PS.07

When is the Critical Path Not the Most Critical Path?

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Today, 50 years after the critical path method (CPM) was invented, there still is no universally accepted definition of the central term, *critical-path*. Among the dozens of more obscure definitions, two conflicting definitions dominate Scheduling glossaries: the *longest-path* basis and the *least-float* basis.

The problem goes much deeper than a lack of agreement on what should be the determining factor when identifying a schedule's *critical-path*. A careful review of current scheduling literature shows that there is virtually no definition to be found for the underlying words "path" or "critical," as standalone terms of significance in their own right.

This paper challenges the conventional thinking, by proposing a new way to understand and use the term critical-path. At stake is much more than a semantic discussion of terminology. Numerous surveys have confirmed that CPM schedules are used for two primary reasons: project management and dispute resolution. To support either use, the *critical-path* must be identifiable in a consistent, objective, and defendable way. In claims, methods for proving delay, acceleration, and time impact center on a schedule's contemporaneous *critical-path*. In project management, the main purpose of the schedule is to help prioritize daily activities, so that what is more "critical" gets earlier and greater attention.

DEFINITIONAL CRITERIA

Note that the word "critical" is an adjective that characterizes the word "path." A "critical" path is distinguished from a "near-critical" or "non-critical" path. Because of its central importance, we will begin by understanding the root word, "path." For, if we cannot agree on a path's composition, we certainly cannot agree on how to distinguish a *critical* path from its *non-critical* cousin. Accordingly, in this section, we will explore definitional criteria for three terms: *path*, *critical*, and *critical-path*. In the second section, we will consider a new paradigm for defining the term "critical path," one that accommodates the definitional criteria developed in this section.

DEFINITIONAL CRITERIA FOR THE TERM, *PATH*

We begin by turning to the American Heritage dictionary to appreciate the common meaning of the word, *path.*

> "The route or course along which something travels or moves. A road, way, or track made for a particular purpose.

Unfortunately, these two general definitions provide little help. More useful, perhaps, is to picture a path through the woods, comprised of evenly spaced stepping stones. Would we consider such a path as being comprised only of the stones themselves, or would the path also include the cleared and leveled dirt between and alongside the stones? To answer this, we envision those same stones, but this time in the plant where they are manufactured. Without the surrounding leveled and cleared ground, the stones lose their context and no longer appear to be a *path*. From this observation, we realize that, implicit in the word *path*, are <u>all</u> of the components that, collectively, constitute a path, not just the stones themselves, even though they are the *primary* component.

We realize that it is important to identify all of the components that give the path its functionality, allowing those who travel on the path to reach their intended destination. In scheduling terms, this would include not just the activity itself, but also the relationships between the activities, date constraints that regulate work flow along a path, calendars that provide the temporal backdrop for work effort, and even software settings that affect the interpretation of work flow intentions and realities.

Further, we must distinguish between (a) knowing that a relationship between two activities exists, and (b) appreciating the nature of that relationship. While activities can be "related" to one another in many different ways (common resource, geography, timing, work type, etc.), when seen as an element in defining the word, *path*, we are interested in the *functional* aspect of relationships. That is, our definition must describe how the activities relate to one another and to the ultimate terminus of the path.

Both dictionary definitions seem to call for such a linkage. While "made for a particular purpose" is a more forceful requirement than "along which something travels or moves," both reference a *purpose* for the path, and not just what might physically comprise a path.

Because we believe that the definition for the term, path, should make reference to the path's point of terminus, as well as its point of origin, we are faced with this difficult question: Where does a path begin and end? If we cannot define a path's starting or ending points, how can we begin to define the term, *critical-path*.

After exhaustive consideration, our studies led us to three possible options. For purposes of this paper, we assume that whatever condition(s) might define the start of a path, would also define the end of a path.

