Module 12

Earned Value Management

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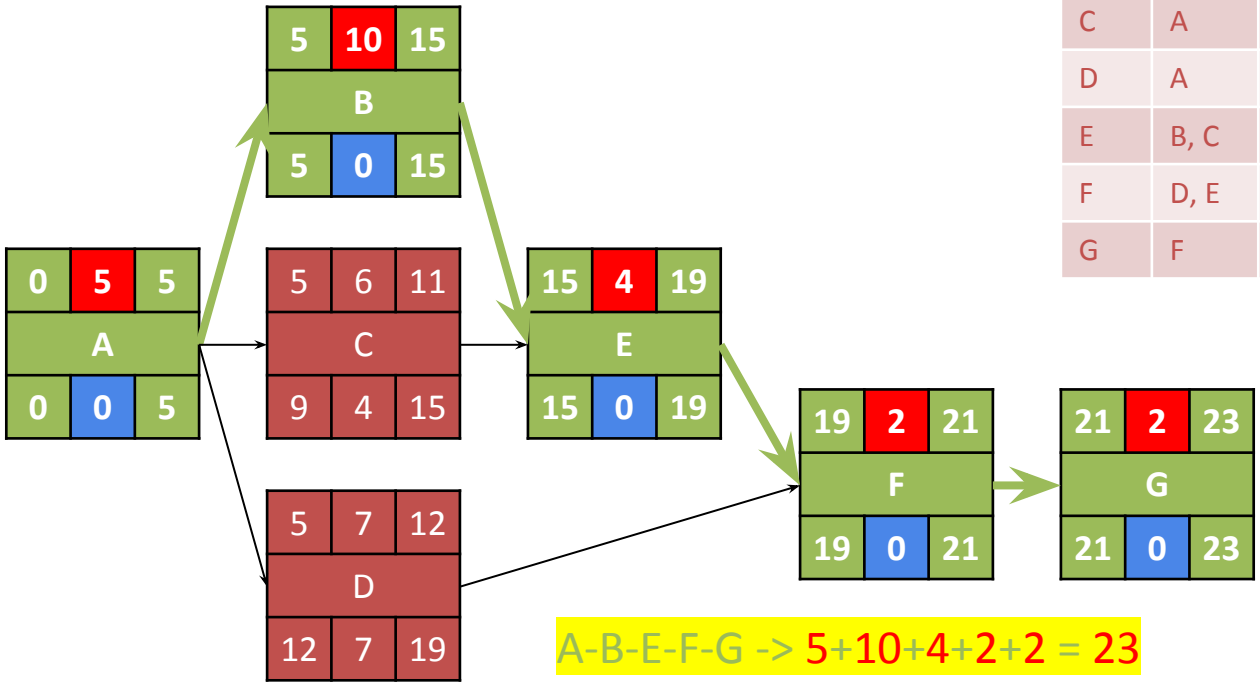
Now... where were we?

