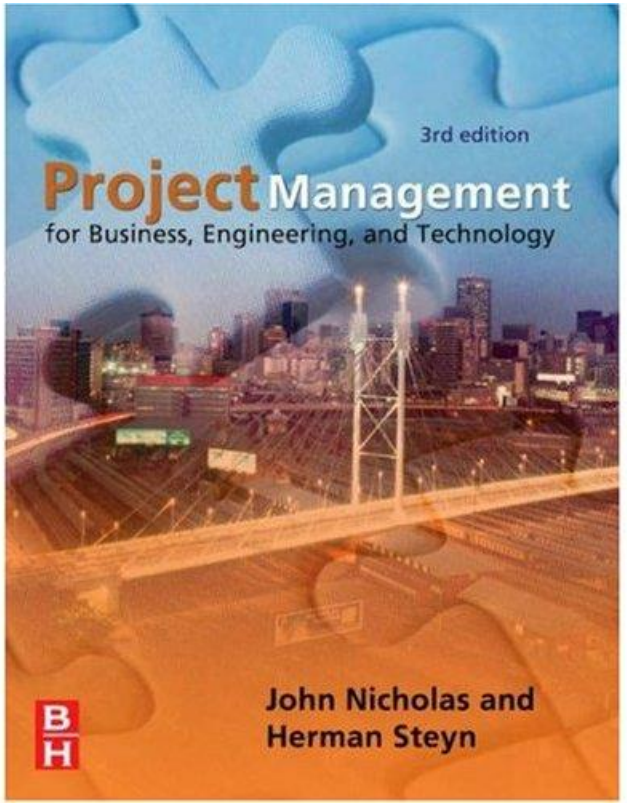
Chapter 7 (Cont'd)

The Critical Chain Method

Project Management for Business, Engineering, and Technology



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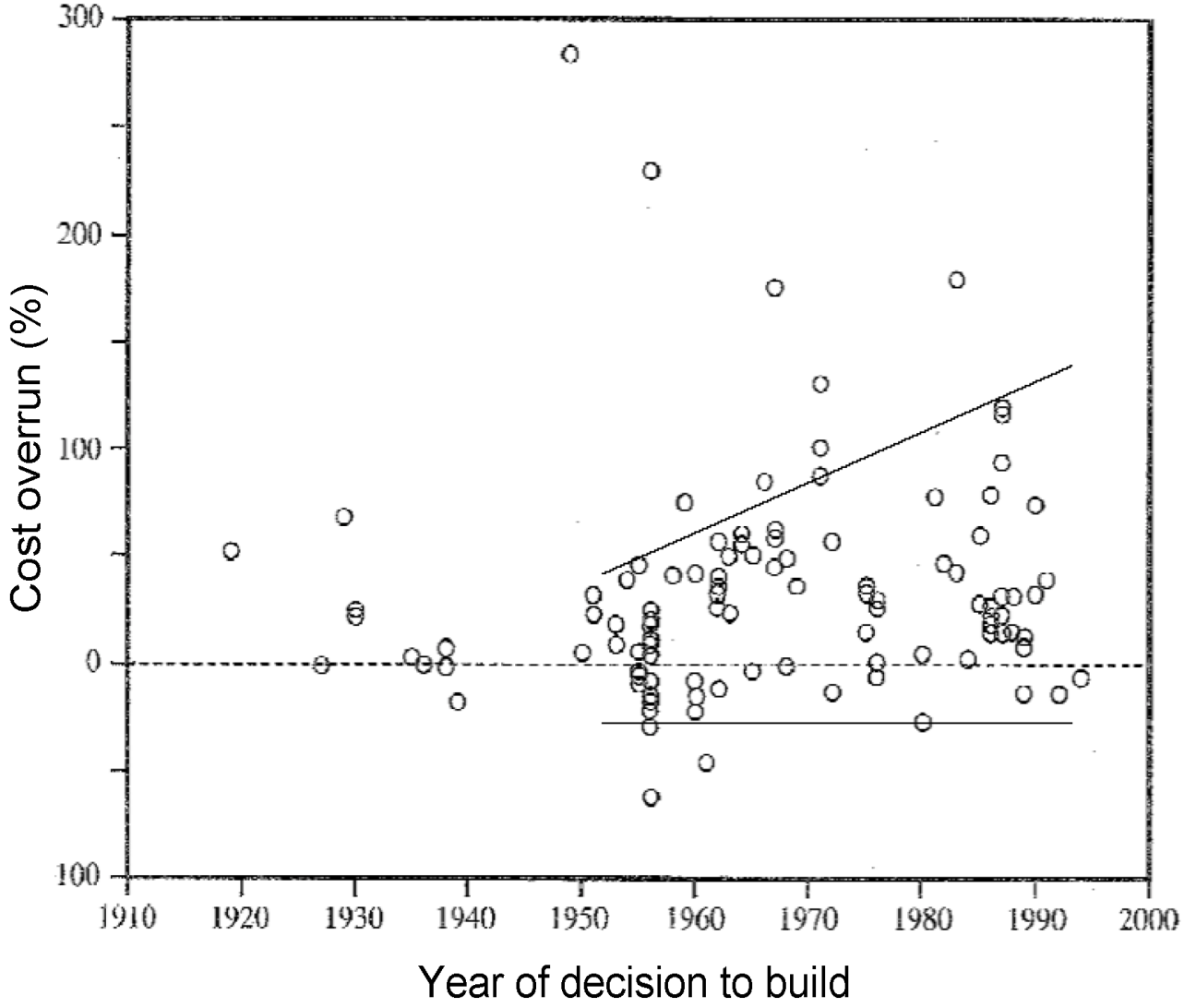
A Common Problem

Meeting all specifications & other requirements

- Within budget
- On time

Overspending
(PM Discipline established in the 1950s)



Cost overrun of 111 transport projects (constant prices)

Adapted from Flyvbjerg. See Chapter 8

A Common Problem

- Why is it so difficult to manage projects to deliver on time, within budget and meet the specifications?
- Why do operations mangers perform better than project managers?
- Uncertainty

A Hypothesis (Tentative Statement)

Projects are (by definition) unique endeavours

$\Rightarrow$

Projects always involve unknowns

$\Rightarrow$

Projects are high-risk endeavours

$\Rightarrow$

The risks cause projects to be late and to overspend

Is The Problem Really Uncertainty?

If uncertainty is the source of the problem, then all high-risk projects (projects with much uncertainty) should be late and over budget

But, there are high-risk projects that were completed well within budget and schedule:

Is The Problem Really Uncertainty?

U2 Reconnaissance Airplane

Is The Problem Really Uncertainty?

U2 Reconnaissance Airplane (1955):

- Met all specifications
- Flew higher than any airplane before (more than 12 miles above the earth) – uncertainties!
- Flew over the USSR within 8 months of project approval
- Spent less than budgeted

Mozal Aluminum Smelter: Case 18-2

The Mozal Smelter - a successful project that had a high level of uncertainty

The state-of-the-art smelter (that uses as much electricity as a whole city) has been erected in Mozambique, one of the poorest countries in the world …

Risks:

- Stability of government
- Legal & commercial framework
- Language
- Security
- Medical facilities & health
- Weather
- Lack of infrastructure
- Logistics e.g. customs clearance
- Labour
  - Work ethic
  - Skills
  - Unions
  - Health
- Expatriate conditions

Alternative hypothesis …

Cases such as the U2 and Mozal Smelter indicate that uncertainty is not the cause of our three problems.

This hypothesis is wrong!

What could explain the three problems and the success of projects such as the Mozal Smelter?

Perhaps it has to do with ***the way we manage*** under conditions of uncertainty!

