ENGR3450 – Project Management

Week 8

The Project Planning

Resource Allocation

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Agenda today

- CPM – Schedule Compression
  - Crashing and Fast Tracking a project
- Creating and Allocating Resources
- Resource loading and leveling
- Constrained resource allocation
  - Heuristic methods and optimization models
- Resource Management summary of PMI

  - The last Workshop – 5 Pts.
  - Problems from Ch 9.

Schedule Compression

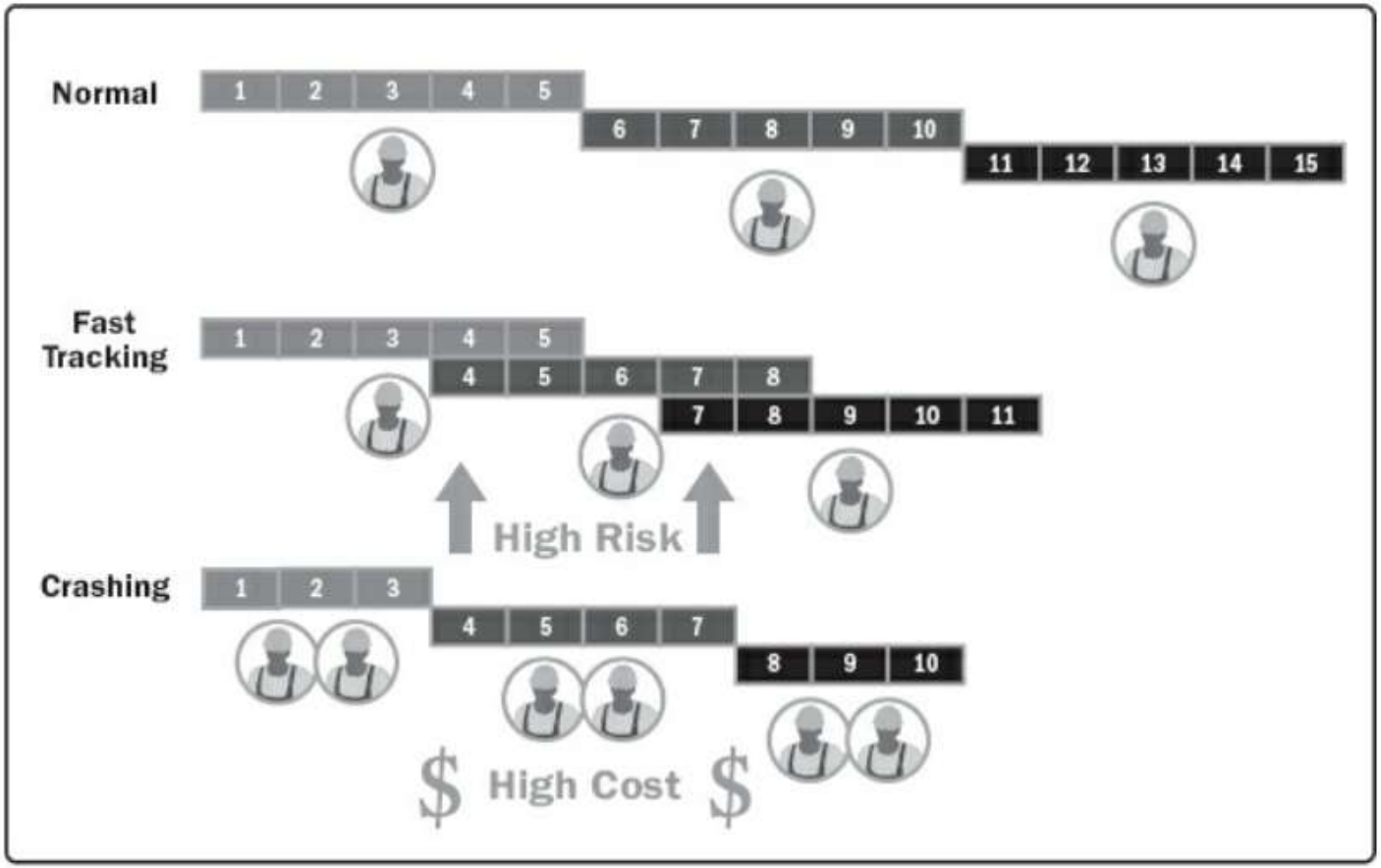


Figure 6-19. Schedule Compression Comparison

Schedule Compression
Crashing

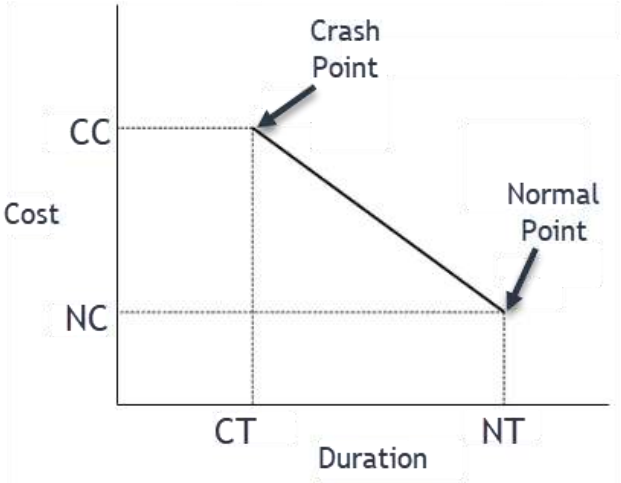
Table 9-1 An Example of Two-Time CPM

Activity	Precedence	Duration, Days (normal, crash)	Cost (normal, crash)
a	—	3, 2	$40, 80
b	a	2, 1	20, 80
c	a	2, 2	20, 20
d*	a	4, 1	30, 120
e**	b	3, 1	10, 80

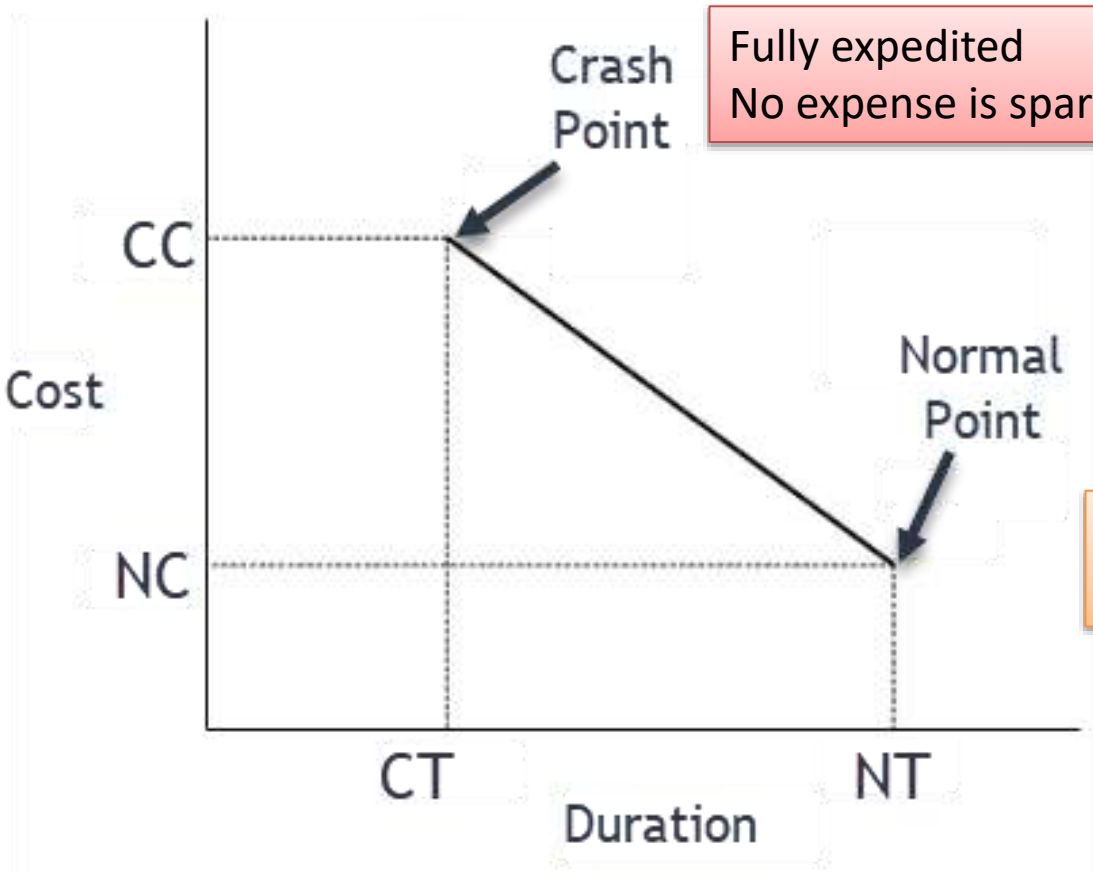
* Partial crashing allowed
** Partial crashing *not* allowed

Table 9-2 Activity Slopes–Cost per Period for Crashing

Activity	Slope ($/day)
a	40/−1 = −40
b	60/−1 = −60
c	—
d	90/−3 = −30
e	−70 (2 days)



Schedule Compression
Crashing



Fully expedited
No expense is spared

$$\text{Slope} = \frac{\text{crash cost} - \text{normal cost}}{\text{crash time} - \text{normal time}}$$

Normal duration
No extra cost

Schedule Compression
Crashing – A CPM Example

Table 9-1 An Example of Two-Time CPM

Activity	Precedence	Duration, Days (normal, crash)	Cost (normal, crash)
a	—	3, 2	$40, 80
b	a	2, 1	20, 80
c	a	2, 2	20, 20
d*	a	4, 1	30, 120
e**	b	3, 1	10, 80

