بسم الله الرحمن الرحيم

ENGINEERING MANAGEMENT

(GE 404)

LECTURE #8

Limited Resource Allocation

Contents

Objectives of the Present lecture

- *To discuss the issues involved in Limited Resource Allocation*
- *To explain how to carry out limited resource allocation using series method*

Resource Allocation

- Resource Allocation is the scheduling of activities and the resources required by those activities (while taking into consideration both the resource availability and the project time).
- Resource allocation permits efficient use of physical assets
  - Within a project, or across multiple projects
  - Drives both the identification of resources, and timing of their application
- There are generally two conditions for allocating resources:
  - "Normal" Most likely task duration
  - "Crashed" Expedite an activity, by applying additional resources together with cost considerations
    - Specialized or additional equipment/material
    - Extra labor (e.g., borrowed staff, temps)
    - More hours (e.g., overtime, weekends)

Why Resource Allocation?

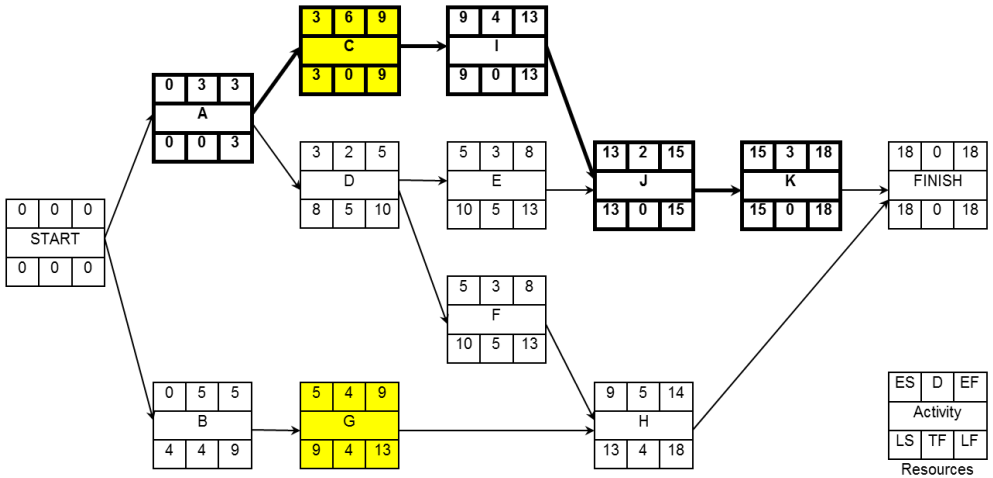
- To complete and finalize project schedule for completion of the project at maximum efficiency of time and cost
- Better managing of resource utilization over the life of the project
- To smooth the use of resources for better assignment and levelling of Manpower, equipment, materials, subcontractors, and information
- To estimate cost properly for finding optimum project budget (money resource) and close management control
- To schedule resource constraints properly to take care of shortage of resources
- Note: **Duration of a project may be increased by delaying the late start** of some of its activities **if resources are not adequate** to meet peak demands

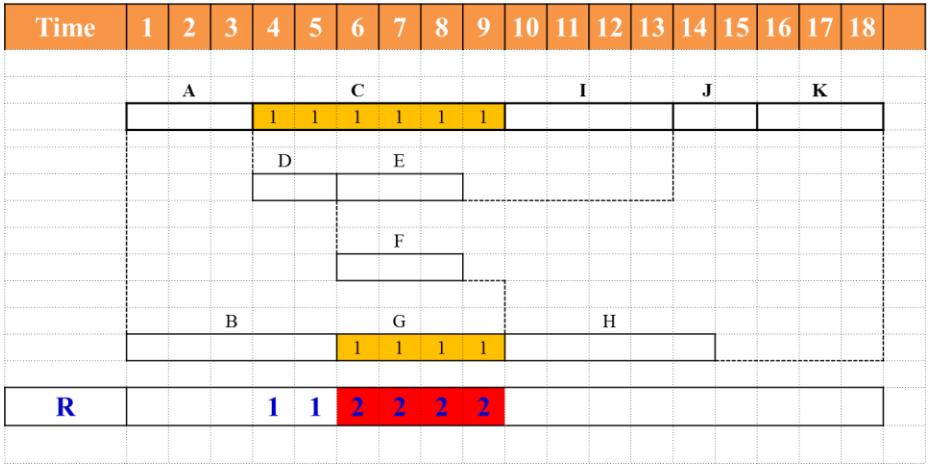
Goal of Resource Allocation/Planning

- The basic objective of resource management is to supply and support field operations with the resources required so that established time objectives can be met and costs can be kept within the budget.
- Hence, the goal is to optimize use of limited resources
- This requires making trade-offs
  - time constrained
  - resource constrained

