

Second Material.

Resource leveling and Resource Constraining (Allocation)

• Resource leveling :

Suggest that Resources can be better allocated than the Peaks and Valleys, while staying within the limits of each activity's Total Float.

- no extension of Project duration is expected with leveling

- Activities move to dates within range between ES - LS.

* Minimum Algorithm Approach *

Resources are smoothed or leveled by making use of available Free Float.

Assumptions :

- Once Activity has been started it can't be interrupted
- Resource Consumption is constant over the duration of an activity.

→ Shifting any non-critical Activity by reducing their float
→ decision based on (IF : Improvement Factor)

$$IF (\text{Activity}, \# \text{ days consumed}) = \frac{R_v - R_o - R \times N_r}{\text{value of } \# \text{ days of FF consumed and duration of activity}}$$

↓

of Resources used by (activity / day)

↓

of Resources days currently assigned to those days that will be vacated when Activity start date is changed.

↓

of Resources days currently Assigned to those days that will be occupied when the activity start date is changed

↓

min value of

→ # of days of FF consumed

→ duration of the activity

*enlivo

• IF $IF < 0 \Rightarrow$ do not move

● Rules : اذا اخذنا أكثر من Activity يعني لا يعتبر
طعناً فقط IF (المفكر)

بأنه ساو بال IF اختر ← الأكثر (Resource / day)

بأنه ساو بال Res/day اختر ← إلى بقدر أخرها أكثر عدد أيام

بأنه ساو بال (عدد الأيام) اختر ← إلى عنده (latest start date)

$Pr = \min \left\{ \begin{array}{l} \text{Not FF days consumed} \\ \text{duration of act} \end{array} \right.$

In-Class Resource Leveling Example

Minimum Moment Algorithm Approach

Activities are arranged according to their early start

Free float is indicated by -

Number of resources are shown in the table

Cycle 0

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	C	C	-	-	-	-	-	F	-	-	-	-	-	-	-	-	-
A	4	4	-	-	-	-	-	4	-	-	-	-	-	-	-	-	-
1	B	B	E	E	E	E	E	G	G	G	I	I	J	J	K	K	L
	6	6	3	3	3	3	3	5	5	5	1	1	3	3	4	4	2
	D	-	-	-	-	-	-	H	H	-	-	-	-	-	-	-	-
	3	-	-	-	-	-	-	3	3	-	-	-	-	-	-	-	-
Resource Sum	1	13	10	3	3	3	3	12	8	5	1	1	3	3	4	4	2

Note that G depends on C&D
 IF (Hct, # of FF) = FF (P₀ - P₀)

Note: G depend on C, D

عند انتهاء اليوم

FF

FF

الوقت المتاح للأنشطة (الوقت المتاح)

هذا يعني 2 أنشطة مع بعضهما البعض (reconsider)

cycle 0 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17

	C	C					F									
A	B	B	E	E	E	E	G	G	G	I	I	I	I	K	K	L
	D						H	H								

1 13 10 3 3 3 3 12 8 5 1 1 3 3 4 4 2

cycle 1 cal:

$$IF(H, 1) = 3 * (12 - 5 - 3 * 1) = 12$$

$$IF(H, 4) = 3 * (20 - 4 - 3 * 2) = 30$$

$$IF(H, 2) = 3 * (20 - 6 - 3 * 2) = 24$$

$$IF(H, 5) = 3 * (20 - 6 - 3 * 2) = 24$$

$$IF(H, 3) = 3 * (20 - 2 - 3 * 2) = 36$$

$$IF(H, 6) = 3 * (20 - 7 - 3 * 2) = 21$$

$$IF(H, 7) = 3 * (20 - 8 - 3 * 2) = 18$$

Thus, Move H 3 days

backplant

الوقت المتاح

	C	C					F									
A	B	B	E	E	E	E	G	G	G	I	I	I	I	K	K	L
	D									H	H					

1 13 10 3 3 3 3 9 5 5 4 3 4 3 5 4 4 2

cycle 2 Calculations:

$$IF(F, 1) = 4 * (9 - 5 - 4 * 1) = 0$$

$$IF(F, 4) = 4 * (9 - 4 - 4 * 1) = 4$$

$$IF(F, 2) = 4 * (9 - 5 - 4 * 1) = 0$$

$$IF(F, 5) = 4 * (9 - 3 - 4 * 1) = 8$$

$$IF(F, 3) = 4 * (9 - 4 - 4 * 1) = 0$$

$$IF(F, 6) = 4 * (9 - 3 - 4 * 1) = 8$$

thus move F 6 days

	C	C														
A	B	B	E	E	E	E	G	G	G	I	I	I	I	K	K	L
	D									H	H					

1 13 10 3 3 3 3 5 5 5 4 4 3 3 4 4 2

cycle 3 calculations: C and D

$$IF(C, 1) = 4 * (13 - 10 - 4 * 1) = 24$$

$$IF(D, 1) = 3 * (13 - 10 - 3 * 1) = 0$$

$$IF(C, 2) = 4 * (23 - 6 - 4 * 2) = 36$$

$$IF(D, 2) = 3 * (13 - 3 - 3 * 1) = 21$$

$$IF(C, 3) = 4 * (23 - 6 - 4 * 2) = 36$$

$$IF(D, 3) = 3 * (13 - 3 - 3 * 1) = 21$$

$$IF(C, 4) = 4 * (23 - 6 - 4 * 2) = 36$$

$$IF(D, 4) = 3 * (13 - 3 - 3 * 1) = 21$$

thus move C, 4 days

$$IF(D, 5) = 3 * (13 - 3 - 3 * 1) = 21$$

enlivo

cycle 3

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
						C ₄	C ₄							F ₄				C ₄ mouni
A ₁	B ₆	B ₆	B ₆	B ₆	B ₆	B ₆	B ₆	G ₅	G ₅	G ₅	I ₁	I ₁	J ₃	J ₃	K ₄	K ₄	L ₂	4 days
	D ₃	-	-	-	-	-	-				H ₃	H ₃	-	-	-	-		
Sum	1	9	6	3	3	7	7	5	5	5	4	4	3	7	4	4	2	

cycle 4 cal : re consider Act D

$$iF(D,1) = 3 * (9 - 6 - 3) = 0$$

$$iF(D,9) = 3 * (9 - 7 - 3) = -3$$

$$iF(D,2) = 3 * (9 - 3 - 3) = 9$$

$$iF(D,5) = 3 * (9 - 7 - 3) = -3$$

$$iF(D,3) = 3 * (9 - 3 - 3) = 9$$

cycle 4) Move D 3 days

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
						C ₄	C ₄							F ₄				
A ₁	B ₆	B ₆	B ₆	B ₆	B ₆	B ₆	B ₆	G ₅	G ₅	G ₅	I ₁	I ₁	J ₃	J ₃	K ₄	K ₄	L ₂	
					D ₃	-	-				H ₃	H ₃	-	-	-	-		
	1	6	6	3	6	7	7	5	5	5	4	4	3	7	4	4	2	

BackFloat Calculations : reconsider (ايدانته جيا، التوقيت) لا تفكر في Back Float - حساب

هذا الـ (2) ج. د

$$iF(C,1) = 4 * (7 - 6 - 4 \times 1) = -12$$

$$iF(D,1) = 3 * (6 - 3 - 3) = 0$$

$$iF(C,2) = 4 * (7 - 6 - 4 \times 2) = -12$$

$$(D,2) = 3 * (6 - 6 - 3) = -9$$

$$iF(C,3) = 4 * (14 - 9 - 4 \times 2) = -12$$

$$iF(D,3) =$$

$$iF(C,4) = 4 * (14 - 12 - 4 \times 2) = -24$$

$$iF(D,3) = 3 * (6 - 6 - 3) = -9$$

thus Move D one day back

don't reconsider C

cycle (s)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
					C ₄	C ₄							F ₄						MO
A ₁	B ₆	B ₆	E ₃	E ₃	E ₃	E ₃	G ₅	G ₅	G ₅	I ₁	I ₁	J ₃	J ₃	K ₄	K ₄	L ₂			10
			D ₃							H ₃	H ₃								one day back
1	6	6	6	3	7	7	5	5	5	4	4	3	7	4	4	2			

cycle 6 cal :