* Partial crashing allowed
** Partial crashing *not* allowed

Table 9-2 Activity Slopes–Cost per Period for Crashing

Activity	Slope ($/day)
a	40/−1 = −40
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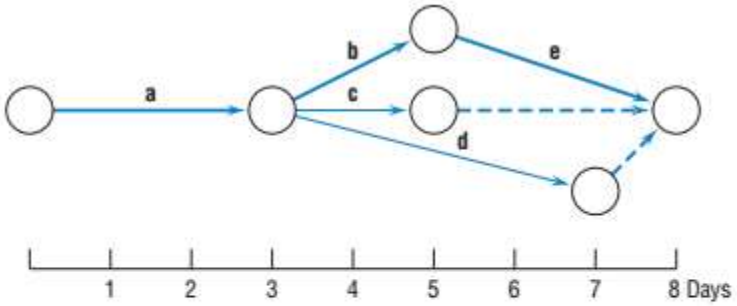
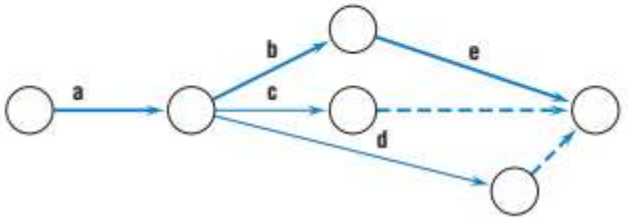
c	—
d	90/−3 = −30
e	−70 (2 days)

a. Normal Schedule, 8 Days, $120

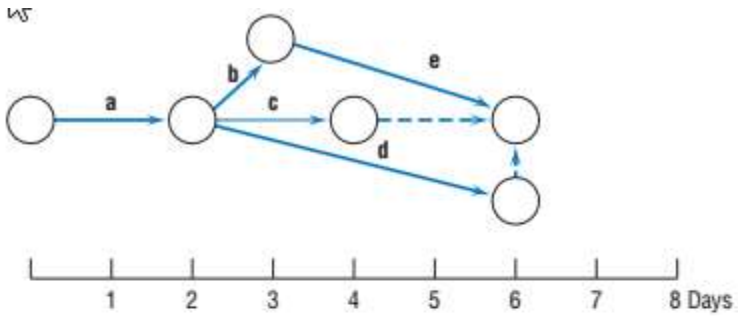


b. 7-Day Schedule, $160

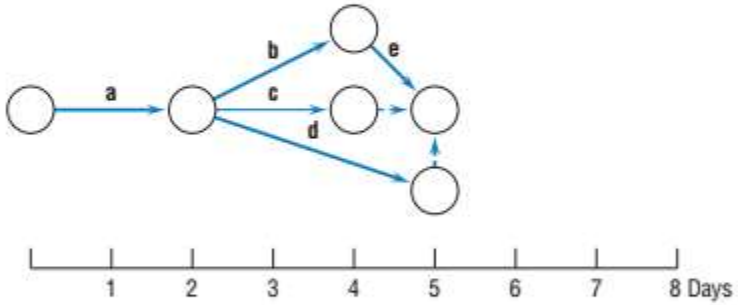


Schedule Compression
Crashing – CPM Example

c. 6-Day Schedule, $220



d. 5-Day Schedule, $260



e. 4-Day Schedule, $350

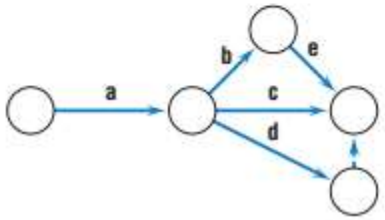


Table 9-2 Activity Slopes–Cost per Period for Crashing

Activity	*Slope ($/day)*
a	40/−1 = −40
b	60/−1 = −60
c	—
d	90/−3 = −30
e	−70 (2 days)

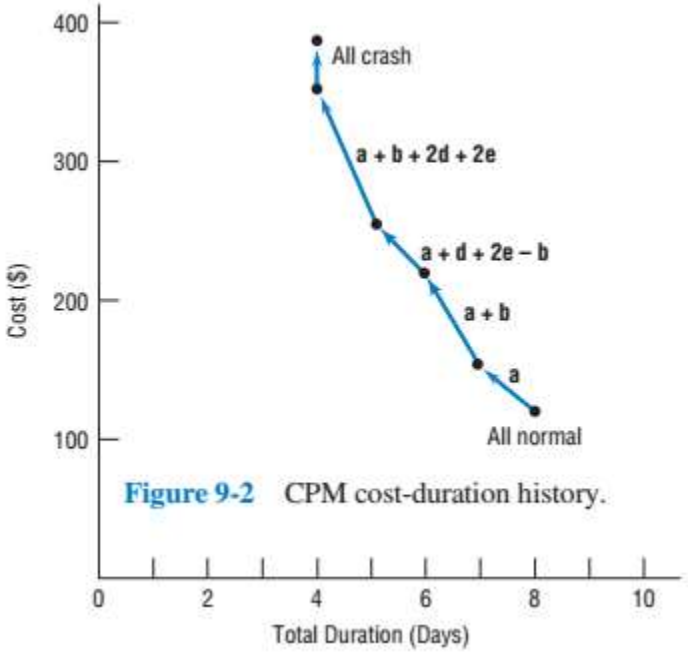
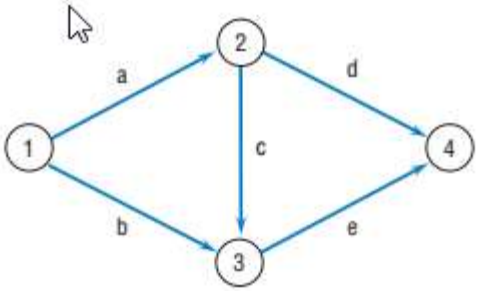


Figure 9-2 CPM cost-duration history.

Schedule Compression
Crashing – A solved problem

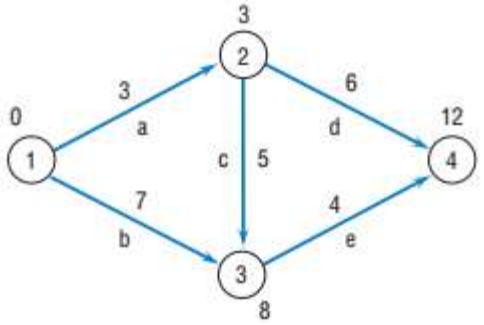
Given the following network (time in days):



Activity	Crash Time, Cost	Normal Time, Cost	Partial Crashing?
a	3, $60	3, $60	No
b	6, 80	7, 30	Yes
c	2, 90	5, 50	No
d	5, 50	6, 30	No
e	2, 100	4, 40	Yes

Find the lowest cost to complete the project in 10 days.

Answer:



Current time and cost: 12 days and $210

Since the critical path is **a-c-e**, we only initially need to consider these three activities:

a: cannot be crashed

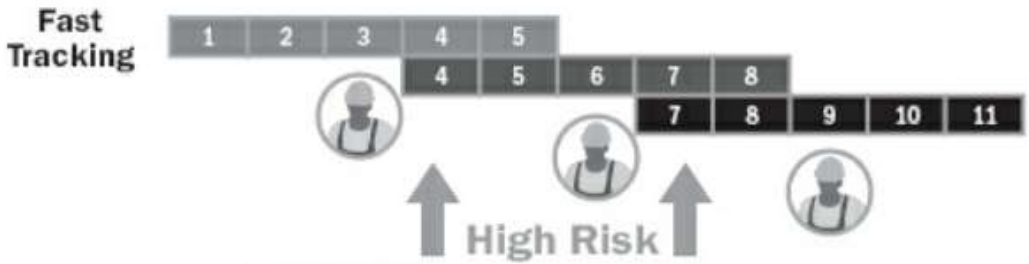
c: can cut 3 days at an extra cost of $40 but, due to **b**, only results in project completion by day 11. To reach 10 days, cut **b** by 1 day, total extra cost $90.

e: can cut **e** by 2 days for an extra cost of $60 and results in project completion by day 10.

Thus, cut **e** 2 days at a cost of $60.

Schedule Compression
Fast Tracking

Fast Tracking: A schedule compression technique in which activities or phases normally done in sequence are performed in parallel for at least a portion of their duration.



Notes for CPM again

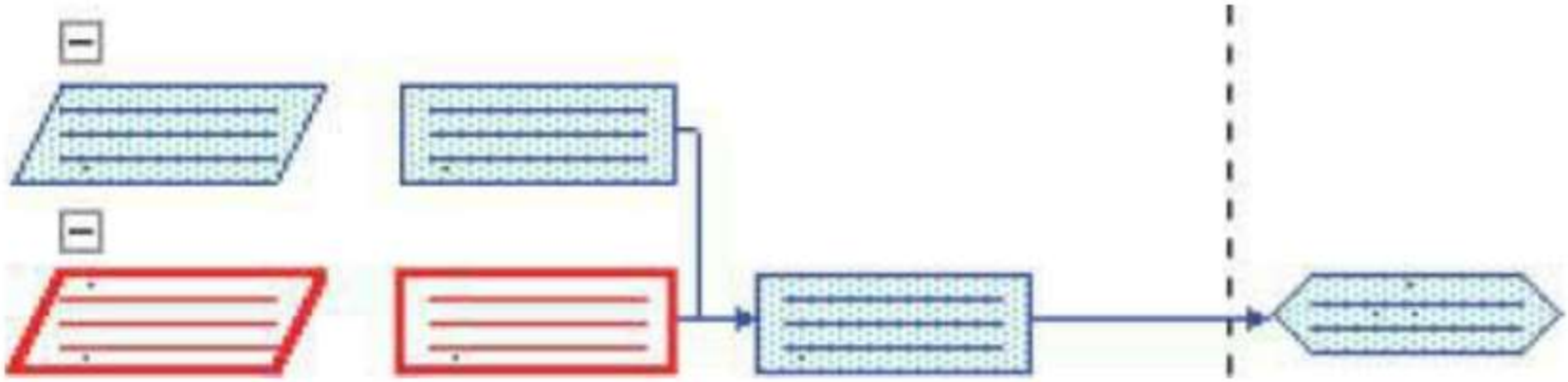
Important Notes about Critical Path Method

- There can be more than one critical paths
- Having several critical paths or having several near critical paths mean project has high risk
- Critical path of the project can change over time
- There can be negative float, it means schedule is behind than the planned
- If there is negative float, you should compress the schedule.
- If you need to cut an activity duration in critical path, cut the earlier activity's duration

Understanding Network Diagram

For your projects

- Summary tasks are trapezoidal –
- Detail tasks are rectangular –
- The Milestone Task is an elongated diamond –



- Summary tasks are positioned to the left at the same level or above detail tasks.
- Summary tasks may be rolled up by clicking on the ⊟ above the task and expanded by clicking on the ⊞ above a rolled up summary task.

