 1 | 6dx22h | 19-Nov-15 08:00 | 21-Nov-15 08:00 | 44.00h | 22.00h | 0.00h |
| A1030 | Machining 2 | 7dx22h | 19-Nov-15 08:00 | 21-Nov-15 20:00 | 55.00h | 33.00h | 11.00h |
| A1060 | Machining3b | 7dx22h | 20-Nov-15 08:00 | 21-Nov-15 20:00 | 33.00h | 33.00h | 11.00h |
| A1020 | Cleanup 1 | 7dx8h | 21-Nov-15 08:00 | 22-Nov-15 17:00 | 16.00h | 32.00h | 32.00h |
| A1040 | Cleanup 2 | 7dx8h | 22-Nov-15 08:00 | 23-Nov-15 17:00 | 16.00h | 24.00h | 24.00h |
| A1100 | Cleanup 3 | 7dx8h | 22-Nov-15 08:00 | 23-Nov-15 17:00 | 16.00h | 24.00h | 24.00h |
| A1080 | Assembly | 5dx8h | 23-Nov-15 08:00 | 26-Nov-15 17:00 | 32.00h | 0.00h | 0.00h |
| A1090 | Finish Project | 5dx8h | | 26-Nov-15 17:00 | 0.00h | 0.00h | 0.00h |



**Figure A- 7: Shop Work – EF/ES Organization, No Constraint (Crit~LP)**

*Shop Work – Free Float Option*

The complexity of seeding and tracing float paths in such projects is illustrated at the right side of Table 5, where seven key relationships demonstrate conflicting free float values. As shown in Figure A- 8, *free float* MFP analysis of the schedule leads to the identification of six different float *paths*, with four paths comprising only a single activity each. Most importantly, non-critical activities in float paths 2 and 4 have displaced several parallel branches of the Longest Path to higher-numbered float paths. Consistent with prior conclusions, the float paths are not correlated with activity float values, so reference to relationship floats is needed to characterize the basis for and relative *criticality* of each float path.

| Pred_ID_Name | Pred_Task_ES | Pred_Task_EF | Succ_ID_Name | Succ_Task_ES | Succ_Task_EF | Pred_ID _FP-FPO | Succ_ID _FP-FPO | Pred-FF | Succ-FF | RFF | RSFF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1050 Machining3a | 19-Nov-15 08:00 | 20-Nov-15 08:00 | 1.1 | 5.1 | 0.00h | 0.00h | 0.00h | 0.00h |
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1010 Machining 1 | 19-Nov-15 08:00 | 21-Nov-15 08:00 | 1.1 | 3.1 | 0.00h | 0.00h | 0.00h | 0.00h |