A Common Problem

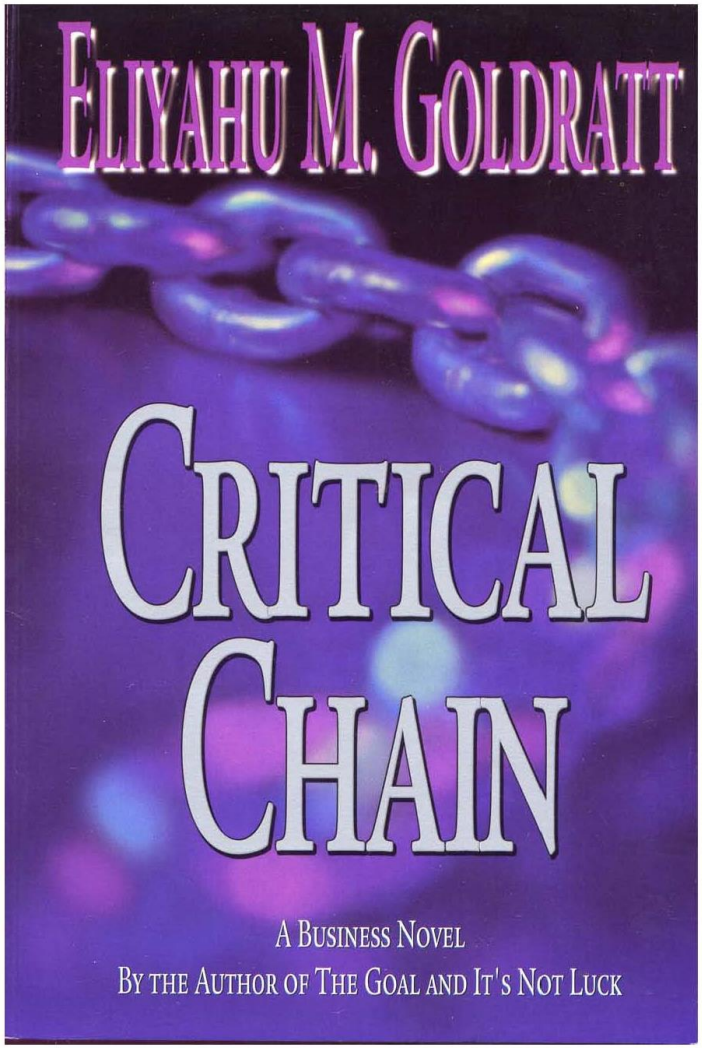
It's an age-old problem in several industries …

Yet, the essential principles of *managing contingency reserves* are often sadly neglected

A Possible Solution

- The Critical Chain Method claims to offer a solution to managing contingency reserves
- Various aspects of the solution have been known for a long time
- These aspects were put together during and after a PhD project
- Popularized in a business novel in 1997

A Possible Solution



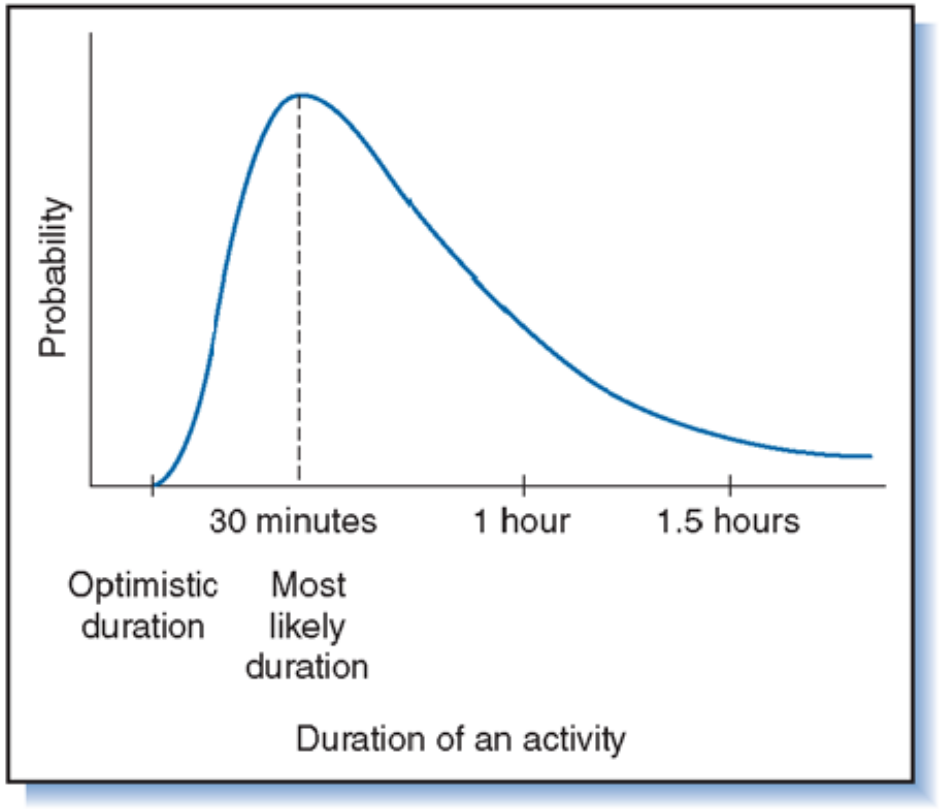
Theory of Constraints

The critical chain method is a Theory of Constraints (TOC) application to projects

Project duration is considered as the constraint:

- The objective of a project is to deliver something that would generate income (or provide some other benefit)
- The project itself costs money
- The sooner the income (or other benefit) can materialize, the better

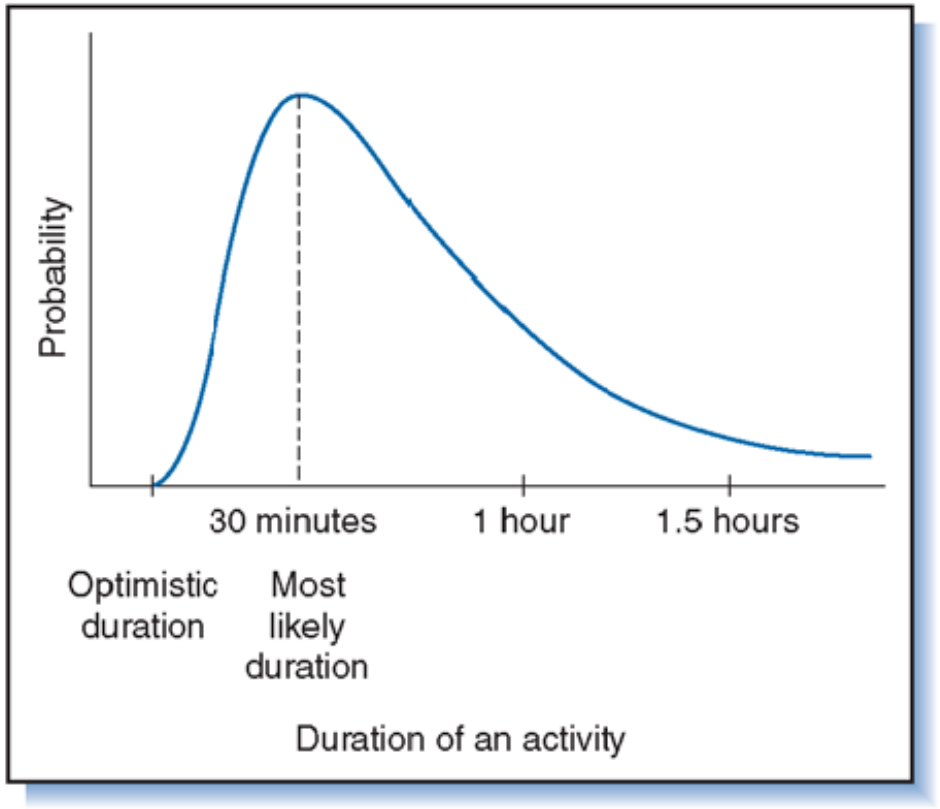
Contingency Reserves – Do We Need them?



An activity such as driving to some destination

Figure 7-8
Variability of activity duration.

Contingency Reserves – Do We Need them?



If you have to make a commitment about duration, how much time will you allow?

And if there is a heavy penalty if it takes longer?

Contingency Reserves – Do We Need them?

If you have to make a commitment about duration, you need to build in a contingency reserve

The project manager always has to make a commitment about the duration of the project

A common idea is that everyone responsible for an activity should also make a commitment

Contingency Reserves – Do We Need them?

