Allocate and Level Project Resources

■ Resource Allocation: Defined

<u>Resource Allocation</u> is the ***scheduling of activities and the resources*** required by those activities while taking into consideration both the <u>resource availability and the project time</u>.

■ Resource Allocation: Defined

- ***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*** to with cost considerations
    - ❖Specialized or additional equipment/material
    - ❖Extra labor (e.g., borrowed staff, temps)
    - ❖More hours (e.g., overtime, weekends)

■ *Resource Levelling: Defined*

Resource leveling is a technique used to examine unbalanced use of resources (usually people or equipment) over time, and for resolving over-allocations or ***conflicts*** resulting from scheduling certain tasks ***simultaneously.*** Such conflicts are:

- ❖ *more resources such as* ***machines or people*** *are needed than are available,* ***or***
- ❖ *a specific person is needed in both tasks, the tasks will have to be rescheduled concurrently or even sequentially to manage the constraint.*

It is used to balance the workload of primary resources over the course of the project[s], usually at the expense of one of the traditional triple constraints ***(time, cost, scope).***

■ Why Resource Allocations and Leveling is important?

- ***To complete and finalize project schedule*** for completion of the project at maximum efficiency of time and cost *(Project network times are not a schedule until resources have been assigned because the basic PERT/CPM procedures are limited in the sense that resource availabilities are* ***not*** *considered in the scheduling process. The procedures assume that available resources are* ***unlimited****).*

- ***To smooth the use of resources*** for better assignment and levelling of **Manpower, equipment, materials, subcontractors, and information** *(better managing of resource utilization over the life of the project)*

- ***To estimate cost properly*** for finding optimum project budget (money resource) and close management control *(cost and a budget can not developed until they have been time-phased with resources assigned)*

- ***To schedule resource constraints properly*** to take care of shortage of resources *(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)*

■ Objective of Resource 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.

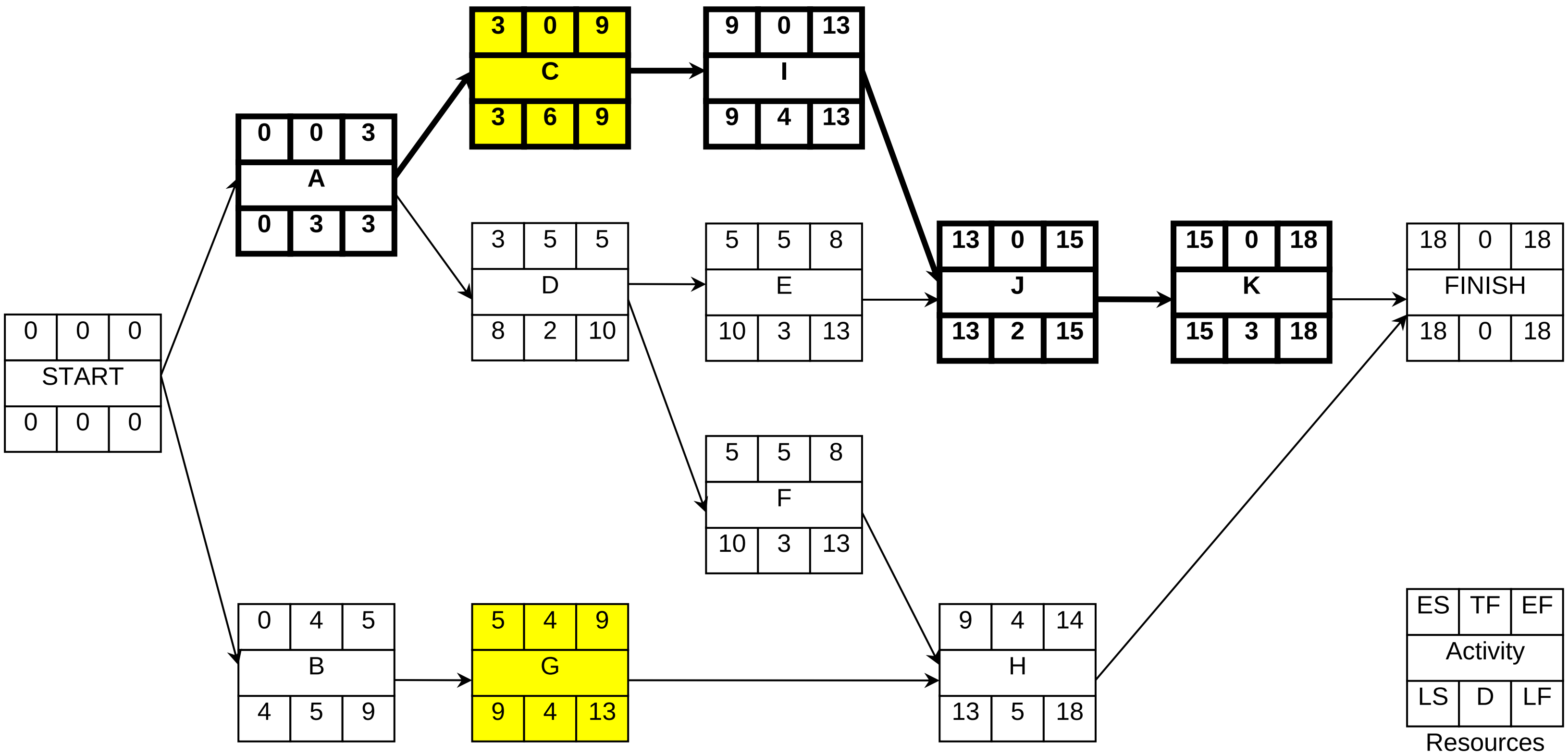
Hence, the goal is to optimize use of limited resources

This Requires making trade-offs

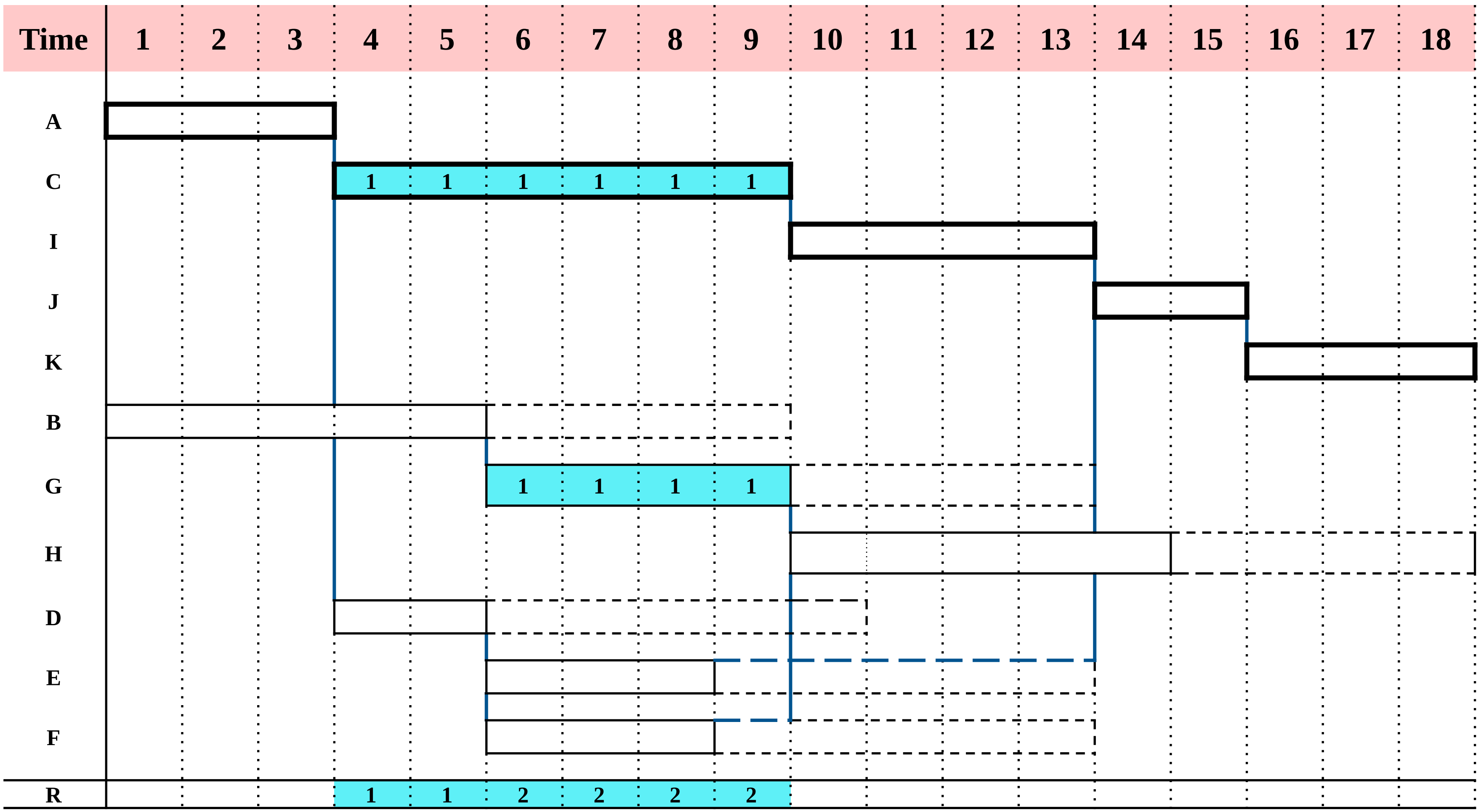
- time constrained
- resource constrained