In the critical path, the slack is 0 and the sum of durations is maximized

Act	Prec	Dur
A	-	5
B	A	10
C	A	6
D	A	7
E	B, C	4
F	D, E	2
G	F	2



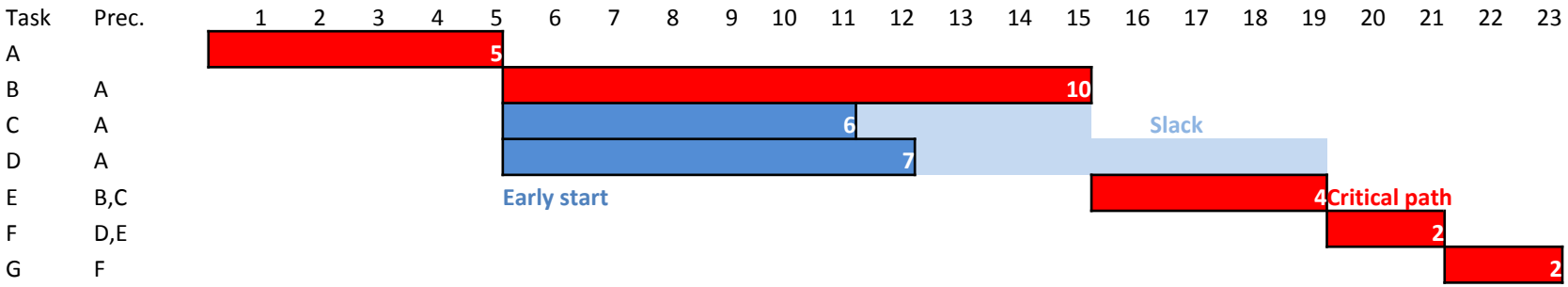
A-B-E-F-G -> 5+10+4+2+2 = 23

A-C-E-F-G -> 5+6+4+2+2 = 19

A-D-F-G -> 5+7+2+2 = 16

Early Start	Duration	Early Finish
Task Name		
Late Start	Slack	Late Finish

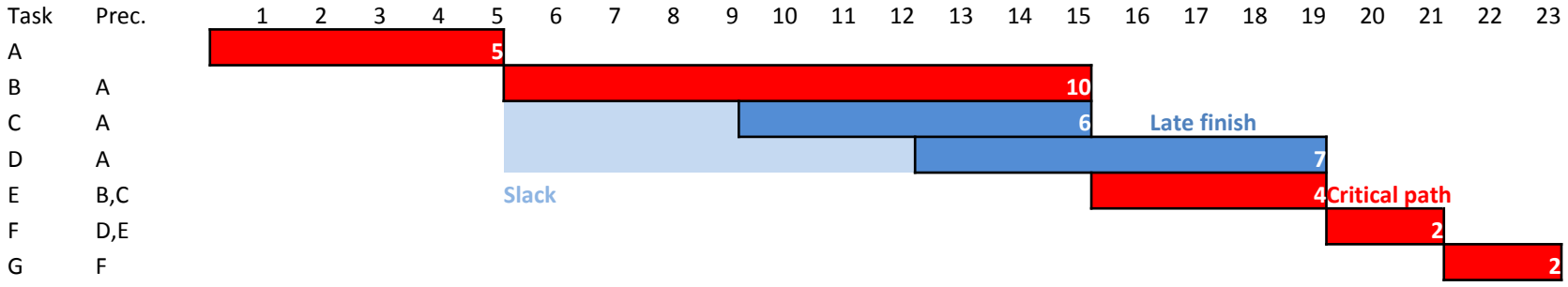
This is the corresponding Gantt



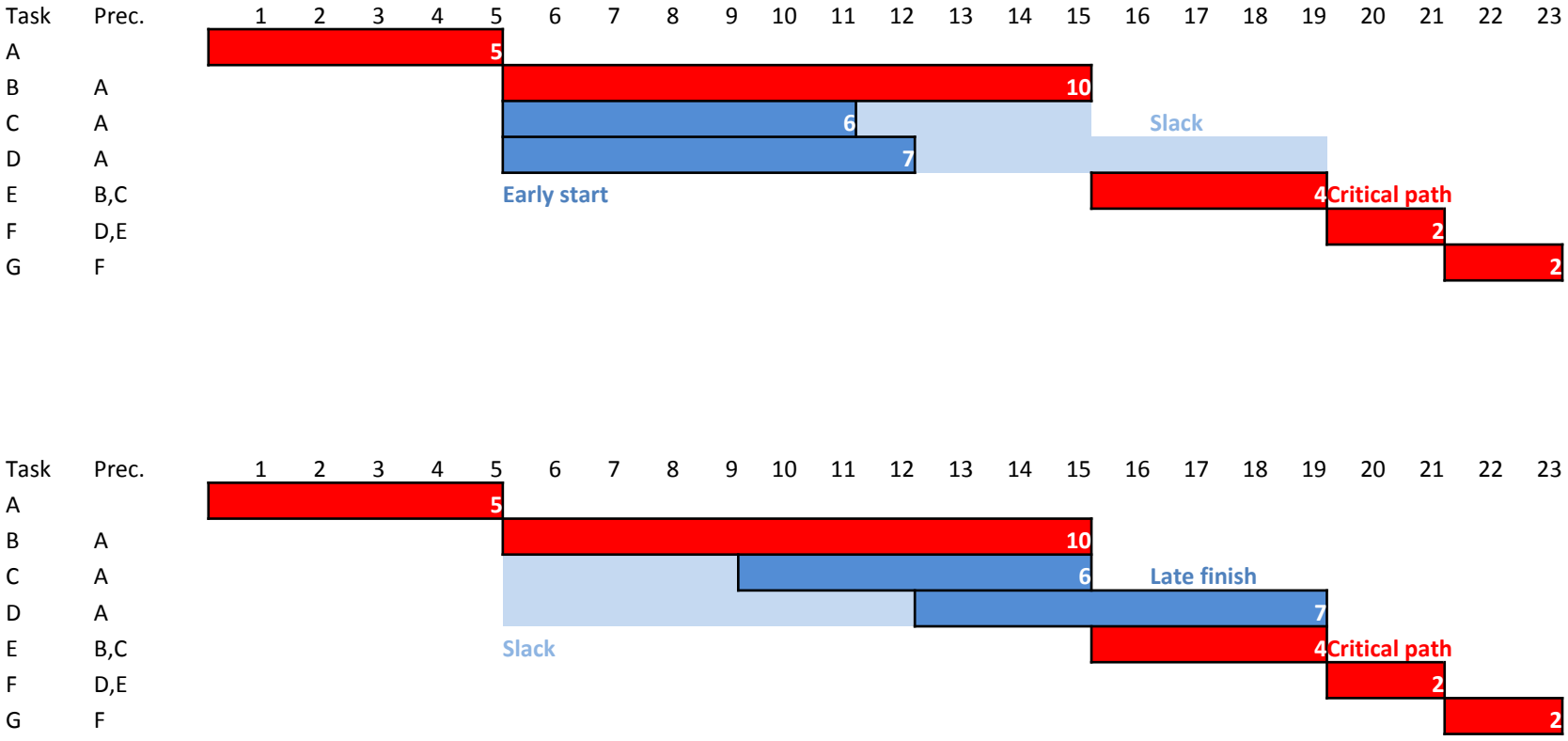
(Assuming tasks C and D start **as early as possible**)

This is the corresponding Gantt

(Assuming tasks C and D start **as late as possible**)

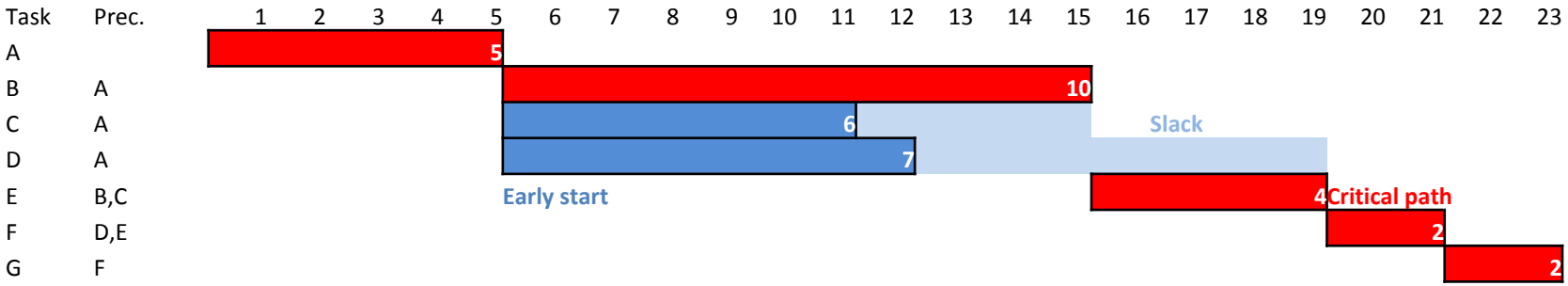


No overall delay: C and D are **NOT** on the critical path

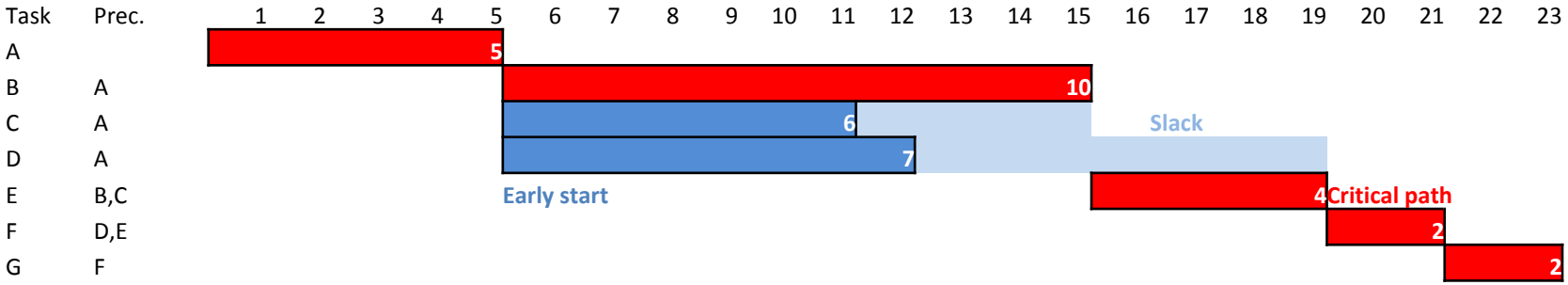


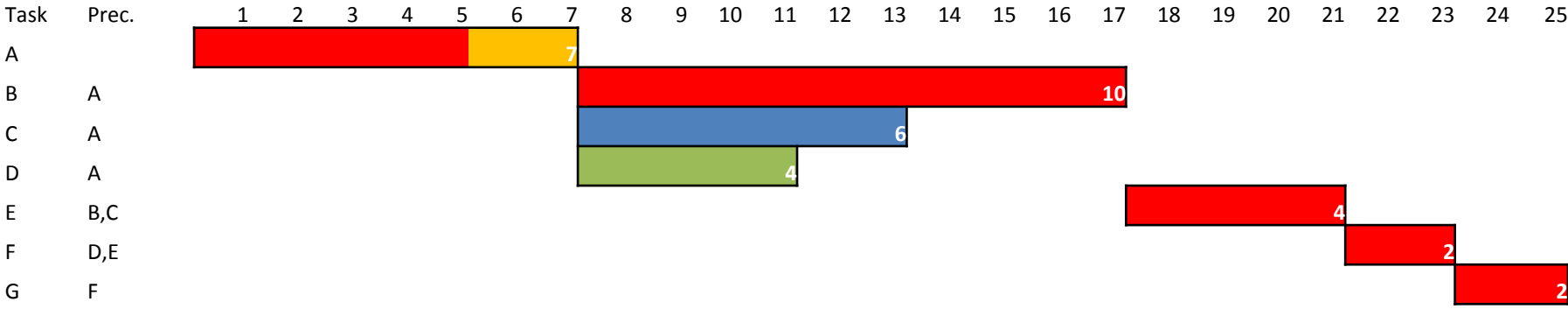
What if a task from the critical path runs late?