Effect of Limited Resources on Schedule slack

- Assume that activities "C" and "G" each require the use of a special piece of equipment, such a **hoist crane**. But only **one crane** is available.
- The direct result of this **resource constraint is that activities "C" and "G" can not be performed simultaneously** as indicated by the ES time-only schedule. **One** or the other of the activities in each pair **must be given priority**.



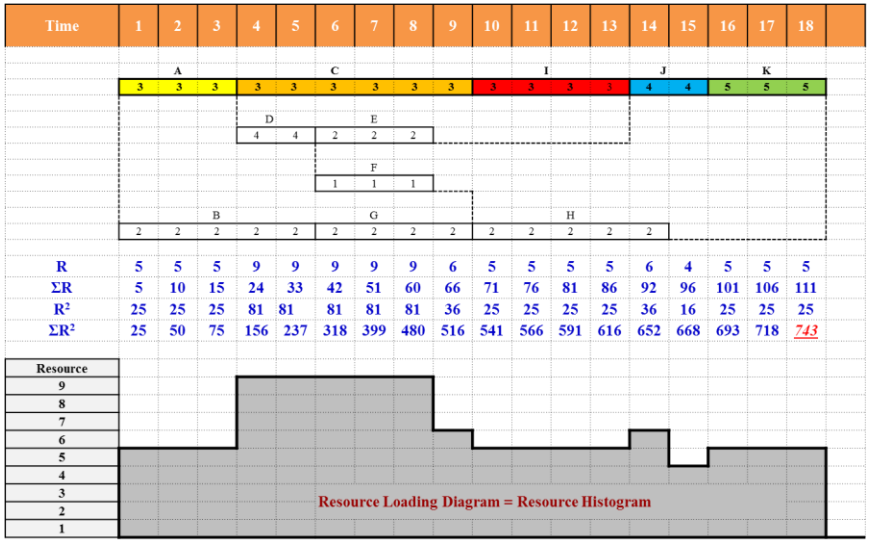


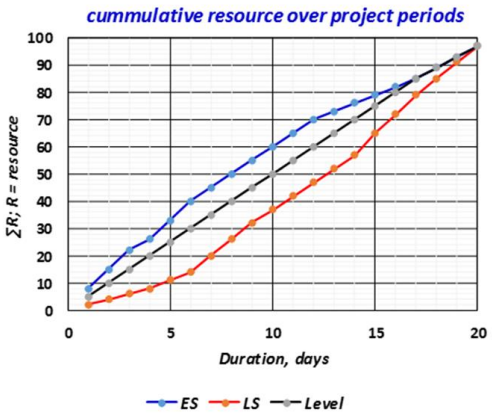
Contd.

- Resource constraints reduce the total amount of schedule slack.
- **Slack** depends both upon **activity relationships** and **resource limitations**.
- The **critical path in resource-constrained schedule** may not be the **same continuous chain(s) of activities** as occurring in the unlimited resources schedule.

Project Resource Requirement

- Resource Loading Diagram
  - **A diagram that highlights the period-by-period** resource implications of a particular project schedule
- Project Resource Requirement =
  - Resource Loading Diagram =
    - Resource Histogram =
      - Resource Profile and S curve



