فرآیند یکپارچه برنامه ریزی، زمانبندی و کنترل پروژه

بخش هفتم:

استاندارد اجرایی: بررسی و تایید مسیر بحرانی

ارائه دهندگان:

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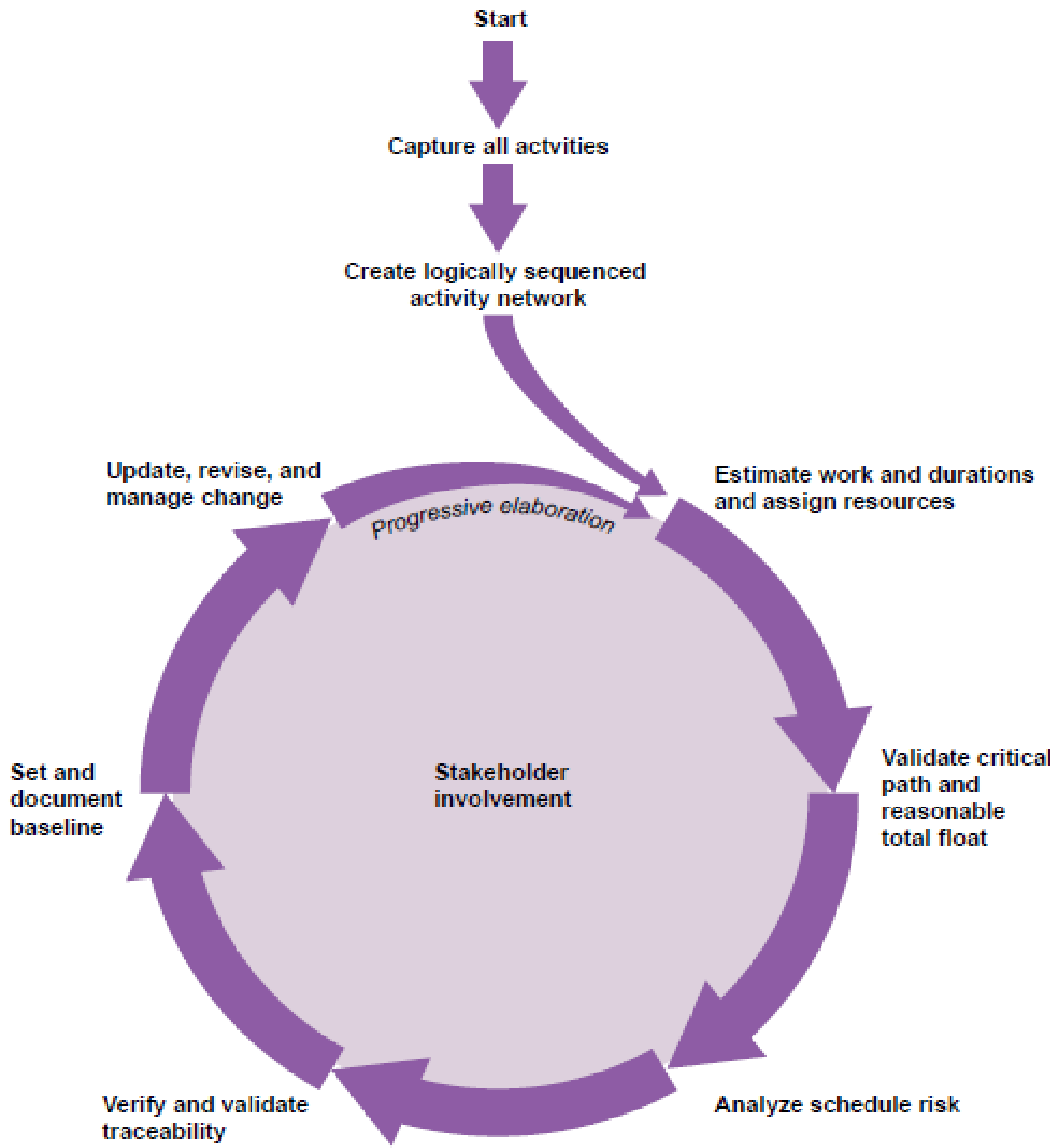
(PhD, PMP, CMIT)

What we will learn?

- What is critical path?
- Common barriers to a valid critical path
- Resource leveling and critical resources
- Critical path management
- Program and project critical paths
- Checklist for a scheduler for critical path determination, assessment, and validation
- An auditor’s key questions and documents for critical path determination, assessment, and validation

A process for creating and maintaining reliable schedules

- This is a cyclic process
- Elaborated through rolling wave process.



A process for creating and maintaining reliable schedules

Process step	Corresponding action	Section
Capture all activities	Capturing all activities	3
Create logically sequenced activity network	Sequencing all activities	4
Estimate work and durations and assign resources	Allocating and leveling resources	5
	Determining and assigning durations to activities	6
Validate critical path and reasonable total float	Critical path determination, assessment, and validation	7
	Ensuring reasonable total float	8
Analyze schedule risk	Schedule constructability and risk analysis	9
Verify and validate traceability	Verifying that the schedule can be traced horizontally and vertically	10
Set and document baseline	Setting, monitoring, controlling, and Maintaining a baseline schedule	11
Update, revise, and manage change	Setting, monitoring, controlling, and Maintaining a baseline schedule	11
	Updating the schedule using actual progress and logic	12

What Is Critical Path?

Definition

- Determines the project's completion date
- It is the longest continuous sequence (not chain) of work
- Exists on every project (no matter CCM, LOB, etc.)
- It is dynamic and can change throughout the course of the project

Critical path in realities

In reality, however, as a schedule becomes more complex, total float values may not necessarily represent a true picture of the critical path.

- **Multiple calendars**, **out-of-sequence progress**, **date constraints**, and **leveled resources** can all **produce misleading values** of **total float** in **complex schedules**, **leading** to a **misrepresentation of the sequence** of activities that actually **drives** the **program finish date**.

Critical path in realities

- **IMPORTANT:**
  - **Historically**, the **critical path** was the path of activities that had **zero total float**.
  - **Zero float** or the least amount of float does **not necessarily mean critical path**.

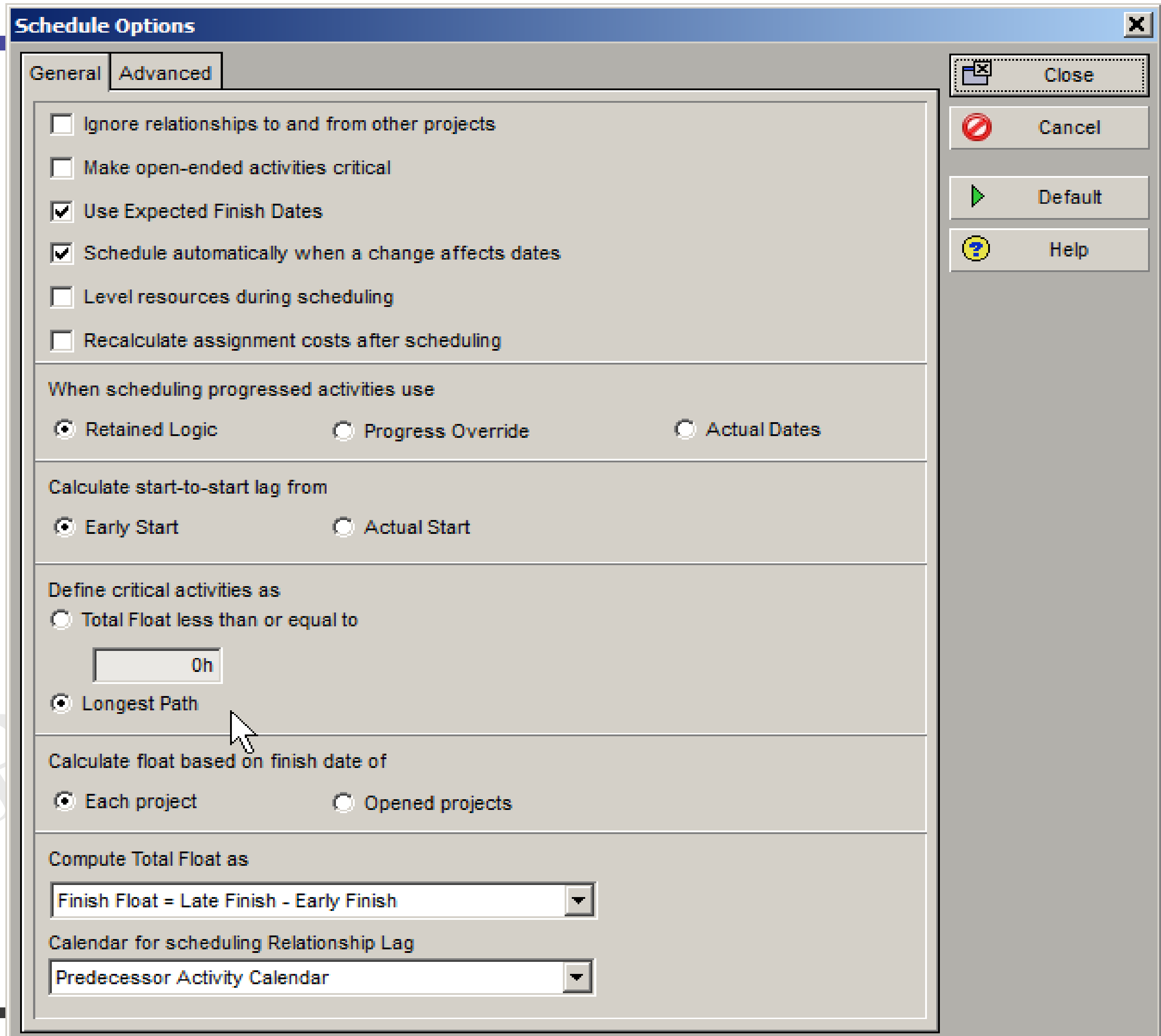
→ Those days are gone.

→ **Float** can still determine the **critical path** but only in schedules that have **limited calendars** and **limited constraints**.

- In order to determine **the critical path**, the analyst **must look** at the **longest path regardless** of what the float calculations say.

→ That is the most accurate way to determine the Project critical path.

Critical path in realities



Critical path in realities

Construction Delays Book, 2018

In the past, when project schedules used only one work calendar and all activity relationships were finish-to-start with no activity constraints, the critical path could be quickly and simply identified as the path of zero float. But "we're not in Kansas anymore, Toto."

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Critical path in realities

We should consider this from two perspectives:

1. **Calendars**
2. **Constraints**

Critical path in realities

We should consider this from two perspectives:

1. **Calendars**
2. **Constraints**

Critical path in realities

Construction Delays Book, 2018

The use of multiple calendars enables the scheduler to account for the many work calendars associated with construction project work activities. These work calendars might be based on environmental limitations (no work in the river during fish spawning season), seasonal limitations (no paving during the winter), or the type of work (concrete cures every hour of every day). To model these situations, modern scheduling software enables users to create work calendars for specific work activities, such as paving, that do not allow these activities to be scheduled during the winter months.

Critical path in realities

Construction Delays Book, 2018

There are many examples of contractual work restrictions that dictate when and where contractors can perform their work. Modern scheduling software incorporates the ability to create multiple work calendars that match the planned means and methods. Such calendars may include calendars that depict 4-day, 10-hour work weeks; 5-day, 8-hour work weeks; 6-day work weeks; 7-day, no holiday work weeks; and no-work weeks or months.