We planned 5 days for task A

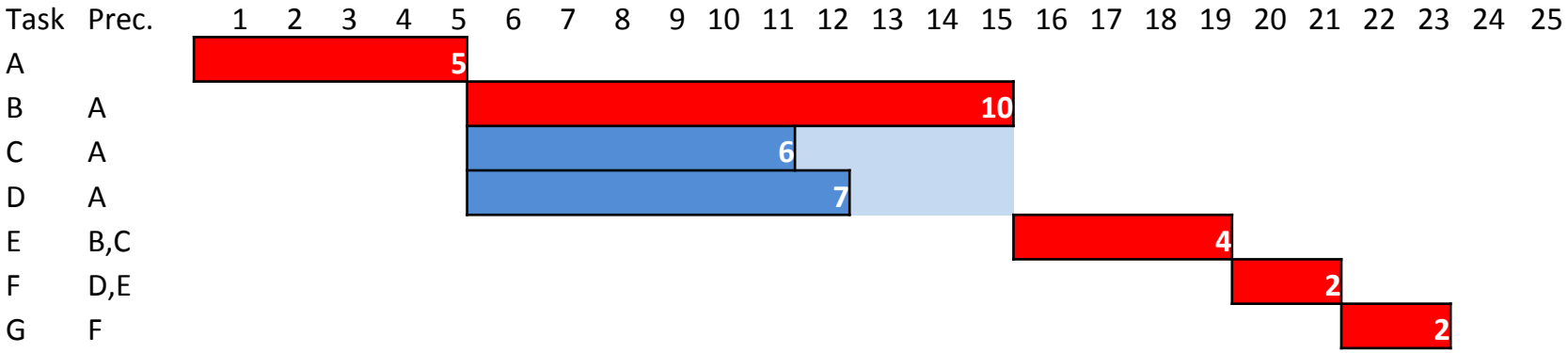


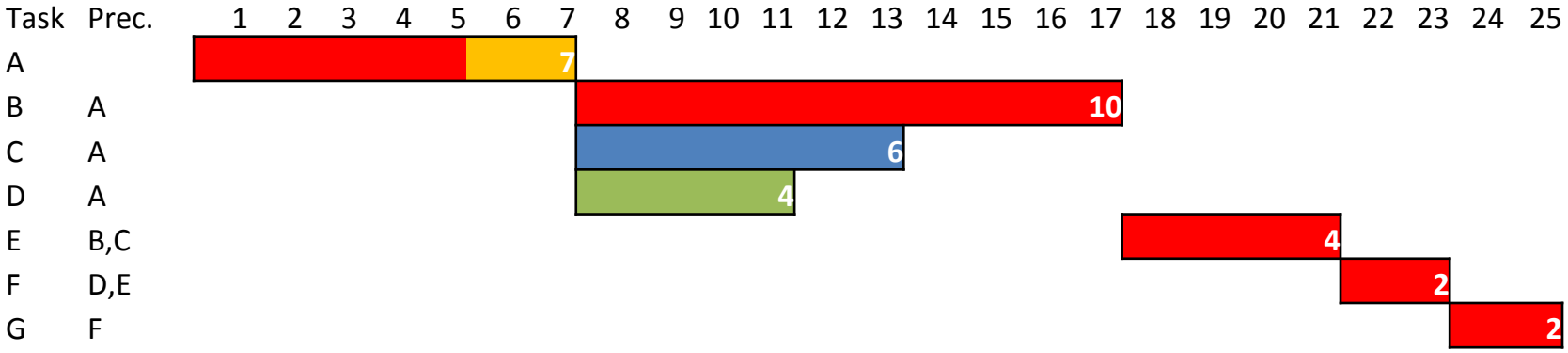
… but task A took 7 days instead of the predicted 5





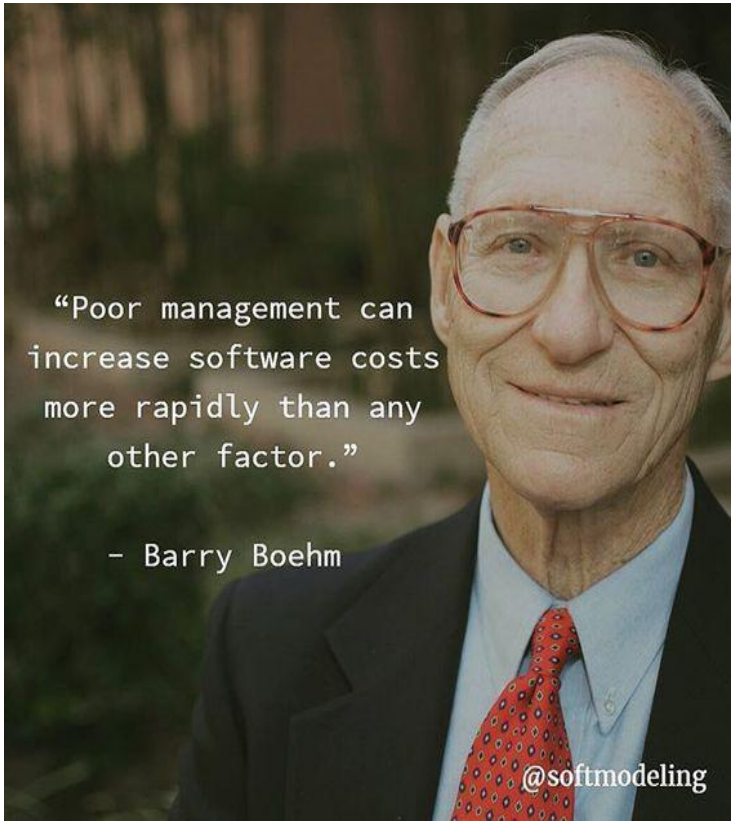
Task A was on the critical path
This delay affects the whole project