- **Open Ends:** We could say that a path begins where it has no predecessor activity, and it ends where it has no successor activity. This definition fully supports the *longest path* definition.
- **Date Constraints:** for this option, we assume that a start-no-earlier-than date constraint is imposed to the first activity in the schedule and that a finish-no-later-than date constraint is imposed to the last activity in the schedule. This option says that a path spans between date constraints.And,
- **Total Float:** We could say that a path can only have one total float value, and that the start and end of a path are identified by a change in total float values.

We tested each option against a sample logic diagram, and then applied the two prevailing *critical-path* definitions. We found that each option introduced problems we could not easily solve.

Open Ends

The immediate problem with the open end option is that it allows a single path to have multiple total float values along the way. This is problematic for two reasons:

- It makes the two prevailing definitions of *critical-path* instantly incompatible. We see that the *longest* path cannot be *least-float* path, because the *longest* path has more than one total float value.And,
- It further complicates the question of: with what schedule element should the total float value be associated?
  - We know that total float does not belong to a single activity.
  - We have always thought it belonged to "*the path." And,*
  - But if a path has more than one total value along its length, then: *with what schedule element should the total float value be associated?*

Date Constraints

This option poses a different problem, for if there were more than two date constraints in the schedule, then we remove the absolute correlation between the longest path and the least-float path.

Total Float

This option has two immediate drawbacks. First, total float can change because of any number of factors, including date constraints, path length, software settings, calendars, and even the choice of relationship types (SS, FS, FF, SF). With each subsequent schedule update, the total float values would change and, with them, the precise identify of the paths themselves. This would be as problematic as having activity identifiers changing with each subsequent update. Second, using this option, the path would no longer necessarily correlate with any particular completion milestone, let alone the project completion milestone.

Path Segments

Realizing that none of the obvious options came without complications, we partially solved the problem by creating a new term, *path segment*:

A *path segment* is any series of connected activities that begins with either a date constraint or two or more predecessor activities, and ends with either a date constraint or two or more successor activities.

The mathematics of forward and backward pass calculations insure that a single path segment can only have one total float value. Further, a path segment can never terminate into more than one completion milestone. Finally, a path segment might be part of a path, but it might not.

We can now use the path segment to define a path as "a series of connected path segments sharing the same total float value and terminating at a completion milestone." [Note: This path definition would not support the longest path computational basis, unless we further qualify the path as spanning between two date constraints – or, at least, terminating at a particular date constraint. Likewise, we could use the least-float computational basis, again provided that we relate the path to a particular terminating date constraint.]

Conclusions

We can now establish these definitional criteria for the word, *Path*:

- It should associate the path to the schedule in which it resides.
- It should identify the material components that comprise the path.
- It should relate the components to one another.
- It should relate the path to its points or origin and terminus. And,
- In some fashion, the definition of the term *path* should acknowledge the presence and computational effect of date constraints, as well as multiple predecessor/successor activities.

DEFINITIONAL CRITERIA FOR THE TERM, *CRITICAL*

Now we turn our attention to the word, *critical.* Based on how the term *critical-path* is routinely used, the word *critical* cannot merely mean "important" or "essential," because every activity in a schedule is important or essential to the completion of the project. As a modifier, the word "critical" implies a degree of urgency to be associated with particular activities.

We also note that the word "critical*,"* as used in CPM jargon, is a comparative one and can be translated to mean: "most critical." In fact, quite often the complete expression is, "*the* critical path," as if to say that one path is preeminently more critical than any others. The two dominant formulas for identifying a *critical-path* also use comparative terms: *longest* path, and *least*-float path. Thus, the criticality of one path is almost always compared to the lesser criticality of others paths.

Esoterically, we consider whether a path's criticality is predicated on the independently-determined criticality of the activities that comprise it, or whether the activities of a path derive their criticality from the path on which they reside. A path cannot obtain its criticality from the activities that reside on it, because there is no independent basis for establishing criticality of an activity. Easiest to dismiss is the "longest path" approach, which relies on activity durations that are aggregated to determine the length of a path. This method gives no thought to activity criticality.