Critical path in realities

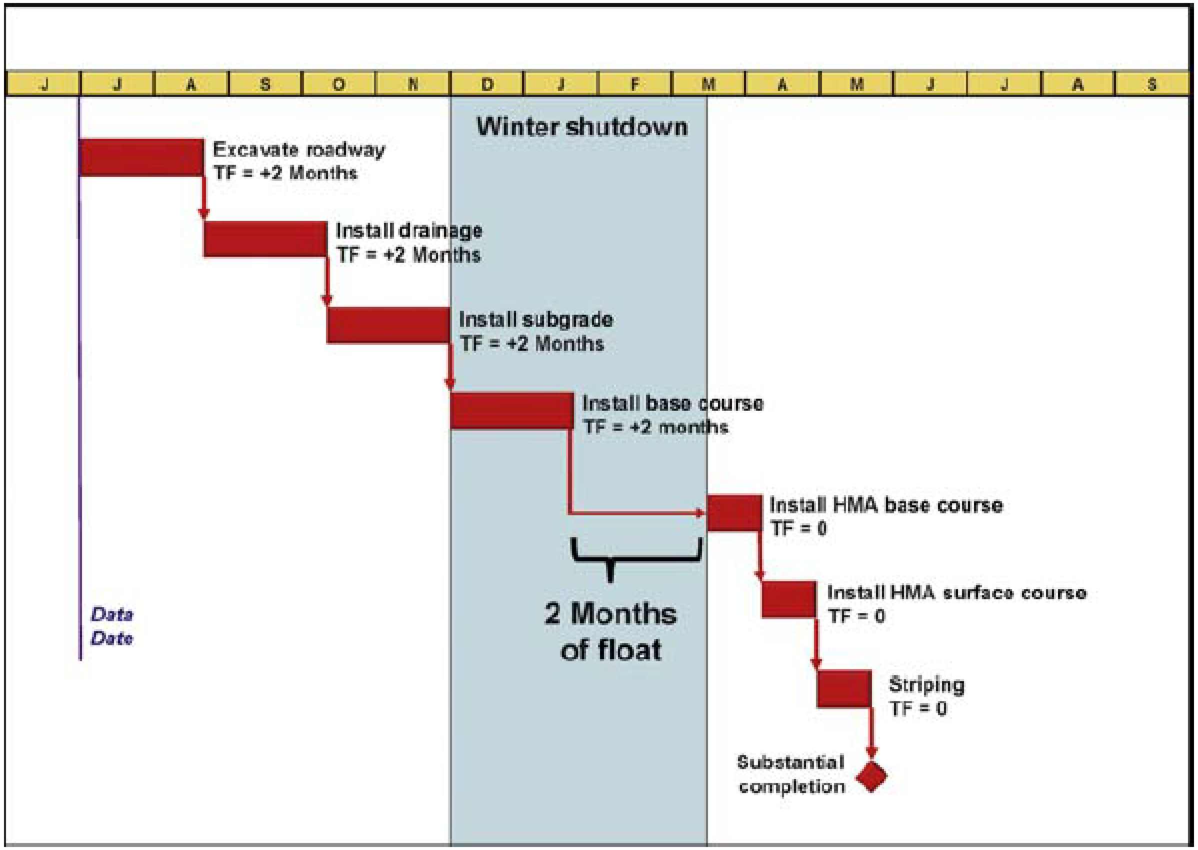
Construction Delays Book, 2018

A consequence of using multiple calendars is that each work calendar contains a different set of available workdays. By having multiple calendars with different available workdays, the calculation of total float values of activities on the same work path can vary if some of those activities are assigned to different calendars. This is why we say that in some schedules, the critical path can only be defined as the longest path.

Let's see why?

Critical activities with positive total float – Example

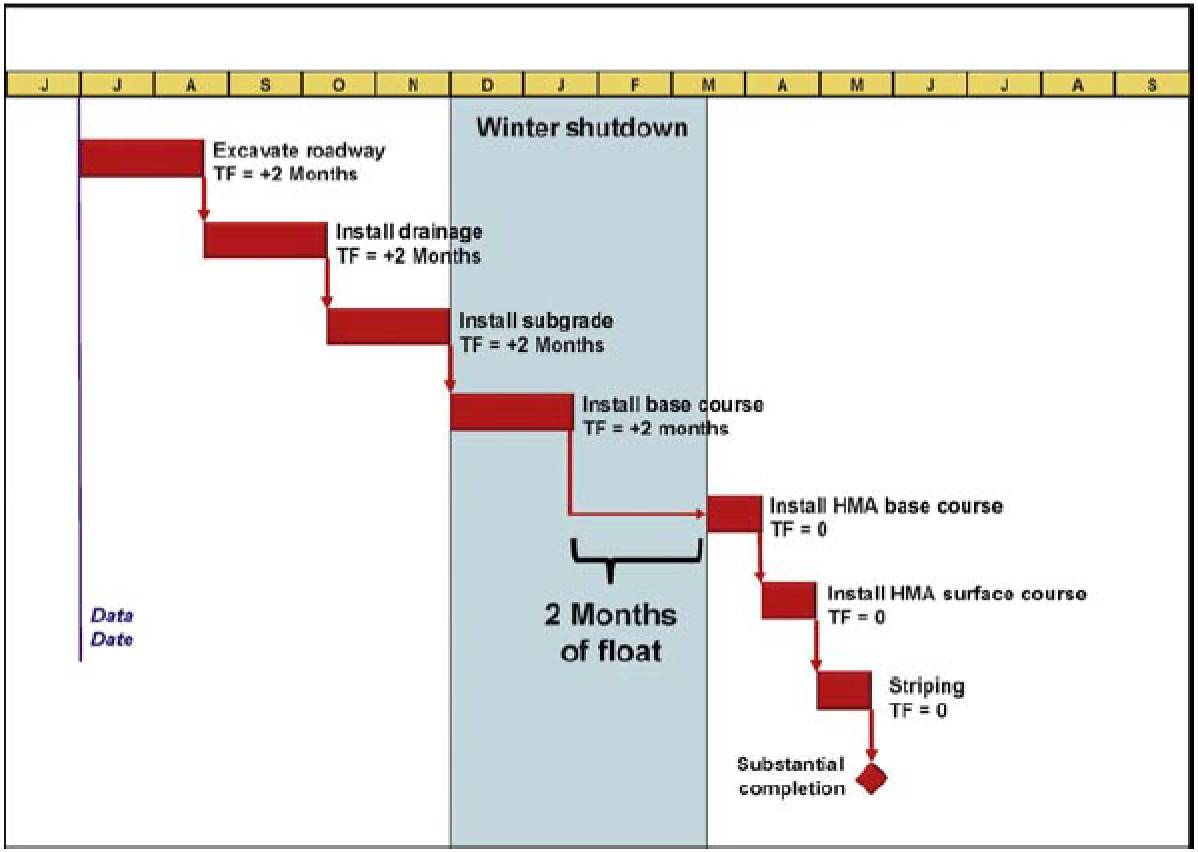
Activities on **critical path do not always have zero float.**



Example 1 critical path with positive float.

Critical activities with positive total float – Example

Only delays to the critical path can **delay the project**,
but **not all delays** to the critical path will **delay the project**.



Example 1 critical path with positive float.

Critical activities with positive total float

Only delays to the critical path can **delay the project**,
but **not all delays** to the critical path will **delay the project**.

See?

Now you understand why adding more calendars complicates delay analysis

Because you should check all paths one by one!

Critical activities with positive total float

You may be tempted to believe that activities on the longest path cannot be critical activities

if they have positive total float values and that the first four activities in Fig. are not critical because they have positive float,

despite the fact that they are on the project's longest path and responsible for pushing the paving activity into the spring.

This dilemma begs the question:
Are all activities on the project's longest path said to be critical activities?

Critical activities with positive total float

This dilemma begs the question:
Are all activities on the project's longest path said to be critical activities?

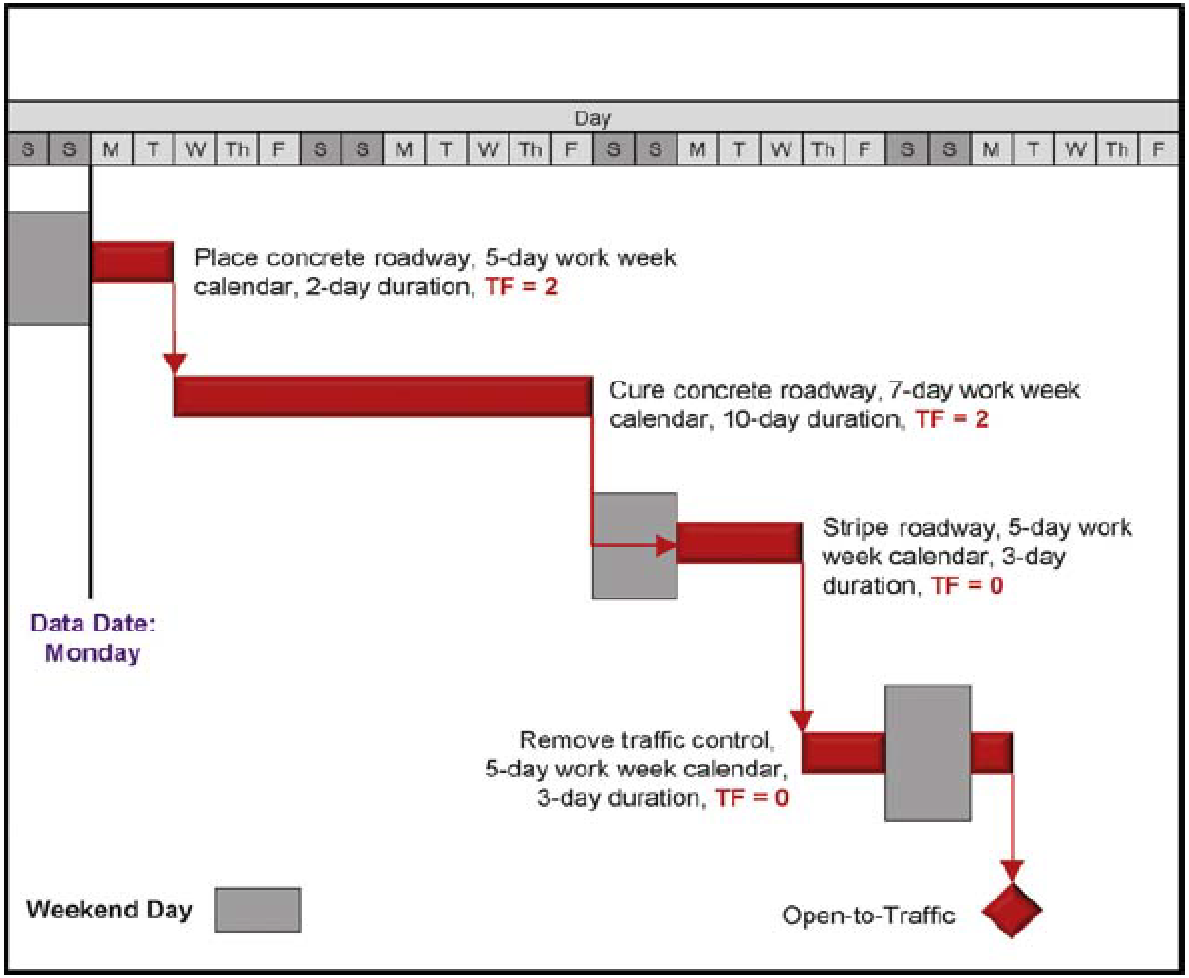
To answer this, you must consider the term "critical" in the context of Critical Path Method scheduling.