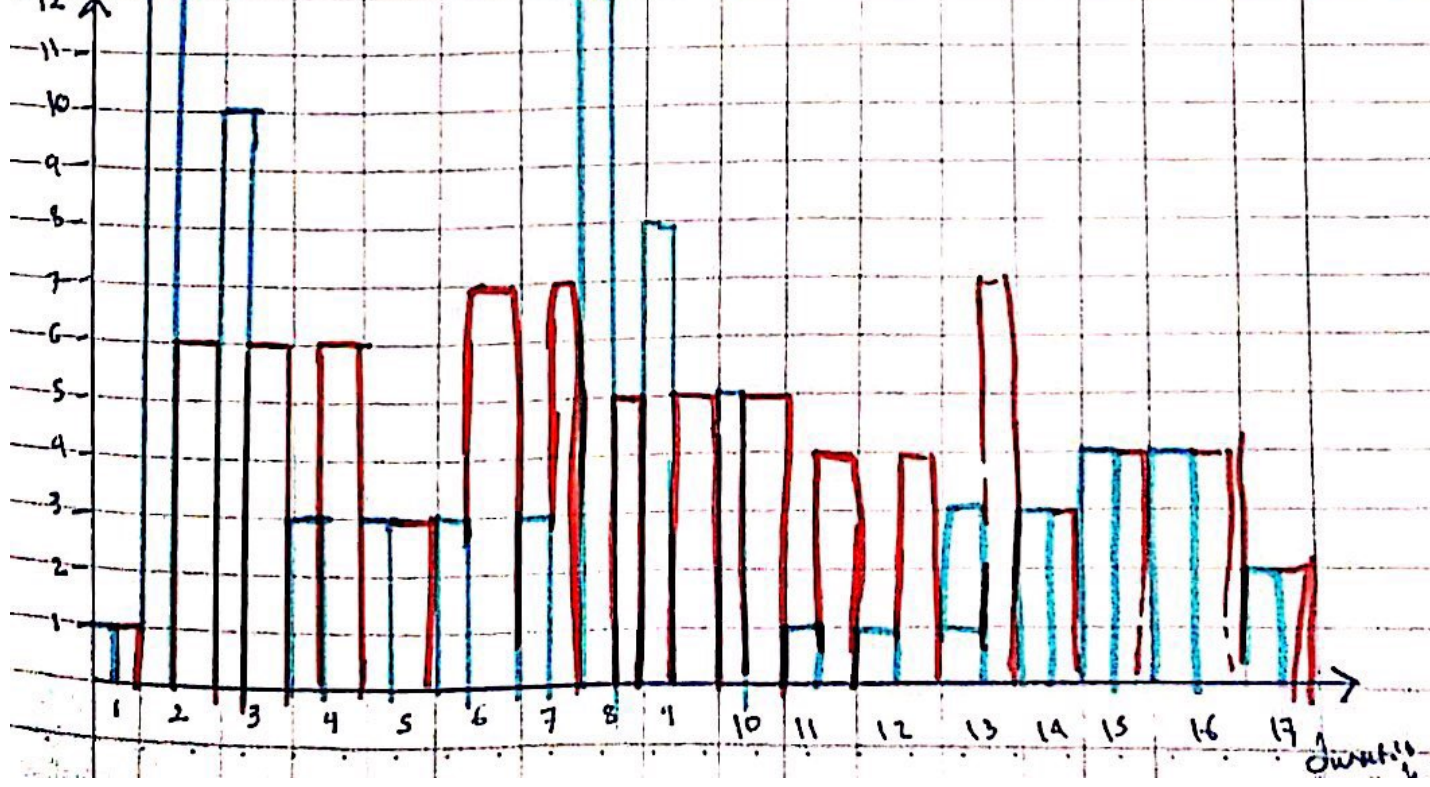
$$\begin{aligned}
 iF(F, 1) &= 4 * (7 - 3 - 4 * 1) = 0 \\
 iF(F, 2) &= 4 * (7 - 4 - 4) = -4 \\
 iF(F, 3) &= 4 * (7 - 4 - 4) = -4 \\
 iF(F, 4) &= 4 * (7 - 5 - 4) = -8 \\
 iF(F, 5) &= 4 * (7 - 5 - 4) = -8 \\
 iF(F, 6) &= 4 * (7 - 5 - 4) = -8
 \end{aligned}$$