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1030 Machining 2 | 19-Nov-15 08:00 | 21-Nov-15 20:00 | 1.1 | 1.2 | 0.00h | 11.00h | 0.00h | 0.00h |
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | 1.1 | 5.2 | 0.00h | 11.00h | 8.00h | 22.00h |
| A1050 Machining3a | 19-Nov-15 08:00 | 20-Nov-15 08:00 | A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | 5.1 | 5.2 | 0.00h | 11.00h | 0.00h | 0.00h |
| A1010 Machining 1 | 19-Nov-15 08:00 | 21-Nov-15 08:00 | A1020 Cleanup 1 | 21-Nov-15 08:00 | 22-Nov-15 17:00 | 3.1 | 6.1 | 0.00h | 32.00h | 0.00h | 0.00h |
| A1030 Machining 2 | 19-Nov-15 08:00 | 21-Nov-15 20:00 | A1040 Cleanup 2 | 22-Nov-15 08:00 | 23-Nov-15 17:00 | 1.2 | 4.1 | 11.00h | 24.00h | 11.00h | 0.00h |
| A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | A1100 Cleanup 3 | 22-Nov-15 08:00 | 23-Nov-15 17:00 | 5.2 | 5.3 | 11.00h | 24.00h | 11.00h | 0.00h |
| A1010 Machining 1 | 19-Nov-15 08:00 | 21-Nov-15 08:00 | A1080 Assembly | 23-Nov-15 08:00 | 26-Nov-15 17:00 | 3.1 | 1.3 | 0.00h | 0.00h | 22.00h | 0.00h |
| A1030 Machining 2 | 19-Nov-15 08:00 | 21-Nov-15 20:00 | A1080 Assembly | 23-Nov-15 08:00 | 26-Nov-15 17:00 | 1.2 | 1.3 | 11.00h | 0.00h | 33.00h | 0.00h |
| A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | A1080 Assembly | 23-Nov-15 08:00 | 26-Nov-15 17:00 | 5.2 | 1.3 | 11.00h | 0.00h | 33.00h | 0.00h |
| A1070 Assembly Plan | 19-Nov-15 08:00 | 19-Nov-15 17:00 | A1080 Assembly | 23-Nov-15 08:00 | 26-Nov-15 17:00 | 2.1 | 1.3 | 0.00h | 0.00h | 0.00h | 8.00h |
| A1020 Cleanup 1 | 21-Nov-15 08:00 | 22-Nov-15 17:00 | A1090 Finish Project | 26-Nov-15 17:00 | 26-Nov-15 17:00 | 6.1 | 1.4 | 32.00h | 0.00h | 32.00h | 32.00h |
| A1040 Cleanup 2 | 22-Nov-15 08:00 | 23-Nov-15 17:00 | A1090 Finish Project | 26-Nov-15 17:00 | 26-Nov-15 17:00 | 4.1 | 1.4 | 24.00h | 0.00h | 24.00h | 24.00h |
| A1080 Assembly | 23-Nov-15 08:00 | 26-Nov-15 17:00 | A1090 Finish Project | 26-Nov-15 17:00 | 26-Nov-15 17:00 | 1.3 | 1.4 | 0.00h | 0.00h | 0.00h | 0.00h |
| A1100 Cleanup 3 | 22-Nov-15 08:00 | 23-Nov-15 17:00 | A1090 Finish Project | 26-Nov-15 17:00 | 26-Nov-15 17:00 | 5.3 | 1.4 | 24.00h | 0.00h | 24.00h | 24.00h |