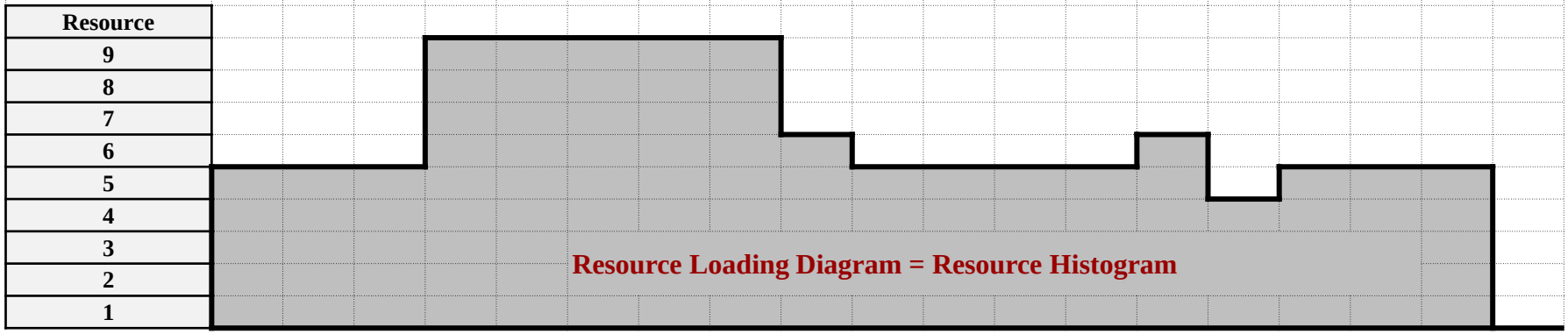


Project Resource Requirement (Contd.)

We need	We make
• Project network • Resource requirement for each activity • Bar chart or time-scaled network	• Resource loading diagram • Period-by-period total requirements of units of resources • Cumulative resource requirement curve (S curve)

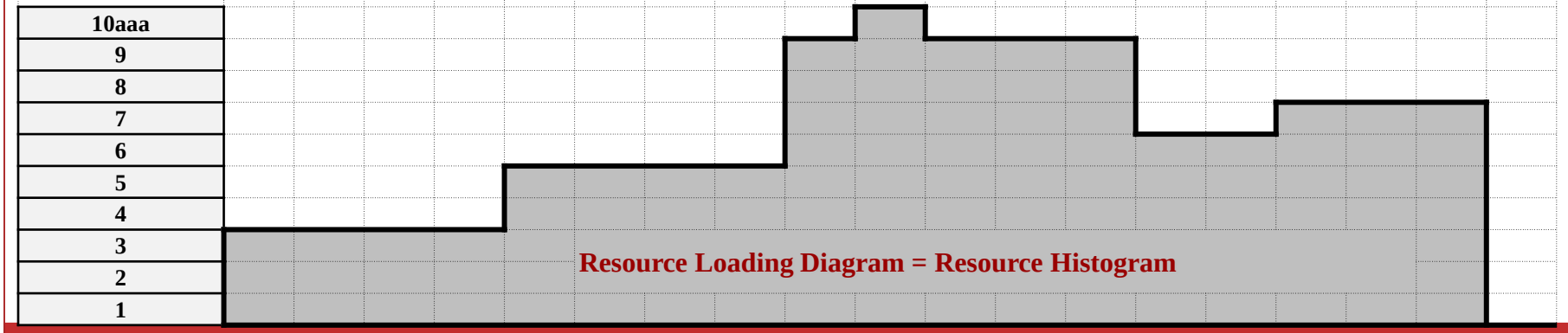
Resource Loading Diagram (Based on ES schedule)

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
		A				C					I			J			K		
	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	5	5	5	
				D			E												
				4	4	2	2	2											
							F												
						1	1	1											
			B				G					H							
	2	2	2	2	2	2	2	2	2	2	2	2	2	2					
R	5	5	5	9	9	9	9	9	6	5	5	5	5	6	4	5	5	5	
ΣR	5	10	15	24	33	42	51	60	66	71	76	81	86	92	96	101	106	111	
R^2	25	25	25	81	81	81	81	81	36	25	25	25	25	36	16	25	25	25	
ΣR^2	25	50	75	156	237	318	399	480	516	541	566	591	616	652	668	693	718	*743*	