The other popular basis for identifying the *critical-path*, "least-float," uses the total float value to determine criticality. We must now ask whether total float is an activity or path variable. It might seem to be an activity variable since the formulaic basis for total float is the difference between early dates and late dates, which are calculated for each activity individually. Yet the *behavior* of total float consumption is entirely *path*-centric. Both forward and backward passes, which yield early/late Dates, are performed across paths. Equally convincing, a change in any single activity's duration will change the total float values for all activities on the path upon which the activity resides. Total float, then, is a *group* possession, (a *path* value) and not the sole dominion of any single or particular activity. Our conclusion, then, is that activities acquire the criticality of the paths they inhabit.

From all of this we realize that, for the term to have any reliable meaning at all, *criticality* must be objectively, and not subjectively, derived. That is, however we ultimately define the word, "*critical,"* it must be measurable

and based on a numerical or statistical range, and not comparative subjectivity. For example, in weather reporting, a *tropical storm* correlates to winds between 39 and 73 miles per hour. Higher winds constitute a *hurricane*. Imagine if we replaced the three separate terms (tropical depression, tropical storm, and hurricane) with one word: "critical." How meaningful or useful would that substitution be?

Conclusions

We can now establish these definitional criteria for the word, *Critical*:

- The word *critical* cannot simply mean "important" or "essential," as every activity in the schedule is important and essential to the project's full and timely completion.
- For a path to be *critical*, it must be dominantly influential upon, and directly related to, some specific project objective.
- A path does not get its criticality from the activities that reside upon it. Instead, an activity derives its criticality from the path upon which it resides. And,
- To be useful and meaningful, criticality must be objectively determined, must be measurable (not subjective), must be numerically based, and must not be comparative.

DEFINITIONAL CRITERIA FOR THE TERM, *CRITICAL-PATH*

Now we examine the term, *critical-path*, in the context of its most common usage and separate from our earlier understanding of the foundational terms, "critical" and "path*."* Immediately we appreciate that the intent behind the term is to deem one particular path as being (the most) "critical," as compared to all other paths in the schedule. In so doing, we come face-to-face with why the overall meaning of the term *critical-path* is so often and easily misunderstood, and why there is so much confusion and debate in scheduling circles as to <u>what IS the "critical path"</u>?

This confusion is fostered by multiple and differing definitions of the term, even 50 years after its invention. We saw earlier that the term is used in a comparative manner, and that explains the bulk of the problem. To fully appreciate the limitation of the comparative context, let us consider three different scenarios. In each, the schedule contains 100 activities, the *critical-path* contains 20 activities, the project's contractual length is 365 calendar days, and the project is working a seven-day calendar.

- Inscenario 1, the longest/least-float path is 386 days long, with total float of -21 (negative 21). The second longest/least-float path is 382 days long, bearing total float of -17. The third longest/least-float path is 378 days long, with total float of -13.
- In scenario 2, the longest/least-float path is 352 days long, with total float of +13. The second longest/least-float path is 348 days long, bearing total float of +17. The third longest/least-float path is 344 days long, with total float of +21.
- In scenario 3, the longest/least-float path is 382 days long, with total float of -17. The second longest/least-float path is 378 days long, bearing total float of -13. The third longest/least-float path is 352 days long, with total float of +13.

Applying either the *longest* or *least-float* path definition to the first scenario, we are quick to identify the 386-day path as the *critical-path*. Yet, we must also agree that the other two paths, both significantly behind schedule, will not be called <u>critical</u>, but merely "near" critical. Specifically, the path with a length of 382 days is not the longest path – and with total float of -17, which is not the *least* float -- it is therefore not <u>the</u> critical-path. Yet, in scenario 3, a path of the <u>same</u> length and <u>same</u> total float <u>IS</u> labeled *critical-path*, simply because, there, it is the *longest* path, or the one with the least float.

Obviously, our definition makes no sense!

We can see this same contradiction, even more starkly, when we compare the 352-day path of scenarios 2 and 3. In scenario 2, the path with positive total float of +13 is critical because it is the *longest* path and has the *least* total float. Yet, in scenario 3, a path of the same length and total float is not critical, because it is not the *longest* or *least-float* path.