**Table 5: Shop Work – Relationship Listing for MFP-FF**

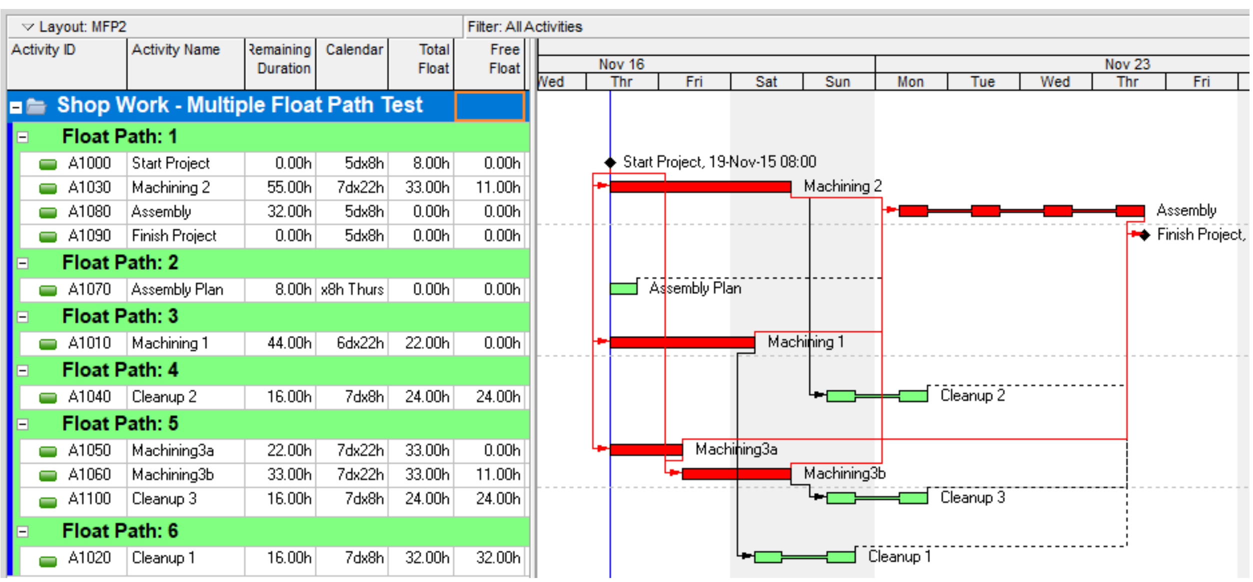



**Figure A- 8: Shop Work – MFP-FF, No Constraint, End @ Activity " ", Path Limit " " (Crit~LP)**

Using the relationship listing of Table 5, the seeding and tracing of these paths can be understood as follows: In the absence of an ending-with activity, float path 1 is seeded by the open-ended activity with the lowest free float, i.e. <u>A1090 Finish Project</u>. Only one of the four predecessor relationships to A1090 Finish Project is driving (RSFF=0), so it (A1080 Assembly) is selected for this path. Three of A1080 Assembly's four predecessor relationships are driving (RSFF=0). The A1030 Machining 2 relationship is selected for this path because its predecessor activity has the earlier start of the two predecessor activities that are driving AND finish at the same time.

The relationship for seeding float path 2 is selected from among those relationships that a) have successors that are already assigned (i.e. in float path 1), and b) have predecessors that have not yet been assigned after calculating float path 1. These are listed in Table 6. With the lowest RFF value, the A1070 Assembly Plan – A1080 Assembly relationship is selected for seeding float path 2. Obviously, this selection bypasses the two driving (and Longest Path) relationships with RSFF=0 in the table, which are relegated to higher-numbered paths. The float path 2 trace begins and ends with A1070 Assembly Plan since this activity has no predecessors.

| Pred_ID_Name | Pred_Task_ES | Pred_Task_EF | Succ_ID_Name | Pred_ID_FP-FPO | Succ_ID_FP-FPO | Pred-FF | Succ-FF | RFF | RSFF |
|---|---|---|---|---|---|---|---|---|---|
| A1010 Machining 1 | 19-Nov-15 08:00 | 21-Nov-15 08:00 | A1080 Assembly | 3.1 | 1.3 | 0.00h | 0.00h | 22.00h | 0.00h |
| A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | A1080 Assembly | 5.2 | 1.3 | 11.00h | 0.00h | 33.00h | 0.00h |
| A1070 Assembly Plan | 19-Nov-15 08:00 | 19-Nov-15 17:00 | A1080 Assembly | 2.1 | 1.3 | 0.00h | 0.00h | 0.00h | 8.00h |
| A1020 Cleanup 1 | 21-Nov-15 08:00 | 22-Nov-15 17:00 | A1090 Finish Project | 6.1 | 1.4 | 32.00h | 0.00h | 32.00h | 32.00h |
| A1040 Cleanup 2 | 22-Nov-15 08:00 | 23-Nov-15 17:00 | A1090 Finish Project | 4.1 | 1.4 | 24.00h | 0.00h | 24.00h | 24.00h |
| A1100 Cleanup 3 | 22-Nov-15 08:00 | 23-Nov-15 17:00 | A1090 Finish Project | 5.3 | 1.4 | 24.00h | 0.00h | 24.00h | 24.00h |

**Table 6: MFP-FF – Candidates for Seeding Float Path 2. (A1070 Assembly Plan selected)**

With RFF values of 22h, 24h, and 24h respectively, the A1010 Machining 1 – A1080 Assembly, A1040 Cleanup 2 – A1090 Finish Project, and A1100 Cleanup 3 – A1090 Finish Project relationships are selected to seed float paths 3, 4, and 5. (The two cleanup-predecessor relationships have identical RFF values, and their predecessors both begin and end at the same time. Ultimately, the choice of one over the other is here based on the Activity IDs.)