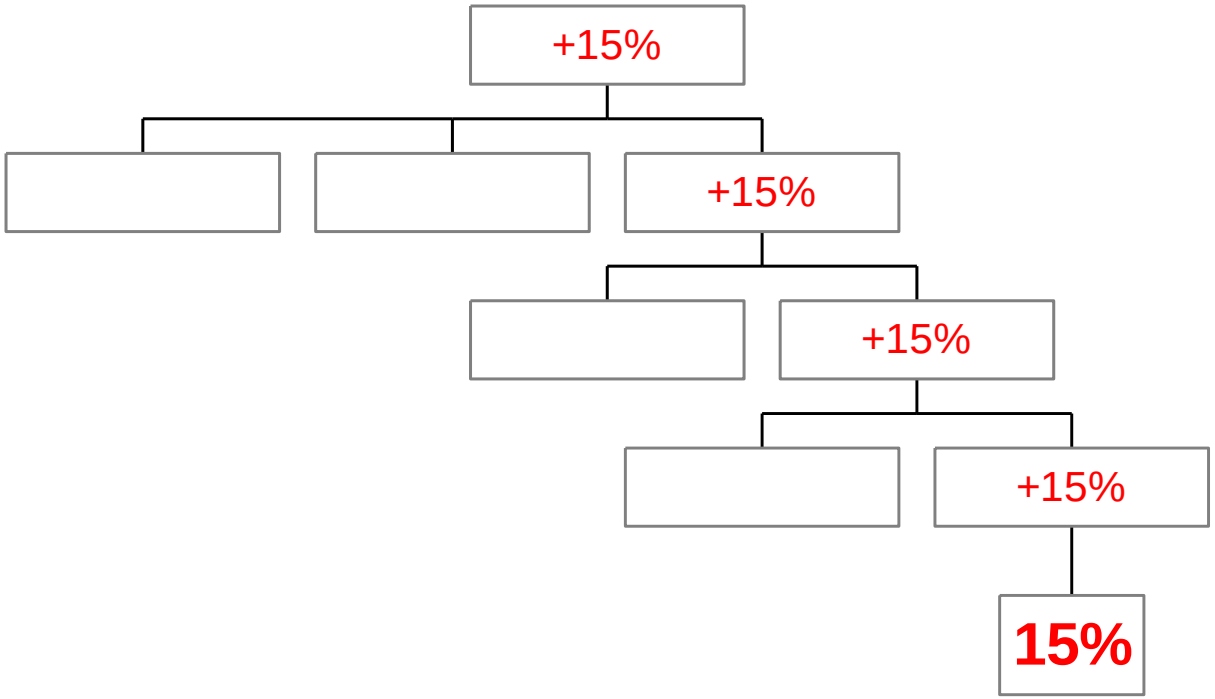
In general, substantial reserves are built into project schedules (and budgets)

Finishing late implies criticism and even penalties

If we expect that the estimate will be cut by seniors, we build in even more reserve

Contingency reserves are built in at more than one level of the WBS

Contingency reserves at more than one WBS level



How much reserve in total?

(It works like compound interest)

$1.15^{5} = 2.01$

The reserve is doubled

Contingency Reserves – Need to be Managed

Contingency reserves are essential

Contingency reserves are of significant size

Contingency reserves need to be managed

Contingency Reserves – Need to be Managed

Conclusion:

In general significant amounts of contingency reserves are built into project schedules and budgets

Contingency Reserves – Why Still Late?

If it is true that there is so much reserve built into project schedules and budgets, why do so may projects still go over budget and over the due date?

Let us explore human behaviour during project execution

Reasons for not Finishing Early

- No incentive for early finish

- Keep on improving the work:
  - Enjoy the work
  - Reduce risk of poor deliverable
- Often leads to adding unnecessary “bells & whistles”

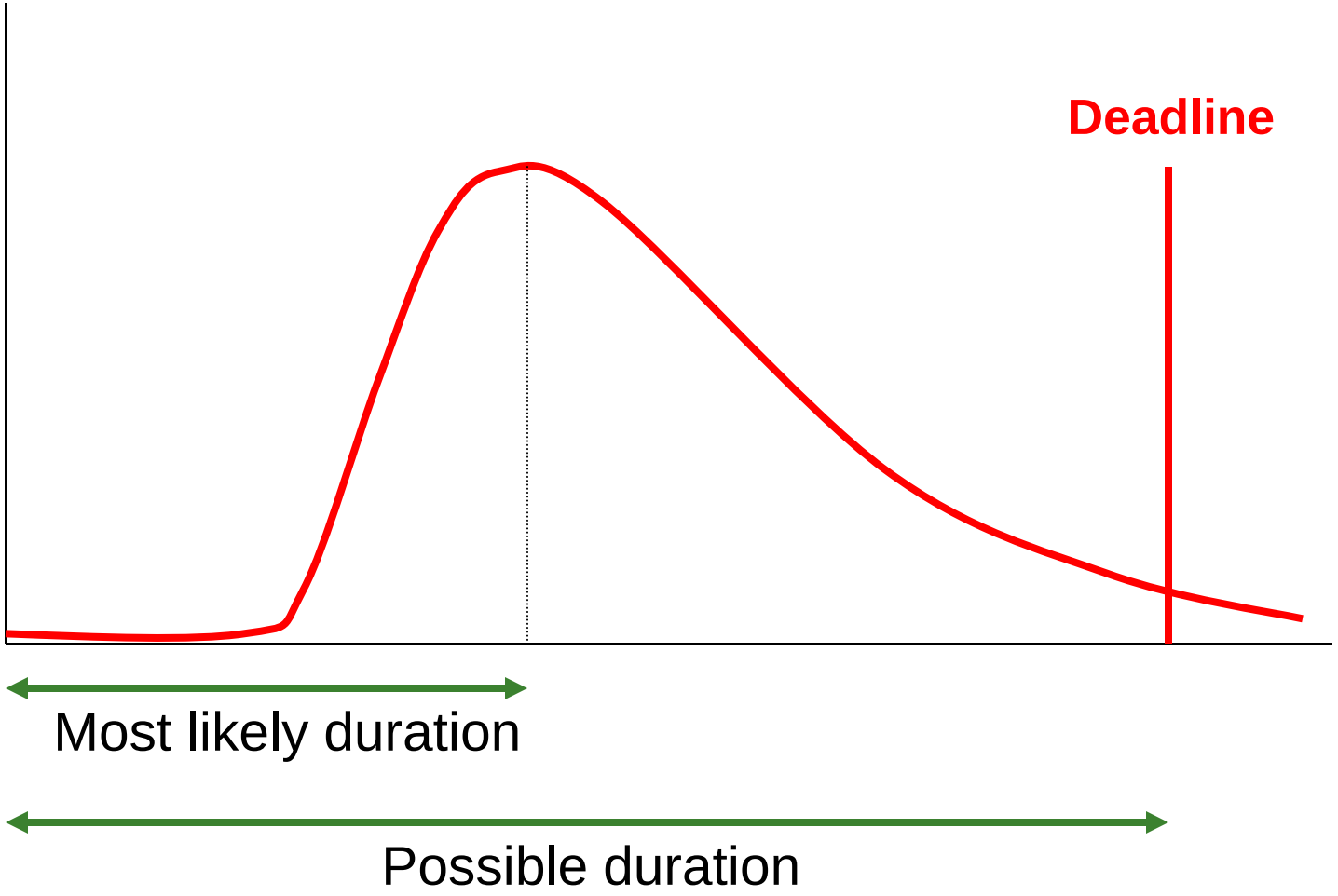
- Argued for long duration - reporting early finish could jeopardise credibility