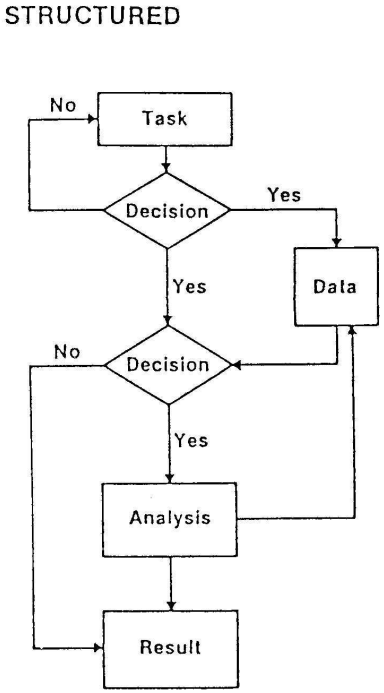


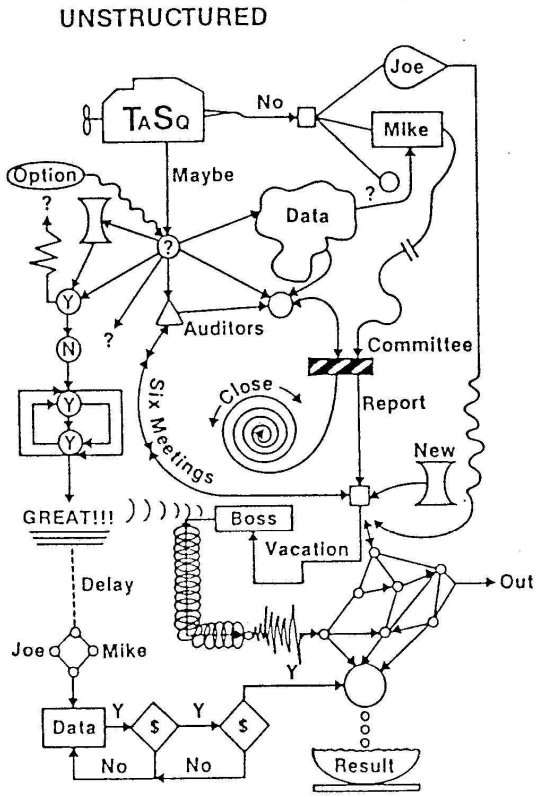


A delay on a task on the critical path will delay the whole project!

Poor management is a huge risk







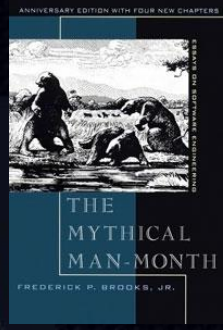
Barry Boehm: "Software Engineering Economics", Prentice-Hall, 1981.

Ok, ok…
This project is late.
We will just add more people to help us get back on track!

{ 9 women }

“9 women can’t make a baby in a month.”

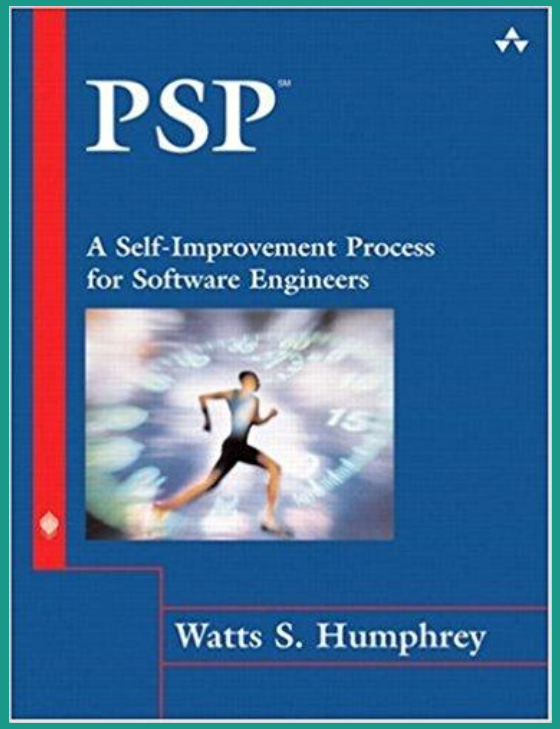
– Fred Brooks

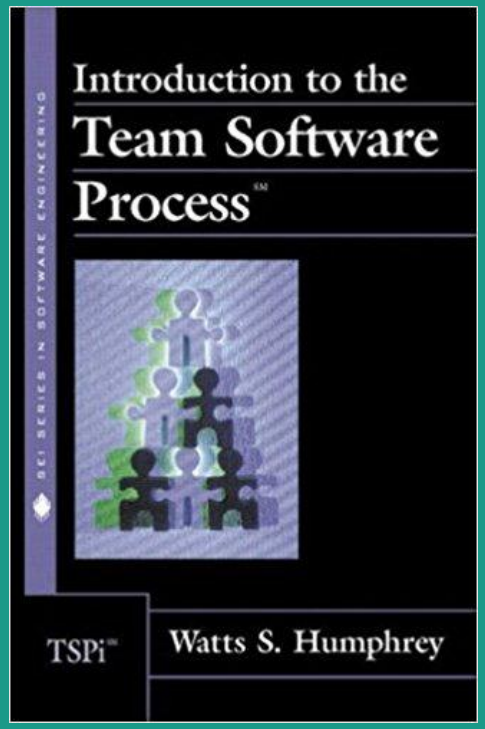


Brook's Law

"Adding manpower to a late software project makes it later"

Making Schedules





Scheduling

- Once you have determined the task order and duration, you can make the project schedule
- This involves both project and period planning
- The project plan consists of the tasks, task times, and task order
- Period planning involves spreading the project tasks over a calendar period

The Importance of Period Plans

- Developers focus on project plans, but live in a periodic world
  - Projects have committed dates
  - Businesses collect revenue, declare dividends, and pay salaries
  - We all pay monthly bills and collect periodic paychecks
  - We also take time off for weekends and scheduled vacations
- The relationship between project plans and period plans is the source of most project problems
- That is why it is important to use sound methods when making the project schedule

Schedule Estimating

- To make a schedule, you need three things
  - the estimated direct project hours for each task
  - a calendar of available direct hours
  - the order in which the tasks will be done
- Then, you need to
  - estimate the hours needed for each task
  - spread these task hours over the calendar of available hours

Available Direct Hours

- Staffing schedule
  - New projects are not instantly staffed
  - You need a committed staffing plan
- Produce a calendar spread of available hours
  - At 52 weeks per year and 40 hours per week,
    1 year = 2080 hours
  - With 3 weeks of vacation and 10 holidays,
    1 year =1880 hours (90%)
  - With 10% for meetings and 15% for email and other interruptions, 1 year ≈ 1000 to 1400 hours (50% to 65%)
  - Additional time is usually spent on project activities that are not related to the direct tasks

Task Order

- The task order is driven by the development strategy
  - You need a conceptual approach
  - Each task needs completion criteria
  - You must consider task interdependencies
  - Also consider cost and cycle-time priorities

- Determine the planned task order
  - The initial task order provides a basis for planning
  - The task order will change with new knowledge

Produce the Schedule

- Estimate the hours that each task will take
  - What portion of total hours have such tasks taken historically?
  - Will anything unusual affect this project?
  - To ensure that tasks are not omitted, consider the tasks for the entire project
- Spread the task hours over the calendar
  - Identify key project checkpoints
  - Use a standard format

The Task Planning Template

- To fill out the task planning template
  - list the tasks in expected completion order
  - enter the estimated hours for each task
  - add the hours in the cumulative hours column

Task	Hours	*Cum. Hours*

Schedule Planning – compute **cumulative hours for each task**

On the **task planning template**, enter the **estimated hours per task**. Then, compute the **cumulative hours**.

Task	Hours	*Cum. Hours*
A	**2**	**2**
B	**5**	**7**
C	**4**	**11**
D	**7**	**18**
E	**3**	**21**
F	**5**	**26**
G	**6**	**32**
H	**3**	**35**
I	**2**	**37**

Schedule Planning Template

- Start filling the schedule planning template
  - list the calendar dates in the left-hand column
  - use days or weeks, depending on project scale
    - for days, list every date
    - for weeks, use a standard day (for example, Monday)
  - list the planned direct project hours available each week
  - add the hours in the cumulative hours column
- Complete the task and schedule templates concurrently

Day	Hours	Cum. Hours

Schedule Planning – compute **cumulative available working hours**, for each day

On the **schedule planning template**, enter the **direct hours** available per **day** or **week** and the ***cumulative direct hours***.