*Shop Work – Total Float Option*

As shown in Figure A- 9, *total float* MFP analysis of the schedule leads to the identification of seven different float *paths*, with five paths comprising only a single activity each. Consistent with prior conclusions, the float paths are not correlated with activity float values, so reference to relationship floats is needed to characterize the basis for and relative *criticality* of each float path. As for the previous example, the seeding and tracing of the float paths can be understood using the relationship listing of Table 7, as follows:

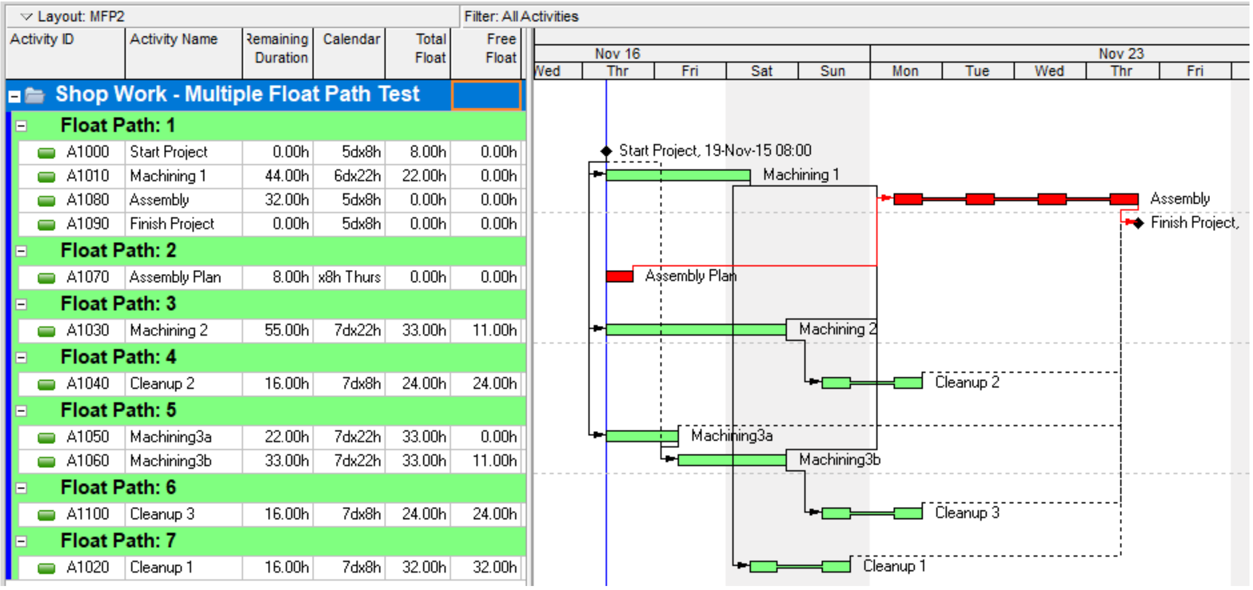



**Figure A- 9: Shop Work – MFP-TF, No Constraint, End @ Activity " ", Path Limit " " (Crit~TF≤0)**

| Pred_ID_Name | Pred_Task_ES | Pred_Task_EF | Succ_ID_Name | Succ_Task_ES | Succ_Task_EF | Pred_ID_FP-FPO | Succ_ID_FP-FPO | Pred-TF | Succ-TF | RTF | RSTF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1050 Machining3a | 19-Nov-15 08 | 20-Nov-15 08:00 | 1.1 | 5.1 | 8.00h | 33.00h | 16.00h | 33.00h |
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1010 Machining 1 | 19-Nov-15 08 | 21-Nov-15 08:00 | 1.1 | 1.2 | 8.00h | 22.00h | 8.00h | 22.00h |
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1030 Machining 2 | 19-Nov-15 08 | 21-Nov-15 20:00 | 1.1 | 3.1 | 8.00h | 33.00h | 16.00h | 33.00h |
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1060 Machining3b | 20-Nov-15 08 | 21-Nov-15 20:00 | 1.1 | 5.2 | 8.00h | 33.00h | 16.00h | 55.00h |
| A1050 Machining3a | 19-Nov-15 08:00 | 20-Nov-15 08:00 | A1060 Machining3b | 20-Nov-15 08 | 21-Nov-15 20:00 | 5.1 | 5.2 | 33.00h | 33.00h | 33.00h | 33.00h |
| A1010 Machining 1 | 19-Nov-15 08:00 | 21-Nov-15 08:00 | A1020 Cleanup 1 | 21-Nov-15 08 | 22-Nov-15 17:00 | 1.2 | 7.1 | 22.00h | 32.00h | 66.00h | 32.00h |
| A1030 Machining 2 | 19-Nov-15 08:00 | 21-Nov-15 20:00 | A1040 Cleanup 2 | 22-Nov-15 08 | 23-Nov-15 17:00 | 3.1 | 4.1 | 33.00h | 24.00h | 77.00h | 24.00h |
| A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | A1100 Cleanup 3 | 22-Nov-15 08 | 23-Nov-15 17:00 | 5.2 | 6.1 | 33.00h | 24.00h | 77.00h | 24.00h |
| A1030 Machining 2 | 19-Nov-15 08:00 | 21-Nov-15 20:00 | A1080 Assembly | 23-Nov-15 08 | 26-Nov-15 17:00 | 3.1 | 1.3 | 33.00h | 0.00h | 33.00h | 0.00h |
| A1010 Machining 1 | 19-Nov-15 08:00 | 21-Nov-15 08:00 | A1080 Assembly | 23-Nov-15 08 | 26-Nov-15 17:00 | 1.2 | 1.3 | 22.00h | 0.00h | 22.00h | 0.00h |