Reasons for not Finishing Early

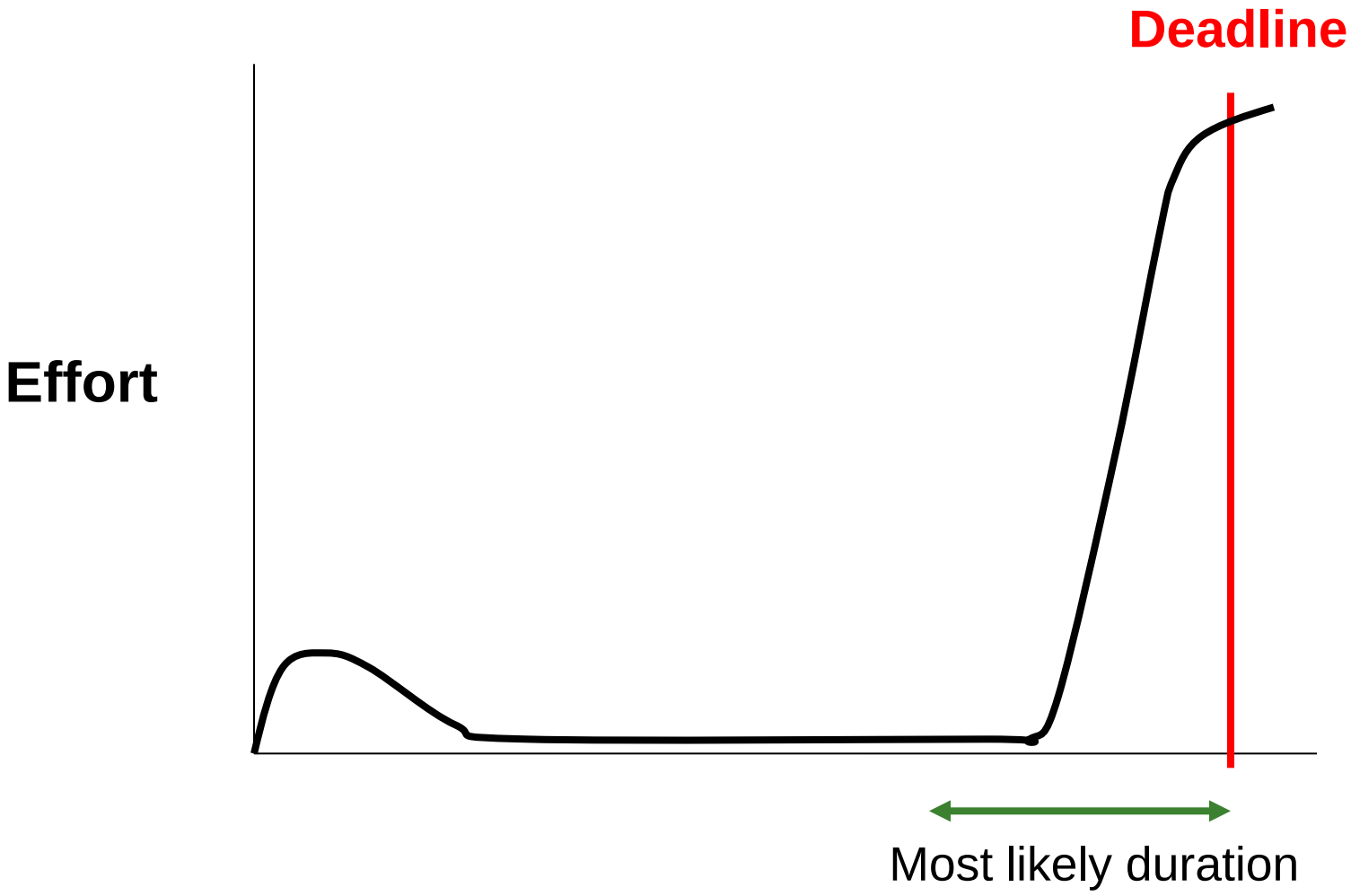
Money on budgets are sometimes spent merely because we have an approved budget

Likewise, work sometimes expands to fill approved schedules

Not Finishing Early: Variability and Deadlines



The "Student's Syndrome"



Reserves Get Wasted

"Student syndrome" is the first way that we waste reserves

A second way is by jumping from one task to another

Then the effect that, when one critical task is late, it delays the whole project, but when a task is completed early, it has no effect

Let us see how this works …

Reserves Get Wasted: Multi-Tasking

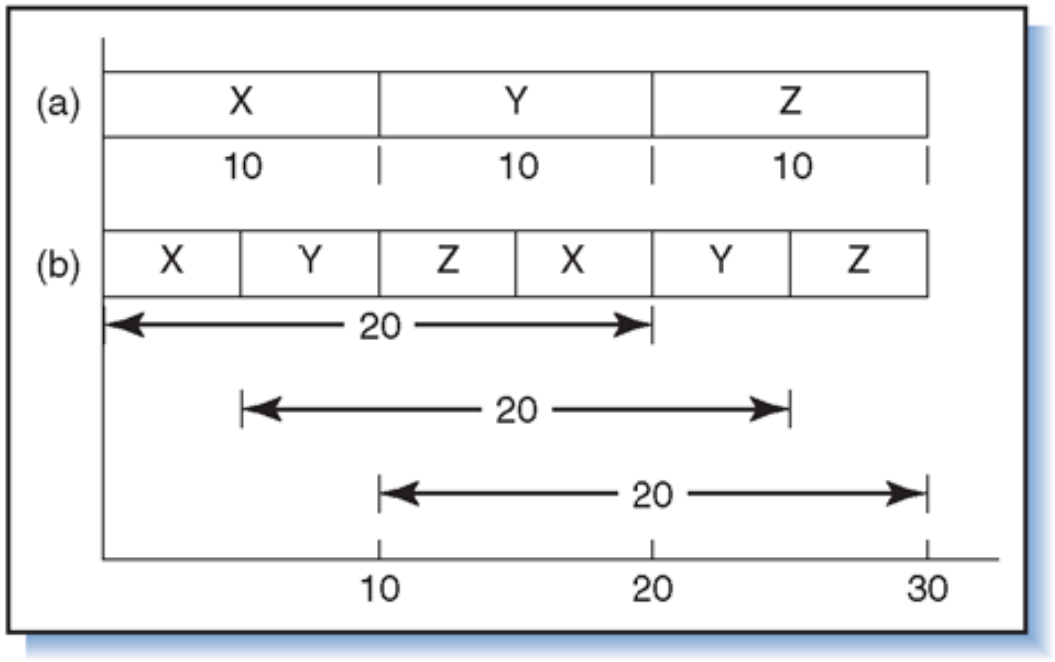


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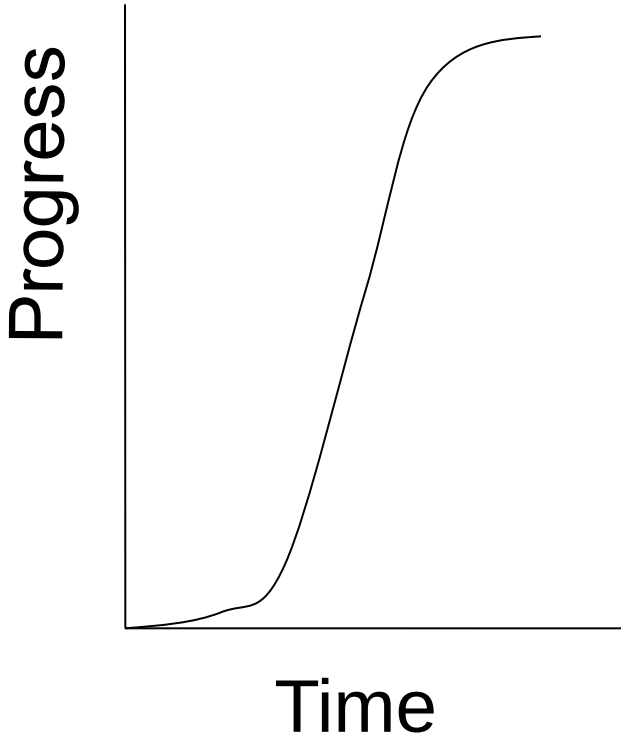
Figure 7-21
Effect of multitasking on elapsed and completion times.