Day	Hours	Cum. Hours
1	3	3
2	5	8
3	5	13
4	5	18
5	4	22
6	6	28
7	5	33
8	5	38

Completing the Plan

- For each task
  - look on the task template for the cumulative hours needed to complete that task
  - on the schedule template, find the week during which those hours are first exceeded
  - on the task template, enter that week's date in the Date column for that task

- You now have the task schedule

Schedule Planning – assign task conclusion to corresponding working days

On the **task schedule**, enter **the day (or week) during which the cumulative hours for each task is reached**.

Task	Hours	Cum. Hours	Day
A	2	2	**1**
B	5	7	**2**
C	4	11	**3**
D	7	18	**4**
E	3	21	**5**
F	5	26	**6**
G	6	32	**7**
H	3	35	**8**
I	2	**37**	**8**

Project tracking

Project Tracking

- Project tracking would be simple if
  - we always completed tasks in the planned order
  - no tasks were added or deleted
- This (pretty much) **never** happens.
  - Requirements often change.
  - Tasks get cancelled or deferred.
  - Some tasks are dropped and others are added.
  - Estimating errors are common.

Project Tracking

- To track project status in a **dynamic environment**, you need a way to assign a value that measures the contribution of each task towards the whole project.
- Then you can
  - add up the value of the completed tasks
  - compare this value to the value of the total job
  - calculate the percentage of job completion
- We use a method called **E**arned **V**alue (EV).

Earned value management

(Team Software Process style)

Earned Value (EV)

- Establishes a value for each task
- Permits progress tracking against the plan
- Facilitates tracking, even with changes to the plan

Earned Value Principles

- Earned value provides a common value for each task.
- **This value is the percentage of the total project hours that this task is planned to take.**
- The **planned value is credited, no matter how long it actually took to do the task**.
- No value is given for partially-completed tasks.
- Major plan changes require new plans.

Establish the Planned Value

- On the task template
  - add the number of project hours
  - calculate the percentage of the total hours for each task
  - enter this percentage as the planned value (PV) for that task
  - calculate the cumulative PV for each task
- On the schedule template, enter the cumulative planned value for the tasks to be completed each day or week.

Earned Value – compute the planned Value

Produce the **PV**, as the planned percentage of the **total job** that each task represents.

Task	Hours	Cum. Hrs.	Day	PV	*Cum. PV*
A	2	2	1	**5.4%**	***5.4%***
B	5	7	2	**13.5%**	***18.9%***
C	4	11	3	**10.8%**	***29.7%***
D	7	18	4	**18.9%**	***48.6%***
E	3	21	5	**8.1%**	***56.7%***
F	5	26	6	**13.5%**	***70.2%***
G	6	32	7	**16.3%**	***86.5%***
H	3	35	8	**8.1%**	***94.6%***
I	2	**37**	8	**5.4%**	***100.0%***

Earned Value – Compute the planned value per day

Enter the cumulative planned value for each day (or week).

Day	Hours	Cum. Hours	Cum. PV
1	3	3	***5.4%***
2	5	8	***18.9%***
3	5	13	***29.7%***
4	5	18	***48.6%***
5	4	22	***56.7%***
6	6	28	***70.2%***
7	5	33	***86.5%***
8	5	38	***100.0%***

Tracking the Plan

- As each task is completed, it earns the planned value.
  - Enter the earned value (EV) for that task.
  - Enter the date on which the task was completed.
  - Add the EV-to-date in the “Cumulative EV” column.

- In the schedule template, enter the cumulative EV for each day or week as it is completed.

- Track earned value versus planned value by day or week.

Tracking the Plan Example -1

During the project, enter on the task planning template the day each task is completed.

Plan						Actual
Task	Hours	Cum. Hrs.	Day	PV	Cum. PV	Done
A	2	2	1	5.4%	5.4%	1
B	5	7	2	13.5%	18.9%	2
C	4	11	3	10.8%	29.7%	4
D	7	18	4	18.9%	48.6%	5
E	3	21	5	8.1%	56.7%	
F	5	26	6	13.5%	70.2%	
G	6	32	7	16.3%	86.5%	
H	3	35	8	8.1%	94.6%	
I	2	37	8	5.4%	100.0%	

Tracking the Plan Example -2

On the schedule template, enter the earned value (EV) for each day.

Plan				Actual
Day	Hours	Cum. Hours	Cum. PV	EV
1	3	3	5.4%	5.4%
2	5	8	18.9%	18.9%
3	5	13	29.7%	18.9%
4	5	18	48.6%	29.7%
5	4	22	56.7%	48.6%
6	6	28	70.2%	
7	5	33	86.5%	
8	5	38	100.0%	

Estimating project completion

Estimating Job Completion

- Assume that the project will continue to earn EV at the same rate as in the past.
- Extrapolate the time to project completion by extending the EV line until it reaches 100%.
- This is the likely project completion date, unless
  - the rate of progress changes
  - work for the remaining tasks deviates from the original plan

Estimating Completion Example

What is the actual EV per day?

Day	Hours	Cum. Hours	Cum. PV	EV	Proj. EV
1	3	3	5.4%	5.4%	5.4%
2	5	8	18.9%	18.9%	18.9%
3	5	13	29.7%	18.9%	18.9%
4	5	18	48.6%	29.7%	29.7%
5	4	22	56.7%	48.6%	48.6%
6	6	28	70.2%		
7	5	33	86.5%		
8	5	38	100.0%		
9					
10					
11					
12					