| A1070 Assembly Plan | 19-Nov-15 08:00 | 19-Nov-15 17:00 | A1080 Assembly | 23-Nov-15 08 | 26-Nov-15 17:00 | 2.1 | 1.3 | 0.00h | 0.00h | 0.00h | 8.00h |
| A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | A1080 Assembly | 23-Nov-15 08 | 26-Nov-15 17:00 | 5.2 | 1.3 | 33.00h | 0.00h | 33.00h | 0.00h |
| A1080 Assembly | 23-Nov-15 08:00 | 26-Nov-15 17:00 | A1090 Finish Project | 26-Nov-15 17 | 26-Nov-15 17:00 | 1.3 | 1.4 | 0.00h | 0.00h | 0.00h | 0.00h |
| A1020 Cleanup 1 | 21-Nov-15 08:00 | 22-Nov-15 17:00 | A1090 Finish Project | 26-Nov-15 17 | 26-Nov-15 17:00 | 7.1 | 1.4 | 32.00h | 0.00h | 32.00h | 32.00h |
| A1040 Cleanup 2 | 22-Nov-15 08:00 | 23-Nov-15 17:00 | A1090 Finish Project | 26-Nov-15 17 | 26-Nov-15 17:00 | 4.1 | 1.4 | 24.00h | 0.00h | 24.00h | 24.00h |
| A1100 Cleanup 3 | 22-Nov-15 08:00 | 23-Nov-15 17:00 | A1090 Finish Project | 26-Nov-15 17 | 26-Nov-15 17:00 | 6.1 | 1.4 | 24.00h | 0.00h | 24.00h | 24.00h |

**Table 7: Shop Work – Relationship Listing for MFP-TF**

Float path 1 is seeded by the Assembly – Finish Project relationship. This relationship has the lowest RTF value (-0h) of all candidate relationships, and its predecessor finishes later than that of the other relationship with the same RTF, Assembly Plan – Assembly. Backward-driving logic is traced from this seed through Assembly, Machining 1, and Start Project. With no predecessors, Start Project terminates the backward trace. Forward-driving logic is traced from this seed, starting and ending with Finish Project since it has no successors. At this point, float path 1 has been fully traced.

To illustrate, Table 8 details the four predecessor relationships of the Assembly activity. Activity A1070 Assembly Plan clearly has the lowest RTF value, but it loses out to A1010 Machining 1 in the float path assignment. Oddly, close examination reveals that A1070 Assembly Plan was omitted NOT because it was driving in only one direction, nor because it had a higher value of RSTF. Rather, it was omitted pre-emptively because the predecessor activity itself had no predecessors. If the missing link from A1000 Start Project to A1070 Assembly Plan is restored, then float path 1 is changed to include A1070 Assembly Plan instead of A1010 Machining 1. Thus, while RTF seems to be of clear importance, it is enforced only after other conditions are met.