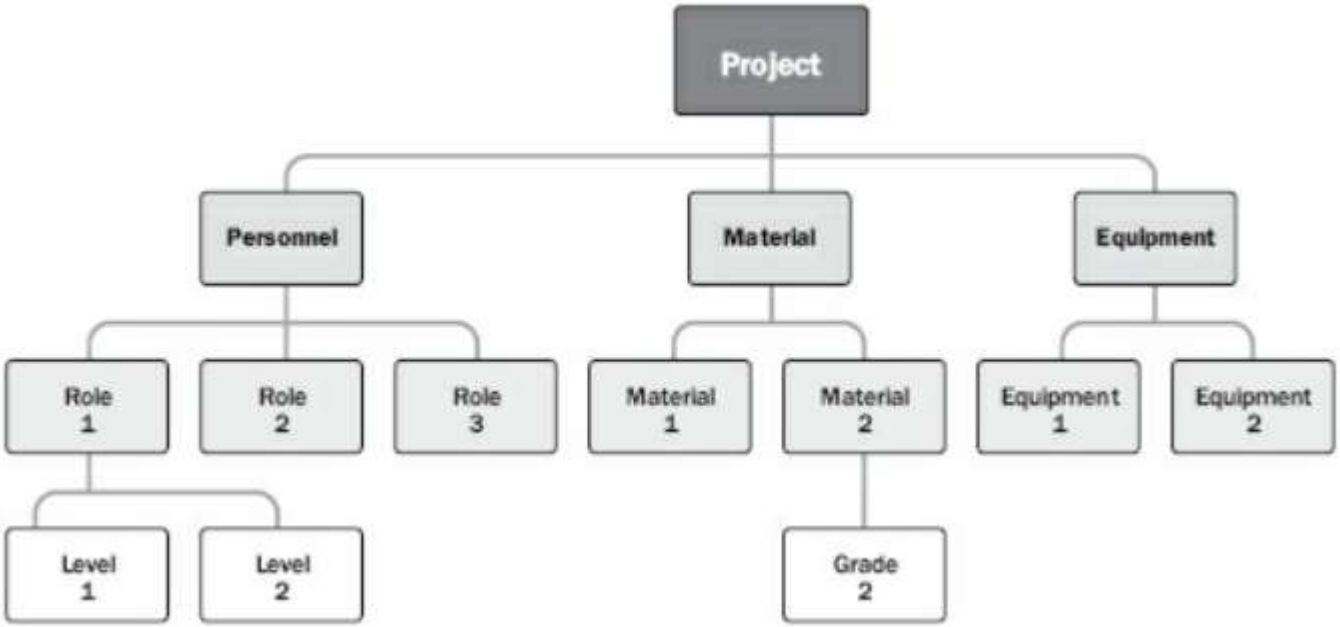
Creating Resources for your project

- A shortcoming of the scheduling procedures covered in the previous chapter is that they do not address the issues of resource utilization and availability.
  - The focus is on time rather than physical resources.
  - Also, in the discussion that follows it will not be sufficient to refer to resource usage simply as “costs”.
  - Instead, we must refer to
    - individual types of labor,
    - specific facilities,
    - kinds of materials,
    - individual pieces of equipment,
    - other discrete inputs that are relevant to an individual project but are limited in availability.

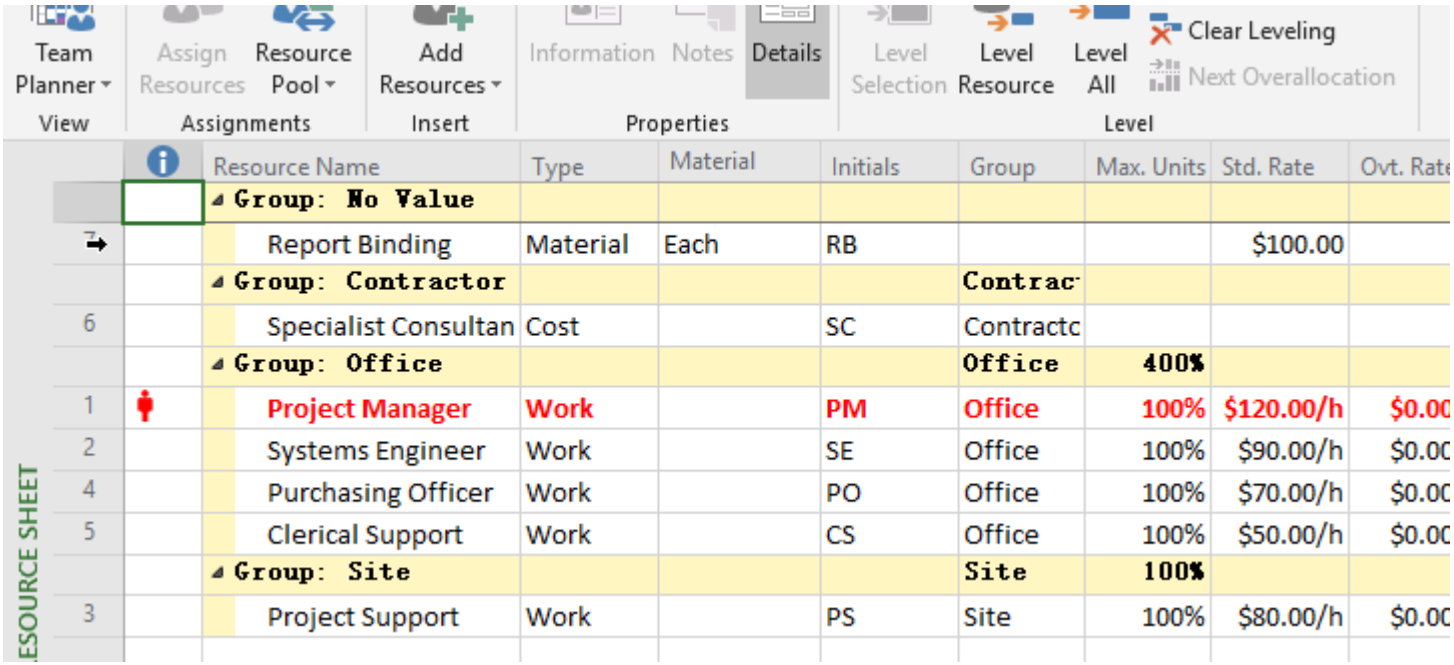
Resource Allocation Problem

- Resources used as Input Resources – Those that are required to complete the work:
  - Individual people by name.
  - Groups of people by trade or skill.
  - Individual equipment or machinery by name.
  - Groups of resources such as Crews or Teams made up of equipment and machinery.
  - Materials or Money.

Resource Breakdown Structure



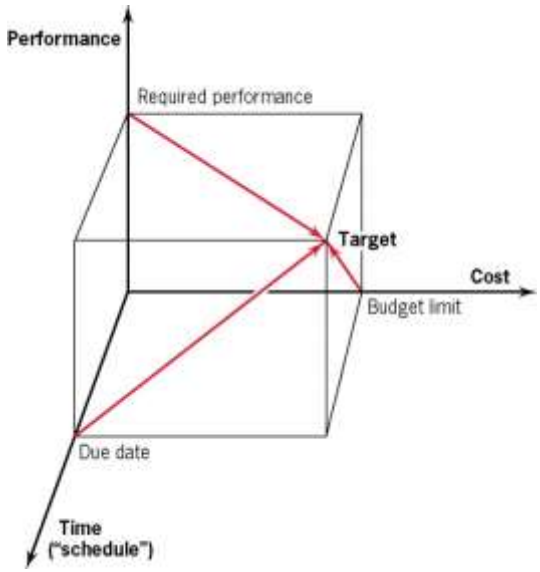
Creating Resources for your project



		Resource Name	Type	Material	Initials	Group	Max. Units	Std. Rate	Ovt. Rate
		Group: No Value							
		Report Binding	Material	Each	RB			$100.00	
		Group: Contractor				Contrac			
6		Specialist Consultan	Cost		SC	Contractc			
		Group: Office				Office	400%		
1		Project Manager	Work		PM	Office	100%	$120.00/h	$0.00
2		Systems Engineer	Work		SE	Office	100%	$90.00/h	$0.00
4		Purchasing Officer	Work		PO	Office	100%	$70.00/h	$0.00
5		Clerical Support	Work		CS	Office	100%	$50.00/h	$0.00
		Group: Site				Site	100%		
3		Project Support	Work		PS	Site	100%	$80.00/h	$0.00

Resource Allocation

One cannot save time—one can only spend more or less of it.



- The PM should be able to do trade offs between TCP
- Otherwise, if TCP are fixed means
  the **project is overdetermined**

A system-constrained task requires a fixed amount of time and known quantities of resources.
Ex : The material “cook-time” is fixed. No trade-offs are possible.
Required resources should be available when needed.

Resource Loading

Assign Resources
To WBS

Career Day Project
Resource Usage Calendar

ID	Resource Name	Work	May				June				July				
			25	2	9	16	23	30	6	13	20	27	4	11	18	25
1	**Secretary**	**1,020 hrs**	24h	40h	40h	40h	88h	120h	102h	40h	40h	40h	40h	40h	40h	40h
	Print forms	240 hrs														
	Gather college particulars	160 hrs	24h	40h	40h	40h	16h									
	Print programs	240 hrs					24h	40h	40h	40h	40h	40h	16h			
	Advertise in college paper	200 hrs					24h	40h	36h	0h	0h	0h	24h	40h	36h	
	Organize posters	180 hrs					24h	40h	26h	0h	0h	0h	0h	0h	4h	40h
2	**Program Manager**	**1,440 hrs**	40h	40h	40h	16h	24h	40h	40h	40h	16h					
	Contact organizations	600 hrs	16h													
	Select guest speaker	560 hrs														
	Organize food	120 hrs	24h	40h	40h	16h										
	Contact faculty	60 hrs					24h	36h								
	Arrange facility for event	100 hrs						4h	40h	40h	16h					
3	**Office Manager**	**180 hrs**	24h	40h	40h	40h	16h				20h					
	Collect display information	160 hrs	24h	40h	40h	40h	16h									
	Transport materials	20 hrs									20h					
4	**Graduate Assistant**	**1,140 hrs**	24h	40h	40h	40h	64h	80h	80h	56h	40h	40h	16h			
	Print participants' certificates	320 hrs														
	Organize refreshments	280 hrs	24h	40h	40h	40h	40h	40h	40h	16h						
	Send invitations	80 hrs														
	Organize gift certificates	220 hrs														
	Arrange banner	200 hrs					24h	40h	40h	40h	40h	16h				
	Class announcements	40 hrs										24h	16h			
5	**Director**	**400 hrs**	24h	40h	40h	40h	40h	40h	40h	40h	40h	40h	16h			
	Organize liquor	400 hrs	24h	40h	40h	40h	40h	40h	40h	40h	40h	40h	16h			