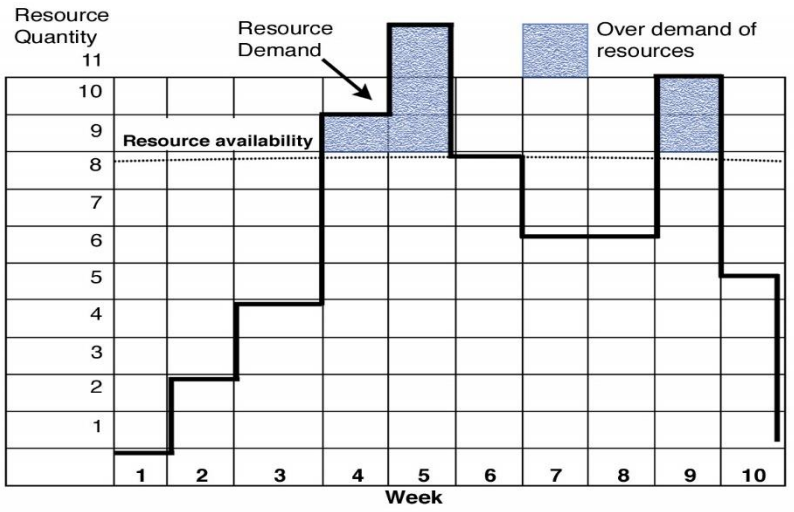
Resource Loading Diagram (Based on LS schedule)

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
		A				C					I			J			K	
	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	5	5	5
									D			E						
									4	4	2	2	2					
												F						
											1	1	1					
							B				G					H		
					2	2	2	2	2	3	3	3	3	2	2	2	2	2
R	3	3	3	3	5	5	5	5	9	10	9	9	9	6	6	7	7	7
ΣR	3	6	9	12	17	22	27	32	41	51	60	69	78	84	90	97	104	111
R^2	9	9	9	9	25	25	25	25	81	100	81	81	81	36	36	49	49	49
ΣR^2	9	18	27	36	61	86	111	136	217	317	398	479	560	596	632	681	730	*779*



Management of Resources—Resource Allocation (Main Aspects)

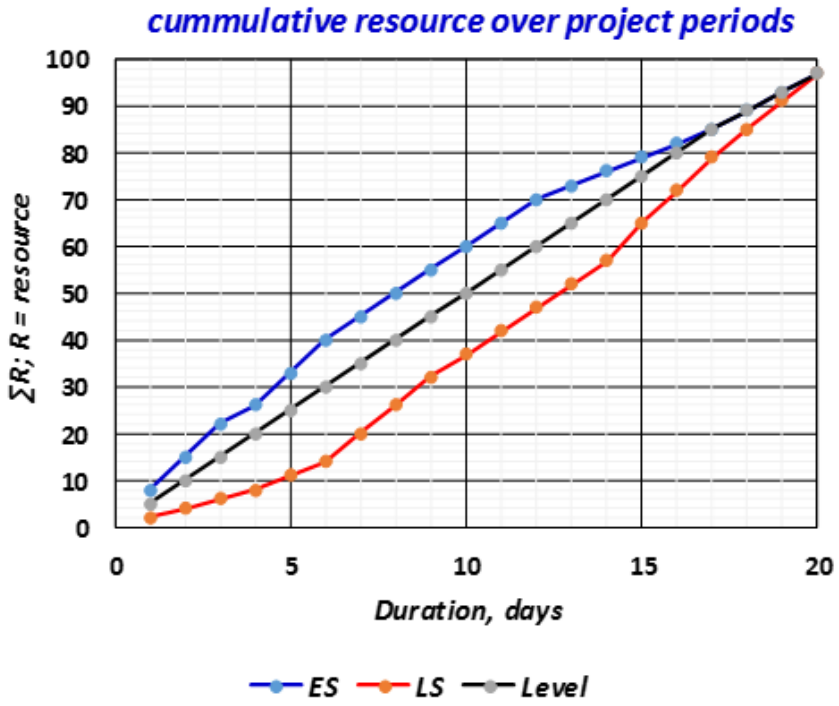
- Also often called *constrained-resource scheduling*
- There are definite limitations on the amount of resources available to carry out the project (or projects) under consideration.
- **Project duration may increase** beyond the initial duration determined by the usual "time only" CPM calculations.
- The **scheduling objective is to minimize the duration of the project** (or projects) being scheduled, **subject to stated constraints on available resources**.
- Note: Resource leveling ensures that resource demand does not exceed resource availability.