| Pred_ID_Name | Succ_ID_Name | Pred_ID_FP-FPO | Succ_ID_FP-FPO | Rel_Path | Driving (B,F) | Pred-Preds | Pred-TF | Succ-TF | RTF | RSTF |
|---|---|---|---|---|---|---|---|---|---|---|
| A1030 Machining 2 | A1080 Assembly | 3.1 | 1.3 | | BF | 1 | 33.00h | 0.00h | 33.00h | 0.00h |
| A1010 Machining 1 | A1080 Assembly | 1.2 | 1.3 | 1 | BF | 1 | 22.00h | 0.00h | 22.00h | 0.00h |
| A1070 Assembly Plan | A1080 Assembly | 2.1 | 1.3 | | B | 0 | 0.00h | 0.00h | 0.00h | 8.00h |
| A1060 Machining3b | A1080 Assembly | 5.2 | 1.3 | | BF | 2 | 33.00h | 0.00h | 33.00h | 0.00h |

**Table 8: MFP-TF – Total Float-based Tracing of Bi-Directional Driving Logic at Assembly Predecessors. (Machining 1 selected.)**

Float path 2 is seeded by the Assembly Plan – Assembly relationship, the candidate relationship with lowest RTF (0h). The backward trace starts and ends with the Assembly Plan activity since it has no predecessors.

Float path 3 is seeded by the Start Project – Machining 2 relationship, which was selected after the following tie-breakers:

- Activity total float
- Activity free float
- Early Finish (latest date)
- Activity ID

Specifically, the following observations are noted:

- Start Project – Machining 2 is one of three candidate relationships with the lowest RTF (16h). (The others are from Start Project to Machining 3a and Machining 3b.)
- The three successor activities of the three candidate relationships all have the same total float (33h).
- Machining 2 and Machining 3b both have the same Early Finish (21-Nov-15 20:00).
- Machining 2 has the alphabetically higher-ranked Activity ID (A1030 vs A1060).

There is no backward trace from this seed relationship because its predecessor is already assigned. The forward trace starts and ends with Machining 2. Its only bi-directional driving successor relationship is to an activity that is already assigned (Assembly). Its other successor relationship (to Cleanup 2) is NOT driving because RTF ≠ $TF_{(predecessor\ activity)}$.

Float paths 4, 5, 6, and 7 can be explained similarly.

*Shop Work – Ending-With Activity*

As for the EPDM example, the impact of the ending-with activity selection is best illustrated by specifying an activity other than the *Finish Project* milestone. Figure A- 10 and Table 9 depict the result of repeating the *total float* analysis after selecting A1100 Cleanup 3 as the ending-with activity. As before, the primary impact of this selection is the pre-filtering of the activities (and relationships) to be analyzed, such that only A1100 Cleanup 3 and its path predecessors are included. The subsequent processes for seeding and tracing logic paths are unchanged, being based on RTF and RSTF. The result is the set of all path predecessors of A1100 Cleanup 3, arranged into float paths according to relationship total float. The selected end activity has no impact on the relationship total floats of its predecessors. Moreover, the only bi-directional driving relationship is between the two Machining (3a and 3b) activities, and the float paths are fragmented. Once again, this result demonstrates why the *total float* option with an ending activity is rarely useful and can be misleading.

Layout: MFP2 | Filter: All Activities

| Activity ID | Activity Name | Remaining Duration | Calendar | Total Float | Free Float |
|---|---|---|---|---|---|
| **Shop Work - Multiple Float Path Test** | | | | | |
| **Float Path: 1** | | | | | |
| A1000 | Start Project | 0.00h | 5dx8h | 8.00h | 0.00h |
| **Float Path: 2** | | | | | |
| A1050 | Machining3a | 22.00h | 7dx22h | 33.00h | 0.00h |
| A1060 | Machining3b | 33.00h | 7dx22h | 33.00h | 11.00h |
| **Float Path: 3** | | | | | |
| A1100 | Cleanup 3 | 16.00h | 7dx8h | 24.00h | 24.00h |
| **No Float Path** | | | | | |
| A1010 | Machining 1 | 44.00h | 6dx22h | 22.00h | 0.00h |
| A1030 | Machining 2 | 55.00h | 7dx22h | 33.00h | 11.00h |
| A1020 | Cleanup 1 | 16.00h | 7dx8h | 32.00h | 32.00h |
| A1040 | Cleanup 2 | 16.00h | 7dx8h | 24.00h | 24.00h |
| A1080 | Assembly | 32.00h | 5dx8h | 0.00h | 0.00h |
| A1070 | Assembly Plan | 8.00h | x8h Thurs | 0.00h | 0.00h |
| A1090 | Finish Project | 0.00h | 5dx8h | 0.00h | 0.00h |