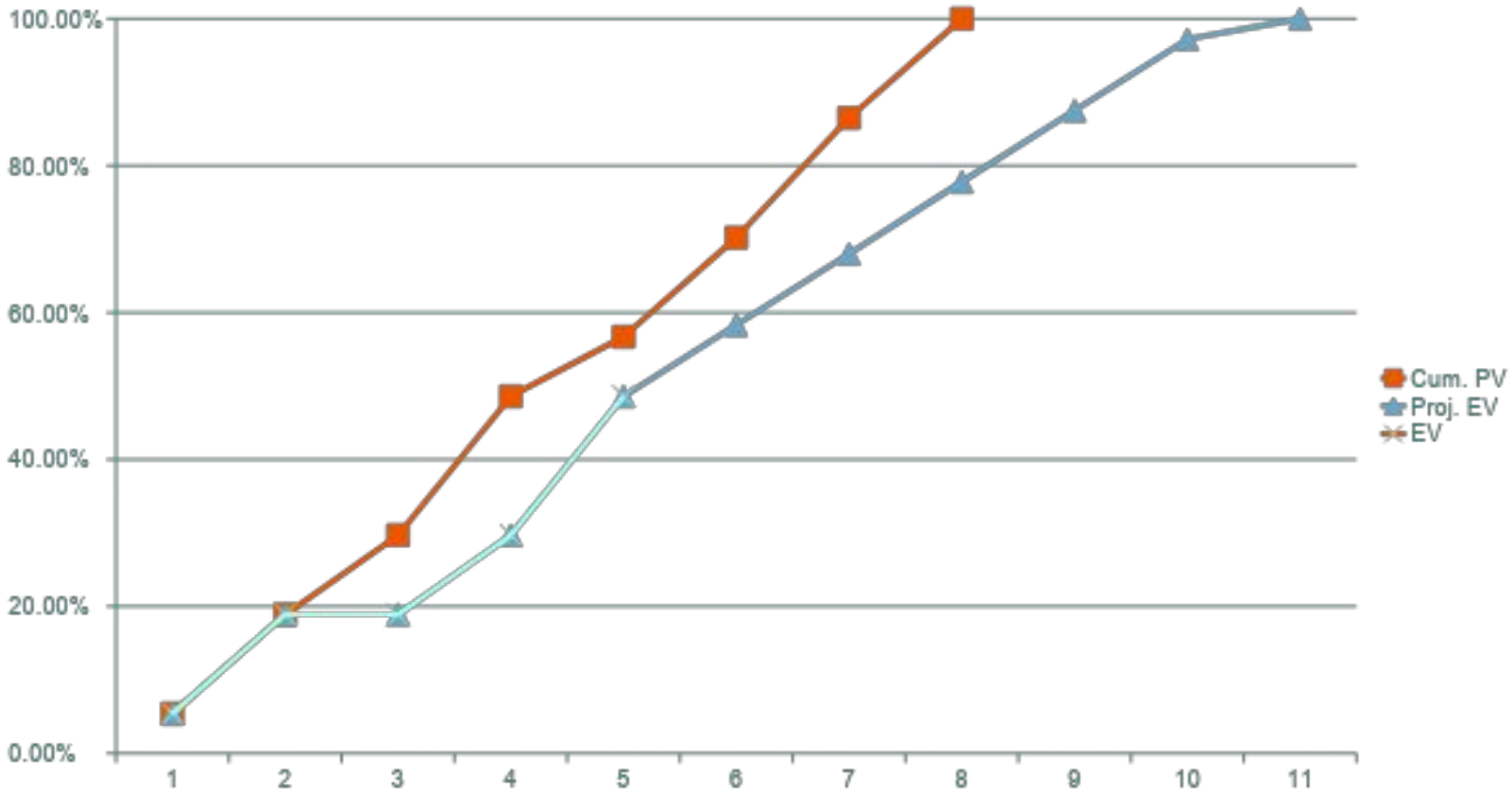
When should you expect to finish?

Estimating Completion Example

Using the actual EV earned per day (48.6/5 = 9.72), enter the projected EV by day to project completion.

Plan				Actual	Projected
Day	Hours	Cum. Hours	Cum. PV	EV	Proj. EV
1	3	3	5.4%	5.4%	5.4%
2	5	8	18.9%	18.9%	18.9%
3	5	13	29.7%	18.9%	18.9%
4	5	18	48.6%	29.7%	29.7%
5	4	22	56.7%	48.6%	48.6%
6	6	28	70.2%		58.3%
7	5	33	86.5%		68.0%
8	5	38	100.0%		77.8%
9					87.5%
10					97.2%
11					100.0%

Estimating completion example



Time to make it on your own!

Exercise #1

- Mary plans to commit 3.5 hours each week to her next programming assignment and has estimated the necessary tasks as follows:
  - Plan: 1.0 hours
  - Design: 4.5 hours
  - Code: 5.0 hours
  - Compile: 0.5 hours
  - Test: 1.5 hours
- That was the plan. In practice:
  - On week 1, she completes the plan and records 2.1 hours of activity.
  - On week 2, she is unable to work on the assignment.
  - On week 3 she records 4.3 hours and completes the design.
- When will Mary finish her project?

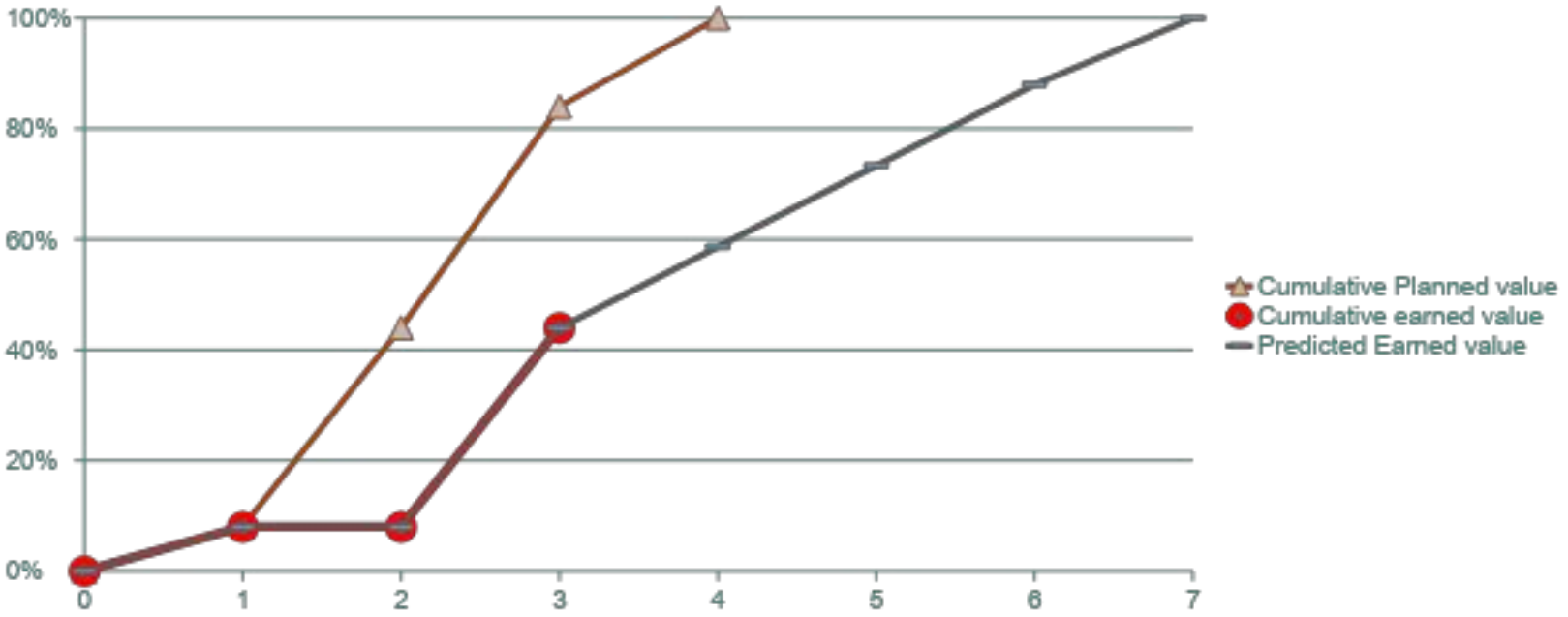
Exercise #1 solution

Task		Planned				Actual		
Task	Planned hours	Planned value	Cumulative hours	Cumulative Planned value	Week number	Week Number	Earned value	Cumulative earned value
Plan	1.0	8%	1.0	8%	1	1	8%	8%
Design	4.5	36%	5.5	44%	2	2	0%	8%
Code	5.0	40%	10.5	84%	3	3	36%	44%
Compile	0.5	4%	11.0	88%	4			
Test	1.5	12%	12.5	100%	4			
Total	**12.5**	**100%**						