■ *How limited resources affect schedule slack?*

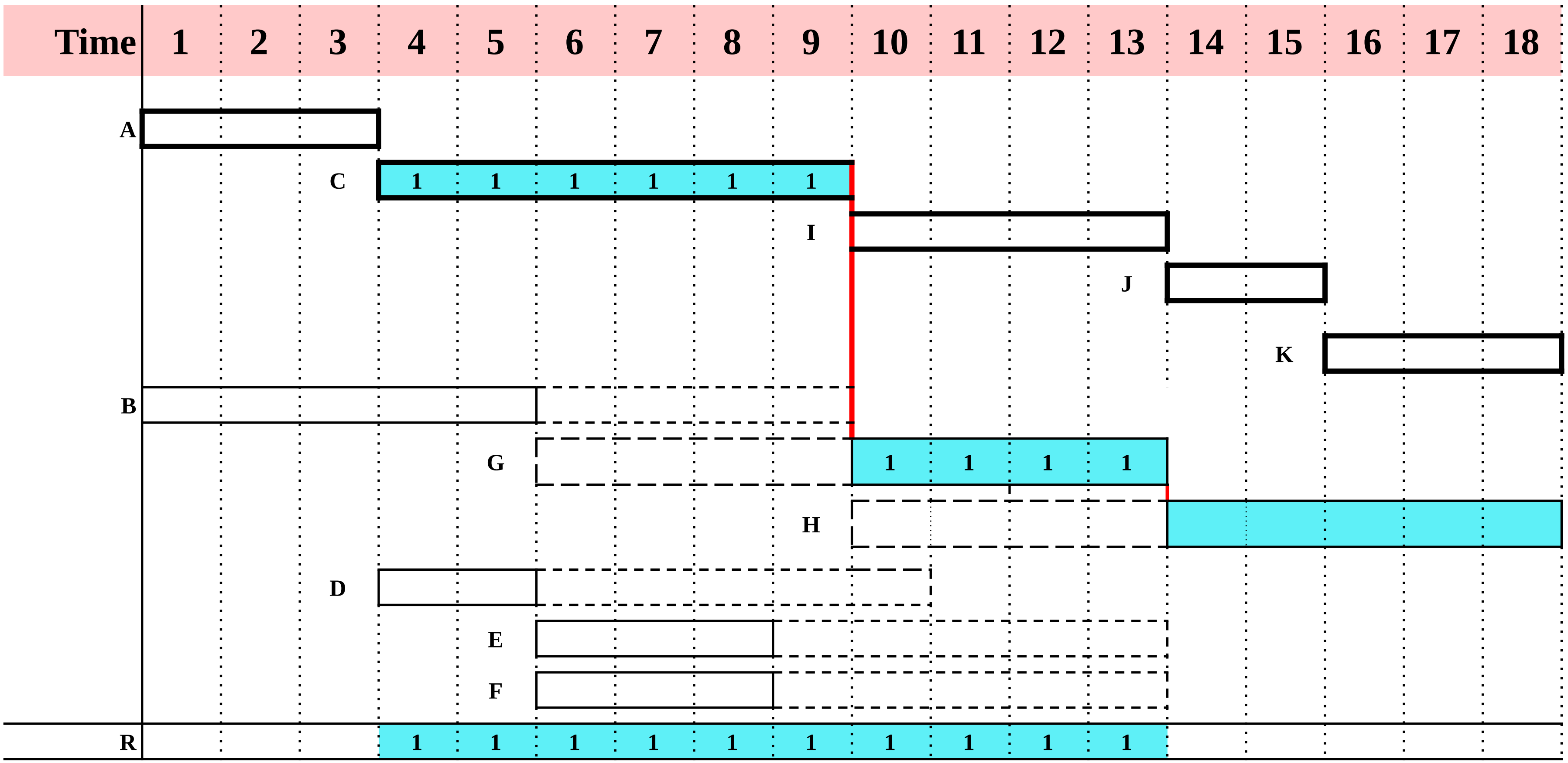
Assume that activities "**C**" and "**G**" each require the use of a special piece of equipment, such a hoist crane. But only one crane is available.



■ How limited resources affect schedule slack?



■ How limited resources affect schedule slack?



■ *How limited resources affect schedule slack?*

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.

In general, the following is true:

- ❑ 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*

Project Resource Requirement = Resource Loading Diagram = Resource Histogram = *Resource Profile and S curve*

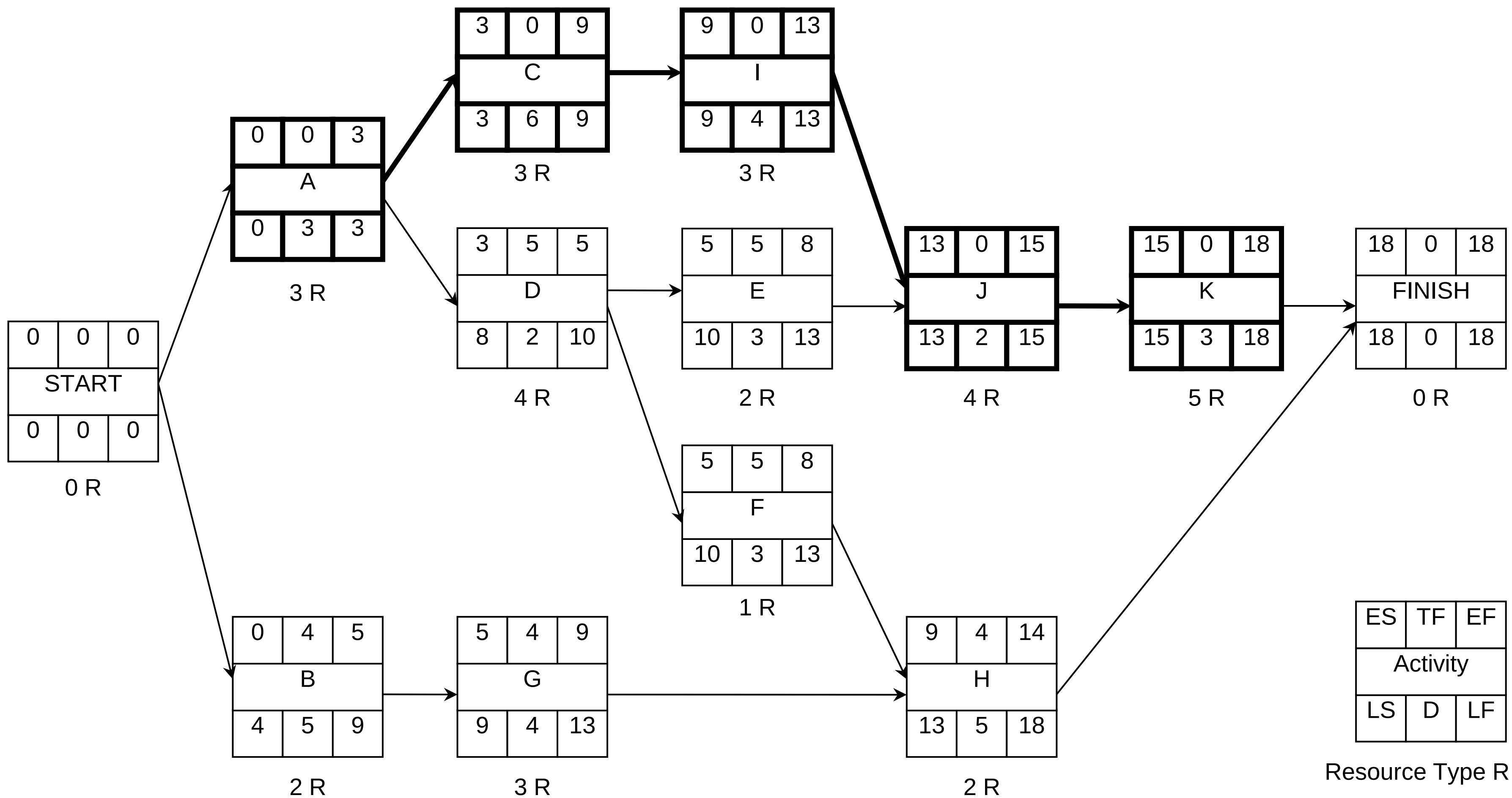
We need:

- ***Project network.***
- ***Resource requirement for each activity.***
- ***Bar chart or time-scaled network.***

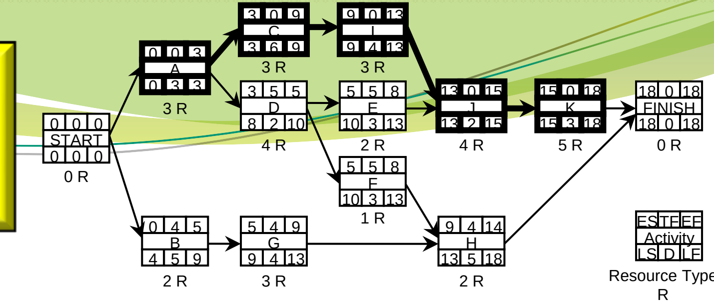
***We make*:**

- Resource loading diagram (a diagram that highlights the period-by-period resource implications of a particular project schedule).
- Period-by-period total requirements of units of resources.
- Cumulative resource requirement curve (S curve).

■ Resource Loading Diagram

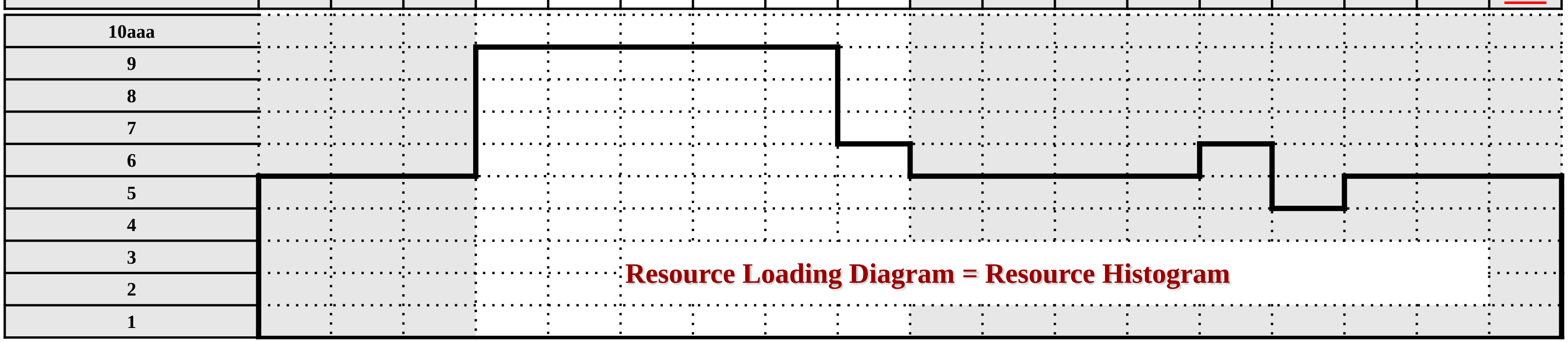


■ Resource Loading Diagram based on ES schedule

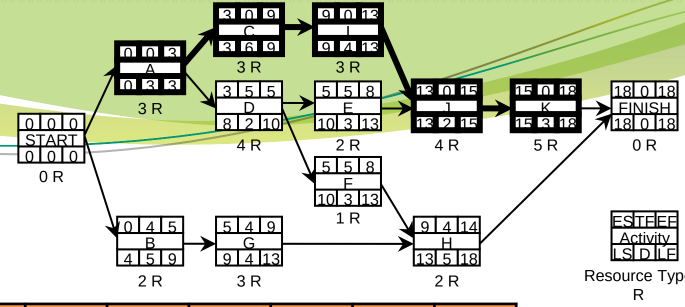


Activity \ Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B	2	2	2	2	2													
G						3	3	3	3									
H										2	2	2	2	2				
D				4	4													
E						2	2	2										
F						1	1	1										

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*

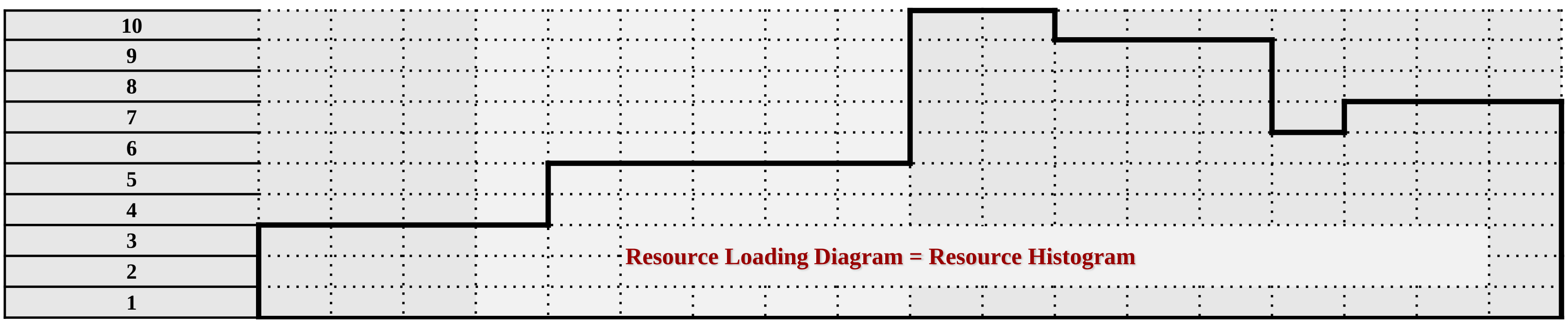


Resource Loading Diagram based on LS schedule



Activity \ Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B					2	2	2	2	2									
G										3	3	3	3					
H														2	2	2	2	2
D										4	4							
E												2	2	2				
F												1	1	1				

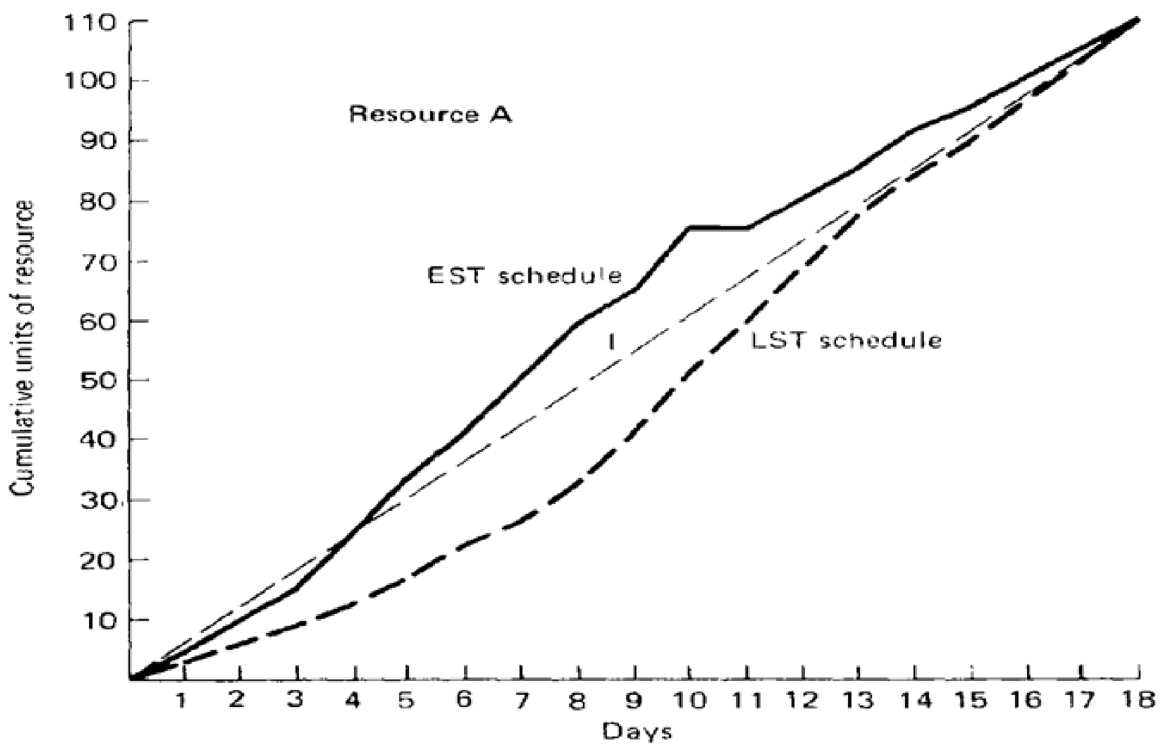
R	3	3	3	3	5	5	5	5	5	10	10	9	9	9	6	7	7	7
ΣR	3	6	9	12	17	22	27	32	37	47	57	66	75	84	90	97	104	111
R^2	9	9	9	9	25	25	25	25	25	100	100	81	81	81	36	49	49	49
ΣR^2	9	18	27	36	61	86	111	136	161	261	361	442	523	604	640	689	738	*787*



■ *Cumulative Resource Requirement Curve*

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

- ❑ Planning and Control of progress
- ❑ Preliminary resource allocation



Cumulative resource requirements of resource A, network

■ Resource Constraint "Criticality"

1.Average Daily Requirement

Avg. daily requirement = 111 / 18 = 6.2 units/day

Suppose the analyzed resource is available at a maximum level of 7 units/day.