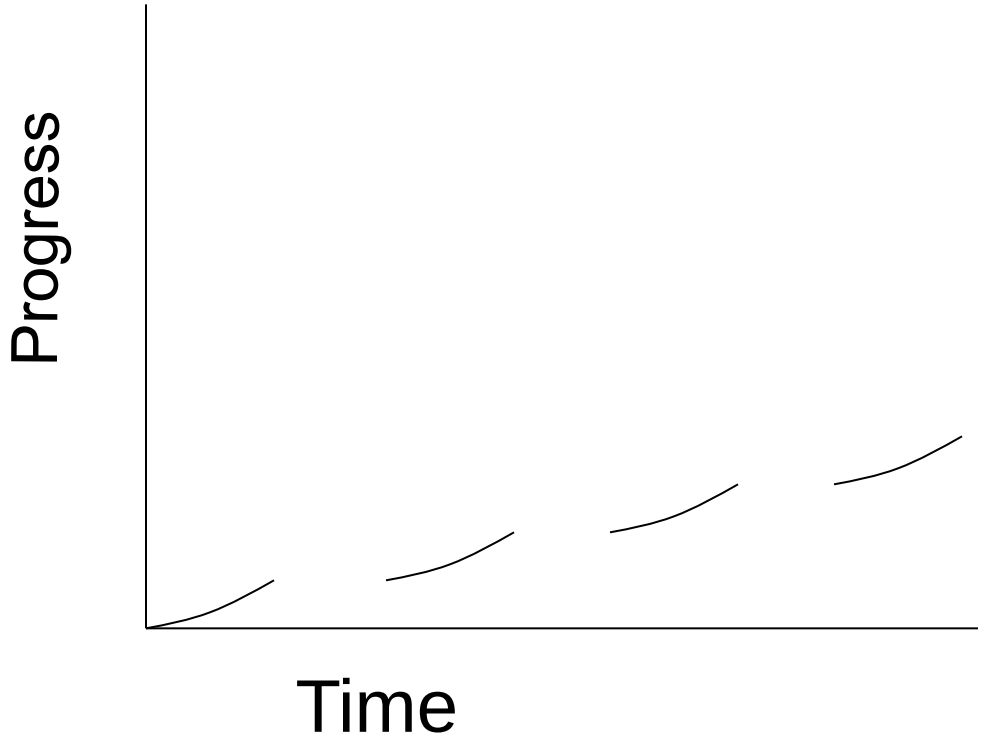
Multitasking cause activities that succeed X and Y to start later

Reserves Get Wasted: Multi-Tasking

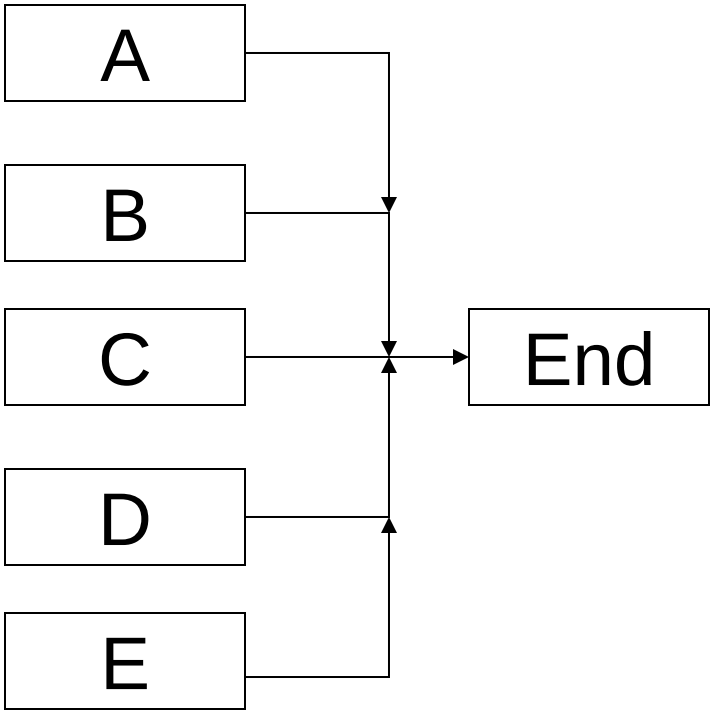
Without multi-tasking



With multi-tasking



Reserves Get Wasted: Delays Add Up but Finishing Early Does not Help



Reserves Get Wasted: Delays Add Up but Finishing Early Doesn't Help

Even where tasks are being done *in series* (not in parallel) gains are not always passed on:

- Other resources may not be ready to start earlier than planned (peoples' diaries, venues and equipment have been booked, …)
- Resources are busy with other work

Early Completion Not Reported

- Parkinson's Law: Work expands to fill the time available

- Because the person negotiated to get the time, he/she could be embarrassed if it is now done in much less time. This could lead to loss of credibility and invite pressure

Reserves Get Wasted: Summary

We build in a lot of contingency reserve (“fat”) and then it gets wasted in one or more of the following ways:

- Student syndrome
- Multi-tasking
- Delays accumulate, but gains (working faster) don’t

Wasting of Reserves: Potential for Improvement

- There are substantial reserves in project schedules
- Reserves should be provided at project level only
- Even if reserves are only built in at the lowest level, the *principle of aggregation* offers potential for significant reduction of the reserves

The Principle of Aggregation

- The basis of, for example the insurance industry
- Sometimes correctly applied in project cost management
- Since 1997 increasingly being applied to project scheduling (as a result of the “Critical Chain” methodology)

Aggregation: The Central Limit Theorem

The variance of the sum equals the sum of the variances

$V_\Sigma = V_1 + V_2 + \ldots + V_n$

If $V_1 = V_2 = \ldots = V_n = V$, then $V_\Sigma = n\,V$

σ indicates risk

$$\sigma^2 = V$$

Therefore:

$$\sigma_\Sigma = (n)^{1/2} \cdot \sigma$$

Therefore the aggregated risk is significantly smaller than the sum of the individual risks

Aggregation

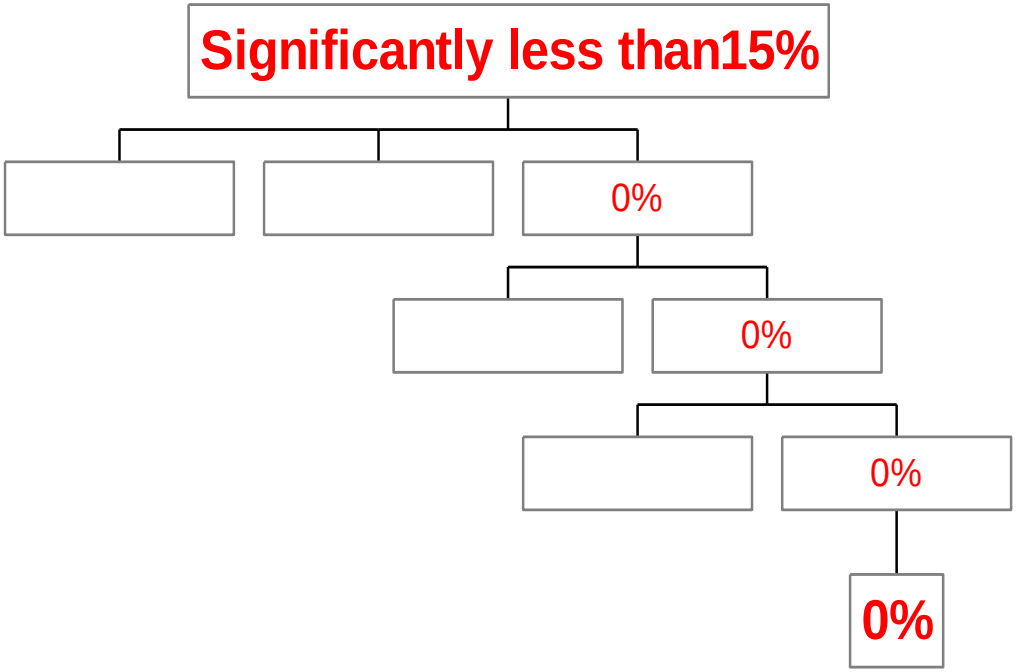
To aggregate project reserves:

Make provision only at project level and nowhere else

Aggregation

Previous example: 15% reserve required for a specific activity

Less than 15% required for that activity if provided at project level



Aggregation

Project managers sometimes take direct control of contingency reserves *in budgets*

Until the advent of critical chain, few project managers utilized the same principle when scheduling projects

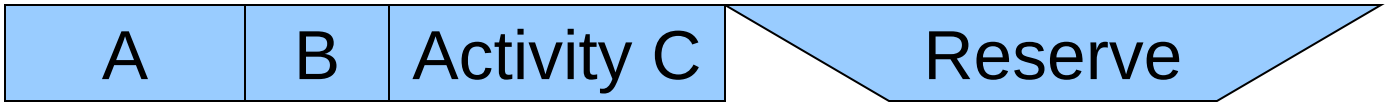
Realization of typical human behavior during planning and execution as well as the effect of aggregation form cornerstones of *Critical Chain* project scheduling

Aggregate Reserves

Consider the critical path (project constraint):

People responsible for activities normally build in reserves

Remove the reserves from activity level and give it to the project manager:



Aggregate Reserves

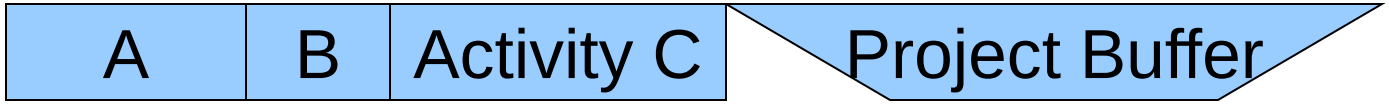
Contingency reserves at project level is referred to as a "*project buffer*"

Two reasons why a project buffer can be smaller than the sum of individual reserves:

- The principle of aggregation
- When a schedule indicates less time, less time is wasted (students' syndrome is minimized)

Aggregate Reserves

Reduce the size of the Project Buffer



Project duration is reduced

Aggregate Reserves in Practice

Reduce the size of the Project Buffer:

- Existing project: cut activity durations

- New project: can work on estimates with very little or no contingency reserve

Aggregate Reserves - Implication

Implication:

Only the project manager makes commitments on due dates (and project cost) – everybody else only makes realistic estimates without reserves

This normally requires a change in project culture – the only difficult aspect of critical chain management

Project Buffer - Implication

Should people responsible for activities be aware of the project buffer?