Exercise #1 solution

		Plan			Actual			
Week number	Date (Monday)	Direct hours	Cumulative hours	Cumulative Planned value	Direct hours	Cumulative hours	Cumulative earned value	Predicted Earned value
0	March 13, 2017	0	0	0	0	0	0	0.0%
1	March 20, 2017	3.5	3.5	8%	2.1	2.1	8%	14.7%
2	March 27, 2017	3.5	7.0	44%	0.0	2.1	8%	29.3%
3	April 3, 2017	3.5	10.5	84%	4.3	6.4	44%	44.0%
4	April 10, 2017	3.5	14.0	100%				58.7%
5	April 17, 2017							73.3%
6	April 24, 2017							88.0%
7	May 1, 2017							**102.7%**

Exercise #1 solution



Exercise #2 – James' plan

- James has a contract to write a program for a local small business. He plans to allocate 5 hours every week to this job and estimates the time for each task as follows:
  - Plan: 1.6 hours
  - Design: 4.9 hours
  - Design Review: 2.4 hours
  - Code: 10.3 hours
  - Code Review: 4.5 hours
  - Compile: 1.2 hours
  - Test: 6.8 hours
  - Post-mortem 1.2 hours

Exercise #2 – what really happens

- In practice:
  - On week 1, James spends 3 hours planning but the planning is not completed.
  - On week 2, he spends a further 3.9 hours and completes both the plan and the design.
  - On week 3, he works for 3.7 hours and completes the design review and starts coding.
  - On week 4, he works for 4.1 hours coding.
  - On week 5, he spends 4.5 hours coding, performing a code review and compiling, not finishing any of these. He starts testing, but does not end it either.
  - On week 6 James works for 4.5 hours, finishing the code, the code review and compiling, and continues testing.
  - On week 7 he spends 2.9 hours but the testing is not yet complete by the end of this.

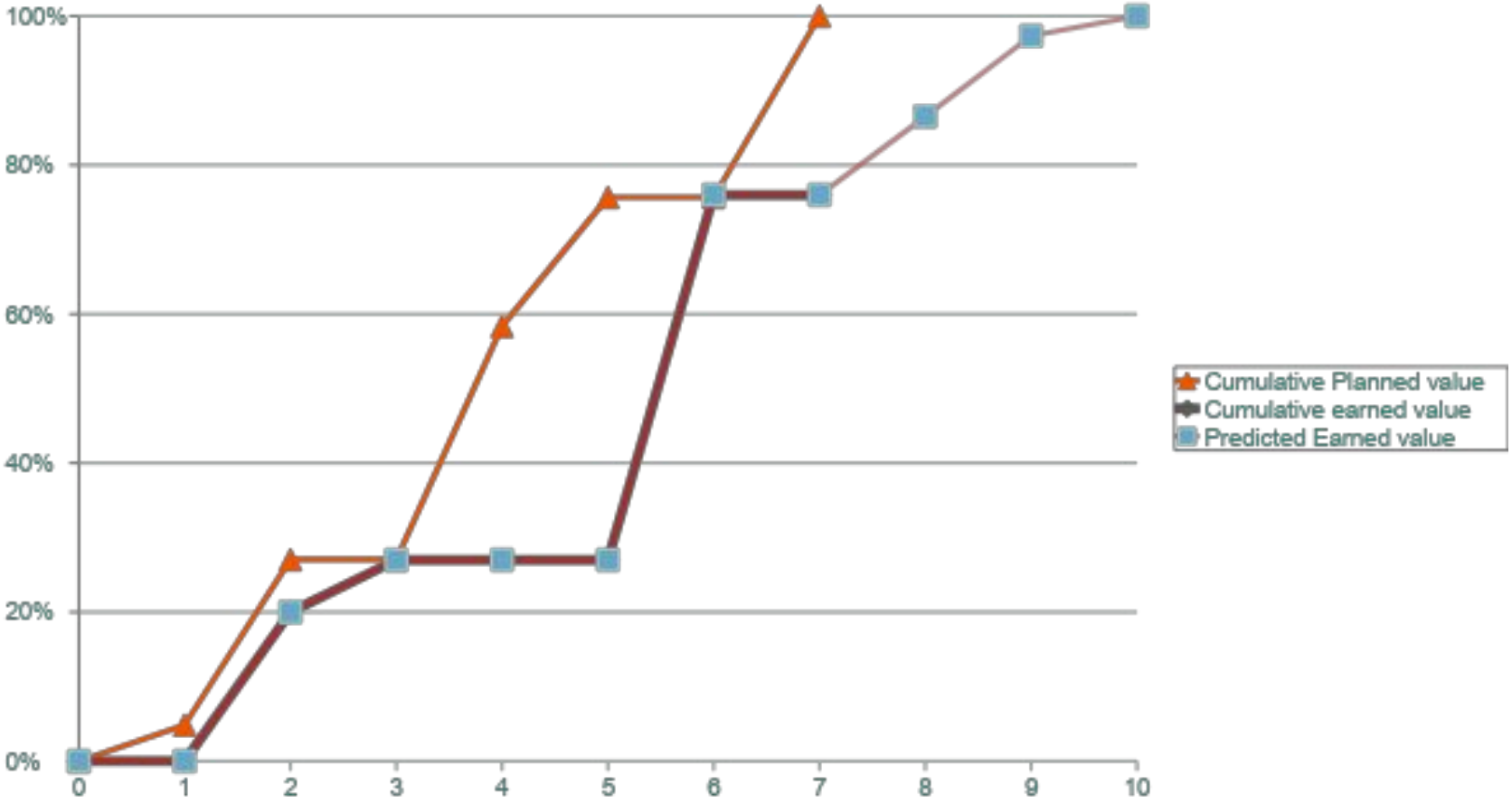
Exercise #2 solution

Task	Planned					Actual		
Task	Planned hours	Planned value	Cumulative hours	Cumulative Planned value	Week number	Week Number	Earned value	Cumulative earned value
Plan	1.6	4.9%	1.6	4.9%	1	1	0%	0.0%
Design	4.9	14.9%	6.5	19.8%	2	2	20%	19.8%
Design review	2.4	7.3%	8.9	27.1%	2	3	7%	27.1%
Code	10.3	31.3%	19.2	58.4%	4	4	0%	27.1%
Code review	4.5	13.7%	23.7	72.0%	5	5	0%	27.1%
Compile	1.2	3.6%	24.9	75.7%	5	6	49%	75.7%
Test	6.8	20.7%	31.7	96.4%	7	7	0%	75.7%
Post-mortem	1.2	3.6%	32.9	100.0%	7			
Total	**32.9**	**100%**						

Exercise #2 solution

Week number	Date (Monday)	Direct hours	Cumulative hours	Cumulative Planned value	Direct hours	Cumulative hours	Cumulative earned value	Adjusted Earned value	Predicted Earned value
0	October 14, 2013	0	0	0.0%	0	0	0.0%		0.0%
1	October 21, 2013	5	5.0	4.9%	3.0	3.0	0.0%		10.8%
2	October 28, 2013	5	10.0	27.1%	3.9	6.9	20.0%		21.6%
3	November 4, 2013	5	15.0	27.1%	3.7	10.6	27.0%		32.4%
4	November 11, 2013	5	20.0	58.4%	4.1	14.7	27.0%		43.3%
5	November 18, 2013	5	25.0	75.7%	4.0	18.7	27.0%		54.1%
6	November 25, 2013	5	30.0	75.7%	4.5	23.2	76.0%		64.9%
7	December 2, 2013	5	35.0	100.0%	2.9	26.1	76.0%		75.7%
8	December 9, 2013	5							86.5%
9	December 16, 2013	5							97.3%
10	December 23, 2013	5							108.1%

Exercise #2 solution



Ooops... The project requirements changed? Now what?