∴ 126 units could be expended over the 18-day project duration, which is more than 111 units. ∴ Project delay is unlikely..

$$DR_A = \frac{T}{D}$$

where ;

DR_A = Avg. daily requirement

T = Total unit of resources

D = Project duration

2.Resource Criticality Index

∴ Criticality index = 6.2/7.0 = 0.88 < 1 ∴ project on time

Suppose the analyzed resource is available at a maximum level of 6 units/day.

∴ Criticality index = 6.2/6.0 = 1.03 > 1 ∴ project will delay

In 18 days a total of only 108 units are will be expended (< 111 units), leaving some work unfinished and thus requiring an extension of the project beyond 18 days.

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

where ;

I_C = Criticality index

DR_A = avg. daily units req'd

A_{Max} = max. am't avail. Daily

■ *Resource Constraint "Criticality"*

2. Resource Criticality Index

- Values of resource criticality index significantly **below** 1.0 typically are associated with **non-constraining** resources, while values around and above 1.0 indicate that project delays beyond the original critical path duration will be encountered.

- **Higher values** of resource criticality index are associated with the most critical (i.e., most tightly **constrained**) resources.

■ *Resource Leveling and Allocation*

- Scheduling Procedures for Dealing with Resource Constraints
  - Resource Leveling (Resource Smoothing)
  - Fixed-limits Resource Scheduling (Limited Resource Allocation)

■ Resource Leveling (Smoothing)

Main Aspects

- ❑ Sufficient **total** resources are available
- ❑ Project must be completed by a specified due date
- ❑ It is desirable or necessary to reduce the amount of **variability (peak and valley)** in the pattern of resource usage over the project duration.
- ❑ The objective is to **level**, as much as possible, the demand for each specific resource during the life of the project.
- ❑ **Project duration is not allowed to increase** in this case.

■ *Fixed Resource Limits Scheduling*

Main Aspects

- Also often called **constrained-resource scheduling**, or **limited resource allocation**
- Much more common
- 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 equivalent to minimizing the duration of the project (or projects) being scheduled, subject to stated constraints on available resources.

■ *Basic General Approach*

The basic general approach followed in both resource leveling and fixed resource limits scheduling is similar:

- Set activity priorities according to some criterion and then

- Schedule activities in the order determined, as soon as their predecessors are completed and adequate resources are available

■ *Resource Leveling (Smoothing)*

- Resource leveling techniques provide a means of distributing resource usage over time ***to minimize the period-by-period variations*** in manpower, equipment, or money expended.

- The essential idea of resource leveling centers about the ***rescheduling of activities within the limits of available float*** to achieve better distribution of resource usage.

- A systematic procedure for leveling resources was developed by ***Burgess.***

- Burgess method utilized a **simple measure of effectiveness** given by the **sum of the squares of the resource requirements for each "day"** (period) in the project schedule.

■ Resource Leveling (Smoothing)

- While the ***sum of daily resource requirements*** over the project duration is **constant** for all complete schedule, the **sum of the squares of the daily requirements decreases as the peaks and valleys are leveled.**

- The measure of effectiveness reaches a minimum for a schedule that is level and equals =

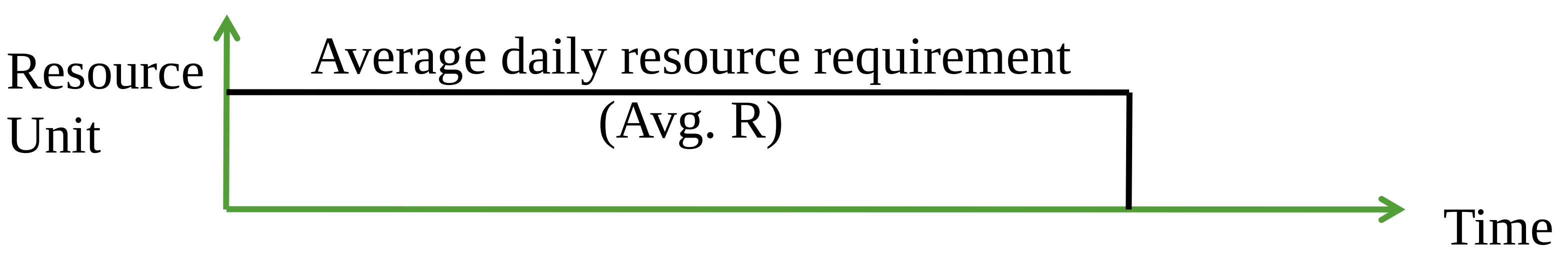
$$Eff = (DR)^2 \times D$$

where ;

Eff = Effectiveness

DR = Average daily requirement

D = Project duration



■ *Burgess Leveling Procedure*

Step 1. List the project activities in order of precedence. Add to this listing the duration, early start, and float (slack) values for each activity.

Step 2. Starting with the ***last*** activity, schedule it period by period to give the ***lowest*** sum of squares of resource requirements for each time unit. If more than one schedule gives the same total sum of squares, then schedule the activity ***as late as possible*** to get as much slack as possible in all preceding activities.

Step 3. Holding the last activity fixed, repeat Step 2 on the ***next to the last*** activity in the network, taking advantage of any slack that may have been made available to it by the rescheduling in Step 2.

Step 4. Continue Step 3 until the first activity in the list has been considered; this completes the ***first rescheduling cycle***.

■ *Burgess Leveling Procedure*

Step 5. Carry out additional rescheduling cycles by repeating Steps 2 through 4 until no further reduction in the total sum of squares of resource requirements is possible, noting that ***only movement of an activity to the right (schedule later)*** is permissible under this scheme.

Step 6. If this resource is particularly ***critical,*** repeat Steps 1 through 5 on a ***different ordering*** of the activities. which, of course, must still list the activities in order of precedence.

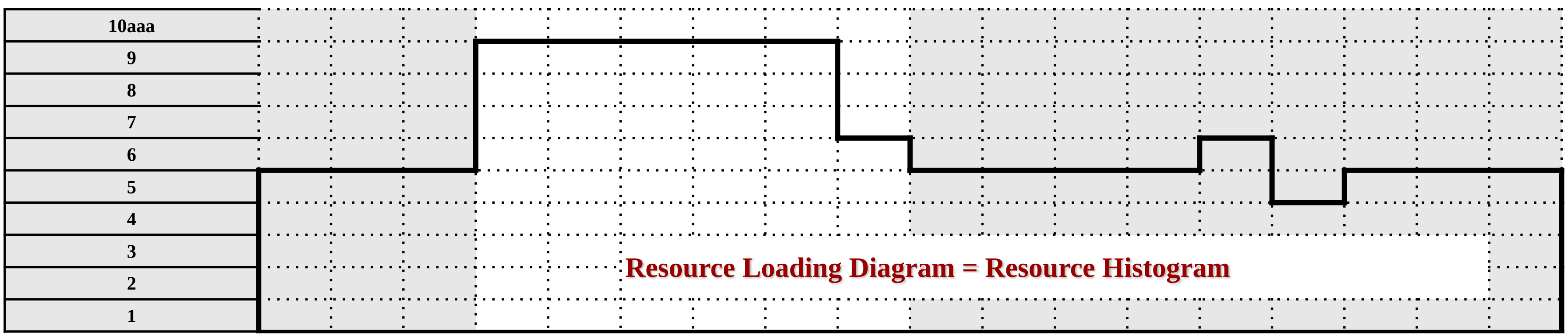
Step 7. Choose the best schedule of those obtained in Steps 5 and 6.

Step 8. Make final adjustments to the schedule chosen in Step 7, taking into account factors not considered in the basic scheduling procedure.