$$\begin{aligned}
 iF(H, 1) &= 3 * (4 - 5 - 3 * 1) = -12 \\
 iF(H, 2) &= 3 * (8 - 10 - 3 * 2) = -24 \\
 iF(H, 3) &= 3 * (8 - 10 - 3 * 2) = -24
 \end{aligned}$$

Move F 1 day back

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
					C ₄	C ₄						F ₄							F Moved 1 day back
A ₁	B ₆	B ₆	E ₃	E ₃	E ₃	E ₃	G ₅	G ₅	G ₅	I ₁	I ₁	J ₃	J ₃	K ₄	K ₄	L ₂			
			D ₃							H ₃	H ₃								
1	6	6	6	3	7	7	5	5	5	4	4	7	3	4	4	2			
1	13	10	3	3	3	3	12	8	5	1	1	3	3	1	4	2			

resover/day



Example 2 - Resource leveling based on Minimum Moment Algorithm approach
Activities are arranged according to their early start

Free float is indicated by -

Cycle 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
			C	C	C	-	-	P	-	-	-	-		
	A	A	B	B	B	B	B	E	E	E	E	E	H	H
	5	5	9	9	9	9	9	10	10	10	10	10	8	8
			D	D	-	-	-	M	M	-	-	-		
			5	5				4	4					
ΣRes.	5	5	20	20	15	9	9	26	14	10	10	10	8	8

cycle 0

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
		C	C	C	-	-	P	-	-	-	-	-	-	-	-	-	-	-	-
A	A	B	B	B	B	B	E	E	E	E	E	H	H	-	-	-	-	-	-
		D	D	-	-	-	N	N	-	-	-	-	-	-	-	-	-	-	-

5 5 20 20 15 9 9 26 14 10 10 10 8 8

cycle (1) calculations

consider P and N

$$iF(P, 1) = 12(26 - 14 - 12) = 0$$

$$iF(N, 1) = 4 \times (26 - 10 - 1 \times 1) = 48$$

$$iF(P, 2) = 12(26 - 10 - 12) = 48$$

$$iF(N, 2) = 4 \times (40 - 20 - 4 \times 2) = 48$$

$$iF(P, 3) = 12(26 - 10 - 12) = 48$$

$$iF(N, 3) = 4 \times (40 - 26 - 4 \times 2) = 48$$

$$iF(P, 4) = 12(26 - 10 - 12) = 48$$

$$iF(N, 4) =$$

Thus, Move P 4 days

Now consider (Resource/day) calculation

cycle (1)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		C	C	C	-	-	-	-	-	-	P	-	-
A	A	B	B	B	B	B	E	E	E	E	E	H	H
		D	D	-	-	-	N	N	-	-	-	-	-