Yes, if not, they will tend to build in contingency reserves at activity level as well

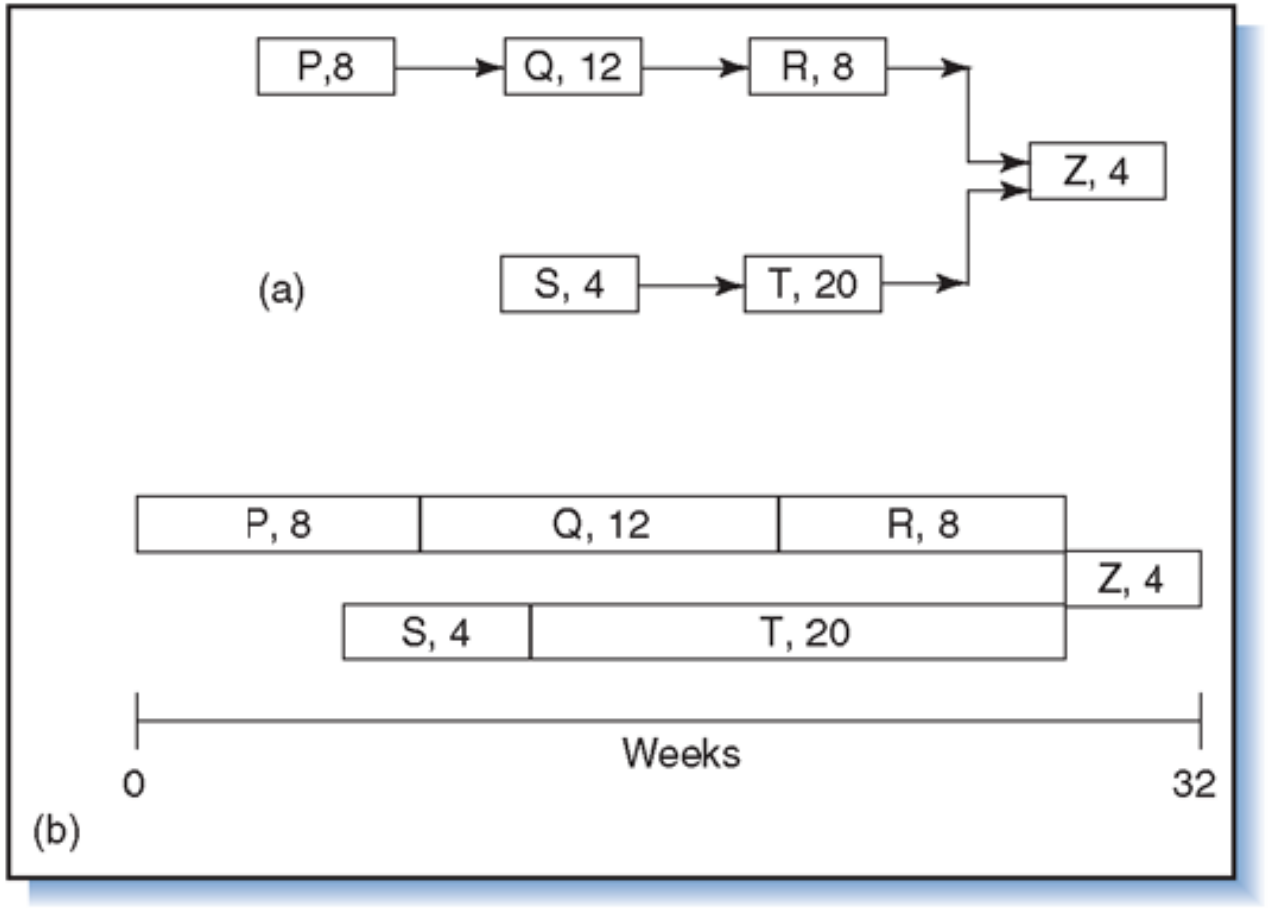
They must trust the project manager to “bail them out” in the event of an unforeseen event

Critical Chain Example

Table 7-4 Activities for small system development project.

Activity Description (From WBS)	Activity Code	Duration (Days)	Resources
Design Subsystem A	P	8	Design Team A
Manufacture Subsystem A	Q	12	Technician
Test Subsystem A	R	8	Test team
Design Subsystem B	S	4	Design Team B
Build Subsystem B	T	20	Technician
Assemble Subsystems A and B	Z	4	Technician

Critical Chain Example



The constraint is the path P-Q-R

Critical Chain Example

Remove reserve from activities and give to the project manager:

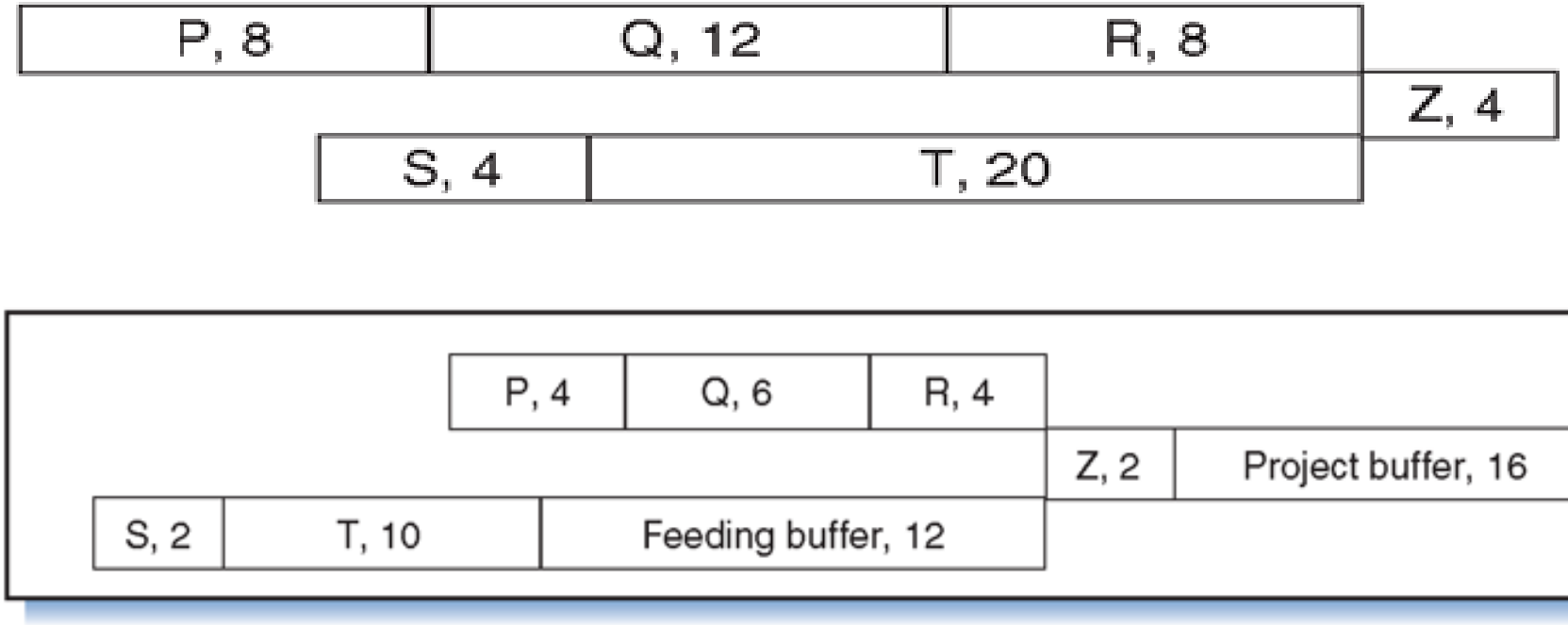


Figure 7-17
Schedule with contingencies reserves allocated to the project manager.