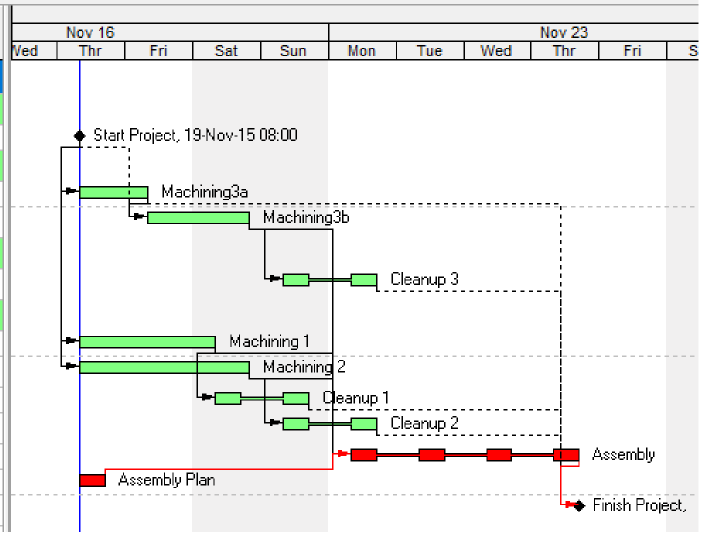



**Figure A- 10: Shop Work – MFP-TF, No Constraint, End @ Activity "A1100 Cleanup 3", Path Limit " " (Crit~TF≤0)**

| Pred_ID_Name | Pred_Task_ES | Pred_Task_EF | Succ_ID_Name | Succ_Task_ES | Succ_Task_EF | Pred_ID_FP-FPO | Succ_ID_FP-FPO | Pred-TF | Succ-TF | RTF | RSTF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1050 Machining3a | 19-Nov-15 08 | 20-Nov-15 08:00 | 1.1 | 2.1 | 8.00h | 33.00h | 16.00h | 33.00h |
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1060 Machining3b | 20-Nov-15 08 | 21-Nov-15 20:00 | 1.1 | 2.2 | 8.00h | 33.00h | 16.00h | 55.00h |
| A1050 Machining3a | 19-Nov-15 08:00 | 20-Nov-15 08:00 | A1060 Machining3b | 20-Nov-15 08 | 21-Nov-15 20:00 | 2.1 | 2.2 | 33.00h | 33.00h | 33.00h | 33.00h |
| A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | A1100 Cleanup 3 | 22-Nov-15 08 | 23-Nov-15 17:00 | 2.2 | 3.1 | 33.00h | 24.00h | 77.00h | 24.00h |

**Table 9: Shop Work – Relationship Listing for MFP-TF, Ending with A1100 Cleanup 3**

As shown in Figure A- 11 and Table 10, performing the *free float* MFP analysis ending with A1100 Cleanup 3 clearly illustrates that all of its path predecessors are members of the driving logic path to the ending activity. As in the previous example, it is no surprise that, with the ending activity not on the longest path, substantial portions of the longest path are excluded from the results.

Layout: MFP2 | Filter: All Activities

| Activity ID | Activity Name | Remaining Duration | Calendar | Total Float | Free Float |
|---|---|---|---|---|---|
| **Shop Work - Multiple Float Path Test** | | | | | |
| **Float Path: 1** | | | | | |
| A1000 | Start Project | 0.00h | 5dx8h | 8.00h | 0.00h |
| A1050 | Machining3a | 22.00h | 7dx22h | 33.00h | 0.00h |
| A1060 | Machining3b | 33.00h | 7dx22h | 33.00h | 11.00h |
| A1100 | Cleanup 3 | 16.00h | 7dx8h | 24.00h | 24.00h |
| **No Float Path** | | | | | |
| A1010 | Machining 1 | 44.00h | 6dx22h | 22.00h | 0.00h |
| A1030 | Machining 2 | 55.00h | 7dx22h | 33.00h | 11.00h |
| A1020 | Cleanup 1 | 16.00h | 7dx8h | 32.00h | 32.00h |
| A1040 | Cleanup 2 | 16.00h | 7dx8h | 24.00h | 24.00h |
| A1080 | Assembly | 32.00h | 5dx8h | 0.00h | 0.00h |
| A1070 | Assembly Plan | 8.00h | x8h Thurs | 0.00h | 0.00h |
| A1090 | Finish Project | 0.00h | 5dx8h | 0.00h | 0.00h |