A splash of common sense jolts us back to reality. How can a path that is 17 days behind schedule *not* be considered "critical," While a path that is 13 days ahead of schedule <u>is</u> considered "critical?" Surely there is something fundamentally wrong with our definitions of what is to be considered *critical*!

Aside from the comparative approach being flawed, there is another, equally important, observation to be made from the above examination. Whether "least" or "longest," there is a fallacy in presupposing that there can only be one *critical-path* per schedule (even if we set aside the occasional condition where two paths are of the same length, or bear the same total float).

Today, most schedules incorporate more than one completion milestones. Yet, both the *longest* path and *least-float* path definitions continue to speak in terms of project completion as the one and only objective of "the" *critical-path*. As we confirmed in our discussion of paths and path segments, the introduction of interim date constraints invalidates both the *longest* path and *least-float* path definitions of the term, *critical-path,* as long as the definition speaks only in terms of project completion, and ignore the presence of intermediate completion milestones.

Conclusions

We can now establish these definitional criteria for the term, *critical-path* (DC-CP):

- Whatever the basis for determining the *critical-path*, it should not be comparative. That one path is longer or shorter than another or whether it has total float greater or lesser than another does not help us understand what is truly most critical with respect to the timely achievement of one or more required completion milestones.
- The notion of one *critical-path* (whether the longest path or the least-float path) is a theoretical concept, but rarely the case in real life. Most projects have multiple completion milestones, and the date constraint locking in the latest finish for each milestone launches a separate backward pass, resulting in a separate set of late dates and resultant total float values.
- The *longest* path basis for determining the *critical-path* is flawed, because of the common use of *internal* start-no-earlier-than and finish-no-later-than date constraints. From a practical standpoint, the prolific use of date constraints cannot be mandated out of existence, and is likely to only increase in the future. Actually, we encourage the discrete use of date constraints as a practical and effective way to simulate project management intentions and their likely consequences. And,
- The *least-float* path basis for determining the *critical-path* is flawed in that it necessarily ignores all but the path with the "least" float. When multiple paths are behind schedule (bearing negative total float), the *least-float* method describes all but the path with the *least* total float as being something other than "critical." If we reserve the term *critical-path* for the path with the least total float, then we are left to find other words to describe other paths that might have frightfully negative total float values. One popular term is "*near-critical path*," but what is near-critical about a path with a negative total float value of -17?

A NEW PARADIGM FOR DEFINING THE TERM, *CRITICAL-PATH*

In the previous section we have identified important definitional criteria for defining the terms, *path, critical,* and *critical-path.* These criteria are intended to inform those who may embark on the bold and much-needed effort to craft a new set of terms to represent and communicate the *absolute* (not comparative) importance of the many paths that transect every project schedule.

The purpose of this paper is not to actually wordsmith a new definition of the term, *critical-path*. One reason for not doing so is that this paper concludes that a single term, *critical-path*, is woefully inadequate when, in most schedules, there are multiple paths that have the potential to impact multiple imposed deadlines. Second, the impetus for this paper is a sincere desire to help lay the groundwork for an effort by others to develop a set of terms that meet the intended uses behind the currently inadequate single term, *critical-path*. Third, the 5,000 word limit to this paper makes the crafting of a definition infeasible.

Two Additional Definitional Criteria

Before we introduce a new paradigm for defining the all-important term, *critical-path* (or its replacement by a set of terms), let us first consider two final points not covered in the previous discussion, but that should be factored into any fresh attempt to redefine (or even replace) the term, *critical-path.*

Singular Modifier is Inadequate [56-1]

Reasonable minds will readily agree that, even in a purely theoretical setting, it is rarely, if ever, the case that one path is "critical" while all others are not critical, at all. Historically, it was in response to this realization that the term "near-critical" was coined. But, today, we are just as uncertain as to what constitutes a "near-critical" path as we are unclear about the representation of the term, *critical-path.*"

For this reason, we invite the reader to shake off the decades-old way of thinking about the mythical "critical-path" and replace it with a completely new and utterly logical alternative. It's all about our initial mindset. The current school of thought has us staring at a schedule and trying to find *the critical-path.* Even though the schedule contains multiple completion milestones, we continue to search for one special, magical path.