In that case, the term "critical" becomes a term of the art for CPM schedules.

Thus, the only logical answer to the question is yes, by definition, critical activities are those activities on the project's longest path.

Critical activities with positive total float – Example

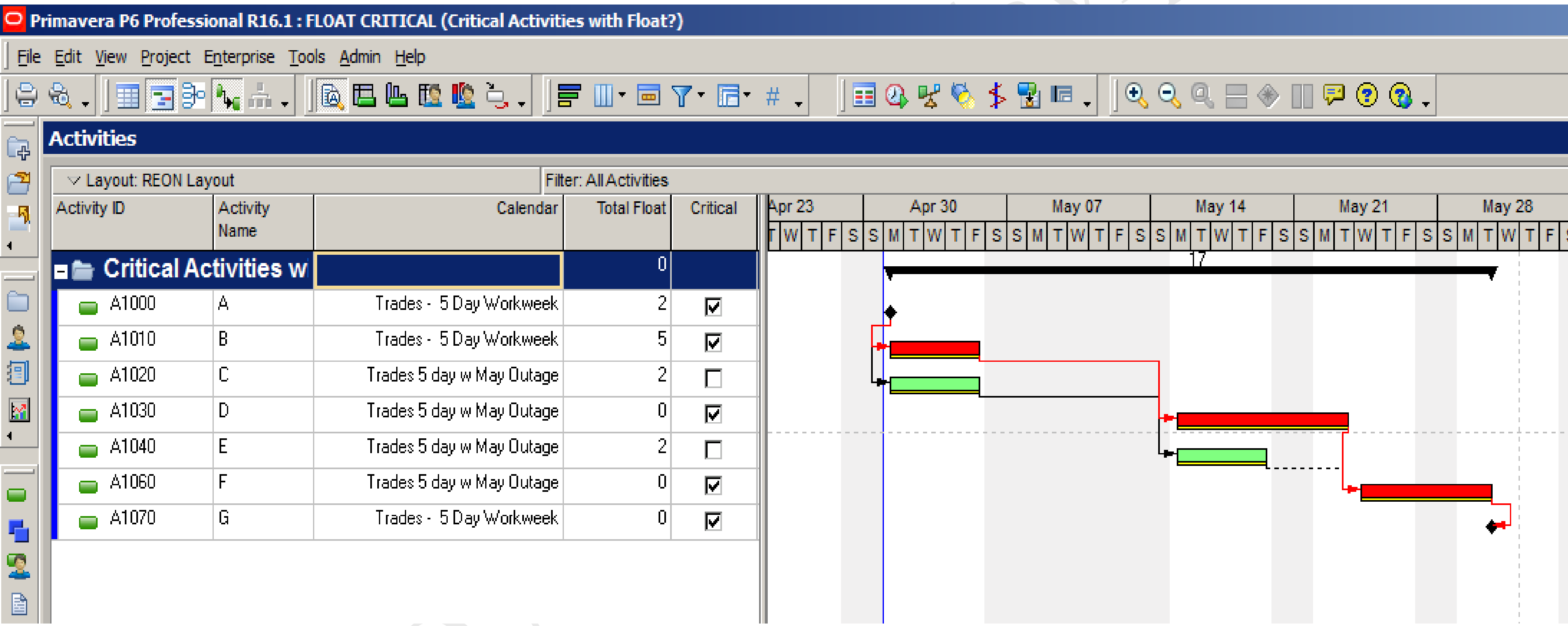
The cure concrete roadway could also be done on Saturday and Sunday!



Example 2 critical path with positive float.

Critical activities with positive total float – Example

Activities on **critical path do not always have zero float.**



Activity ID	Activity Name	Calendar	Total Float	Critical
Critical Activities w			0	
A1000	A	Trades - 5 Day Workweek	2	☑
A1010	B	Trades - 5 Day Workweek	5	☑
A1020	C	Trades 5 day w May Outage	2	☐
A1030	D	Trades 5 day w May Outage	0	☑
A1040	E	Trades 5 day w May Outage	2	☐
A1060	F	Trades 5 day w May Outage	0	☑
A1070	G	Trades - 5 Day Workweek	0	☑

Critical activities with positive total float – Example

How to address this problem?

Critical activities with positive total float – Example

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To address the problem with identification of the critical path when float is not sufficient, P6 incorporates a "Longest Path" filter. This filter allows the identification of the critical path without relying on the use of float. In fact, the Oracle Primavera P6 Professional Help website recognizes the difficulty of using float to identify the critical path:

> *If your project uses multiple calendars, defining critical activities based on the longest path in the project provides an alternative to viewing critical activities based on float. Defining float in a multicalendar project is more complicated, since P6 Professional bases float calculations on calendar definitions, including workperiods, holidays, and exceptions. Using float to identify critical activities may prove misleading, since some activities have large float values due to their calendar assignments but are still critical to the completion of the project.*

Critical path in realities

We should consider this from two perspectives:

1. **Calendars**
2. **Constraints**

Critical activities with negative total float – Example

GAO

- **Date constraints** may **cause** activities to **become critical**, **regardless** of the **total float** that may be available **if not constrained** in the **network**.
  - Specifically, **backward-pass date constraints** on activities **other than** the **finish milestone** will **influence** the **criticality of activities**.

Hence, where constraints are many, there may be many more activities with zero or negative total float than activities that are actually driving the key program completion milestone.

Let's see why!

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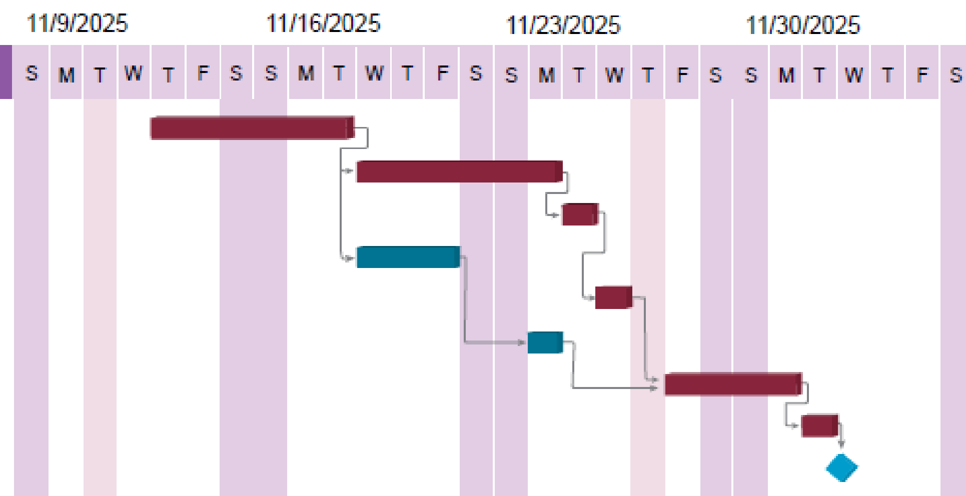
Critical activities with negative total float – Example

- This figure shows in the construction schedule **two sequences** of activity necessary to complete **interior rough-in**: **critical activities (in red)** and **noncritical activities (in blue).**

The Critical Path and the Longest Path

Activity	Duration	Total float
Install exterior doors and windows	4 days	0 days
Rough in interior electrical	4 days	0 days
Inspect in-wall rough-in electrical	1 day	0 days
Rough in interior HVAC, and through-roof penetration	3 days	2 days
Install exterior wall insulation	1 day	0 days
Inspect rough-in HVAC	1 day	2 days
Install interior vapor barrier	2 days	0 days
Inspect wall insulation and vapor barrier	1 day	0 days
Interior rough-in complete	0 days	0 days



Source: GAO. | GAO-16-89G

- **What if** the **general contractor** were to introduce **a backward-pass date constraint** on **"inspect rough-in HVAC"**—directing, for example, that the **inspection** be performed on **November 24.**

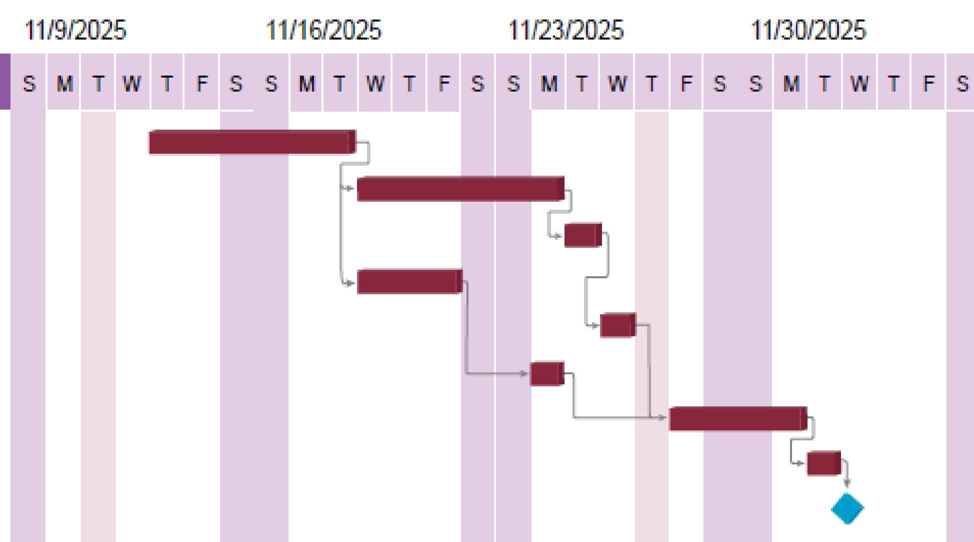
Critical activities with negative total float – Example

- The network **now has 2 more critical activities** than the network without the date constraint and shows **2 parallel critical paths** in terms of total float.
- However, the **longest path—in terms of duration**—**remains the same**, **regardless** of the **date constraint**.

The longest path is also referred to as the driving path because it determines the date of the key milestone.

Critical Path Activities Not on the Longest Path

Activity	Duration	Total float
Install exterior doors and windows	4 days	0 days
Rough in interior electrical	4 days	0 days
Inspect in-wall rough-in electrical	1 day	0 days
Rough in interior HVAC and through-roof penetration	3 days	0 days
Install exterior wall insulation	1 day	0 days
Inspect rough-in HVAC	1 day	0 days
Install interior vapor barrier	2 days	0 days
Inspect wall insulation and vapor barrier	1 day	0 days
Interior rough-in complete	0 days	0 days



Source: GAO. | GAO-16-89G

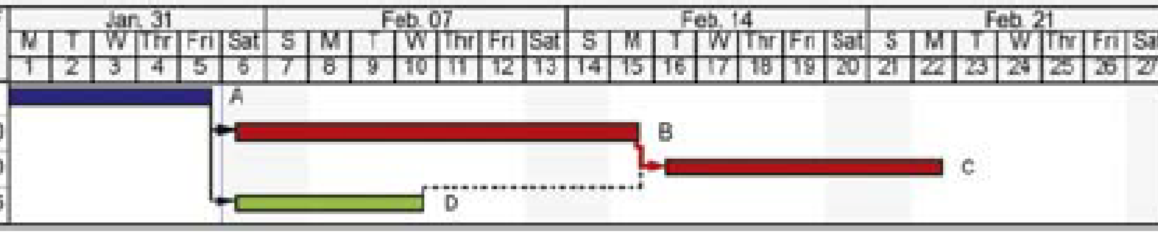
Critical activities with negative total float

ARE YOU READY TO SEE THIS MORE IN DETAIL?