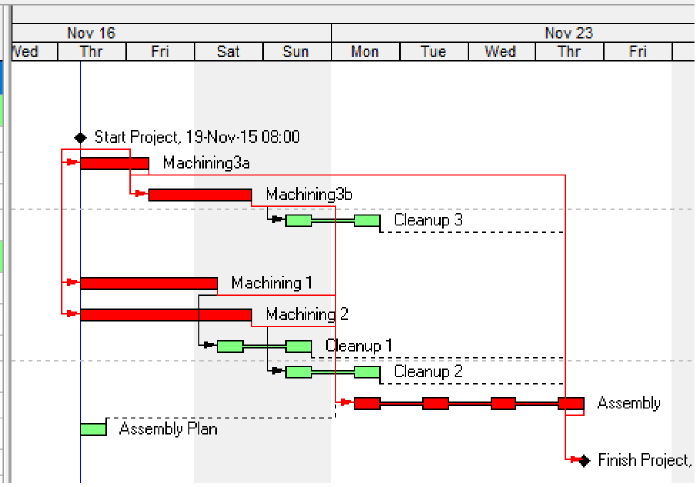



**Figure A- 11: Shop Work – MFP-FF, No Constraint, End @ Activity "A1100 Cleanup 3", Path Limit " " (Crit~LP)**

| Pred_ID_Name | Pred_Task_ES | Pred_Task_EF | Succ_ID_Name | Succ_Task_ES | Succ_Task_EF | Pred_ID_FP-FPO | Succ_ID_FP-FPO | Pred-FF | Succ-FF | RFF | RSFF |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1050 Machining3a | 19-Nov-15 08:00 | 20-Nov-15 08:00 | 1.1 | 1.2 | 0.00h | 0.00h | 0.00h | 0.00h |
| A1000 Start Project | 19-Nov-15 08:00 | 19-Nov-15 08:00 | A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | 1.1 | 1.3 | 0.00h | 11.00h | 8.00h | 22.00h |
| A1050 Machining3a | 19-Nov-15 08:00 | 20-Nov-15 08:00 | A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | 1.2 | 1.3 | 0.00h | 11.00h | 0.00h | 0.00h |
| A1060 Machining3b | 20-Nov-15 08:00 | 21-Nov-15 20:00 | A1100 Cleanup 3 | 22-Nov-15 08:00 | 23-Nov-15 17:00 | 1.3 | 1.4 | 11.00h | 24.00h | 11.00h | 0.00h |

**Table 10: Shop Work – Relationship Listing for MFP-FF, Ending with A1100 Cleanup 3**

*Shop Work Example - Conclusions*

This example demonstrates that P6's proprietary algorithms for seeding and tracing float paths are more nuanced than might be suggested by the initial (EPDM) paper or by the user documentation. In particular, the rules for preferring or pre-qualifying specific activities and relationships prior to tie-breaker testing – when parallel driving logic is most likely – remain unclear.

More importantly, the example demonstrates the fragmentation and dispersal of the Longest Path – with some parallel branches relegated to float paths much higher than expected – when multiple calendars are not perfectly aligned. This phenomenon exists with both *total float* and *free float* options, and it provides the primary argument against specifying any limit on the number of float paths to be analyzed. Unfortunately, the observation of such fragmentation, whether on the Longest Path or on the driving path to some other ending activity, means that the entire float path sequence resulting from the MFP analysis may be essentially unreliable.

The shop work example is not representative of typical construction or fabrication projects, and it was developed explicitly to explore the behavior of P6's MFP analysis in schedules with multiple, unaligned calendars. While some limits to the validity of the analysis are evident, these appear to exist primarily in *edge-case* conditions like those of the example.