Cumulative Resource Requirement Curve

Cumulative resource requirement curve (*S*-curve) may be used for:

- Planning and Control of progress
- Preliminary resource allocation



Resource allocation measures

1 – Average daily requirement, $DR_A = \dfrac{\text{Total unit of resources}}{\text{project duration}} = \dfrac{T}{D}$

2- Criticality index, $I_C = \dfrac{DR_A}{A_{\max}}$

3- Effectiveness, $Eff = (DR_A)^2 \times D$

4 - Total units of resources; $T = \sum_{j=1}^{j=n} R_j$

5 - Sum of squares of rousources; SUM $= \sum_{j=1}^{j=n} R_j^2$

where,

D = Project duration

$A_{\max}$ = Maximum Avaliable Resourcs

n = Number of periods

Resource per period = R

Significance of Resource Criticality Index

$$I_C = \frac{DR_A}{A_{max}}$$

- Higher values of resource criticality index are associated with the most critical (i.e., most tightly constrained) resources.
- Values of resource criticality index significantly below 1.0 typically are associated with non-constraining resources.
- Values around and above 1.0 indicate that project delays (beyond the original critical path duration) will be encountered.

Scheduling Activities with Limited Resources

- Series Method
  - The series method relies on the assumption that once an activity has been started, it cannot be interrupted.
- Parallel Method
  - The parallel method is similar to the series method with one basic difference: The parallel method permits activities to be interrupted.

Series Method

- Schedule activities to **start as soon as their predecessors have been completed**
- Determine the **Eligible Activity Set (EAS)** i.e. those activities with all **predecessor activities completed**.
- From among the members of the current EAS, determine the **Ordered Scheduling Set (OSS)** of activities giving priority to the earliest **late start**
- If the activities are **tied** for the early late start date, give priority to the activity with **least activity duration**
- If the activities are **tied** for activity duration, give **priority to the activity with the largest number of resources**
- If no activity has been selected with the above rules, **start the activity that occurs first in the input order**

Form for the Resource Allocation

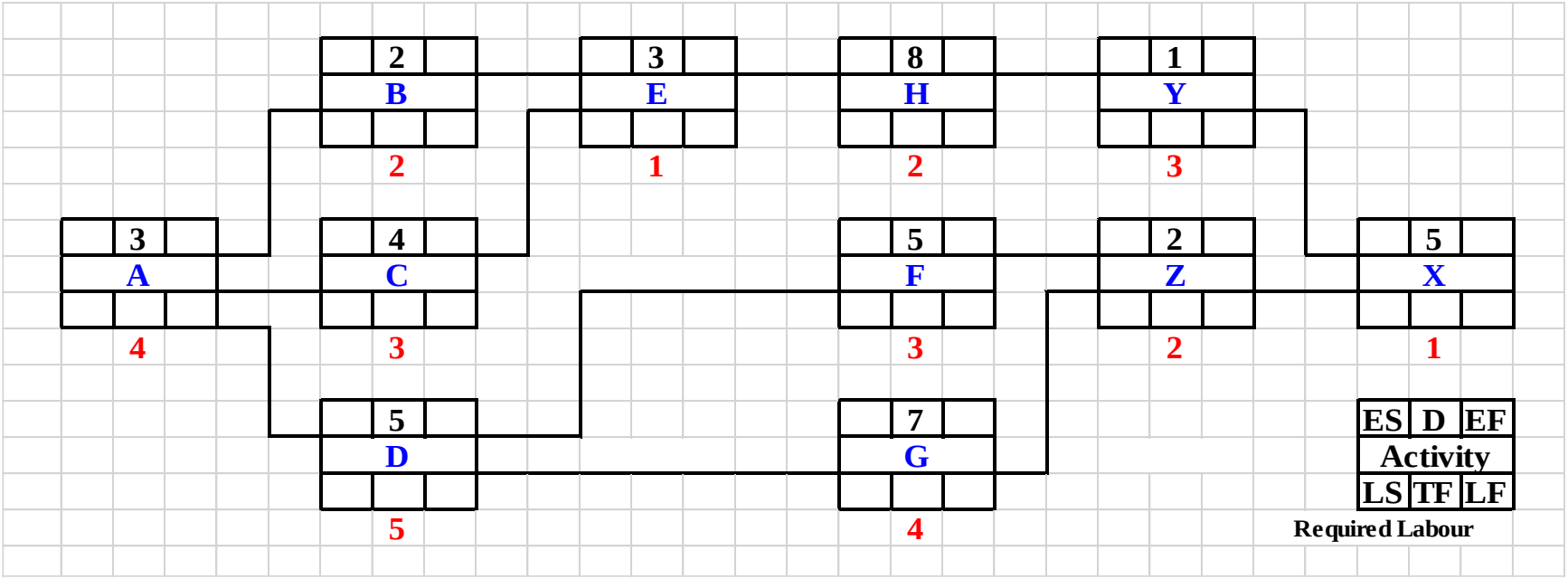
Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
EAS																															
OSS																															
use																															
R																															