Let’s go!

Critical activities with negative total float – Example

OD	RD	Start	Finish	TF
5	0	2/1/16A	2/5/16A	
10	10	2/6/16	2/15/16	0
7	7	2/16/16	2/22/16	0
5	5	2/6/16	2/10/16	5



Example represented in P6 without any constraints.

Let’s see this from three constraints:

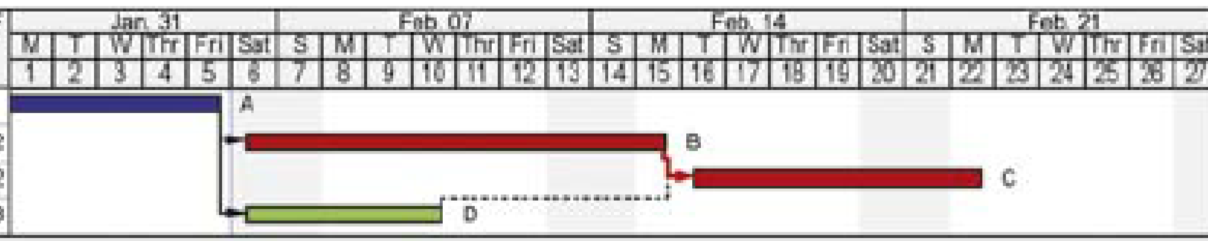
1. **Finish No Later Than (Hard Constraint)**
2. **Must or Mandatory (Hard Constraint)**
3. **As Late As Possible (Soft Constraint)**

Critical activities with negative total float – Example

1. ***Finish No Later Than <u>(Hard Constraint)</u>***

❖ **"Finish On or Before"** constraint of **Day 20**, or February 20, 2016, is applied to Activity C.

OD	RD	Start	Finish	TF
5	0	2/1/16A	2/5/16 A	
10	10	2/6/16	2/15/16	-2
7	7	2/16/16	2/22/16*	-2
5	5	2/6/16	2/10/16	3



"Finish On or Before" constraint on Activity C in P6 ("Late Finish" constraint in P3).

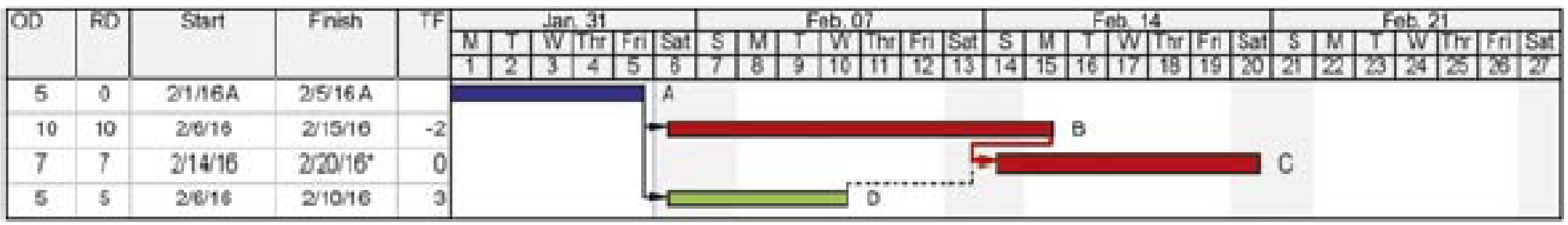
❖ When a **"Finish On or Before"** constraint of Day 20 is applied to Activity C,

1. Total float values of the critical path activities <u>(activities B and C)</u> are **reduced from 0 workdays to 22 workdays**
2. Total float value of <u>activity D</u> is reduced from **5 workdays to 3 workdays.**

Critical activities with negative total float – Example

2. ***Must or Mandatory <u>(Hard Constraint)</u>***

❖ **"Mandatory Finish"** constraint of **Day 20**, or February 20, 2016, is applied to Activity C



OD	RD	Start	Finish	TF
5	0	2/1/16A	2/5/16 A	
10	10	2/6/16	2/15/16	-2
7	7	2/14/16	2/20/16*	0
5	5	2/6/16	2/10/16	3

"Mandatory Finish" constraint on Activity C in P6 (and P3).

❖ The software forces two changes:

1. <u>Activity C</u> is **forced** to finish on Day 20, the software changes the **early dates of Activity C**, forcing work on **Activities B and C to be performed concurrently** <u>for 2 days—Day 14 and 15</u>.
2. The **finish-to start relationship** between Activity B and C is **essentially ignored**.

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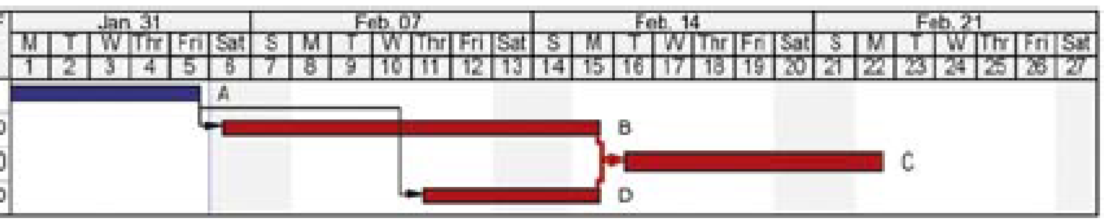
Critical activities with negative total float – Example

3. *As Late As Possible <u>(Soft Constraint)</u>*

❖ **“As Late As Possible” constraint is applied to Activity D**

OD	RD	Start	Finish	TF
5	0	2/1/16 A	2/5/16 A	
10	10	2/6/16	2/15/16	0
7	7	2/16/16	2/22/16	0
5	5	2/11/16	2/15/16	0



“As Late As Possible” constraint on Activity D in P6 ("Zero Free Float" in P3).

1. **Activity’s early dates** being **changed to its late dates**
2. Activity’s **total float** value being changed to **0 workdays**.
3. **P6** places this **constraint** on the **critical path**, in the **<u>longest path sort</u>**.

WHY?

✓ If it is **delayed**, it will <u>delay the project</u>.

*In effect, the use of this constraint **placed the activity on the longest path**.*

❑ This constraint may be used to model **“just-in-time delivery.”**

❑ It is **<u>not</u>** inappropriate or unrealistic.

Critical activities with negative total float

How to address this problem?

Critical path activities not on the longest path

- When the **critical path is not the longest path**, the **longest path is preferred** because it represents the **activities** that are **driving** the **sequence of start dates** directly **affecting** the **estimated finish date**, **if** we **ignored** the **presence of date constraints**.

- Therefore, **rather than simply filtering** on **activities** that are **marked critical** by the **scheduling software**,

management should be aware of the activity "drivers" that are determining the schedule finish date.

Critical path activities not on the longest path

Construction Delays Book, 2018

Note that P6 also states that critical activities and, therefore, the critical path can be "defined by either total float or the longest path in the project network." But a word of caution is necessary here. In some schedules, the critical path can only be defined as the longest path.

Critical path activities not on the longest path

AACE 10S-90 “Cost Engineering Terminology” (2010)

The AACE International *Recommended Practice No. 10S-90*, "Cost Engineering Terminology" (2010), defines the critical path as:

> The longest continuous chain of activities (may be more than one path) which establishes the minimum overall project duration. A slippage or delay in completion of any activity by one time period will extend final completion correspondingly. The critical path by definition has no float. (p. 31)

Critical path activities not on the longest path

AACE 10S-90 "Cost Engineering Terminology" (2010)

The AACE International *Recommended Practice No. 10S-90,* "Cost Engineering Terminology" (2010), also defines the longest path as the:

> Longest continuous path of activities through a project, which controls project early completion. It is possible for otherwise defined critical path activities to not be on the longest path and longest path activities to not show calculated critical float. The longest path analysis is unaffected by activity calendars. The longest path is determined by the string of activities, relationships, and lags that push the project to its latest, early finish date. The longest path is calculated by first performing a CPM "forward pass" to determine driving relationships and the project's latest, early finish date. The activity (or activities) with the latest, early finish dates are then identified and all predecessor driving relationships traced back to the project start date. These activities constitute the project's longest path. The longest path depends upon relationships driving the timing of activity starts, thus use of constraints and resource leveling can interrupt and invalidate longest path analysis. Use of interruptible activities can also result in false longest path indications. For complete accuracy, longest path analysis should take place absent of constraints, resource leveling, and/or interruptible activities. (p. 63)

Important notes

- **Important activity** is **not necessarily** "**critical**."
- **Some activities—training**, for example— may be **on the critical path** and **not particularly risky** but can **delay the program** finish date.
- An activity of **long duration** should **not be referred** to as a **"critical path activity"** simply because it will take a long time to accomplish.

"Critical activity" in scheduling has a specific definition that should be adhered to.

Near-critical path

- **Activities** with **total float** within a **narrow range of the critical path total float** are **“near-critical”** because they can **quickly become critical.**
  - **Near-critical paths** need **only a small extension** of time to **become critical**.

- **Management** must **monitor** **critical** and **near-critical activities** through **sound schedule management** because any **delay in them** will delay the **entire program**.

Let’s see how to monitor near-critical activities!

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Near-critical path

- **Near-critical paths** are **monitored** according to a **float threshold** **tailored** to the program.

*For example, a **brief schedule** might consider a **5-day slip to be a near-critical threshold**.*

*In **programs scheduled** to **take years**, a **2- or 3-month's slip** in **near-critical paths** might make the path critical.*

*Because **prolonging a schedule** by **5 days on a short project** is as easily possible as prolonging a **multiyear project several months**,*

***program managers** should manage all **near-critical and critical paths**.*

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Dynamic critical path

- The **critical path** assists program management in **prioritizing** **resources** to have the **most positive effect** on **program performance**.

- The **critical path** is **not constant**.

- We discuss the ***deterministic* critical path**—that is, the path as defined by the **initial or current set** of inputs in the schedule model.

However, the true critical path of a schedule is uncertain because durations of activities are uncertain.

In the next 2 sections, we will discuss a *probabilistic* or *risk* critical path that is based on assumptions about estimating error and risk.

Common Barriers To a Valid Critical Path

Continuous through all activities

- **Unless** the **IMS** represents the **entire scope** of effort, the **scheduling software** will report an **incorrect** or **invalid** **critical path**.

- **IMS** must include planning for **all activities** that have to be **accomplished** in the **program**.
  - A **critical path** for **one block**, **increment**, or **contract** for a **multiyear multiphased program** is not a sufficient plan to **forecast the finish date**.

In general, the sequence of activities should have no breaks and no large gaps of unaccounted time.

Continuous through all activities

- **Breaks** in the **critical path** should be **examined immediately** and **justified** or **otherwise addressed**.

- **Common causes** of **non-continuous critical paths** are that
  - The **start or finish date** of an activity is **driven by a constraint**;
  - A **successor activity** is driven by an **unexplained lag**;
  - The **start date of an activity** is driven by an **external predecessor**;
  - **Activities** are **scheduled** according to **different calendars**, as **when a predecessor activity ends** in a **nonworking period for the successor**;
  - **Resource leveling** is **causing delays**.