Instead, how about this approach? We propose that when we look at the schedule, the first target for our gaze might be the various completion milestones, and work backwards from there. We identify all of the paths that lead into a completion milestone, and we proceed to rank each path as to the extent to which it actually or potentially impacts the deadline. With this approach, there are one or more essential paths that affect each deadline. We then use the word "critical" to refer to a certain level of *real* impact to deadlines, and not as a poor-choice word to mean "longest" or "least-float."

The conventional wisdom, that there is some magical *critical-path*, lacks wisdom altogether. Imagine highlighting a single road on a large city map and declaring it to be, the *critical-road!* A critical route toward one destination (and from one starting point) may not be a critical route for any another destination. It depends on where you are headed.

If we recall our intention, to provide project management with an objective sense of priorities and urgency, then would they not be better served by a set of modifiers that reflect *degrees* of such criticality, than one singular term? In the field of medicine, a patient's medical condition may be reported as good, stable, poor, acute, severe, intensive, critical, or terminal. In meteorology, the public may be issued a tornado *watch*, *warning*, or *alert*.

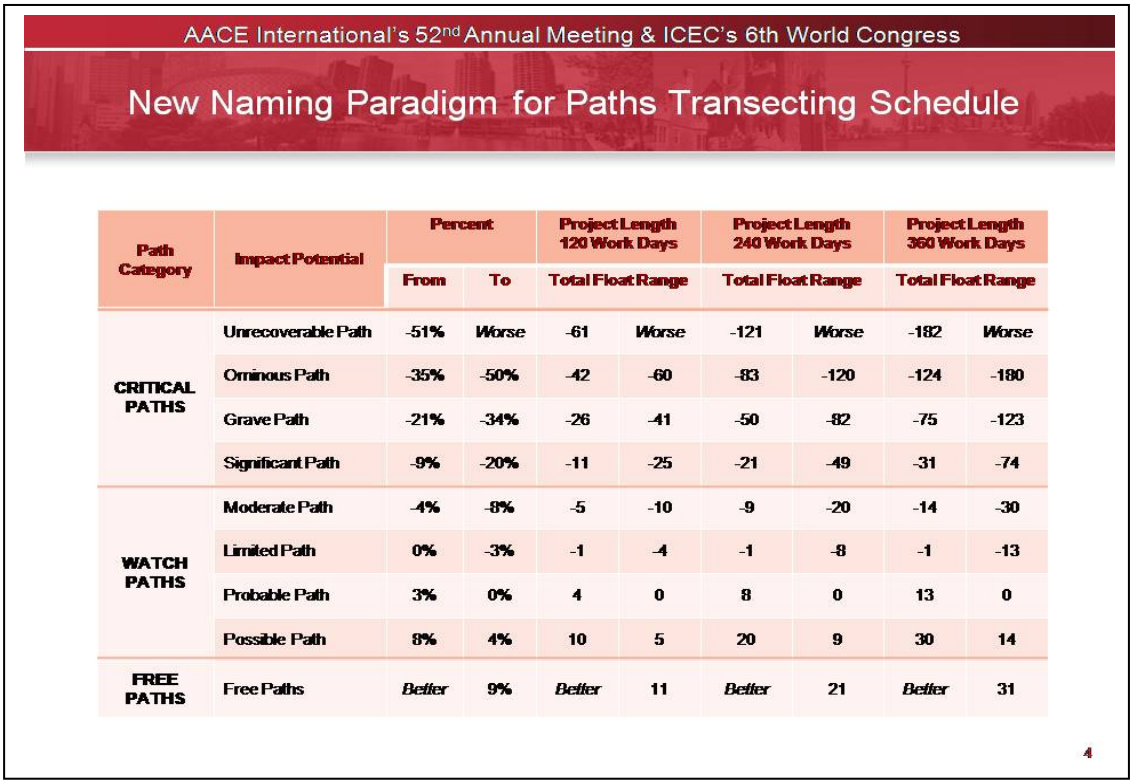
Each Completion Milestone Has Its Own Set of Affecting Paths

We know that each completion milestone launches a separate backward pass, which in turn generates a different set of late dates and accordant total float values. Therefore, each completion milestone is affected by one or more paths, each with its own path-long total float value. And since an activity has the ability to reside on multiple paths simultaneously, each activity often affects one or more completion milestones.