■ Application of Burgess Procedure (initial)

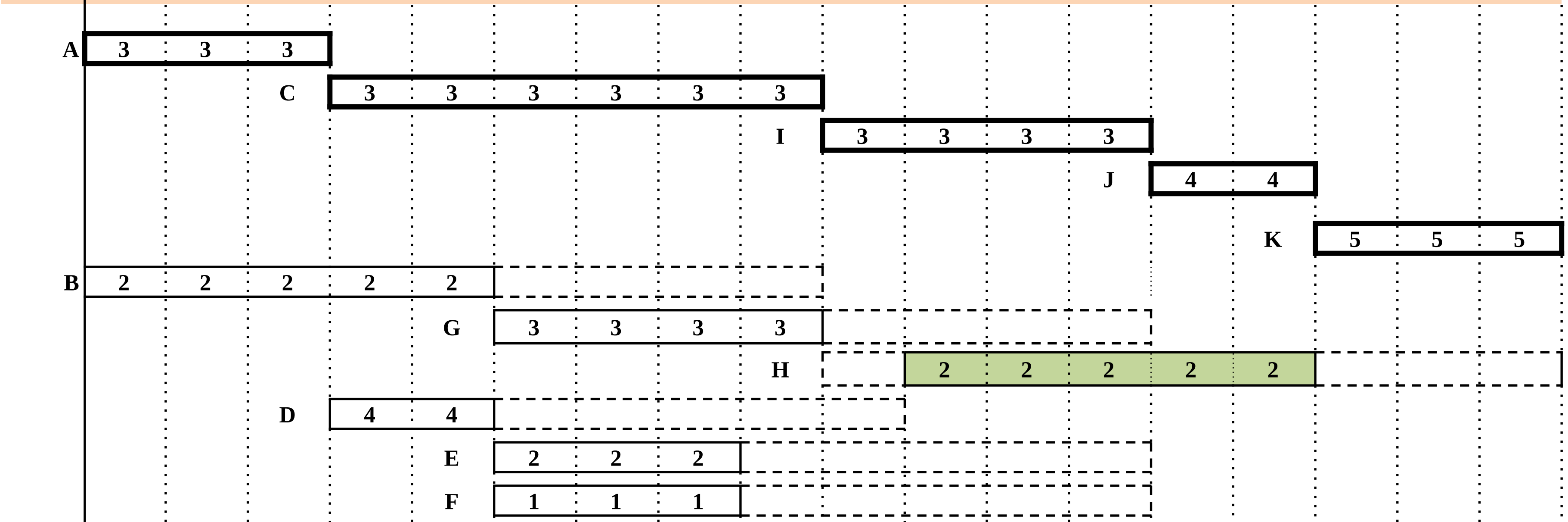
Activity \ Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B	2	2	2	2	2													
G						3	3	3	3									
H										2	2	2	2	2				
D				4	4													
E						2	2	2										
F						1	1	1										

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



■ Application of Burgess Procedure

Start with Delay activity "H" <u>one</u> period



Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
R	5	5	5	9	9	9	9	9	6	3	5	5	5	6	6	5	5	5
R^2	25	25	25	81	81	81	81	81	36	9	25	25	25	36	36	25	25	25

Delay activity "H" <u>one</u> period .: $\sum R^2 = 747$

■ *Application of Burgess Procedure*

with Delay activity "H" 2 periods

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B	2	2	2	2	2													
G						3	3	3	3									
H												2	2	2	2	2		
D				4	4													
E						2	2	2										
F						1	1	1										
R	5	5	5	9	9	9	9	9	6	3	3	5	5	6	6	7	5	5
R^2	25	25	25	81	81	81	81	81	36	9	9	25	25	36	36	49	25	25

Delay activity "H" 2 periods ∴ $\sum R^2 = 755$

■ *Application of Burgess Procedure*

with Delay activity "H" 3 periods

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B	2	2	2	2	2													
G						3	3	3	3									
H													2	2	2	2	2	
D				4	4													
E						2	2	2										
F						1	1	1										
R	5	5	5	9	9	9	9	9	6	3	3	3	5	6	6	7	7	5
R^2	25	25	25	81	81	81	81	81	36	9	9	9	25	36	36	49	49	25

Delay activity "H" 3 periods $\therefore \sum R^2 = 763$

Application of Burgess Procedure

with Delay activity “H” 4 periods

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B	2	2	2	2	2													
G						3	3	3	3									
H														2	2	2	2	2
D				4	4													
E						2	2	2										
F						1	1	1										
R	5	5	5	9	9	9	9	9	6	3	3	3	3	6	6	7	7	7
R^2	25	25	25	81	81	81	81	81	36	9	9	9	9	36	36	49	49	49

Delay activity “H” 4 periods $\therefore \sum R^2 = 771$

Hence, $\therefore$ Lowest $\sum R^2 = 747$ with Delay activity “H” 1 period

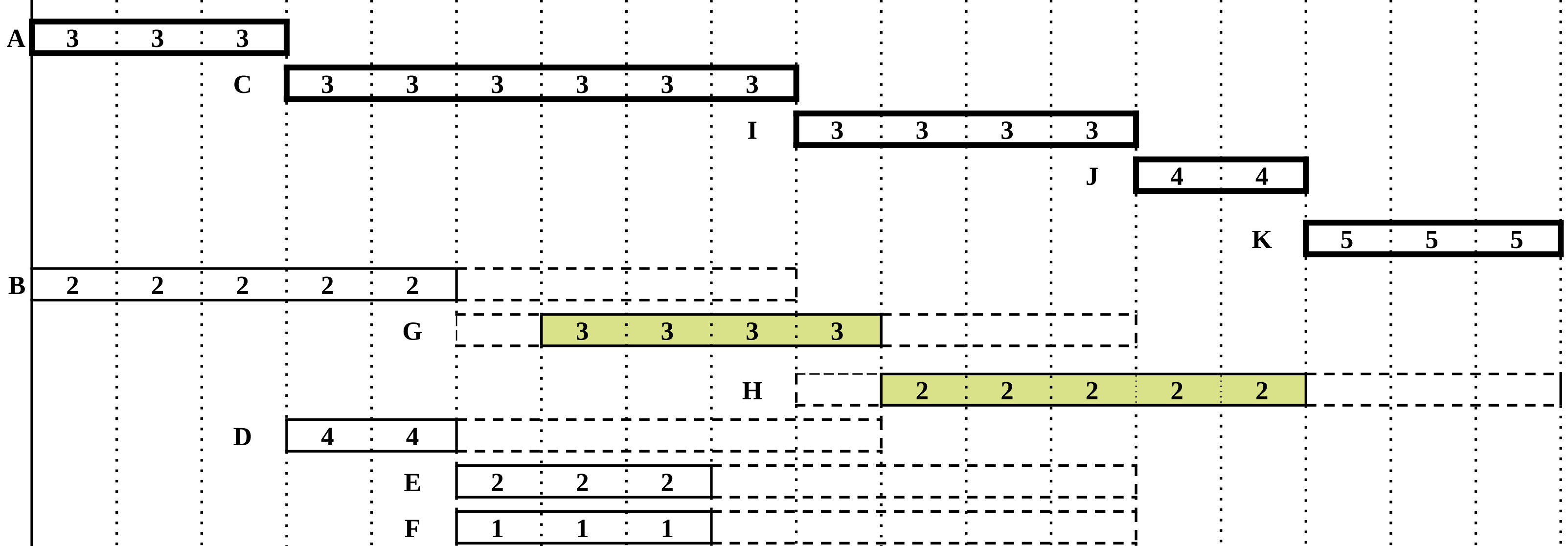
■ *Application of Burgess Procedure*

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B	2	2	2	2	2													
G						3	3	3	3									
H											2	2	2	2	2			
D				4	4													
E						2	2	2										
F						1	1	1										
R	5	5	5	9	9	9	9	9	6	3	5	5	5	6	6	5	5	5
R^2	25	25	25	81	81	81	81	81	36	9	25	25	25	36	36	25	25	25

The result = Delay activity "H" <u>one</u> period .: $\sum R^2 = 747$

■ Application of Burgess Procedure

Start Delay activity "G" 1 period



Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
R	5	5	5	9	9	6	9	9	6	6	5	5	5	6	6	5	5	5
R^2	25	25	25	81	81	36	81	81	36	36	25	25	25	36	36	25	25	25

Delay activity "H" one period & Delay activity "G" one period $\therefore \sum R^2 = 729$