Meredith

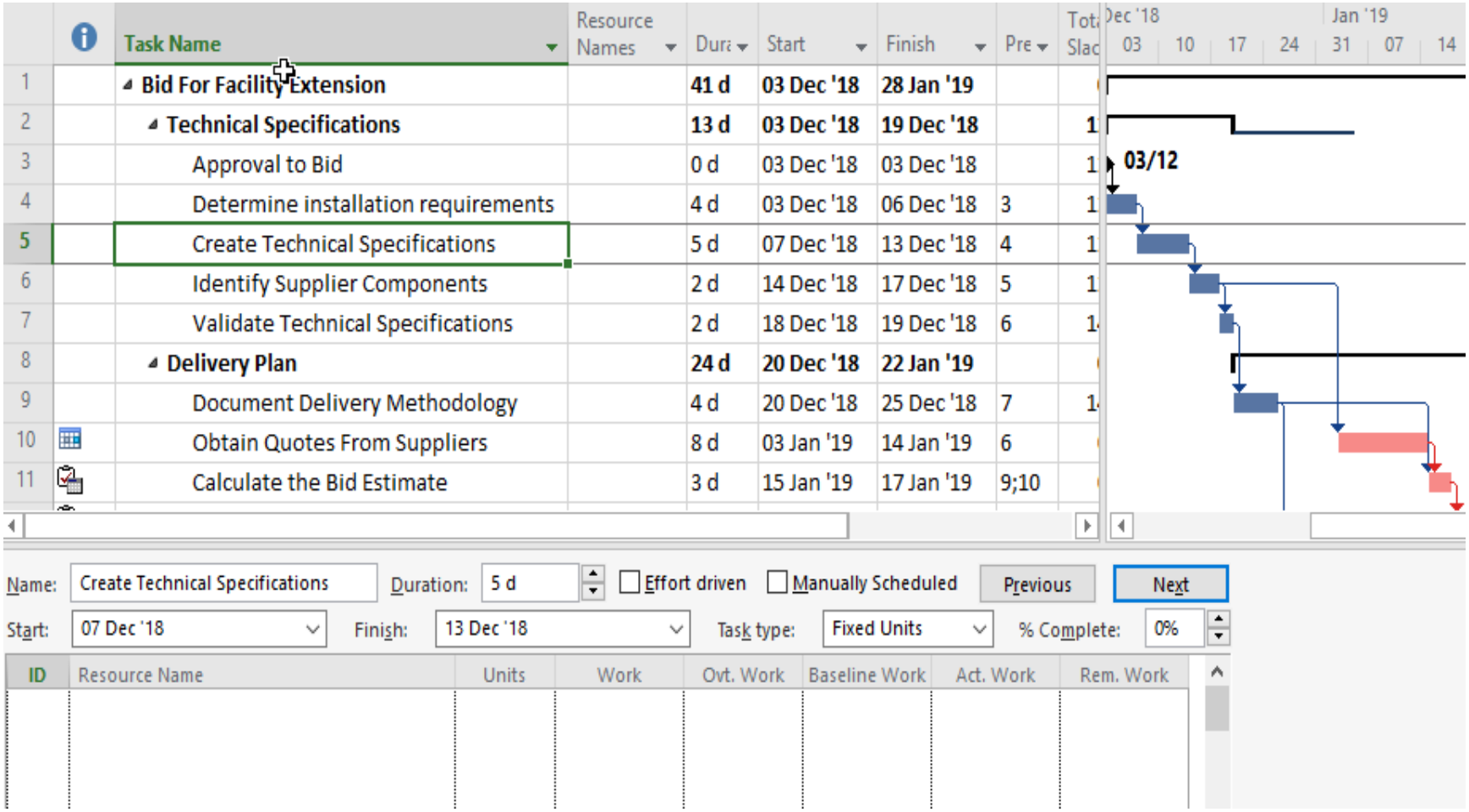
RACI Chart
Responsible – Accountable – Consult – Inform

RACI Chart	Person				
Activity	Ann	Ben	Carlos	Dina	Ed
Create charter	A	R	I	I	I
Collect requirements	I	A	R	C	C
Submit change request	I	A	R	R	C
Develop test plan	A	C	I	I	R

R = Responsible A = Accountable C = Consult I = Inform

Figure 9-4. Sample RACI Chart

Resource Loading
in MS-Project



Resource Loading in AoA

Table 8-2 Expected Activity Times (TE), Variances (σ^2), and Standard Deviations (σ)

Activity	Expected Time, TE	Variance, σ^2	Standard Deviation, σ
a	20	4	2
b	20	0	0
c	10	4	2
d	15	25	5
e	10	4	2
f	14	4	2
g	4	0	0
h	11	5.4	2.32
i	18	28.4	5.33
j	8	4	2

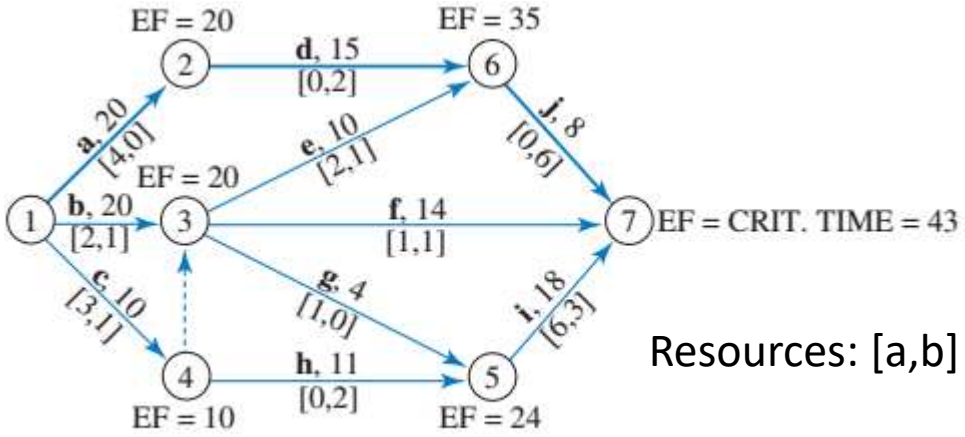
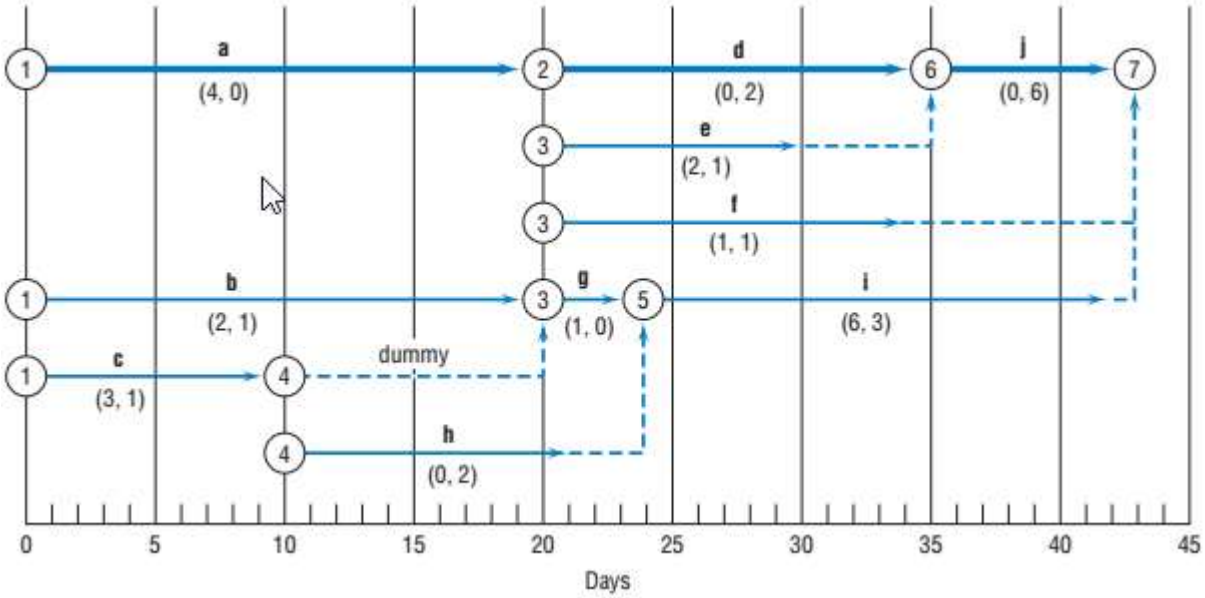


Figure 9-4 The AOA network of Table 8-2.

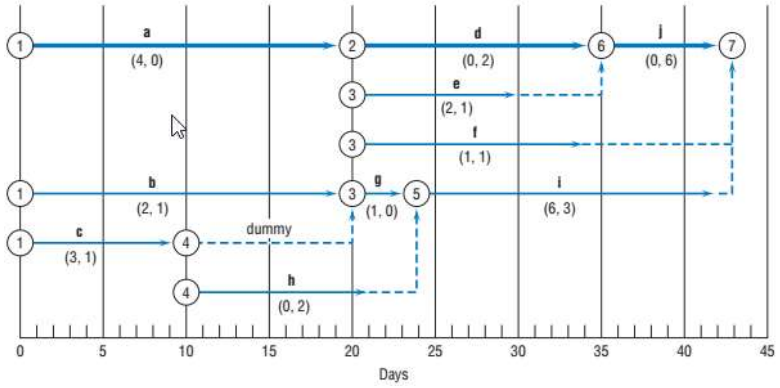
Resources: [a,b]