5 5 20 20 15 9 9 14 14 10 10 22 8 8

P moved 4 days

reconsider N

$$iF(N, 1) = 4 \times (14 - 10 - 4 \times 1) = 0$$

$$iF(N, 2) = 4 \times (28 - 20 - 4 \times 2) = 0$$

Therefore Move N 2 days

$$iF(N, 3) = 4 \times (28 - 32 - 4 \times 2) = -48$$

cycle 2

1	2	3	4	5	6	7	8	9	10	11	12	13	14
		C	C	C	-	-	-	-	-	-	P	-	-
A	A	B	B	B	B	B	E	E	E	E	E	H	H
		D	D	-	-	-	-	-	N	N	-	-	-

5 5 20 20 15 9 9 10 10 14 14 22 8 8

N moved 2 days

cycle (3) calculations: $iF(C, 1) = 6 \times (20 - 9 - 6 \times 1) = 30$

$$iF(C, 2) = 6 \times (40 - 18 - 6 \times 2) = 60$$

$$iF(D, 1) = 5 \times (20 - 15 - 5 \times 1) = 0$$

$$iF(D, 2) = 5 \times (40 - 24 - 5 \times 2) = 30$$

$$iF(D, 3) = 5 \times (40 - 28 - 5 \times 2) = 60$$

therefore Move C 2 days

تأثير من 10 الى 15 (معدل)

Cycle (3)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
	-	-	-	C	C	C	-	-	-	-	P		
A	A	B	B	B	B	B	C	C	C	C	C	11/2	14/8
		D	D	-	-	-	-	-	14/4	14/4			
5	5	14	14	15	15	15	10	10	14	14	22	2	8

C moved

2 days

reconsider D $IF(D, 1) = 5 \times (14 - 15 - 5 \times 1) = -50$

$IF(D, 2) = 5 \times (28 - 30 - 5 \times 2) = -60$

$IF(D, 3) = 5 \times (28 - 30 - 5 \times 2) = -60$

Don't Move D, Now Back Floats →

consider C

$IF(C, 1) = 6 \times (15 - 14 - 6 \times 1) = -36$ Don't Move C

$IF(C, 2) = 6 \times (30 - 28 - 6 \times 2) = -60$

consider P and M

$IF(P, 1) = 12 \times (22 - 14 - 12 \times 1) = -18$ $IF(M, 1) = 4 \times (14 - 10 - 4 \times 1) = 0$

$IF(P, 2) = 12 \times (22 - 14 - 12 \times 1) = -18$ $IF(M, 2) = 4 \times (28 - 20 - 4 \times 2) = 0$

$IF(P, 3) = 12 \times (22 - 10 - 12) = 0$ IF

$IF(P, 4) = 12 \times (22 - 10 - 12) = 0$

Move P, 4 days back

	-	-	-	C	C	C	P	-	-	-	-		
A	A	B	B	B	B	B	E	C	C	C	C	11/2	14/8
		D	D	-	-	-	14/4	14/4	-	-	-		
5	5	14	14	15	15	15	26	14	10	10	10	8	8

P move 4 days

back

cy999

→ H

• Constraints

(constraints) لحدود

- to limit when activity can start or end.

* Planner في Constraints

- include :

- 1) Owner imposed schedule dates
- 2) Limit imposed by material supplier
- 3) Subcontractor availability

Types of Constraints:

- 1) Conditional constraints
- 2) Mandatory constraints
- 3) Zero-Float constraints

(Conditional, Mandatory) can be applied to:

* start / finish of an activity

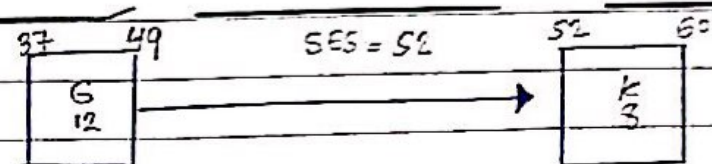
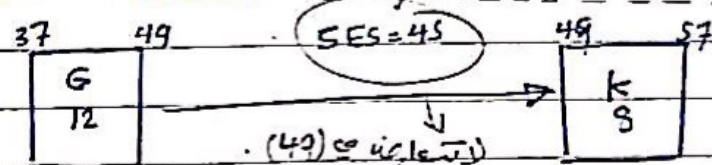
* Early / Late times