Problem-1

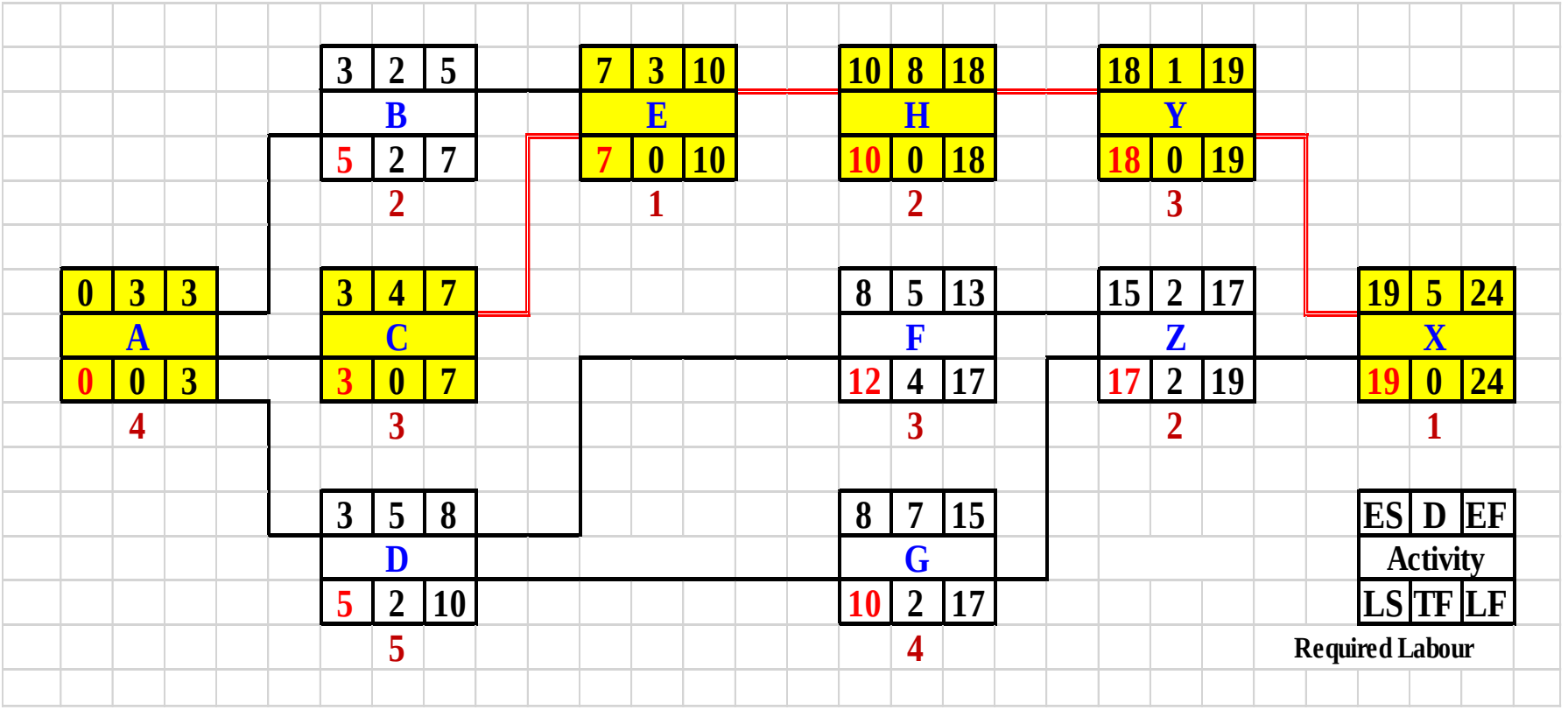
The work of a small engineering project is planned according to the AON shown below. The labour requirement of each activity is shown below each activity box.