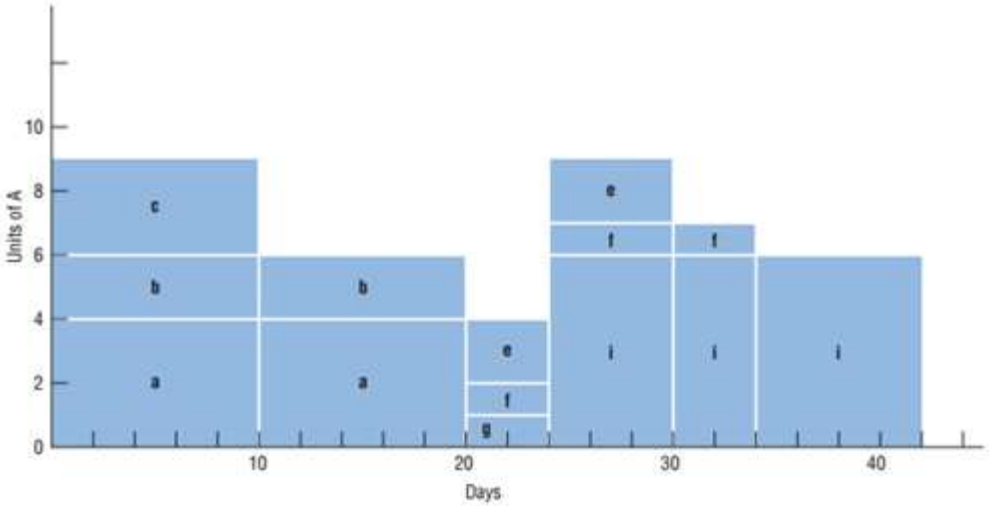
Modified AoA

Resources: (a, b)

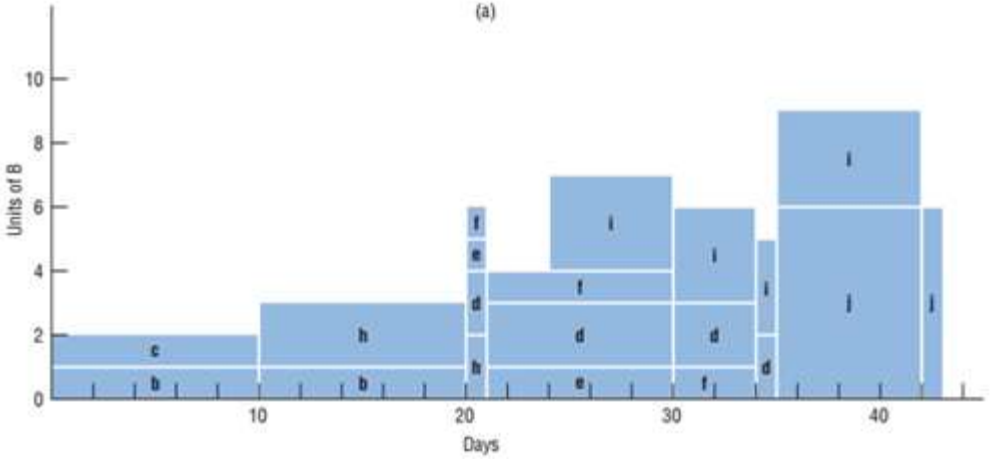


Resource Leveling





(a)

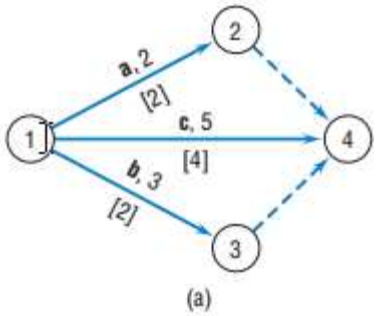


Try to level over time
Meaning smother usage

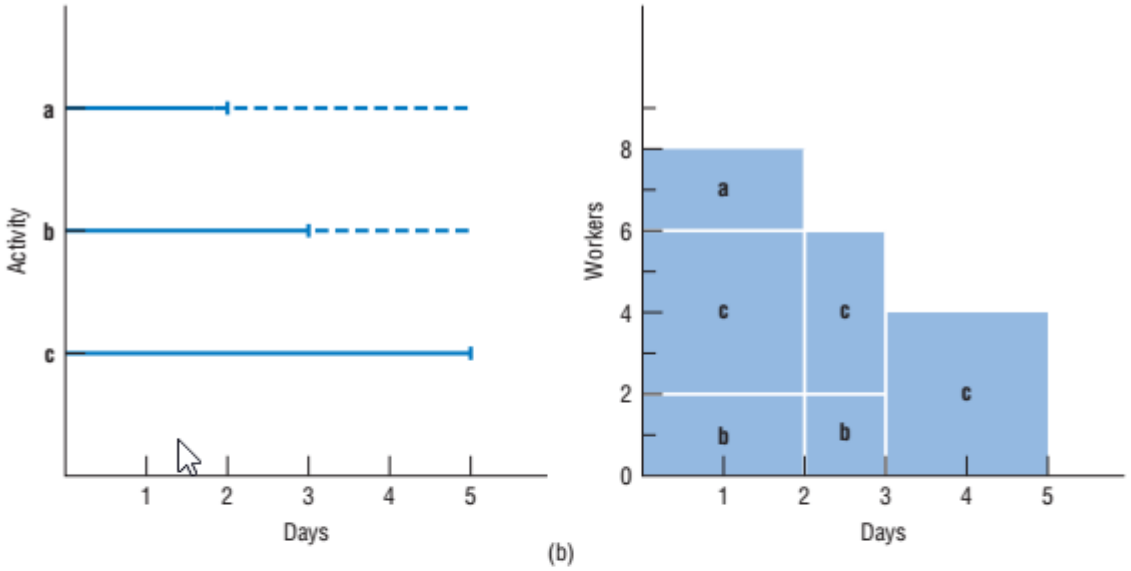
What are the advantages of Smooth resource usage:

Resource Leveling example

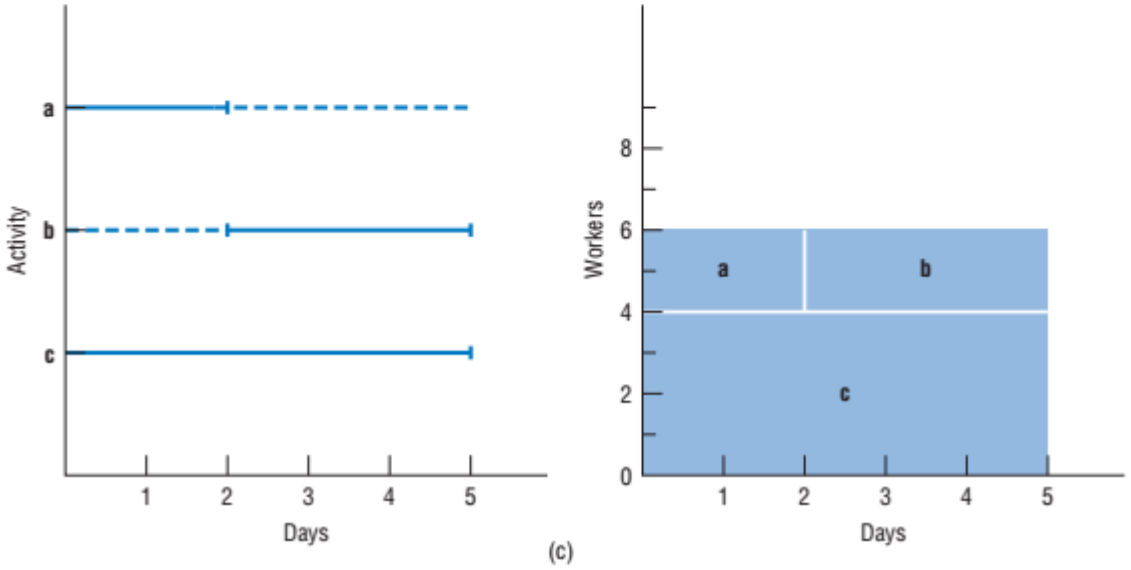
One resource
Road workers



(a)

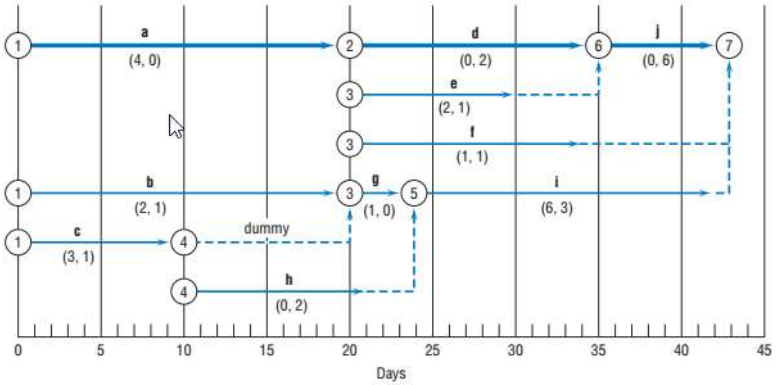


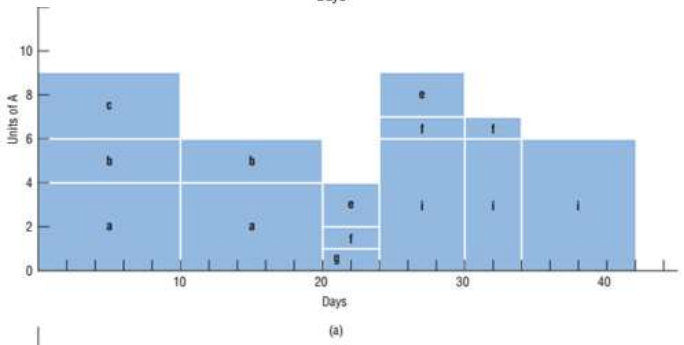
(b)

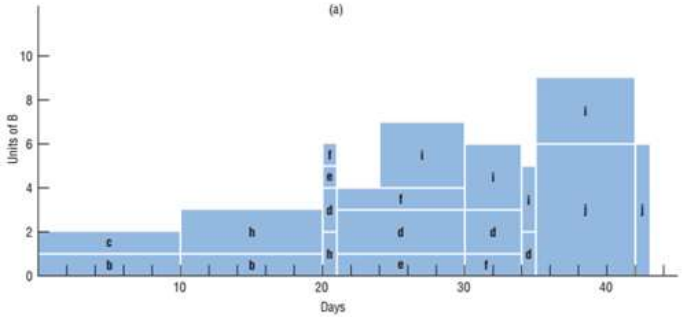


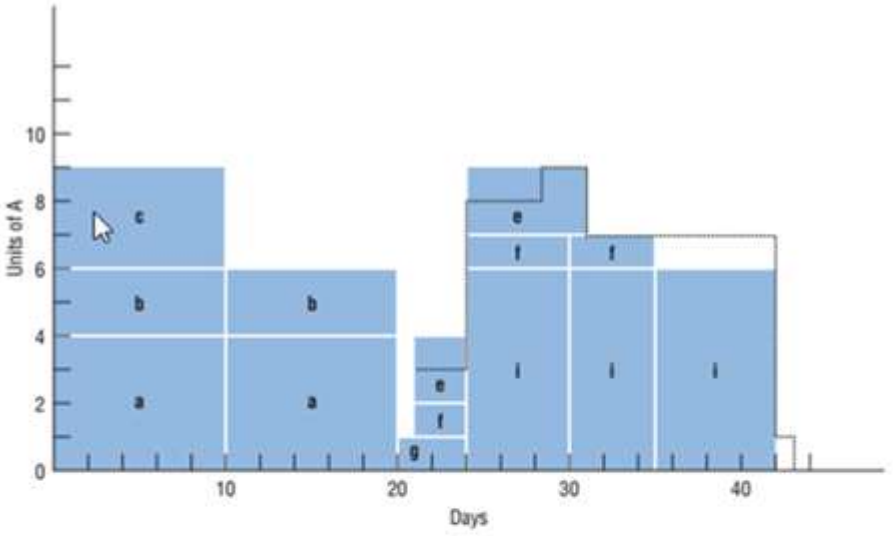
(c)