Continuous through all activities – Example

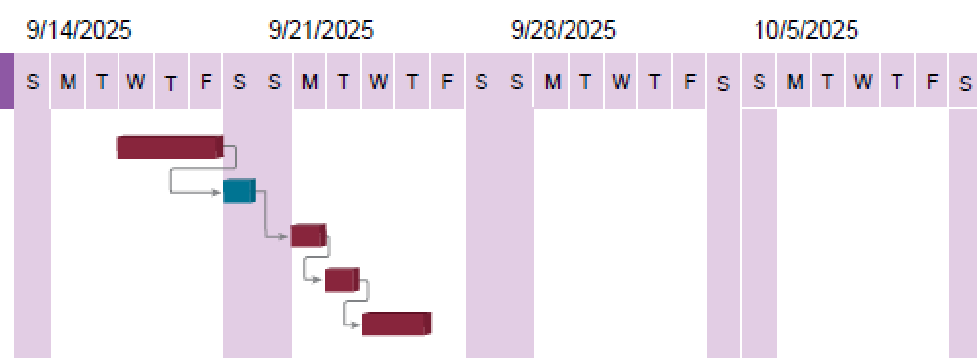
- **<u>All activities and resources</u>** are assigned **<u>standard 5-day workweek calendars</u>** **<u>except</u>** **<u>“install footing and pier rebar.”</u>**

- The **<u>installation activity</u>** is assigned a **<u>7-day workweek calendar</u>** as well as **<u>resources</u>** that can work on **Saturdays and Sundays**.
  - Because **<u>Sunday is a valid workday</u>** for this activity, it has **<u>one day of total float</u>** available.
    - ✓ However, **its successor**, **<u>“inspect footing and pier rebar,”</u>** can **occur only** on **<u>Monday through Friday</u>**, so **its early and late start dates** are **Monday**, September 22.

The critical path (red activities), as defined by total float, is discontinuous at the weekend.

The Effect of Multiple Calendars on the Critical Path

Activity	Early start	Late start	Total float
Lay out and form footings and pier pads	9/17	9/17	0 days
Install footing and pier rebar	9/20	9/21	1 day
Inspect footing and pier rebar	9/22	9/22	0 days
Pour footings and pads	9/23	9/23	0 days
Cure footings and pads	9/24	9/24	0 days



Source: GAO. | GAO-16-89G

Number of critical activities

- In general, **assessing the quality** of the **critical path** by **predetermining** the **number of activities** that **should be critical** is **not useful**.
  - The **number of activities** on the **critical path** depends on the **visibility** required to **manage the program** and **reduce risk**.
  - However,
    1. **If** the **ratio** of **critical path activities** to the **total remaining activity** count is nearly **100 percent**,

       then the **schedule** may be **overly serial** and **resource limited**.
    2. **If only a few activities** are on the **critical path** and if **all represent LOE**, then the **critical path** is being **driven** by **supporting effort** and will **not identify** effort that is **driving key milestones**.

Use 80/20 rule of thumb
80% non-critical
20% critical

Logical sequencing

- **Float calculations** are **directly related** to the **logical sequencing** of events.
- **If activities:**
  - Are missing dependencies
  - Linked incorrectly
  - Performed out of sequence

float estimates will be **miscalculated**.

Date constraints

- The **temporary use of hard constraints** is also **valuable** for **assessing** the **likelihood** that **using available resources** can **achieve** the **planned activity date**.

- **However**, using **hard constraints** imply to **fix activity dates** at **certain points** in time
  1. **Immediately convolutes** critical path **calculations**.
  2. **Reduces** the **credibility** of any **schedule date** on activities that logically **occur after** the **hard constraint**.

In this case, the critical path is no longer the longest path;

instead,

each hard constraint in the schedule generates its own sequence of critical activities, and the purpose of CPM scheduling is defeated.

Lags

- **Lags** are **often misused** to **force successor** activities to **begin** on **specific dates**.

The critical path should be free of lags because they make the identification and management of critical activities ambiguous.

WHY?

1. **Evaluating** a **critical path** that includes **lags** can be **difficult** because the **lag** may or **may not** represent **work** that has to be **accomplished** by **some resource**.
2. **Because lags** are **not represented** in a schedule as an **activity**, they can **easily be overlooked** as **drivers** of the **finish milestone date**.

Let's take a look!

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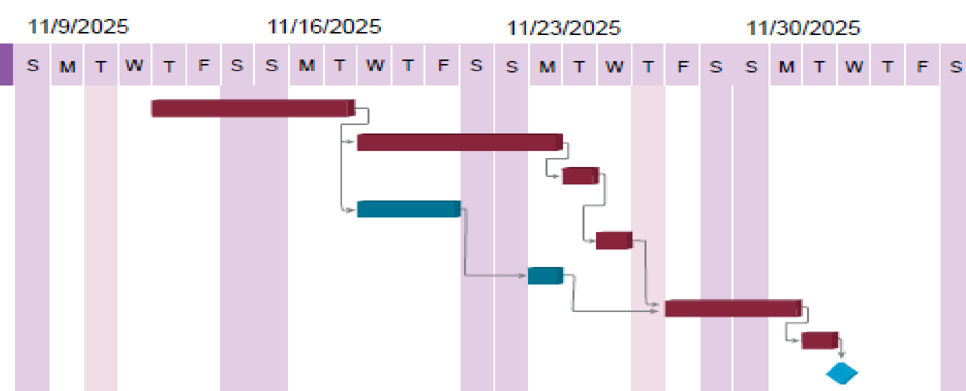
Lags – Example

- “**Inspect rough-in HVAC”** now has a **2-day lag** representing 2 days of **paperwork** that the **general contractor’s company** must perform.
- The **GC could not** perform the **paperwork** and the **activity** becomes **critical** because the 2-day lag consumes its 2 days of total float.
- A **report** to the general contractor **listing the current critical activities** in the project would list **“inspect rough-in HVAC” as critical but** **fails** to mention that the **problem in paperwork** caused this activity to **become critical**, **not** the **inspection activity itself**.

The Critical Path and the Longest Path

Activity	Duration	Total float
Install exterior doors and windows	4 days	0 days
Rough in interior electrical	4 days	0 days
Inspect in-wall rough-in electrical	1 day	0 days
Rough in interior HVAC, and through-roof penetration	3 days	2 days
Install exterior wall insulation	1 day	0 days
Inspect rough-in HVAC	1 day	2 days
Install interior vapor barrier	2 days	0 days
Inspect wall insulation and vapor barrier	1 day	0 days
Interior rough-in complete	0 days	0 days



Source: GAO. | GAO-16-89G

Level-of-effort and other long duration activities

A critical path cannot include LOE activities because, by their very nature, they do not represent discrete effort.

- The **duration of LOE activities** is **determined** by the **overall duration** of the **discrete work they support**.

Therefore, an LOE activity cannot drive any successor and become critical.

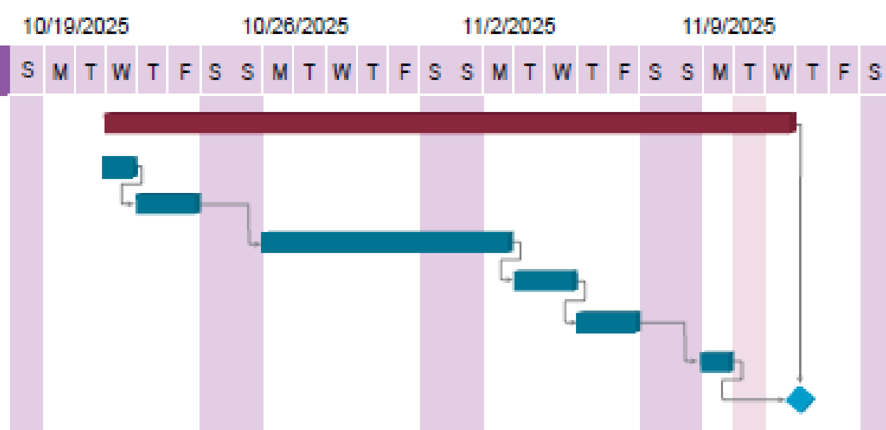
Level-of-effort and other long duration activities – Example

- A general contractor **project management activity** planned to ensure that **all framing activities** are **managed properly** and **all documentation** is **created** and **filed appropriately**.
  - This **LOE project management activity** now determines the **minimum duration** of the **framing sequence** of activities, **rather than** the sequence of **actual work**.

Using this schedule, management has no indication of which activities can slip and which will respond positively to additional resources and reduce risk of finishing late.

An Incorrect Critical Path with Level-of-Effort Activities

Activity	Duration	Total float
Manage Framing	15 days	0 days
Set steel columns and beams	1 day	1 day
Install first floor joists and decking	2 days	1 day
Frame first floor walls; install exterior wall sheathing	6 days	1 day
Install roof trusses	2 days	1 day
Install roof decking	2 days	1 day
Inspect rough-in framing	1 day	1 day
Framing complete	0 days	0 days



Source: GAO. | GAO-16-89G

Level-of-effort and other long duration activities

- **Long-duration non-LOE activities** in the **detail planning period** should be **reevaluated** to determine **if** they can be **broken down** into **more manageable pieces**, **particularly if** they appear on the **critical path**.
  - **If** work is broken into **smaller pieces**, **some portions** of it might be able to **start earlier** or in **parallel** with other portions or might be **reassigned** to **other available resources**, **saving time** and possibly **moving** the activity **off the critical path**.

In particular, summary activities should never be on the critical path.

- **If** a **summary activity** becomes **critical**, there is **no way** to **determine** which **subactivities** are **critical** and which **are not**.

Predetermined critical activities

- **Separate summary schedules** should **not** be created by **selectively choosing lower-level milestones** and **detail activities** that **management** has determined are **important** to monitor.
  - **Activities** may be **important** in terms of **cost or scope**, but there is **little guarantee** that **hand-picked activities** will **determine** the **finish milestone**.

*By **only reporting** on or **monitoring** the **progress of favorite activities**, management risks **losing sight** of previously **unimportant activities** that may now be d**riving the program's finish date.***

Resource Leveling and Critical Resources

Resource critical path

- The **critical path method** of scheduling assumes **unlimited resources** to **accomplish** the project.
  - This is **true even** when the **schedule** is **resource loaded** because the **critical path** does **not** take into account **resource overallocation**.

That is, a worker can be assigned to any number of parallel activities, regardless of workload.

How to solve?

Resource critical path

- **If** **resource allocation** is an issue that **must be addressed** in the schedule, the **program end date** will be **determined**
  1. Through **network logic**
  2. By considering **resource availability**
  - The sequence of activities that drive the program finish date, based on both network logic and resource availability, is called the **resource-constrained scheduling problem**.
    - ✓ It may be called **resource critical path** or the **resource constrained critical path** or **critical chain.**.

Resource critical path

- Although the **resource critical path** is complex **and not easily derived** by even the most **sophisticated schedule software**,

it represents the **most realistic model** of activities and resources that **determine** the **minimum possible duration** of the program.

If management focuses solely on critical activities without taking into account critical resources, it risks jeopardizing the project's timely completion.