■ Application of Burgess Procedure

Continue Delay activities of non critical

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B	2	2	2	2	2													
G							3	3	3	3								
H											2	2	2	2	2			
D						4	4											
E											2	2	2					
F								1	1	1								
R	5	5	5	5	5	7	10	7	7	7	7	7	7	6	6	5	5	5
R^2	25	25	25	25	25	49	100	49	49	49	49	49	49	36	36	25	25	25

Delay activity "H" 1 period, Delay activity "G" 1 period, Delay activity "F" 2 periods, Delay activity "E" 5 periods, and Delay activity "D" 2 periods $\therefore \sum R^2 = 715$

■ *Application of Burgess Procedure*

Minimum values results are:

<u>Sequence of major moves of the first rescheduling cycle</u>:

Delay activity "H" one period $\therefore \sum \mathbf{R^2 = 747}$

Delay activity "G" one period $\therefore \sum \mathbf{R^2 = 729}$

Delay activity "F" two periods $\therefore \sum \mathbf{R^2 = 727}$

Delay activity "E" five periods $\therefore \sum \mathbf{R^2 = 723}$

■ Estimated Method

Step 1: *Draw the network in a time scaled diagram using the early start schedule method.*

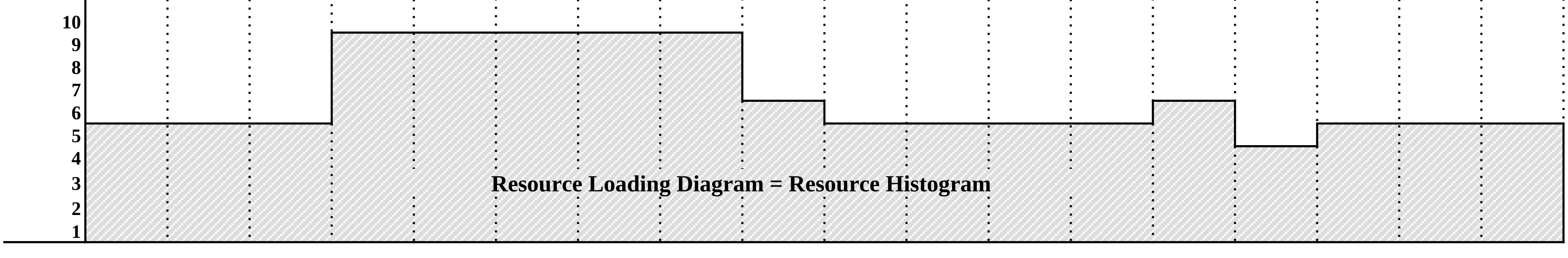
Step 2: *Perform resource loading for the activities* and calculate the total number of resources at each period.

Step 3: *Reschedule non-critical activities to reduce peaks* and to smooth resource usage in the resource loading chart in order to ***minimize SUM*** Y_i^2, where Y_i is the number of resource usage in the resource loading chart.

Step 4: Continue Step 3 until you reach the schedule of having minimum value of *SUM* Y_i^2.

Resource Leveling within the limits of available Floats

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

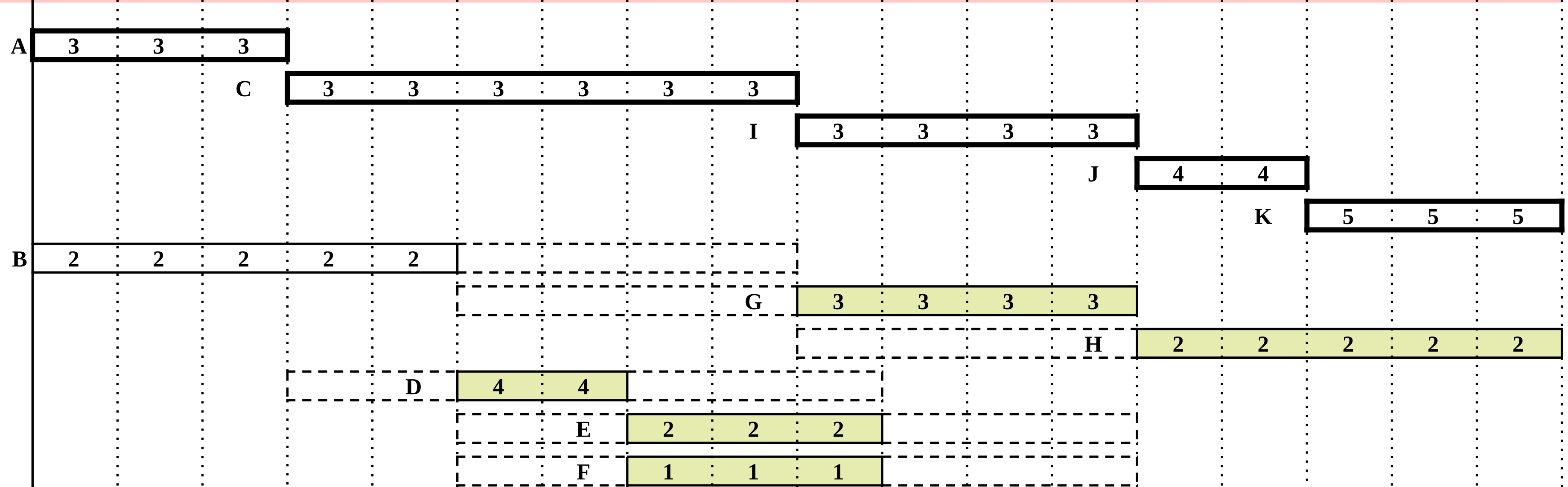


■ First Trial

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B	2	2	2	2	2													
G										3	3	3	3					
H														2	2	2	2	2
D				4	4													
E						2	2	2										
F						1	1	1										
R	5	5	5	9	9	6	6	6	3	6	6	6	6	6	6	7	7	7
R^2	25	25	25	81	81	36	36	36	9	36	36	36	36	36	36	49	49	49

Delay activity "H" 4 periods & Delay activity "G" 4 period $\therefore \sum R^2 = 717$

■ Second Trial



Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
R	5	5	5	5	5	7	7	6	6	9	6	6	6	6	6	7	7	7
R^2	25	25	25	25	25	49	49	36	36	81	36	36	36	36	36	49	49	49

Delay activity "H" 4 periods, Delay activity "G" 4 periods, Delay activity "E" 2 periods, Delay activity "F" 2 periods, and Delay activity "D" 2 periods $\therefore \sum R^2 = 703$

■ Another Trial

Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
A	3	3	3															
C				3	3	3	3	3	3									
I										3	3	3	3					
J														4	4			
K																5	5	5
B	2	2	2	2	2													
G										3	3	3	3					
H														2	2	2	2	2
D						4	4											
E								2	2	2								
F											1	1	1					
R	5	5	5	5	5	7	7	5	5	8	7	7	7	6	6	7	7	7
$\sum R^2$	25	50	75	100	125	174	223	248	273	337	386	435	484	520	556	605	654	*703*

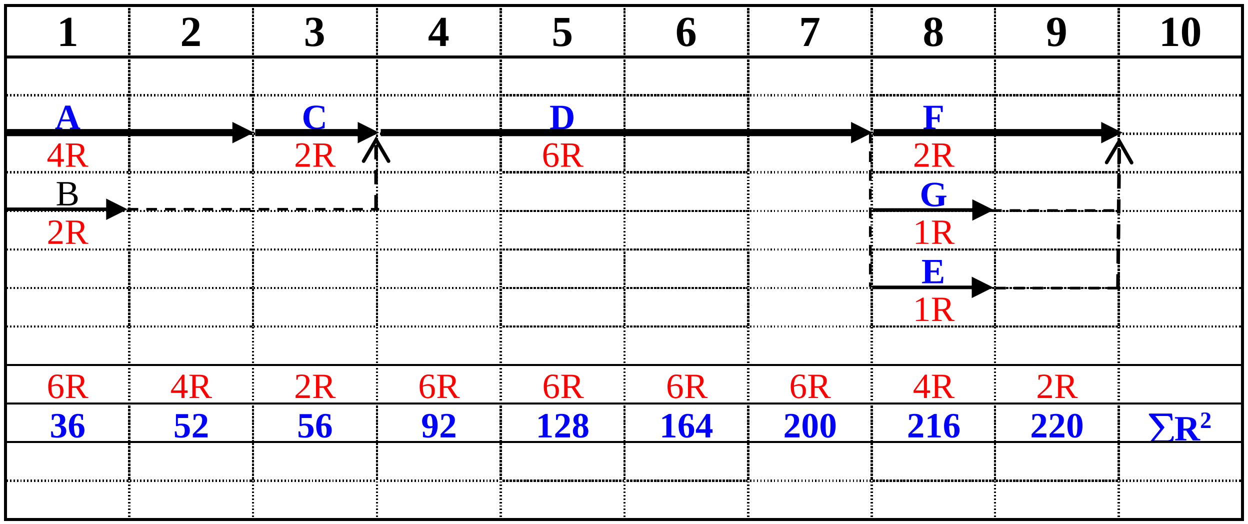
Delay activity "H" 4 periods, Delay activity "G" 4 periods, Delay activity "F" 5 periods, Delay activity "E" 2 periods, and Delay activity "D" 2 periods ∴ $\sum R^2 = 703$