Resource Leveling example









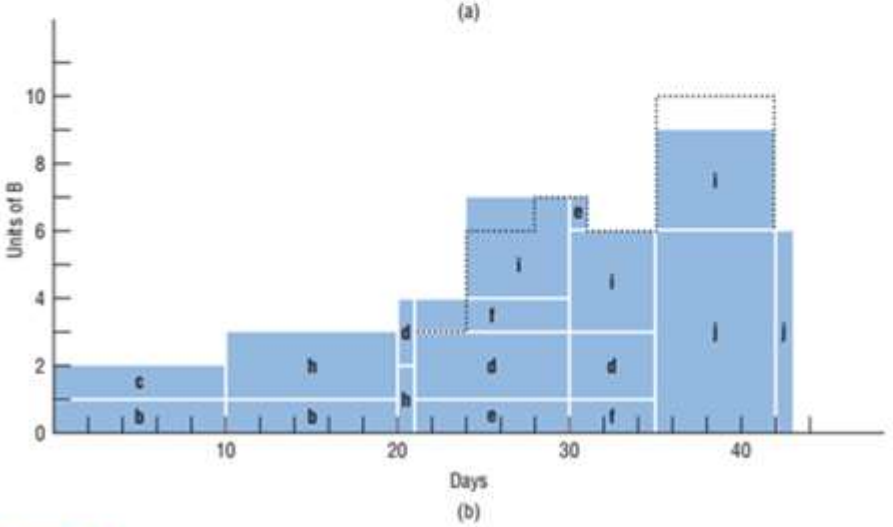


Figure 9-8 (a) Load diagram for resource A with activities e and f delayed by 1 day each. (b) Load diagram for resource B with activities e and f delayed by 1 day each.

Resource Loading/Leveling Uncertainty

PM should use its operational abilities against uncertainties

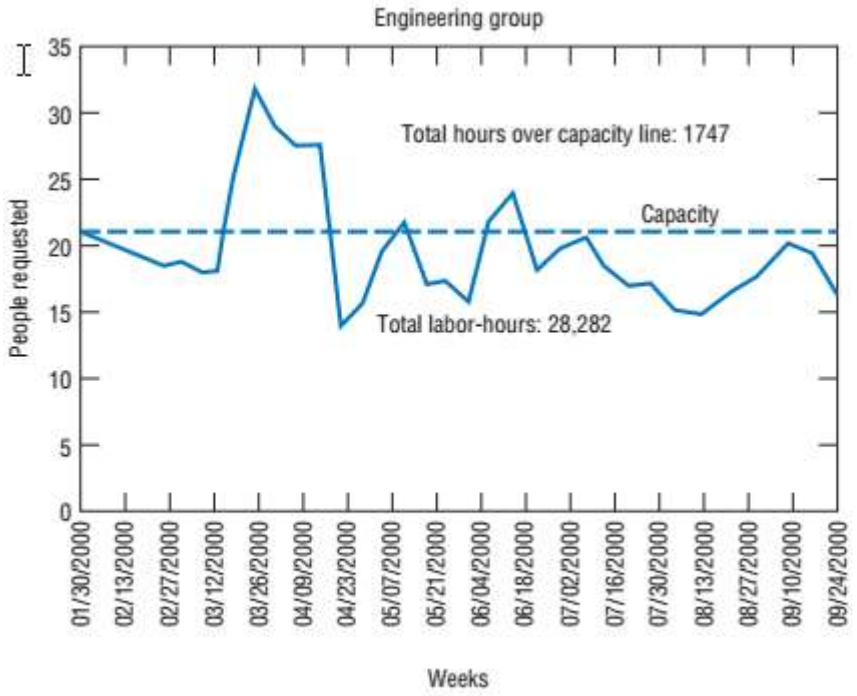


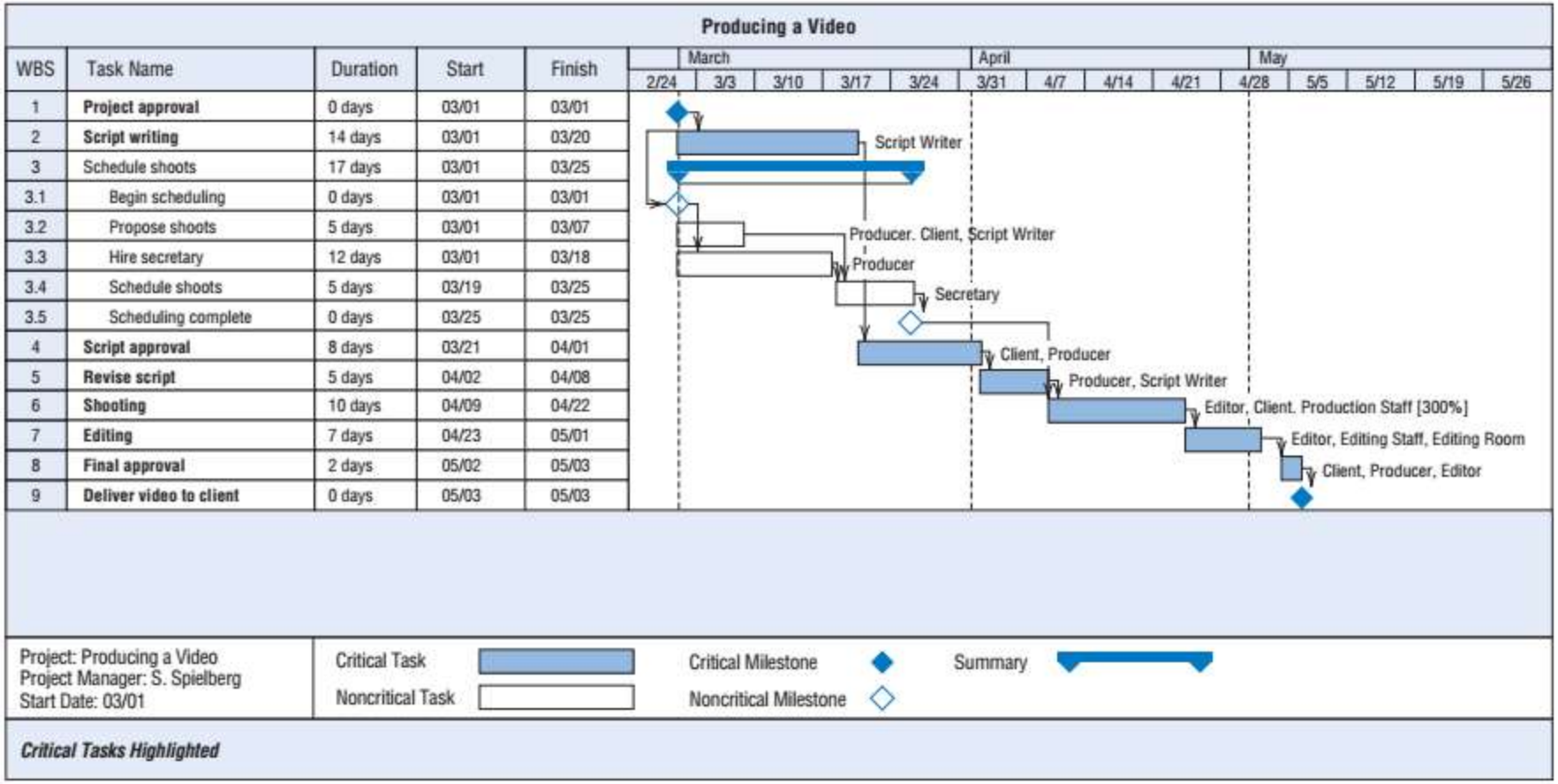
Figure 9-9 Thirty-four-week resource logging chart for a software engineering group.

Constrained Resource Scheduling

- Heuristic methods
  - Most suitable for large, complex, real life projects
    - Shift some activities according to some rules
      - Minimum slack first gives best result usually
- Optimization models

Heuristic Methods

Only feasible method for large and complex problems of the Real World

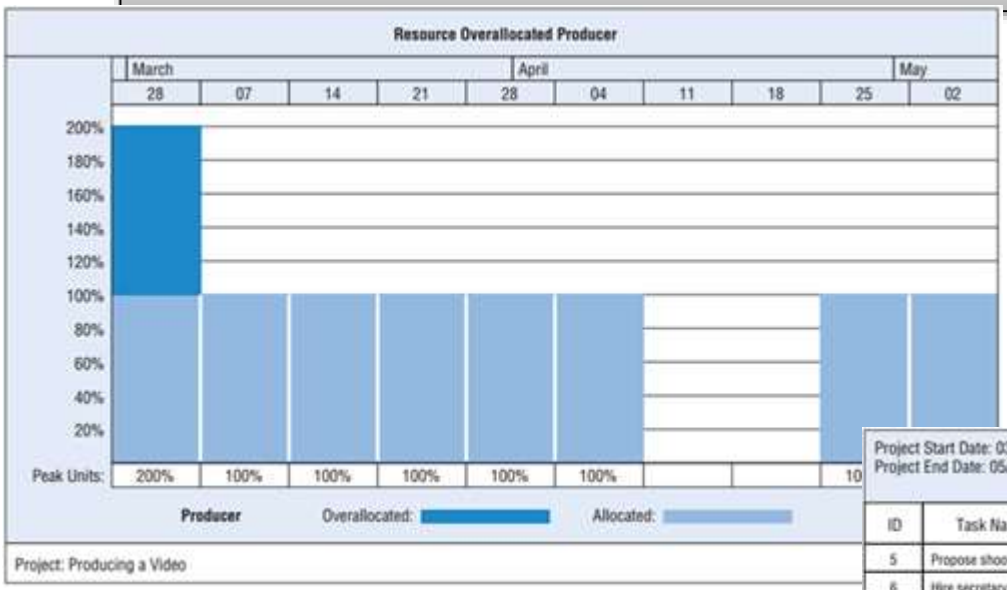


WBS	Task Name	Duration	Start	Finish
1	**Project approval**	0 days	03/01	03/01
2	**Script writing**	14 days	03/01	03/20
3	Schedule shoots	17 days	03/01	03/25
3.1	Begin scheduling	0 days	03/01	03/01
3.2	Propose shoots	5 days	03/01	03/07
3.3	Hire secretary	12 days	03/01	03/18
3.4	Schedule shoots	5 days	03/19	03/25
3.5	Scheduling complete	0 days	03/25	03/25
4	**Script approval**	8 days	03/21	04/01
5	**Revise script**	5 days	04/02	04/08
6	**Shooting**	10 days	04/09	04/22
7	**Editing**	7 days	04/23	05/01
8	**Final approval**	2 days	05/02	05/03
9	**Deliver video to client**	0 days	05/03	05/03

Figure 9-10 MSP Gantt chart of video project showing resource needs.