Critical Path Management

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Critical path and longest path reevaluation

- **Critical path and longest path** must be **reevaluated** after **each status update**.
- **Critical path and longest path** should be **compared** to the **previous period's paths** after **each status update**.
- **Responsible resources** should be **alerted** if **previously noncritical** and **nondriving** activities are **now critical or driving**.
- Likewise, **resources that had been assigned** to **previously critical activities** may now need to be **reassigned** to **other critical activities**.
- **Critical and longest paths** should make **intuitive sense** to subject **matter experts** and should be **checked** in terms of:
  1. Sequence
  2. Logic
  3. Duration of critical activities

Management of near-critical activities

- **Management** may benefit by **monitoring near-critical activities** as well.
  - For example, management may **wish to monitor** activities with **5 days** or **less total float.**
  - Unfortunately, **no easy method** of calculating the "**near longest path**"
  - Conducting a **schedule risk analysis** may **reveal that**, with risks considered, the **path most likely to delay** the program is **not the critical path** or the **longest path** in the static CPM schedule.
    - ✓ The **risk analysis** may identify a **different path** or paths that are **"risk critical."**
      - o **Risk mitigation** should focus on those **risk-critical paths** for best effect.

Critical path management – CPLI

The Critical Path Length Index (CPLI) is a metric used to measure the relative efficiency to complete a milestone on time. It's used to calculate and graphically display the Critical Path; longest series of scheduled activities to complete a project.

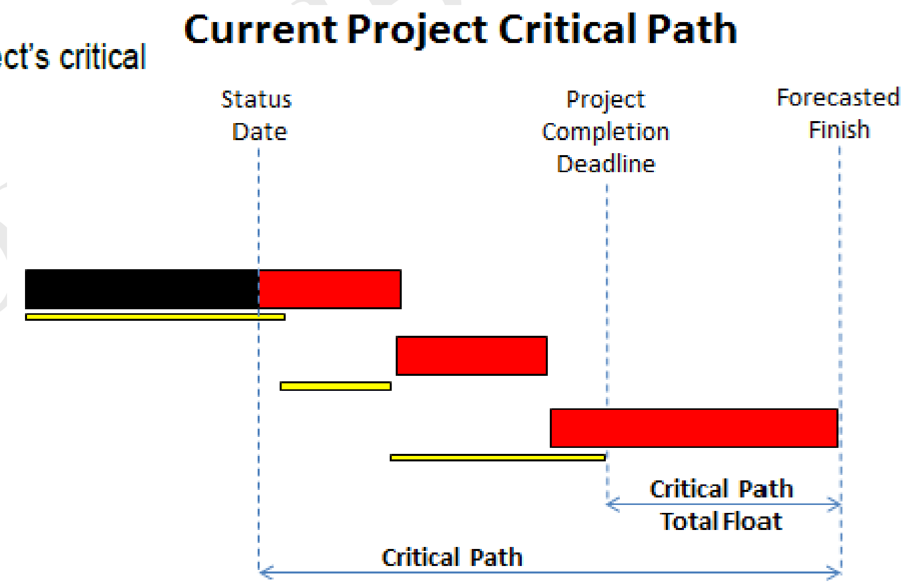
Critical path management – CPLI

Critical path length index (CPLI)

$$CPLI = \frac{Critical\ Path\ Length\ +\ Critical\ Path\ Total\ Float}{Critical\ Path\ Length}$$

- **Critical Path Length**
  - The remaining duration of the project. It is the number of working days from the current status date to the end of the project critical path.
- **Critical Path Total Float**
  - The calculated total float on the final activity along the project's critical path.

Here we have <u>negative float</u> and CPLI would be <u>less than 1</u>



Note: In order to calculate the total float on a critical path, the final task/milestone will need have a constraint or deadline to indicate the due date for the project completion.

Critical path management – CPLI

- Critical path length index (CPLI)

CPLI Value	Implication
> 1.00	LOWER RISK - The project can absorb a certain amount of schedule slippage and still complete on plan
= 1.00	MODERATE RISK - The project is currently forecasted to complete on plan
< 1.00	HIGHER RISK - Future opportunities must be realized in order to offset past schedule slippage

CPLI Value	Implication
> 1.05	BLUE ("well ahead") - Higher likelihood meeting project completion target
1.00 - 1.05	GREEN ("on track) - The project is forecasted to complete on or slightly ahead of plan
0.95 - 0.99	YELLOW ("caution") - The project is forecasted to complete slightly behind the plan. Increased risk to on-time completion
< 0.95	RED ("well behind") - The project is forecasted to be significantly late, greatly lowering the chance of completing on plan

What is the relationship between CPLI and SPI? How to analyze that?

This has been taught in Strategic level of this course!

https://dralavipour.com/applied-tutorials/show/web23

Critical path management – CPLI: Example

Example:

Through April the supplier network schedule calculates a program critical path length of 720 work days (3 years) with 60 work days (3 months) of negative float from contract award to completion:

CPLI = [(720 – 60) / 720] = 0.917

At present, the supplier's CPLI of less than 1.00 indicates that program will not achieve its baseline completion date without corrective action and the CPLI should be tracked to gauge the realism of completing the contract on time.

What is the problem with this metric?

This has been taught in Strategic level of this course!

https://dralavipour.com/applied-tutorials/show/web23

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Critical path management – Best Practice

PMI Best Practice

Best Practices

Using the project critical path provides a valuable project planning and management tool for: (a) time management, (b) monitoring on-going progress of activities that can delay a project, and (c) providing project information for early problem detection and decision making.

The best practices for utilizing the critical path to assure project success and address any project delays, are:

- Validation through the planning process of the:
  - Inclusion in the schedule of the full scope of work (see Section 3.4.1, Work Breakdown Structure);
  - Identification of all activities requiring time and resources to meet deliverables;
  - Reasonable and appropriate logical sequencing of these activities, taking into account available and concurrent resource needs. With all activities (other than the start and completion) containing appropriate logical relationships, there should be no open-ended activities.
  - Estimated activity durations are based on productivity that represents the available resources, as well as concurrent resource needs.
  - Schedule is calculated using both forward and backward passes, to identify the sequence of activities that cannot be delayed without impacting the project end date and the critical path (Note: There may be multiple critical paths.); and
  - Review and concurrence of critical path activities with the project team.

Critical path management – Best Practice

PMI Best Practice

Best Practices

Using the project critical path provides a valuable project planning and management tool for: (a) time management, (b) monitoring on-going progress of activities that can delay a project, and (c) providing project information for early problem detection and decision making.

The best practices for utilizing the critical path to assure project success and address any project delays, are:

- Continuous review and monitoring of critical and near-critical path needs, to be performed on an established periodicity (usually the status period), since as activities are initiated, completed, or delayed the critical path can change.
- Monitoring of non-critical path work to ensure that missing logic will not allow stacking of work that does not appear on the critical or near-critical path early enough.
- Constant monitoring of predictions of achievement of milestone completions. If slippage to project or contract commitments occurs, the scheduler should work with the project team to identify potential recovery and efficiencies that can be implemented.
- Project critical path reporting mechanisms need to be clearly defined, understood, and consistent.

Critical path management – Recommended Practice

PMI Best Practice

When a periodic update of project status is performed, the project controls personnel should look into the impacts from the as-built condition of the schedule, analyze the as-planned condition of the schedule, perform the trending and completion prediction analysis, and determine what has changed on the critical path and notify the appropriate project personnel. Tasks which fall on the critical path should receive attention by both the project manager and the personnel assigned to them, to prevent delaying the project.

Critical path management – Advisories

PMI Best Practice

Advisories

The critical path is one of the primary tools of project scheduling for planning and monitoring the accomplishment of project commitments. As such, the following advisories identify potential pitfalls in using the critical path most efficiently:

- Always define the use of the term critical path so everyone understands the meaning.
- Minimize the use of constraints and apply only where true ones exist.
- Minimize the use of multiple milestones; however, when utilized, monitor the critical path for each milestone for slippage.
- Too few relationships in the network logic could mean that the schedule is probably underdeveloped or missing logic.
- Too many relationships in the network logic could also mean that the schedule is more than likely over-developed or may include heavy resource linkage, or an attempt to sequester float by inappropriate relationships.
- The only activity that should have no predecessor is the project start milestone. Likewise, the only activity to have no successor is the project completion milestone.

Program and Project Critical Paths

Management of near-critical activities

- When an **IMS** is constructed from **multiple projects**, **two levels of critical paths** need to be managed:
  1. **Overall IMS** critical path
  2. **Project** critical paths

- When an **IMS** is created from **several projects**, the **IMS-level critical path** **may or may not** contain the **same activities** as those **driving individual projects**.

Both levels of critical paths should be monitored because a failure in one project critical path can cause that project to become part of the program critical path at any time.

Checklist For a Scheduler For Critical Path Determination, Assessment, and Validation

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Checklist

- **The schedule's critical path is valid. That is, the critical path or longest path (in the presence of constraints)**
  - does not include LOE activities, summary activities, or other unusually long activities, except for future planning packages;
  - is a continuous path from the status date to the finish milestone;
  - does not include constraints that cause unimportant activities to drive a milestone date;
  - has no lags or leads;
  - is derived in summary schedules by vertical integration of lower-level detailed schedules, not by preselected activities that management has presupposed are important.

Checklist

- If backward-pass date constraints are present on activities other than the finish milestone, both the critical path and the longest path have been identified.
- With a number of constraints, activities with zero or negative total float may outnumber activities that are actually driving the key program completion milestone.
- The critical path, or longest path (in the presence of constraints), is used as a tool for managing the program. That is, management:
  - has vetted and justified the current critical path as calculated by the software;
  - uses the critical path to focus on activities that will be detrimental to the key program milestones and deliveries if they slip;
  - examines and mitigates risk in activities on the critical path that can potentially delay key program deliveries and milestones;

Checklist

- The critical path, or longest path (in the presence of constraints), is used as a tool for managing the program. That is, management:
  - has reviewed and analyzed near-critical paths because these activities are likely to overtake the existing critical path and drive the schedule;
  - recognizes not only activities with the lowest float but also activities that are truly driving the finish date of key milestones;
  - evaluates the critical path before the schedule is baselined and after every status update to ensure that it is valid.

An Auditor's Key Questions and Documents For Critical Path Determination, Assessment, and Validation

Key questions

1. Is the critical path, or longest path (in the presence of date constraints), calculated by the scheduling software valid?
   a. Are any activities in the schedule missing logic or constrained without justification? Are these issues resulting in an unreliable critical path?
   b. Is the critical path a continuous path from the status date to the major completion milestones?
   c. Does the critical path start with a constraint so that other activities are unimportant in driving the milestone date? If so, is there justification for that constraint?
   d. Does the critical path include LOE activities? Is the critical path driven by activities of unusually long duration that are not considered planning packages?
   e. Is the critical path driven in any way by lags or leads?
2. Does management use the critical path to focus on activities that will detrimentally affect key program milestones and deliveries if they slip?

Key Documents

1. Important program deliverables or milestones for which critical paths should be established are identified.
2. Printouts of the logic diagram indicate the longest paths to the important milestones, as well as critical paths based on total float to all major milestones.
3. Near-critical paths are identified.