■ Example 2

Data for small project is listed below:

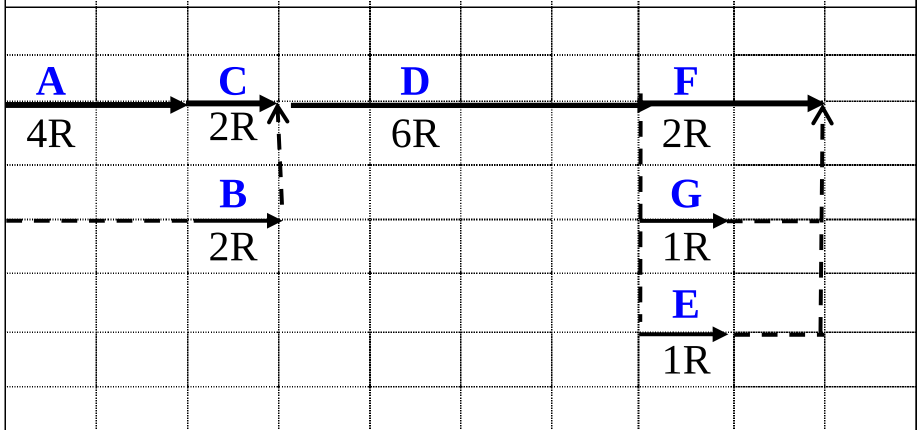
Activity	Depends on	Duration	Resource Rate	Activity	Depends on	Duration	Resource Rate
A	—	2	4	F	D	2	2
B	—	1	2	G	D	1	1
C	A	1	2	E	D	1	1
D	B, C	4	6				

1. Draw <u>Early Start Time-scaled</u> schedule and calculate the corresponding used resource.



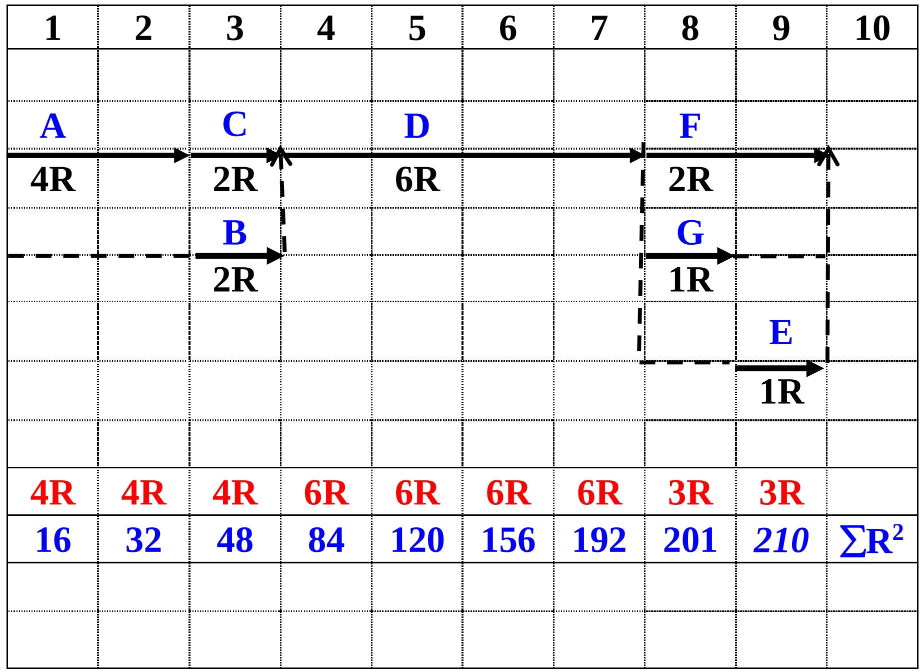
2. Perform 2 trials Resource Leveling. Also, specify which one of the two trials Time-scaled schedules is the final schedule and why..

■ Example 2 (First Trial)



1	2	3	4	5	6	7	8	9	10
4R	4R	4R	6R	6R	6R	6R	4R	2R	
16	32	48	84	120	156	192	208	212	$\sum R^2$

■ Example 2 (Second Trial)



The 2nd trial schedule is the best Resource Leveling result because it has ***lowest*** $\boldsymbol{\sum R^2}$.

■ Limited Resource Allocation

START

↓

Set ES of the START activity equals 1, calculate initial early start (ES) and late start (LS) time for each activity in the project, and set time now equal to 1, i.e., $T = 1$.

↓

Determine the initial eligible activity set (EAS), i.e., those activities with $ES \leq T$ and with all predecessor activities completed.

↓

From among the members of the current EAS, determine the ordered scheduling set (OSS) of activities, i.e., activities with $ES \leq T$, ordered according to LS with smallest values first and within this characteristic, according to least activity duration first.

↓

Consider the activities in OSS in the order listed and schedule those activities for which sufficient resources are available for the duration of the activity. As activities are scheduled update the level of resources available, and update the members of EAS.

↓

Have all activities been scheduled, i.e., is EAS an empty set?