Heuristic Methods

MS-Project can handle the problem. Result may not be optimal but quite good.



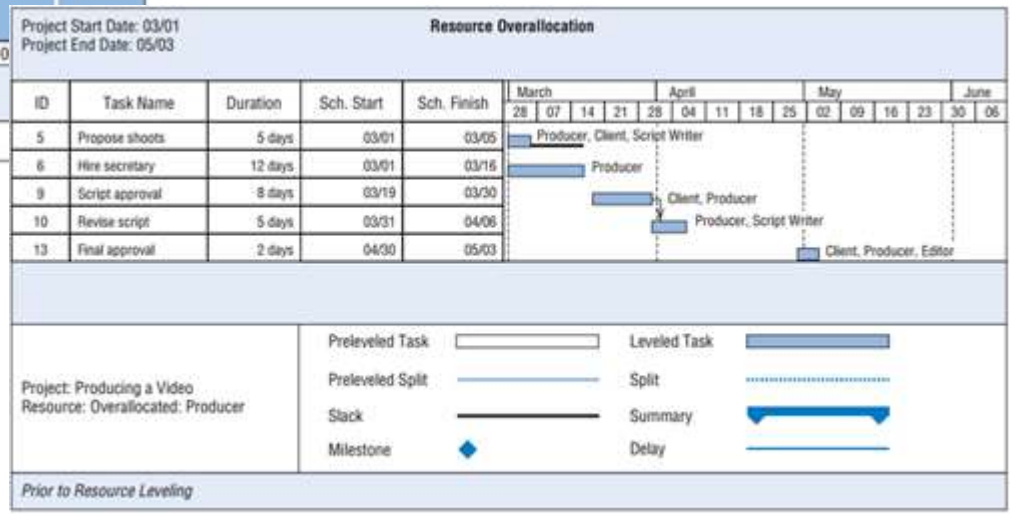


Figure 9-11 MSP load diagram showing resource conflict (producer used beyond capacity).

Heuristic Methods

MS-Project can handle the problem. Result may not be optimal but quite good.

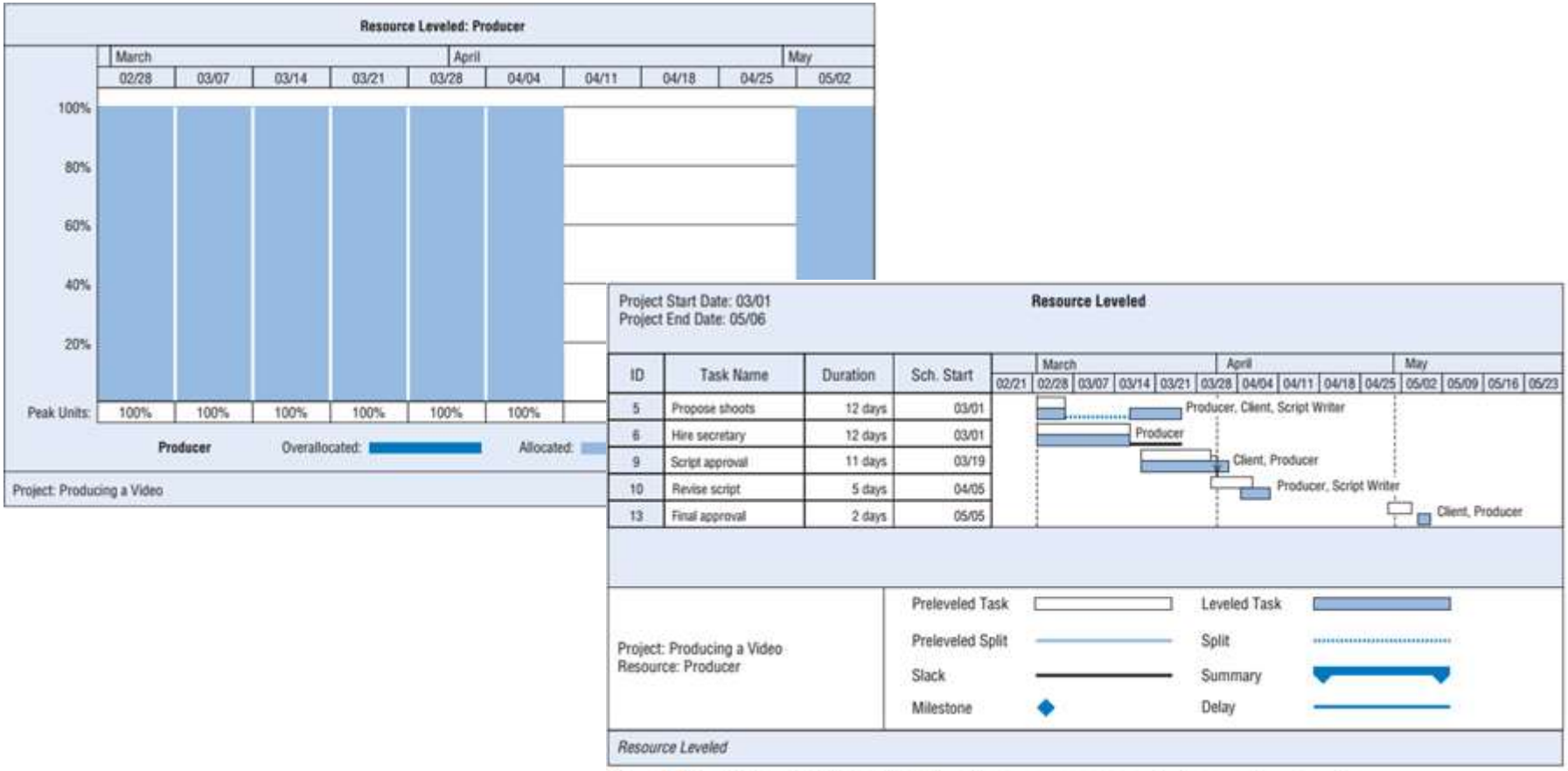


Figure 9-12 MSP rescheduling to level producer resource usage without exceeding capacity.

Priority rules for Heuristic

PM may apply simulation test. If a significant improvement is not the outcome then your first heuristic approach is good for the PM.

- As soon as possible – Default for MS-Project.
- As late as possible – Use slacks to defer payments.
- Shortest task first – Maximizes number of tasks that can be completed.
- Most resources first – Assumes most important tasks use highest resources.
- Minimum slack first – Reduces risk on project duration.

  Gives best result usually.
- Most critical followers – Reduces risk of the PM.
- Most successors – Similar to previous but not only for the critical path.
- Arbitrary – No rule at all. According to the ideas of stakeholders or the boss.

Optimization Models

There were lots of attacks since 1970ies.
Do not create better results in most practical cases against Heuristic yet.

- Linear programming
- Programming and Enumeration techniques

Multi project approach

Then you may shift resources between projects.

Also you may decompose one big project task into smaller and manageable ones.
And you may shift resources between.
It is an optimization too.
Dividing too much may cause increase in managerial and other costs.

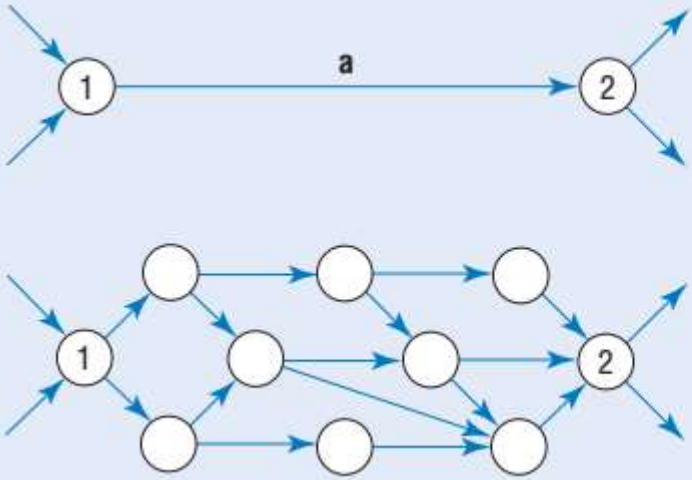


Figure 9-13 Task **a** decomposed into a network of subtasks.

Dividing projects into sub-projects

How much to decompose is an optimization too and needs Expert Judgement.