Putting the Two Innovative Concepts Together

If we combine these two concepts, then we arrive at the following suggestions with respect to labeling the paths that actually or potentially affect a completion milestone:

- For each completion milestone, all paths that affect, or pose a potential or real impact on, a particular milestone should be identified.
- The label we assign to a path should make reference to the completion milestone it affects. Examples would include building dry-in path or substantial completion path. And,
- Every path should be characterized as to the degree to which it affects, or has the potential to affect, the timely achievement of a completion milestone. For instance, consider the following set of labels, as just one possible example of how to reflect a path's *threat level* with respect to timely achievement of a completion milestone, (see figure 1).



Path Category	Impact Potential	Percent		Project Length 120 Work Days		Project Length 240 Work Days		Project Length 360 Work Days	
		From	To	Total Float Range		Total Float Range		Total Float Range	
CRITICAL PATHS	Unrecoverable Path	-51%	*Worse*	-61	*Worse*	-121	*Worse*	-182	*Worse*
	Ominous Path	-35%	-50%	-42	-60	-83	-120	-124	-180
	Grave Path	-21%	-34%	-26	-41	-50	-82	-75	-123
	Significant Path	-9%	-20%	-11	-25	-21	-49	-31	-74
WATCH PATHS	Moderate Path	-4%	-8%	-5	-10	-9	-20	-14	-30
	Limited Path	0%	-3%	-1	-4	-1	-8	-1	-13
	Probable Path	3%	0%	4	0	8	0	13	0
	Possible Path	8%	4%	10	5	20	9	30	14
FREE PATHS	Free Paths	*Better*	9%	*Better*	11	*Better*	21	*Better*	31

Figure 1— New Naming Paradigm for Paths Transecting Schedule

Critical Path

Any path that poses a real and extreme threat to the timely completion of one or more schedule milestones, and which requires urgent, substantive, and deliberate management response in order to reverse, mitigate, or eliminate the impending impact.

Watch Path

Any path that poses a potential or easily reversible threat to the timely completion of one or more schedule milestones, and which warrants close and special monitoring and control in order to reverse, mitigate, or eliminate the likely impact.

Free Path

Any path that, based on indicators such as total float or path segment volume, poses no real or potential threat to any schedule milestones, and requires no special monitoring and control, beyond that provided by normal work activity supervision and oversight.

CONTRASTING THE PROPOSED PARADIGM TO THE CURRENT MODEL

The labels, percentages, and ranges in the above table are presented merely as an example of how we might differently approach the matter of path characterization. But it should be obvious that the new thinking eliminates the deficiencies posed by the *longest* and *least-float,* one-project-deadline definitions. A few obvious advantages gained by this new paradigm are:

- We are no longer bound to a single word ("critical") to describe all paths that are not non-critical. We can use different words to describe increasing degrees of potential or actual impact to the timely achievement of more than one specific completion milestone.
- The new path labels (e.g. ominous path, moderate path, etc.) are not comparative to one another. Instead, they describe the extent of the potential or real impact to a completion milestone that a particular path poses. And,
- The term "critical-path" now refers to a category of real impacts, ranging from "significant" to "unrecoverable." Likewise, other paths with potential or easily reversible impacts that range from "possible" to "moderate," are classified as Watch-Paths.

How would we use this set of labels in combination with milestone-specific completion deadlines? A narrative report, using the following headings, might read as follows:

Project Substantial Completion Milestone, Confidence Level

The project's Substantial Completion milestone is in serious jeopardy with the presence of six Critical paths, as follows. Confidence in achieving this milestone in a timely manner is all but gone.