Buffers Reduced

Reduce buffer size (as motivated earlier)

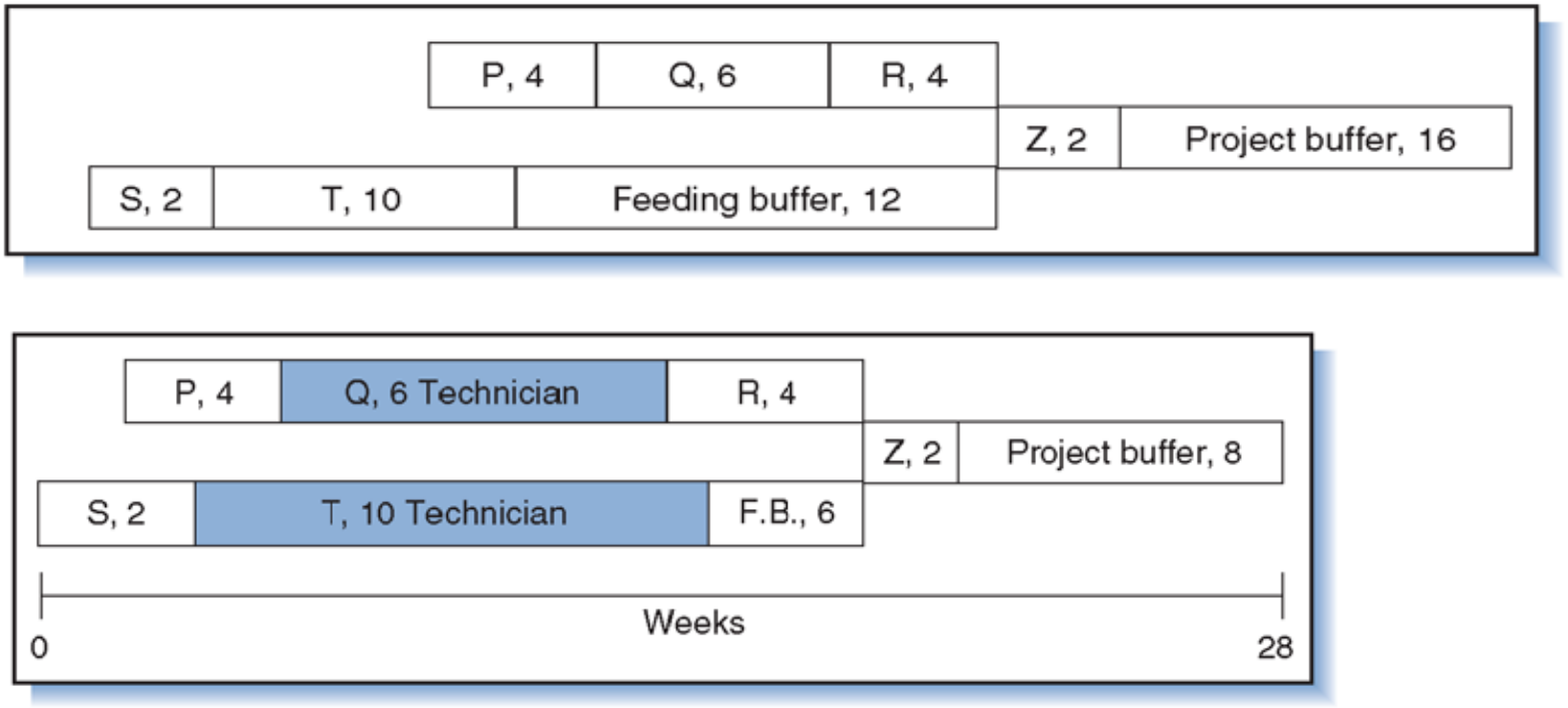
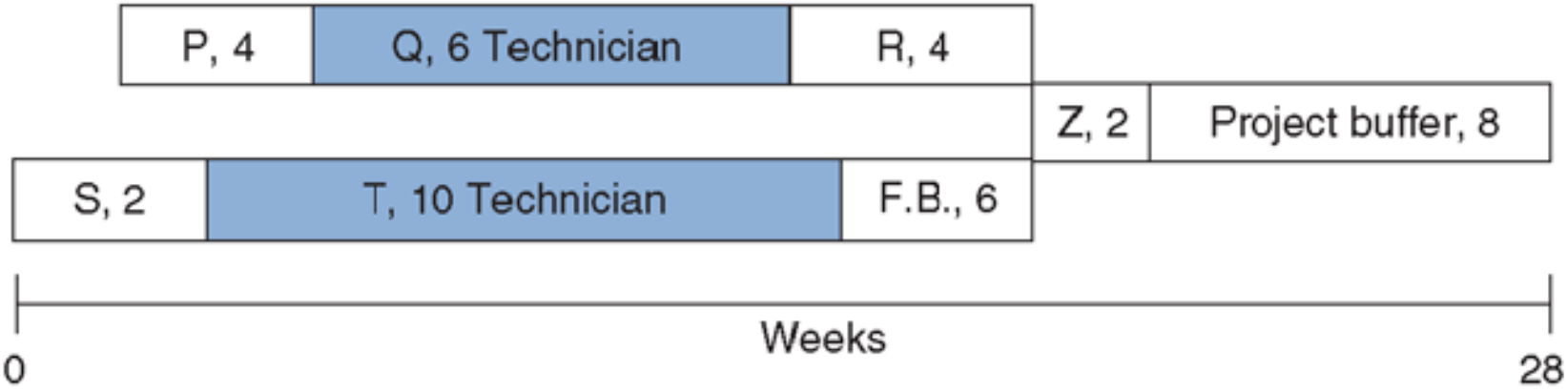


Figure 7-18
Schedule with buffer sizes reduced. F.B.: feeding buffer.

A Resource Does One Activity at a Time

A resource (the technician) is overloaded



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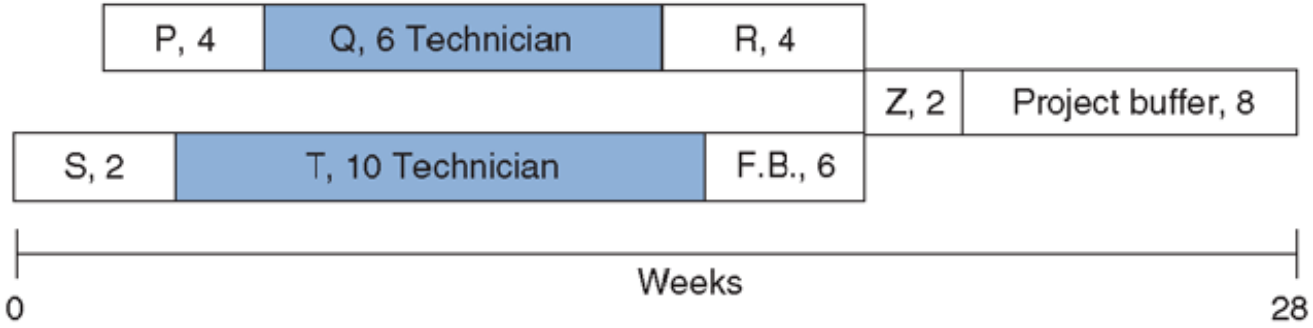
Design Subsystem B	S	4	Design Team B
Build Subsystem B	T	20	Technician
Assemble Subsystems A and B	Z	4	Technician