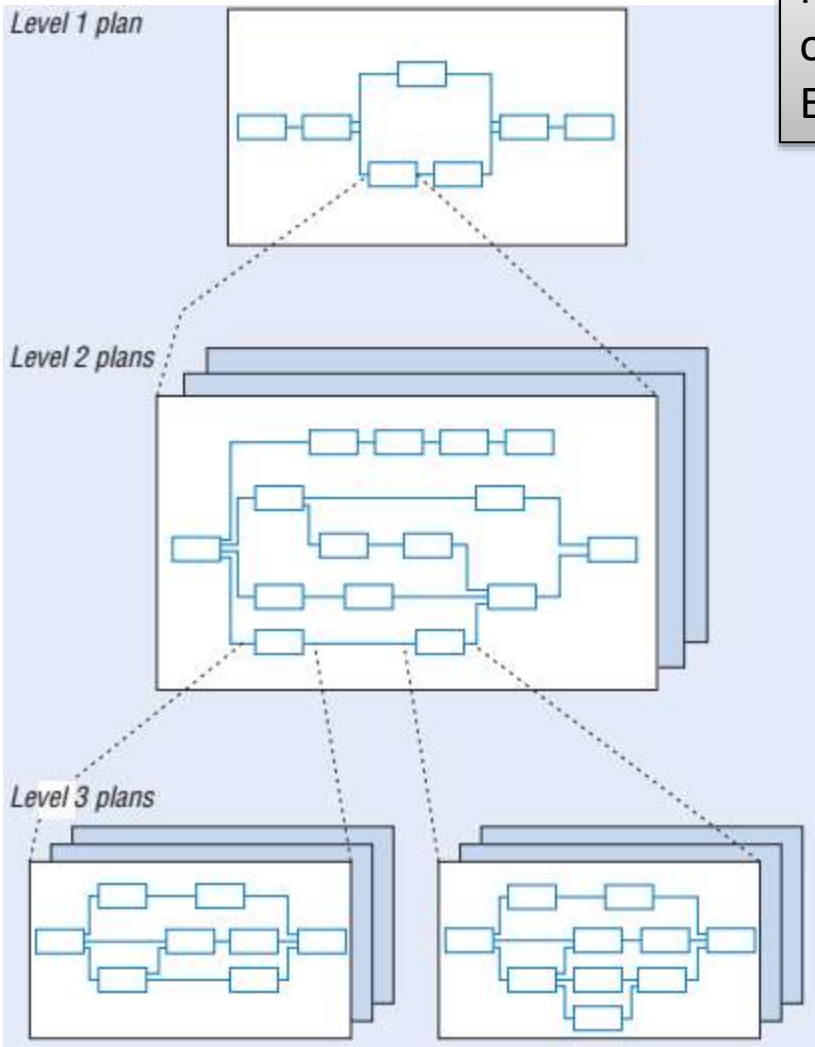


Figure 9-14 Hierarchy of Gantt charts. *Source*: F. L. Harrison (1983). *Advanced Project Management*. Hants, U.K.: Gower.

Project Planning Completed

Next is Execution

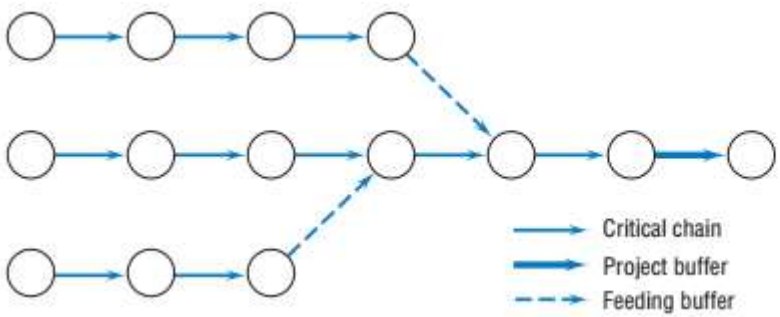


Figure 9-18 Project and feeder buffers.

- Be aware of human complex psychology and try to be a leader not manager.
- Keep buffer high if you meet complexity. (And do not tell to any body)
- Use motivation factors high if you are able.
  (Use anything to motivate, never punish with salary cut)
- Keep it simple to be able to manage
  Do not bother your team with complexity
  (which makes them afraid and working less).
- Share the success with visible numbers.
- Try to use tools to manage projects,
  but do not advertise before feeling the comfort and success with them.

Resource Management Overview

Figure 9-1. Project Resource Management Overview

The Last Workshop

Do not forget to complete the last workshop – 5 Pts.

Problems – Ch 9

4. Given the following highway rerouting project,

Activity	Immediate Predecessor	Activity Time (months)
A: Schedule crew	—	4
B: Schedule equipment	—	6
C: Plan new route	A	2
D: Costs meet budget?	B	6
E: Inform public	C, B	3
F: Put out signs	C, B	3
G: Begin rerouting	D, E	5

(a) Draw the network.

(b) Find the ESs, LSs, and slacks.

(c) Find the critical path.

(d) If the project has a 1 1/2-year deadline for reopening, should we consider crashing some activities? Explain.

6. Consider the following activity information and the constraint that the project must be completed in 16 weeks.

Activity	Prec. Evt.	Suc. Evt.	TE (weeks)	Prec. Activ.
a	1	2	3	none
b	1	3	6	none
c	1	4	8	none
d	2	5	7	a
e	3	5	5	b
f	4	5	10	c
g	4	6	4	c
h	5	7	5	d,e,f
i	6	7	6	g

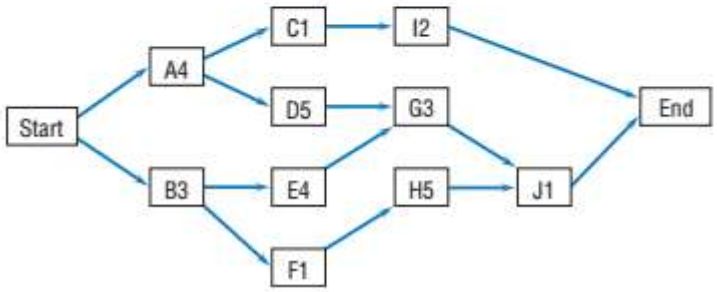
In addition, activities **c, f, h**, and **i** may be crashed as follows. Assume partial crashing.

Activity	Crash Time (weeks)	Additional Cost per Week
c	7	$40
f	6	20
h	2	10
I	3	30

Find the best schedule and its cost

Problems – Ch 9

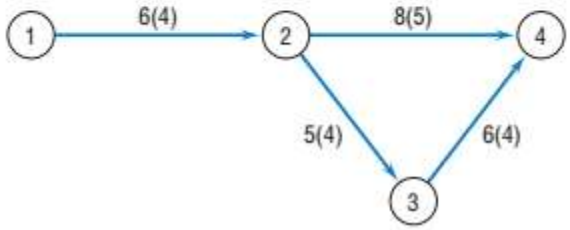
9. Consider the project network below. Suppose the duration of both activities **A** and **D** can be reduced to one day, at a cost of $15 per day of reduction. Also, activities **E**, **G**, and **H** can be reduced in duration by one day at a cost of $25 per day of reduction. What is the least-cost approach to crash the project two days? What is the shortest "crashed" duration, the new critical path, and the cost of crashing?



Task Code Duration

10. Given a network for an HR training project with normal times and crash times (in parentheses), find the cost-duration history. Assume indirect costs for facilities and equipment are $100 per day. The data are:

Activity	*Time Reduction, Direct Cost per Day*
1–2: Obtain room	$30 first, $50 second
2–3: Select trainer	$80
3–4: Invite personnel	$25 first, $60 second
2–4: Check budget	$30 first, $70 second, $90 third



12. The network for shooting a TV commercial as shown in the table has a fixed cost of $90 per day, but money can be saved by shortening the project duration. Find the least-cost schedule.

Activity	*Normal Time*	*Crash Time*	*Cost Increase (1st, 2nd, 3rd day)*
1–2: Contract personnel	7	4	$30, 50, 70
2–3: Obtain stage props	9	6	40, 45, 65
1–3: Rent equipment	12	10	60, 60
2–4: Contract studio	11	9	35, 60
3–4: Set time and date	3	3	—

Problems – Ch 9

13. Given the following project to landscape a new building site,

Activity	Immediate Predecessor	Activity Duration (days)	Resource Used
A: Get plants	—	2	X, Y
B: Get flowers	A	2	X
C: Obtain soil	A	3	X
D: Obtain fertilizer	B, C	4	X, Y
E: Select labor	D	3	W, X
F: Set date	D	1	W, X, Y
G: Begin	E, F	2	X, Y

(a) Draw a Gantt chart using MSP.

(b) Find the critical path and project duration in days.

(c) Given that each resource is assigned 100 percent to each task, identify the resource constraints.

(d) Level the resources and determine the new project duration and critical path.

(e) Identify what alternative solutions can be used to shorten the project duration and not over-allocate the resources.

15. Given the following project (all times are in days):

Activity	Pre-decessor	Normal Time	Normal Cost	Crash Time	Crash Cost
a	—	5	$50	3	$150
b	—	4	40	2	200
c	b	7	70	6	160
d	a, c	2	20	1	50
e	a, c	3	30	—	—
f	b	8	80	5	290
g	d	5	50	4	100
h	e, f	6	60	3	180

(a) Draw the network and find the critical path, time, and cost for an all-normal level of project activity.

(b) Calculate the crash cost-per-day (all activities may be partially crashed).

(c) Find the optimal way of getting an 18-day delivery time. What is the project cost?

(d) Find the optimal way of getting a 16-day delivery time. What is the project cost?

(e) Calculate the shortest delivery time for the project. What is the cost?

Resources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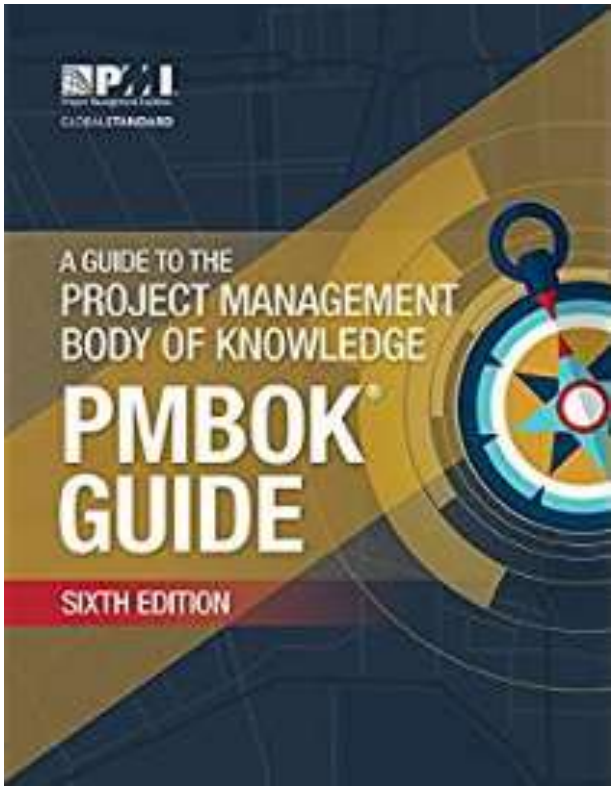
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Questions

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NEXT WEEK: Project Execution – Monitoring and Control