- One *ominous path*, passing through electrical activities on the fourth floor, poses the greatest threat to this milestone, with a total float value of -87.
- Two *grave paths*, both passing through civil activities on the second and third floors, further threaten this milestone's timely completion. These paths carry total float values of -52 and -61. And,
- Three *significant paths,* passing through various mechanical activities in the penthouse and boiler room, also threaten this milestone's timely completion. The total float values for these paths are: -27, -29, and -31.

Building Dry-In Completion Milestone, Confidence Level

- The project's building dry-in milestone is in fairly good shape, with only three watch paths (one moderate and two probable), as follows. confidence in achieving this milestone in a timely manner is guarded, but optimistic.
- There is one moderate path running through exterior window walls on the sixth floor, with a total float value of -9. While this is a negative total float value, it *is* entirely recoverable, and efforts are underway to reverse the impact of this path on the Building Dry-In milestone. And,
- The other two watch paths are ones that hold the *possibility* (but not immediate real threat) of negatively impacting the building dry-in commitment. nonetheless, because these are watch paths, they are being closely monitored.

PROJECT FINAL COMPLETION MILESTONE, CONFIDENCE LEVEL

The project final completion milestone has no critical or watch paths leading to it. Instead, the five free paths that lead to it all enjoy significant positive total float. Confidence in achieving this milestone in a timely manner is quite high.

Overall Project, Confidence Level

Overall, the project schedule contains 113 paths. Despite 13 critical paths and 35 watch paths, confidence in the project completing on time, and the vast majority of interim deadlines being met, remains fairly high, (see table 1).

MILESTONE	CRITICAL	WATCH	FREE	TOTAL
Earthwork Complete	0	2	4	6
Demolition Complete	1	0	4	5
Phase I Complete	1	5	1	7
Building Dry-In	0	3	7	10
Phase II Complete	1	5	11	17
Permanent Power	2	4	6	12
Phase III Complete	2	8	14	24
Substantial Completion	6	8	15	29
Final Completion	0	0	3	3
Overall	**13**	**35**	**65**	**113**

Table 1—Overall Project Confidence Level

The current standard – using a singular term, *critical-path*, to represent all paths in the schedule that are not "non-critical" – is useless, confusing, and misleading.

- The word *critical,* as it is commonly employed, is used in a comparative way, thereby creating conditions where paths with positive float are critical and ones with negative float are not.
- The current standard insists that there is only *one* critical-path (e.g., "*the critical path"*), even though the schedule has multiple completion deadlines.

- The two most prevalent formulaic bases for the identification of the *critical-path* (the *longest* path, and the *least-float* path) are both inadequate in a multi-deadline schedule environment. And,
- The current wisdom insists that, to be a good schedule, there must only be one starting activity and one ending activity, despite overwhelming evidence, from the field of practice, that schedules routinely incorporate multiple date constraints. This "standard," not to have any "open ends," has encouraged the redundant (and often random) tying of activities to adjacent activities, merely to conform to some arbitrary rule.

So, we return to the title of this paper, which is: *When is the Critical Path not the Most Critical Path?*

Answer: *What do you mean by "critical?"*

Until the worldwide community of scheduling practitioners can agree on the meaning of that one eight-letter word, *critical*, we cannot answer the above, or any other, questions that concern the use of the term, *critical-path.* Until we reach that level of global consensus, we can only expect continued and increased confusion about the critical path method, our processes, our work products, our conclusions, and – most of all – our professional credibility.

This paper urges the leadership of the scheduling practice to commission and conduct a comprehensive study of this most important topic**.**

[Note: As part of the development of this paper, 22 definitions of the term "critical-path" were found using Google. We applied each definition to the sample logic discussed in this paper. The study confirmed inconsistent and conflicting results between the *longest-path* and *least-float path* definitions. The results of the study are included at the end of the PowerPoint presentation, beginning on Slide 71.]

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