فرآیند یکپارچه برنامه ریزی، زمانبندی و کنترل پروژه

بخش هشتم:

استاندارد اجرایی: اطمینان از مناسب بودن شناوریهای تخصیص یافته

ارائه دهندگان:

سید محمدرضا علوی‌پور

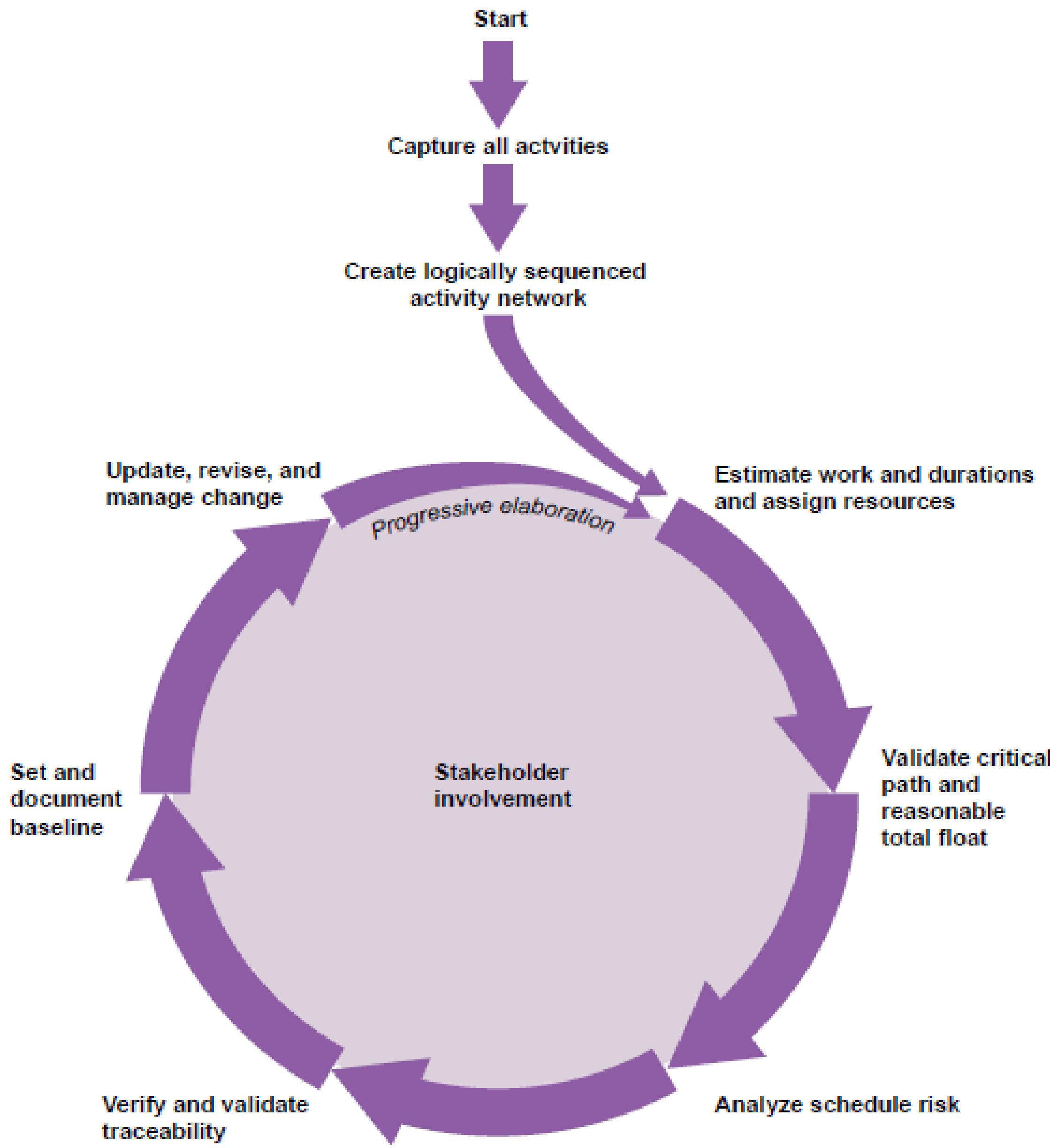
(PhD, PMP, CMIT)

What we will learn?

- What is float?
- Float management
- Checklist for a scheduler for ensuring reasonable total float
- An auditor’s key questions and documents for ensuring reasonable total float

A process for creating and maintaining reliable schedules

- This is a cyclic process
- Elaborated through rolling wave process.



A process for creating and maintaining reliable schedules

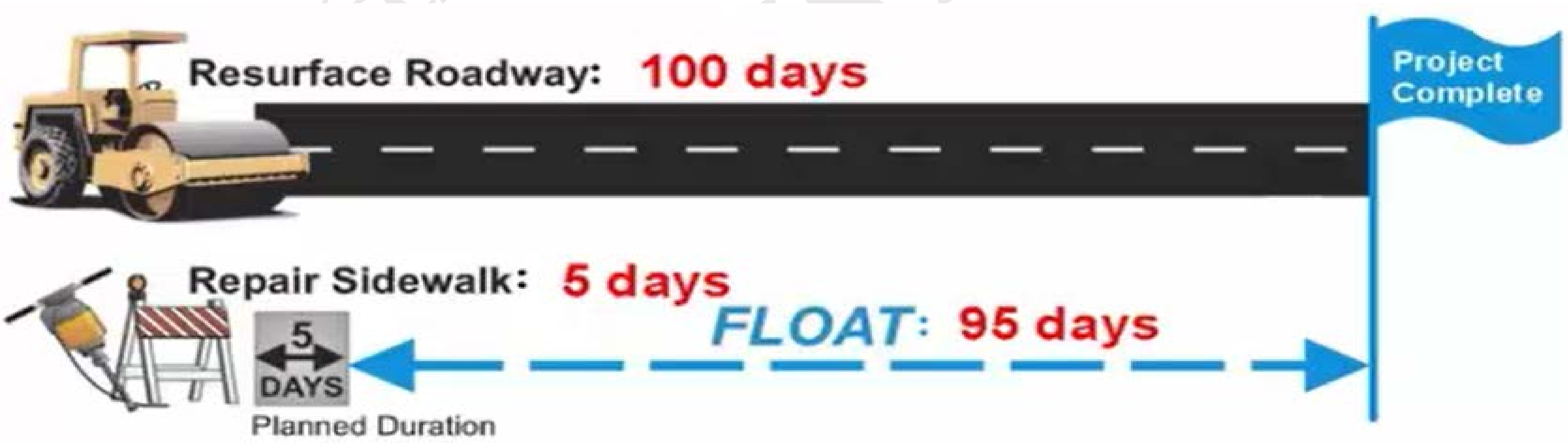
Process step	Corresponding action	Section
Capture all activities	Capturing all activities	3
Create logically sequenced activity network	Sequencing all activities	4
Estimate work and durations and assign resources	Allocating and leveling resources	5
	Determining and assigning durations to activities	6
Validate critical path and reasonable total float	Critical path determination, assessment, and validation	7
	Ensuring reasonable total float	8
Analyze schedule risk	Schedule constructability and risk analysis	9
Verify and validate traceability	Verifying that the schedule can be traced horizontally and vertically	10
Set and document baseline	Setting, monitoring, controlling, and Maintaining a baseline schedule	11
Update, revise, and manage change	Setting, monitoring, controlling, and Maintaining a baseline schedule	11
	Updating the schedule using actual progress and logic	12

What is Float?

Float – As a concept

- It is the **amount of time an activity** can be **delayed without** causing **delay to the completion of the project**
- When an activity **consumes** its **available float**, it will **become critical** and **may delay the Project**.

This definition is based on how the CPM was originally developed, but may no longer be accurate.

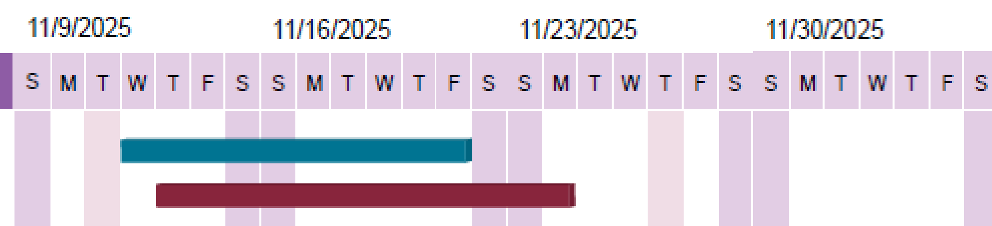


Float – As a concept

- The difference between an **activity's early** and **late dates** is known as **<u>total float or slack.</u>**
- **Total float** is an **essential output** of **<u>critical path method scheduling</u>**, and its **<u>proper management</u>** is the **foundation of this section**.
- As a **<u>general rule</u>**, activities along the **critical path** have the **least float**.
- **<u>Unreasonably high total float</u>** on an activity or path indicates that **schedule logic** might be **missing or invalid**.

Early and Late Dates

Activity		Duration	Start	Finish
Set steel columns and beams	Early	8 days	11/12	11/21
	Late	8 days	11/13	11/24



Source: GAO. | GAO-16-89G

Total float – Definition

- The **amount of time** an **activity can be delayed** or extended before **delay affects** the **program's finish date**, can be:
  1. Positive
  2. Negative
  3. Zero

Total float – Positive

- If positive, it **indicates** the amount of **time** that an activity **can be delayed without delaying the program's finish date**.
  - Typically, **total float** is calculated by the **scheduling software** to the **last activity in the schedule file**, but

    other activities or **interim milestones** may be **monitored** for **total float**, using **constraints** on **key interim milestones**.

With these constraints, using total float to identify the critical path to the finish milestone is a flawed method.

Total float – Negative

- Negative total float **indicates** the time that **must be recovered** so as **not to delay** the **program's finish date** **beyond** the **constrained date**.

- **Negative total float arises** when:
  - An **activity's completion date** is **constrained**—that is, when the **constraint date** is **earlier than** an **activity's calculated late finish**.

In essence, the constraint states that an activity must finish before the date the activity may finish as calculated by network logic.

Total float – Zero

- **Zero total float** means that any **amount of activity delay** will **delay** the **program's finish date** by an **equal amount** <u>if no constraints exist</u>.

- An **activity** with **<u>negative</u>** or **<u>zero total float</u>** is considered to be **critical** <u>if no constraints exist</u>.

Total float – Zero

PMI Best Practice

Purpose

A zero total float constraint is mostly used to enforce a priority or make a certain task critical without imposing a date constraint. A zero total float constraint not only makes the early and late dates the same for the activity, but also causes driving predecessor activities to have zero total float, thus making a path critical. A zero total float constraint is also occasionally used to prioritize resources due to resource planning considerations.

Default Condition

The default software settings for zero total float constraints are typically turned off. To apply them, the last activity which is usually a milestone or a flag is assigned a zero total float constraint.

Total float – Zero: Best Practice

PMI Best Practice

Best Practices

Use of zero total float constraint is generally not recommended. Some contract conditions, validation guidelines, and organizational best practices disallow the use of this constraint as a float suppression technique. When using zero total float constraints, it is best to tag these activities to ensure that the constraint is monitored, slippages are noticed, and its impact assessed in project performance.

Free float

- **Free float** is the **portion** of an **activity's total float** that is **available before** the **activity's delay** affects its **immediate successor**.

- Depending on the sequence of events in the network, an activity with total float may or may not have free float.

For example, it may be possible that an activity slips 2 days without affecting the finish date (2 days of total float), but this delay will cause a 2-day slip in the start date of its immediate successor activity (zero free float).

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Free float – Zero

PMI Best Practice

The use of constraints in the critical path method of scheduling is discussed in Section 3.9. However, most modern scheduling software allows imposition of additional constraints that affect CPM calculation for available float. Zero free float constraint is one such additional constraint that can be applied to alter the free float available to an activity, mostly for resource considerations.

Most software allows only complete suppression of available free float, also defined as a zero free float constraint. It is also known as the "as late as possible" constraint.

A zero free float constraint enforces the activity to start as late as possible without affecting the early start of the succeeding activity. Note that doing so does not affect the succeeding early start and, hence, is not necessarily the same as the late start of the activity.