Plan Changes

- To track job progress, you must follow the plan.
- Since plans (almost) always change, you must regularly update the plan so that it represents what you currently plan to do.
- Of course, you must always keep copies of the original plans.
- Unless the plan differs significantly from the way that you now plan to work, merely add any new tasks and delete the cancelled ones.

Plan Changes

- Adding tasks reduces the earned value of all of the planned and completed work.
- Similarly, deleting tasks increases the earned values of the planned and completed tasks remaining in the plan.
- Most support tools will make these EV and PV adjustments for you.
- For major plan changes, you must make a new plan.

Project reporting

Project Reporting

- When all team members consistently record their data, teams will know precisely where they stand.
- They can track, manage, and report on their work.
- The following charts show how you can use these data to run a project.
- You can use these exact same methods to manage your personal work.

Example: consider the following scenario

Week 7			
Weekly data	**Plan**	**Actual**	**Plan / Actual**
Schedule Hours for this week	121.0	126.7	0.95
Schedule Hours this cycle to date	467.0	493.4	0.95
Earned value for this week	7.6	6.4	1.19
Earned value this cycle to date	28.2	22.3	1.26
To-date hours for tasks completed	354.3	458.0	0.77
To-date average hours per week			

When all team members consistently record their data, teams can precisely track and manage their work.
They know the planned and actual data for each week and for the project to date.
They can precisely measure job status and estimate how long it will take to finish the work.

Is this team ahead or behind schedule? How much?

Week 7			
Weekly data	**Plan**	**Actual**	**Plan / Actual**
Schedule Hours for this week	121.0	126.7	0.95
Schedule Hours this cycle to date	467.0	493.4	0.95
Earned value for this week	7.6	6.4	1.19
Earned value this cycle to date	28.2	22.3	1.26
To-date hours for tasks completed	354.3	458.0	0.77
To-date average hours per week			

They are 26.5% late!

Week 7			
Weekly data	**Plan**	**Actual**	**Plan / Actual**
Schedule Hours for this week	121.0	126.7	0.95
Schedule Hours this cycle to date	467.0	493.4	0.95
Earned value for this week	7.6	6.4	1.19
Earned value this cycle to date	28.2	22.3	1.26
To-date hours for tasks completed	354.3	458.0	0.77
To-date average hours per week			

The team had planned 28.2 EV but has earned only 22.3 EV,
so **they are around 26.5% behind**.
At the current rate, it will take around 1.85 (26.5%*7)weeks to reach the planned 28.2 EV, so they are around 1.85 weeks behind schedule.

Why is this team behind schedule?

Week 7			
Weekly data	**Plan**	**Actual**	**Plan / Actual**
Schedule Hours for this week	121.0	126.7	0.95
Schedule Hours this cycle to date	467.0	493.4	0.95
Earned value for this week	7.6	6.4	1.19
Earned value this cycle to date	28.2	22.3	1.26
To-date hours for tasks completed	354.3	458.0	0.77
To-date average hours per week			

The work is going slower than planned

Week 7			
Weekly data	**Plan**	**Actual**	**Plan / Actual**
Schedule Hours for this week	121.0	126.7	0.95
Schedule Hours this cycle to date	467.0	493.4	0.95
Earned value for this week	7.6	6.4	1.19
Earned value this cycle to date	28.2	22.3	1.26
To-date hours for tasks completed	354.3	458.0	0.77
To-date average hours per week			

Although the team is working more than its planned weekly hours, **the work is taking 23% (1-0.77) longer than planned**.

At this rate, will the team finish on the originally planned 25 weeks? If not, how late will they be?

Week 7			
Weekly data	**Plan**	**Actual**	**Plan / Actual**
Schedule Hours for this week	121.0	126.7	0.95
Schedule Hours this cycle to date	467.0	493.4	0.95
Earned value for this week	7.6	6.4	1.19
Earned value this cycle to date	28.2	22.3	1.26
To-date hours for tasks completed	354.3	458.0	0.77
To-date average hours per week			

They are 6.2 weeks behind schedule and will not make it on time

Week 7			
Weekly data	**Plan**	**Actual**	**Plan / Actual**
Schedule Hours for this week	121.0	126.7	0.95
Schedule Hours this cycle to date	467.0	493.4	0.95
Earned value for this week	7.6	6.4	1.19
Earned value this cycle to date	28.2	22.3	1.26
To-date hours for tasks completed	354.3	458.0	0.77
To-date average hours per week			

The team has earned EV at 22.3/7 = 3.186 EV/week.
At this rate, it will take (100-22.3)/3.186 = 24.2 more weeks to finish (i.e., it will **finish in week 31.2**). This is 6.2 weeks behind the 25-week plan.

Can this 5-person team meet the original schedule? If not, what can management do to help them?

Week 7			
Weekly data	**Plan**	**Actual**	**Plan / Actual**
Schedule Hours for this week	121.0	126.7	0.95
Schedule Hours this cycle to date	467.0	493.4	0.95
Earned value for this week	7.6	6.4	1.19
Earned value this cycle to date	28.2	22.3	1.26
To-date hours for tasks completed	354.3	458.0	0.77
To-date average hours per week			

Example: consider the following scenario

Week 7			
Weekly data	**Plan**	**Actual**	**Plan / Actual**
Schedule Hours for this week	121.0	126.7	0.95
Schedule Hours this cycle to date	467.0	493.4	0.95
Earned value for this week	7.6	6.4	1.19
Earned value this cycle to date	28.2	22.3	1.26
To-date hours for tasks completed	354.3	458.0	0.77
To-date average hours per week			

To meet the schedule, they need to do **77.7 EV** of work in **17 weeks**, which corresponds to **4.57 EV** a week.
To increase their average EV rate of 3.186 EV a week by 35%, they must work 35% more hours, or add a team member (who is ready to be productive from start).

Extra material, for using in the labs: performance indicators in EVM

Actual cost (AC)

This is the **actual cost of the activities performed**.

Cost Variance (CV) = EV – AC

This is the the **difference between the earned value, in monetary terms and the actual cost of the activities performed**.

- CV > 0, the project is under budget
- CV = 0, the project is on target with its budget
- CV < 0, the project is over its budget

Cost Performance Index (CPI) = EV / AC

The Cost Performance Index (CPI) is a measure of the cost efficiency of budgeted resources, expressed as a ratio of earned value to actual cost.
In other words, **how much are we earning for each spent euro?**

- CPI < 1, we are earning less than what we are spending. The project is over budget.
- CPI = 1, the project is on target with its budget
- CPI > 1, we are earning more than we are spending. The project is under budget.

Schedule Performance Index (SPI) = EV / PV

The Schedule Performance Index (SPI) is a measure of schedule efficiency, expressed as the ratio of earned value to planned value.

- SPI < 1, we are completing less work than what we planned. We are behind schedule.
- SPI = 1, we are completing the project according to the planned schedule
- SPI > 1, we are completing the work faster than planned. We are ahead of schedule.

Messages to Remember

You can accurately plan and track your own work.
With earned value, you can precisely judge job status and estimate the likely project completion date.
This information will help you to make accurate and timely management reports.
When your reports indicate potential problems, you should report recommended remedial actions.
On a self-directed team, you must tell management what you are doing to solve your own problems.