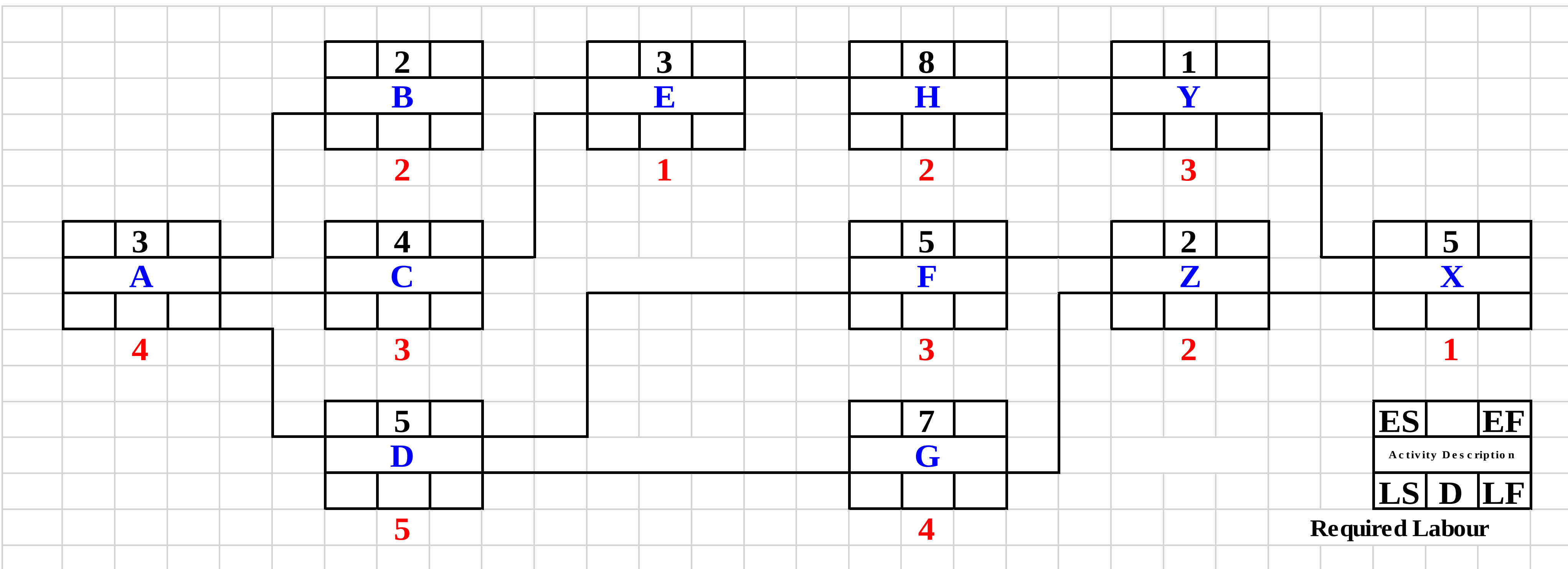
Yes → STOP

No ↓

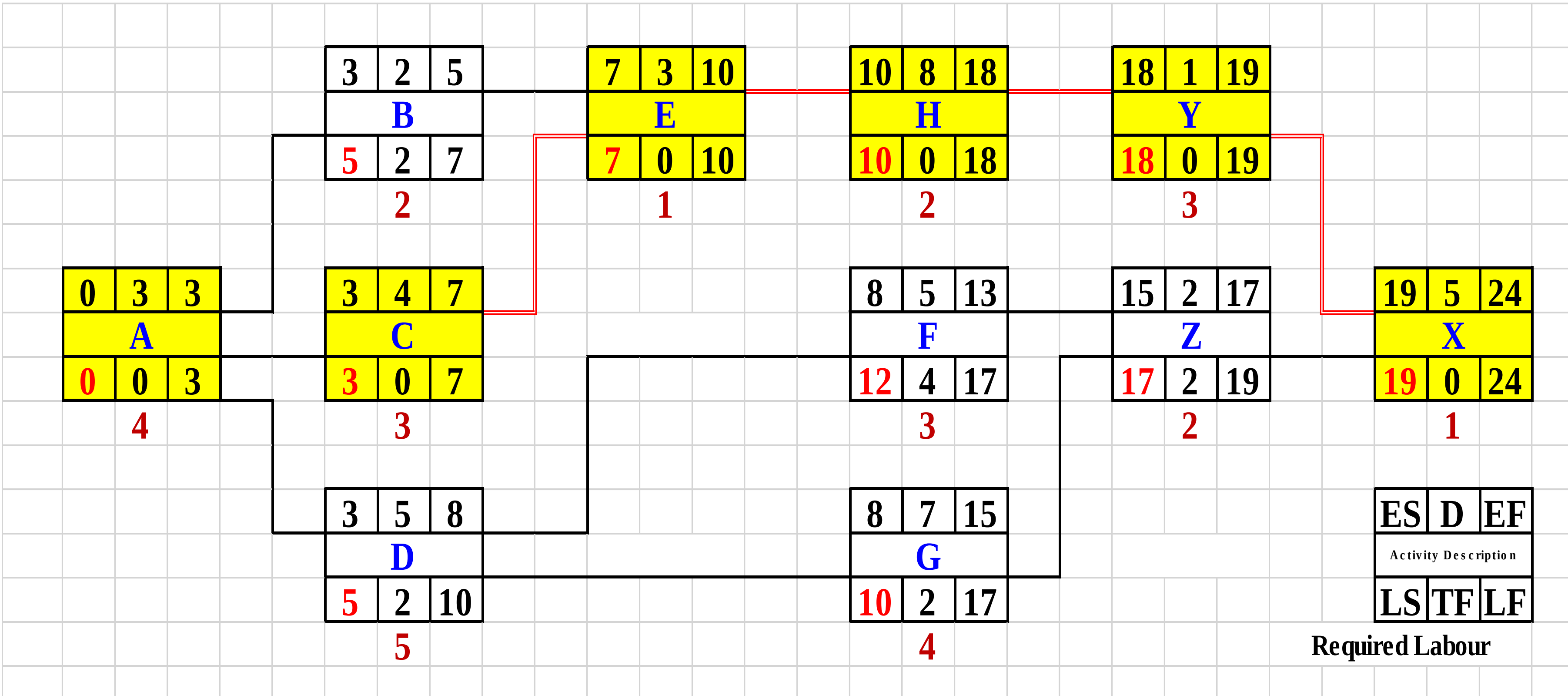
Set $T_{new} = T_{old} + 1$ and compute new *ES* times for the updated EAS. (→ loops back to the OSS step)

■ Example

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. 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?



■ Example



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 Description
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
ΣR	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
ΣR^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

DR =(ΣR/D) =

127/24 = 5.292

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
ΣR	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
ΣR^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

Eff =DR²*D =

$(5.291)^2 * 24 =$

5.292 =672.042

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																															
Daily R																															

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
E A S	A			B C D	D	D	D	D E			H	H	H F G	F	F	F	F	F	F	F	Y				Z		X				
O S S	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***

■ *Another Procedure*

Step 1: T = 1
ES ≤ 1
E.A.S. {A}
O.S.S. {A}

Step 2: T = 4
ES ≤ 4
E.A.S. {B, C, D}
LS 6, 4, 6
D 2, 4, 5
O.S.S. {C, B, D}

Step 3: T = 8
ES ≤ 8
E.A.S. {E, D}
LS 8, 6
O.S.S. {D, E}

Step 4: T = 13
ES ≤ 13
E.A.S. {H, F, G}
LS 11,13, 11
D 8, 5, 7
O.S.S. {G, H, F}

Step 5: T = 20
ES ≤ 20
E.A.S. {F}
O.S.S. {F}

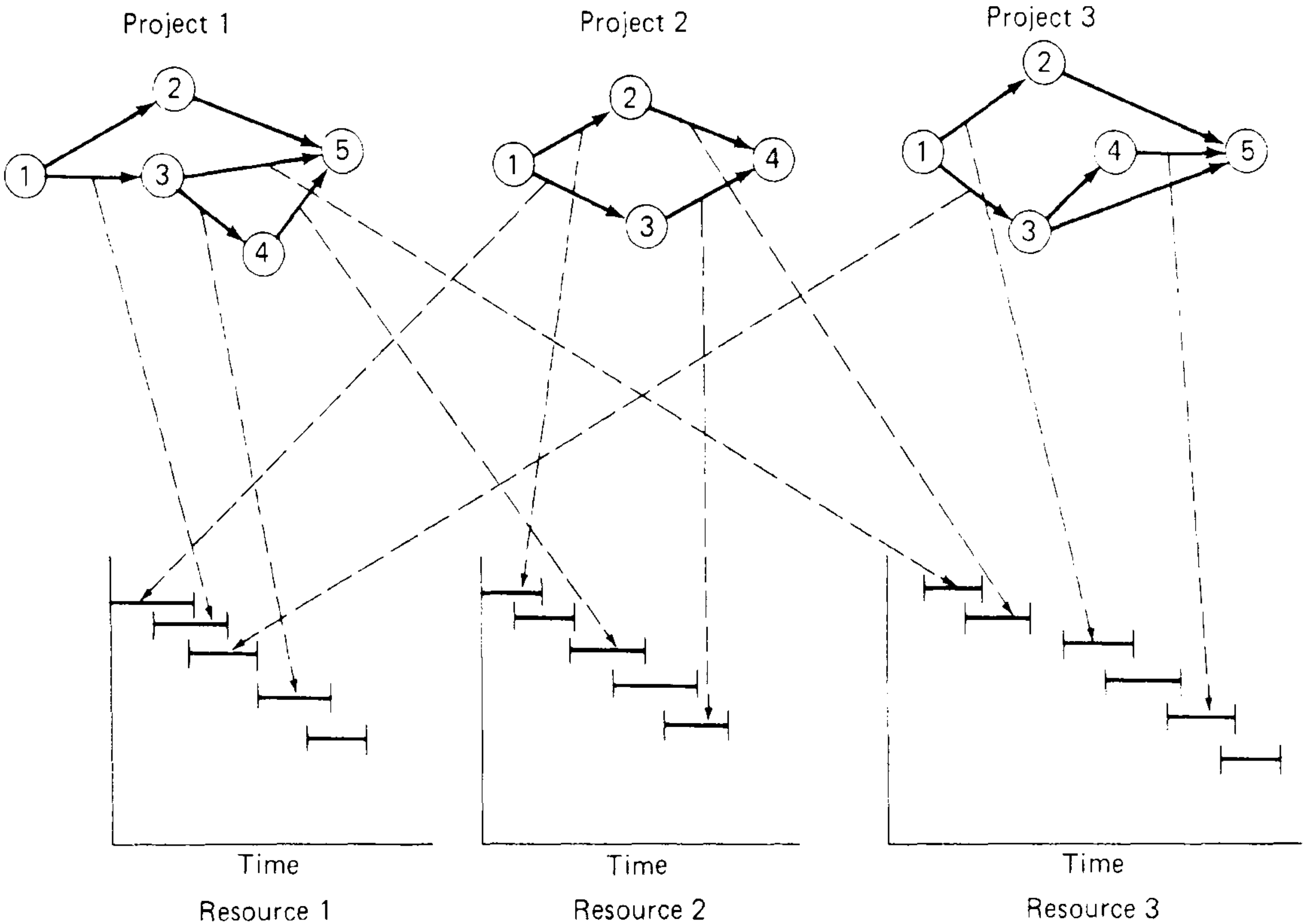
Step 6: T = 21
ES ≤ 21
E.A.S. {Y}
O.S.S. {Y}

Step 7: T = 25
ES ≤ 25
E.A.S. {Z}
O.S.S. {Z}

Step 8:T = 27
ES ≤ 27
E.A.S. {X}
O.S.S. {X}

■ Another Procedure

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
	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



Example of multiproject scheduling interactions.