A Resource Does One Activity at a Time

Decide which activity the Technician should do first



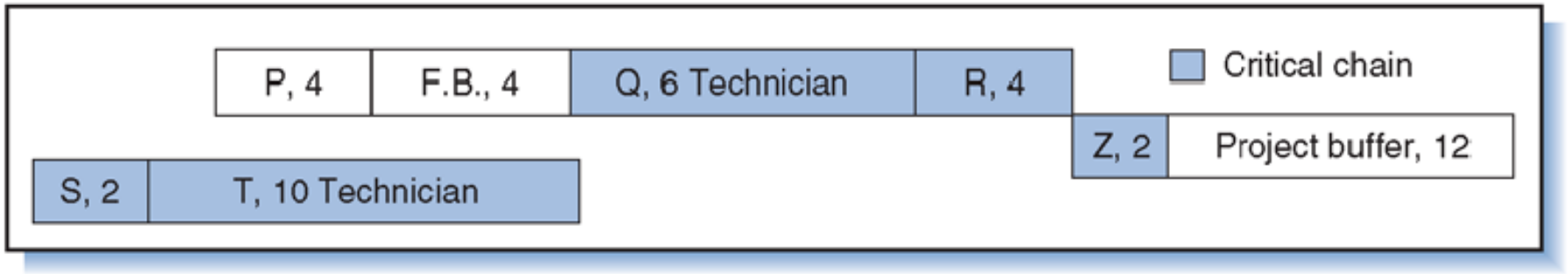
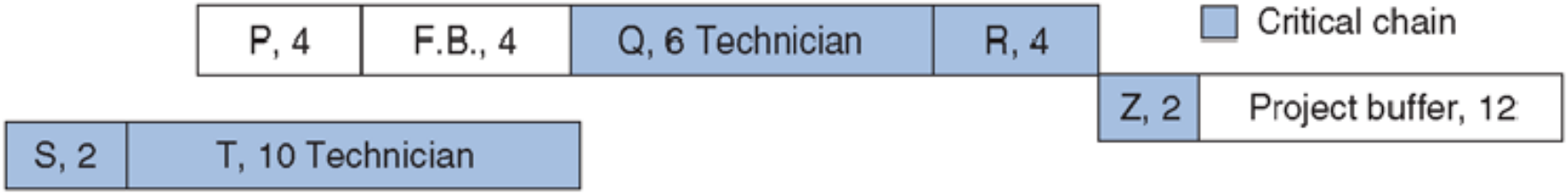


Figure 7-19
Schedule adjusted so that every resource performs only one task at a time. F.B.: feeding buffer.

The Critical Chain

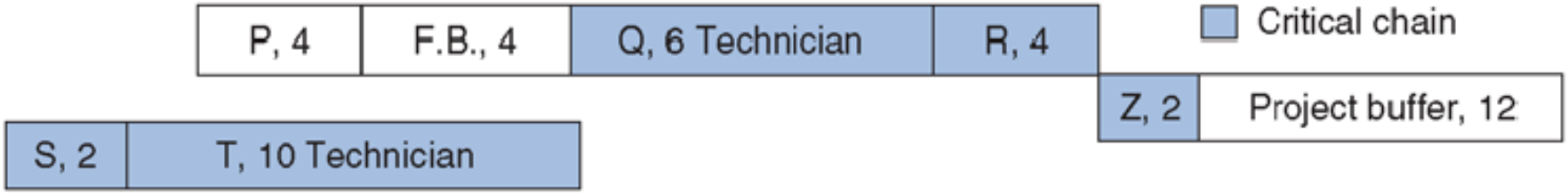
The path S-T-Q-R-Z is the critical *chain*



The *Critical Chain* is similar to the *Critical Path* but takes into account that a resource can do only one activity at a time

The Critical Chain

Alternative critical chains



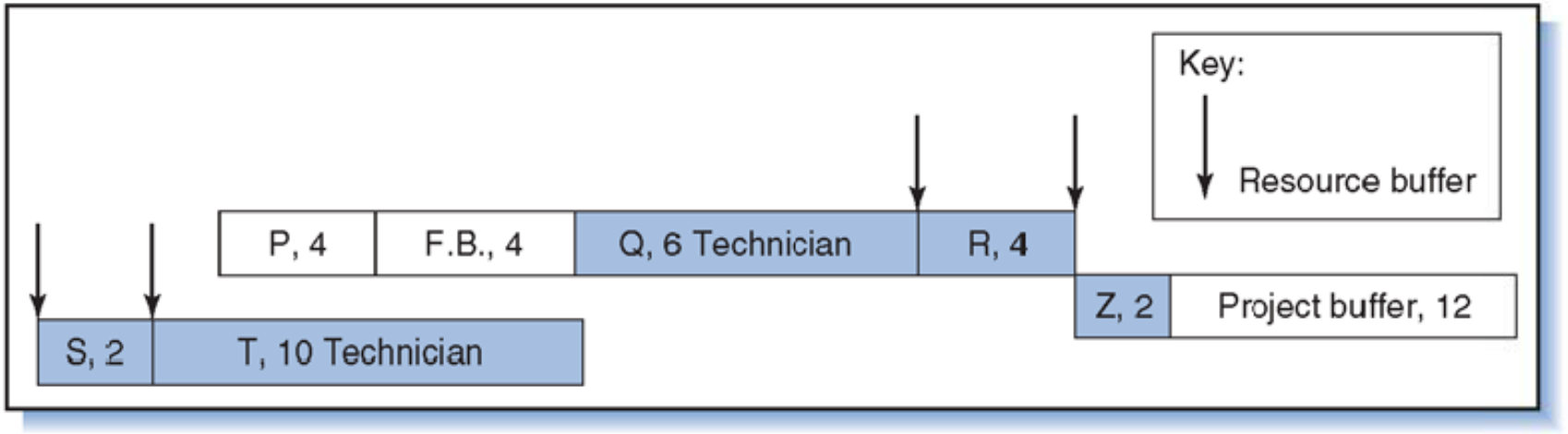
As you might wish to verify, the project can be done slightly faster if the Technician does Activity Q before Activity T

Finishing an Activity Early

- When a project activity finishes early, successor activities are often not expedited
- In the case of relay races, however, a runner starts early if an earlier runner runs faster than planned
- For critical activities only: Give a count-down to the start in order to expedite if a predecessor works faster than planned

Early Finishing of an Activity

Figure 7-20
Resource buffers providing countdown on when to start critical activities.
F.B.: feeding buffer.



Resource buffers are early warnings on critical activities (flagging the need for early starts)

Buffers - Summary

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Table 7-5 Summary of buffer types for a single project.

Buffer Type	Function of the Buffer
Project buffer	Comprised of aggregated contingency reserves taken from activities on the critical chain; provides a contingency reserve between the earliest completion date possible and the committed date.
Milestone buffer	Similar to a project buffer but used when a project phase or milestone has a fixed due date.
Feeding buffer	Comprised of aggregated contingencies taken from noncritical paths; stabilizes the critical chain by preventing noncritical activities from delaying critical activities.
Resource buffer	An early warning or "count down" to the start of a critical activity that ensures that resources are ready to do work on the critical chain as soon as all preceding activities have been completed.

Buffers

- Buffers provide a practical way to convert a complex stochastic problem into a deterministic one
- Feeding buffers stabilize the critical chain – unlike the critical path, the critical chain does not change as activities fall behind schedule or are completed early.
- Monitoring of feeding buffers (discussed in Chapter 11) ensures that an early warning is received in the event that the critical chain would change
- The project manager always know where to focus her attention

Buffers

- Feeding buffers provide the answer to the question of when to do non-critical activities: as early as possible or as late as possible…

- As late as possible, but with an appropriately sized buffer

As Early as Possible or Not

- During scheduling and during project execution, non-critical activities start as late as possible but with buffers
- During execution, critical activities start as soon as possible (and are expedited by means of resource buffers when predecessors finish early)

The Change Process

- To convince people to give estimates without significant reserve built in, everybody in the organisation must understand that the durations on the schedule are merely estimates
- This means that only the project manager makes a commitment on due date
- There are no due dates (deadlines) on activities

The Change Process

- Executives, clients must understand the basics
- If they don't understand it, they may for example want to eliminate the project buffer and insist on delivery on the date at the beginning of the buffer
- Executive support is necessary for successful implementation
- Working with subcontractors adds another level of complications

Software and Critical Chain

Can you simply insert buffers as “activities” in all project scheduling software and schedule non-critical activities as late as possible?

No. While popular software allows you to schedule activities as late as possible, resource leveling then does not work because resource leveling works on moving activities *later* (not earlier)

Software That Supports Critical Chain

- MSProject **plus** Prochain www.prochain.com
- Project Scheduler 8 (PS 8) www.sciforma.com
- Concerto www.realization.com