(a) Calculate the requirements of labour each day when all the activities start at their (i) early start and (ii) late start.

(b) What will be the minimum contract duration if no more than 6 labours can be made available for the work and if it is assumed that having started an activity it must be completed without a break?



Solution


3 2 5
B
5 2 7
2
7 3 10
E
7 0 10
1
10 8 18
H
10 0 18
2
18 1 19
Y
18 0 19
3
0 3 3
A
0 0 3
4
3 4 7
C
3 0 7
3
8 5 13
F
12 4 17
3
15 2 17
Z
17 2 19
2
19 5 24
X
19 0 24
1
3 5 8
D
5 2 10
5
8 7 15
G
10 2 17
4
ES D EF
Activity
LS TF LF
Required Labour

EST

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A	4	4	4																					
C				3	3	3	3																	
E								1	1	1														
H											2	2	2	2	2	2	2	2						
Y																			3					
X																				1	1	1	1	1
B				2	2																			
D				5	5	5	5	5																
F									3	3	3	3	3											
G									4	4	4	4	4	4	4									
Z																2	2							
R	4	4	4	10	10	8	8	6	8	8	9	9	9	6	6	4	4	2	3	1	1	1	1	1
∑R	4	8	12	22	32	40	48	54	62	70	79	88	97	103	109	113	117	119	122	123	124	125	126	127
R^2	16	16	16	100	100	64	64	36	64	64	81	81	81	36	36	16	16	4	9	1	1	1	1	1
$\sum R^2$	16	32	48	148	248	312	376	412	476	540	621	702	783	819	855	871	887	891	900	901	902	903	904	905

LST

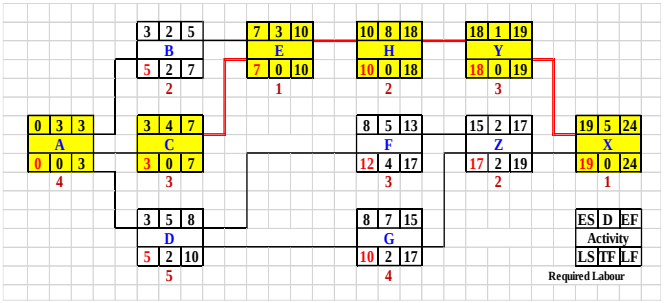
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
A	4	4	4																					
C				3	3	3	3																	
E								1	1	1														
H											2	2	2	2	2	2	2	2						
Y																			3					
X																				1	1	1	1	1
B						2	2																	
D						5	5	5	5	5														
F													3	3	3	3	3							
G											4	4	4	4	4	4	4							
Z																		2	2					
R	4	4	4	3	3	10	10	6	6	6	6	6	9	9	9	9	9	4	5	1	1	1	1	1
∑R	4	8	12	15	18	28	38	44	50	56	62	68	77	86	95	104	113	117	122	123	124	125	126	127
R^2	16	16	16	9	9	100	100	36	36	36	36	36	81	81	81	81	81	16	25	1	1	1	1	1
$\sum R^2$	16	32	48	57	66	166	266	302	338	374	410	446	527	608	689	770	851	867	892	893	894	895	896	897

Solution (a)

$DR_A = (\Sigma R/D) = 127/24 = 5.292$

$Eff = DR_A^2 \times D = (5.291)^2 \times 24 = 5.292 = 672.042$

Solution (b)