Why this needs to be used?

Free float – Zero

PMI Best Practice

Zero free float constraints are used for various reasons, mostly related to resources. Resource leveling algorithms typically prefer utilization of free floats to move activities before total float is considered, because moving such activities would have the least impact on early planning. But applying a zero free float constraint only allows it to be leveled with available total float. Other applications of zero float constraint is for tracking material deliveries. Zero free float constraints allow delivery activities to be scheduled as "just-in-time." This kind of application is often used for scheduling conveniences, such as meeting requirements of accurate spending projections.

Default Condition

The default software settings for zero free float constraints are typically turned off.

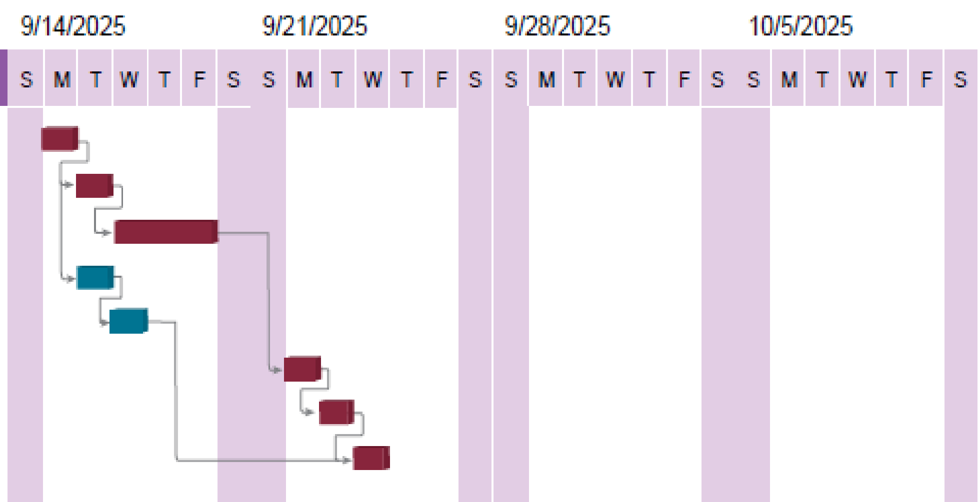
Free float – Zero

- **Leveling overallocated resources** on the "**inspect underground sewer"** activity is much **easier** than on **"excavate for and install underground sewe**r" because of the former activity's available **free float**.

- **Leveling resources** will always **consume float** along a path of activities.

Total Float and Free Float

Activity	Early start	Late start	Free float	Total float
Lay out and stake property and excavation	9/15	9/15	0 days	0 days
Dig foundation and basement	9/16	9/16	0 days	0 days
Lay out and form footings and pier pads	9/17	9/17	0 days	0 days
Excavate for and install underground sewer	9/16	9/22	0 days	4 days
Inspect underground sewer	9/17	9/23	4 days	4 days
Install footing and pier rebar	9/22	9/22	0 days	0 days
Inspect footing and pier rebar	9/23	9/23	0 days	0 days
Pour footings and pads	9/24	9/24	0 days	0 days



Source: GAO. | GAO-16-89G

Free float – Best Practice

PMI Best Practice

Best Practices

Use of zero free float constraint is generally not recommended. Some contract conditions even disallow the use of these constraints as float suppression techniques. The best alternate practice recommended is use of lags or defined activities with durations that make the intent transparent to the project team.

Float Management

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Purpose and default condition

PMI Best Practice

Purpose

Float can be beneficial and destructive to a project at the same time. Successfully controlling how it is used will help the project complete on time, more efficiently, and with less disputes.

Default Condition

Float should be addressed for every schedule. Usually the contract will dictate who owns the float, but if it does not, the project team needs to agree to ownership and the float management technique up front.

Common barriers to valid float

- These items **commonly prevent** the **valid calculation** of **total float**:
  - Missing activities
  - Missing or convoluted logic
  - Date constraints

- The **reasonableness** of **total float** depends on:
  - Capturing all activities
  - Properly sequencing activities
  - Realistic resource assignments
  - Accurate status updates

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General guide

- **Activities' float** differs by **status period**, given the **logical sequence** of activities in the network and the **program's remaining duration**.

- Management **should not adhere solely** to a **target float value** (for example, maximum 2 working periods) or specific float measure (for example, **10 percent of program duration**).

- **Large amounts of float** may be **justified**, given an **activity's place** in the flow.
  - *For example, nonessential activities in a 2-year project may have far more float available than the same activities in a 6-month project*

General guide

In general, total float should be evaluated relative to the program's projected finish date.

- The remaining activities in the schedule should be **sorted by total float**, and those values should be **assessed for reasonableness**.
  - *For instance, management should ask, is it reasonable that an activity with 55 days of total float can actually slip 55 working days before the program's finish date is affected? Is the manager of that particular activity aware of this float?*

Total float is also tied to the overall confidence level of a schedule, assuming that a schedule risk analysis has been performed.

1. **The more optimistic a schedule == the lower the available float**
2. **The more pessimistic a schedule == the greater the available float**

- **Total float values** that appear to be **excessive** should be **documented** to show that the program management team, having already performed an **analysis**, has **agreed**.

General guide

- Activities with the **lowest total float values** constitute the **highest risk** to completing the **schedule** or meeting **interim milestones**.

- **Total float** may **not** be a **completely accurate measure** of **flexibility** **if** the schedule has **date constraints** or **deadlines** such that low or even negative float values for activities do not drive the finish milestone.
  - Thus, it is imperative that **managers** for both the **owner** and the **contractor** **proactively** **manage total float** as activities are completed.

Therefore, when reviewing any CPM schedule, the analyst must develop a clear understanding of how the network was constructed and ascertain exactly what meaning any float values may have.

General guide

- **Scheduling software** automatically calculates **total** and **free float** for activities.
  - **However**, these values of float must be **examined** for **reasonableness**.
    - ✓ **Unreasonable float** might be **negative**, **positive**, or **zero**.
      - *That is, a network that displays large negative values of total float, such as –300 days for some activities, most likely indicates either* ***missing logic*** *or an* ***unrealistic sequencing*** *of activities.*
        - ✓ For example, **dangling logic** can create **unrealistic free float**.
- ✓ A **complex schedule** whose **majority of remaining activities** is **critical** is not a **realistic plan** and should be **assessed** for:
  - ✓ Reasonable **logic**
  - ✓ Practicality of **resource assignments**
  - ✓ Reasonableness of the **project's duration**

General guide

- **Significant changes** in **float** potentially indicate that:
  - A **logic link** has been **broken** or
  - An **out-of-sequence activity** has been **completed**.

- **All activities** with **negative float** should be **questioned**.
  - Management should be aware of activities that are **behind schedule** with respect to a **constrained activity**.
  - **If** the **negative float** **cannot** be **mitigated**, then the **milestone** should **forecast** a slip to **eliminate** the **negative float**.

General guide

- **Nonworking periods** are **not float**.
  - **Nonworking periods** are defined in **project** and **resource calendars** and **dictate** the **availability of resources** to work, **not the flexibility** of an activity's start or finish dates.

- **Float** should **not be treated** as **schedule contingency**.
  - Because **float is shared** along a **sequence of activities**, it is **available** for **use** by any activity along that **sequence**.
    - ***Be careful, the owner may also use it with no right for you as a contractor!***

General guide

- **Free float** is particularly important in **leveling resources** because leveling generally targets activities with **free float first**.
  - **Delaying an activity** that has **total float** but **no free float** does **not affect** the **project's completion date** but **does disturb successor** activity dates.
    - ✓ This, in turn, may **disrupt resource availability** for assignments along the **entire path of successor activities**.

General guide

- **Float on the critical path** should be commensurate with **program risk**, **urgency**, **technological maturity**, **complexity**, and **funding profile**.

- **Periodic reports** should **routinely report** the **amount of float consumed** in a period and **remaining** on the **critical and near-critical paths**.

- **As a program** schedule becomes **less flexible**, the **probability** of having to **consume near-critical path** and **critical path float** is **increased**.

General guide – DCMA

High Float – activities may not be linked properly and can cause stress on the Critical Path. Total Float values are limited to 44 days, therefore review tasks that have greater than 2 months total float and limit their usage to 5% of incomplete tasks.

$$\% \textit{High Float} = \frac{\textit{Total \# of Incomplete Tasks with High Float}}{\textit{Total \# of Incomplete tasks}} x100$$

One may still ask: why is 44-days total float the derived cutoff point for achieving this perspective? Well, there appears to be nothing magical about the duration 44-days except that is comes to about two months, or roughly two reporting periods in a typical earned value management integrated system. Two months total float duration is a value, most likely, derived from practical experience and/or analysis on schedules of varying length. We are taking DCMA's 44-day high float definition on face value.

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Best Practices, Recommended Practice, Advisories

PMI Best Practice

Best Practices

The project should own the float and each case in which the float is being used should be discussed as part of the standard project meetings.

Recommended Practice

The regular discussion of float allocation and use keeps the various parties aware of the risks and consequences of consuming the float. Each conversation should distinguish between the use of free float versus total float, discuss how much float is being used, and what can be done to preserve the float. Schedulers are usually aware of the consequences of using all the float and the high risk situation that it leaves the project in. Often, other parties (owners, contractors, suppliers, etc.) feel as if the float can be taken up as they see fit and then they cause problems for any work that needs to follow behind them.

Excessive and/or sparse amounts of float can indicate that the logic is not correct or that resources have not been properly accounted for. In each instance the logic and resources should be reviewed by the team to see if it properly represents the project's plan. If the project review shows that the nature of the project has a high/low level of float, everyone needs to be aware of the fact and know the project team's plan for dealing with it.

Advisories

When the float is gone, everything is critical: this point needs to be emphasized to the project teams. There will be no more room for any errors or unforeseen events.

Never add logic with the purpose of eliminating float. If the logic is wrong, make the correction because the logic is wrong. If the resources are not right, make corrections to the resources.

Checklist For a Scheduler For Ensuring Reasonable Total Float

Checklist

- The total float values calculated by the scheduling software are reasonable and accurately reflect a schedule's flexibility.
- The program really has the amount of schedule flexibility indicated by the levels of float.
- Remaining activities in the schedule are sorted by total float and assessed for reasonableness. Any activities that appear to have a great deal of float are examined for missing or incomplete logic.
- Total float values that appear to be excessive are documented to show that the program management team has performed an assessment and agreed that the logic and float are consistent with the plan.
- Total float is calculated to the main deliveries and milestones as well as to the program's completion.

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Checklist

- Total and free float inform management as to which activities can be reassigned resources in order to mitigate slips in other activities.
- Management balances the use of float with the fact that total float is shared along a path of activities.
- Periodic reports routinely show the amount of float consumed in a period and remaining on the critical and near-critical paths.
- Date constraints causing negative float have been justified. If delay is significant, plans to recover the implied schedule slip have been evaluated and implemented.

An Auditor's Key Questions and Documents For Ensuring Reasonable Total Float

Key questions

1. Are the total float values that the scheduling software calculates reasonable and do they accurately reflect true schedule flexibility?

2. Are excessive values of total float being driven by activities that are missing logic?

3. Is total float monitored? Does management have a plan to mitigate negative total float?

4. Does management rely on free float to level resources or reassign resources to assist critical activities?

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Key Documents

1. The program team can use a list of activities sorted by their total float values to determine whether the total float values correctly reflect flexibility in the program schedule.

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