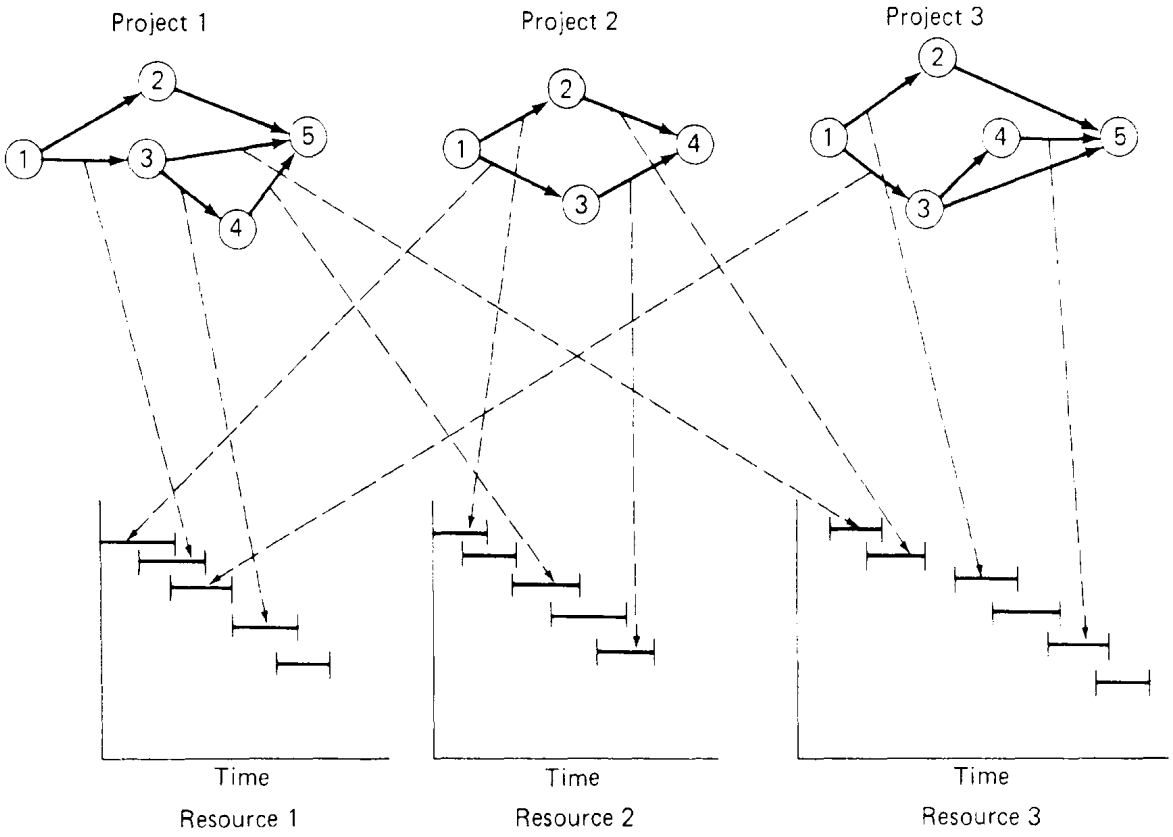


T	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
EAS	A			B C D	D	D	D	D E			H	H	H F G	F	F	F	F	F	F	F	Y				Z		X				
OSS	A			C B D				D E					G H F							F	Y				Z		X				
	A																														
	4	4	4	C																											
				3	3	3	3																								
				B																											
				2	2			D																							
								5	5	5	5	5																			
								E																							
								1	1	1			G																		
													4	4	4	4	4	4	4												
													H																		
													2	2	2	2	2	2	2	2											
																				F											
																				3	3	3	3	3							
																					Y										
																					3				Z						
																									2	2					
																											X				
																											1	1	1	1	1
R	4	4	4	5	5	3	3	6	6	6	5	5	6	6	6	6	6	6	6	5	6	3	3	3	2	2	1	1	1	1	1

R	4	4	4	5	5	3	3	6	6	6	5	5	6	6	6	6	6	6	6	5	6	3	3	3	2	2	1	1	1	1	1
ΣR	4	8	12	17	22	25	28	34	40	46	51	56	62	68	74	80	86	92	98	103	109	112	115	118	120	122	123	124	125	126	127
R^2	16	16	16	25	25	9	9	36	36	36	25	25	36	36	36	36	36	36	36	25	36	9	9	9	4	4	1	1	1	1	1
ΣR^2	16	32	48	73	98	107	116	152	188	224	249	274	310	346	382	418	454	490	526	551	587	596	605	614	618	622	623	624	625	626	***627***

Minimum contract duration if no more than 6 labours can be made available = 31 days

Multiple Project Scheduling Interactions



Example of multi project scheduling interactions

Further Reading

Read more about the resource allocation from:

Jimmie W. Hinze. “Construction Planning and Management,” Fourth Edition, 2012, Pearson.

Thank You

Questions Please