* Start Constraints

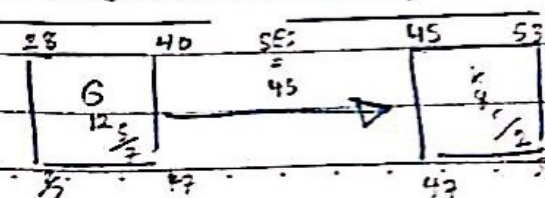
Schedule-Early-Start (SES) : start no earlier than.

used when : when delivery of material, ability of subcontractor, will not be available until a certain day

So, (SES) used to delay earlier calculated start times.



So $ES \text{ of constrained activity} = \text{Max of } (ES \text{ of } \dots) \text{ or } (SES)$

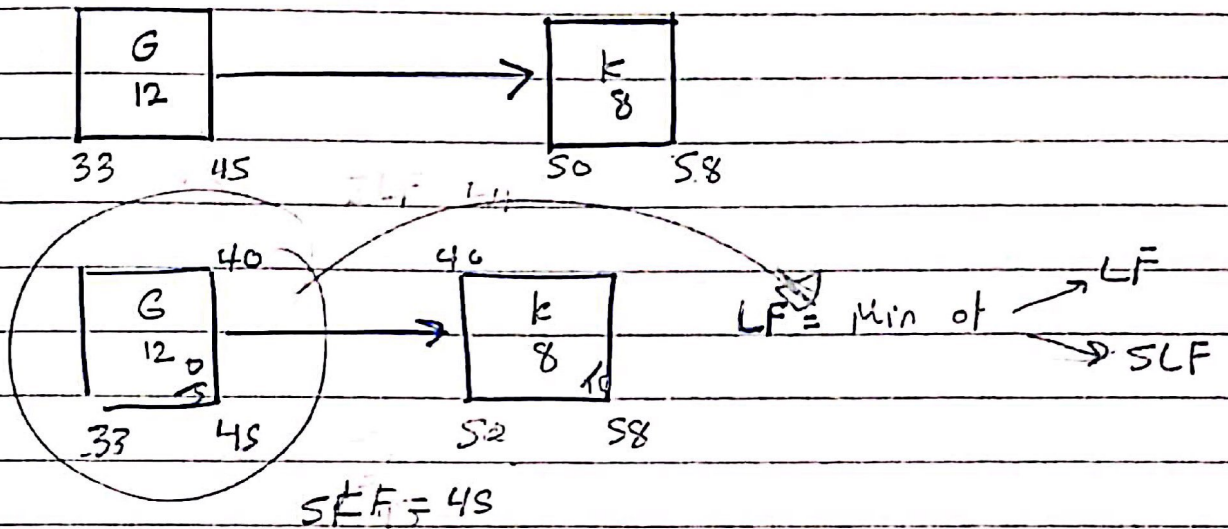


الوقت المتاح
FF
FT
con of
المدة

● Finish Constraints :

Schedule Late Finish (SLF) : Finish no Later than.

$$SLF = 45$$



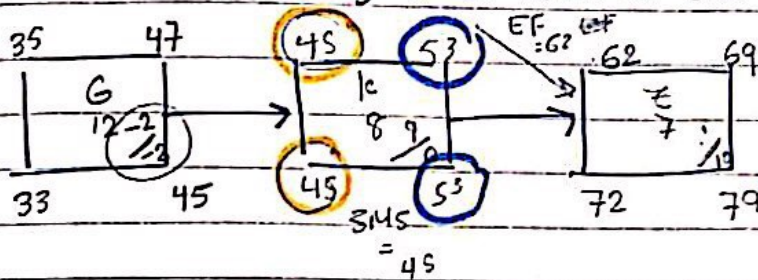
$$SLF = 40$$

Mandatory Constraints :

MSO : Must Start On

SMS : Schedule Must Start

- when : Activity must start or end on a specific date



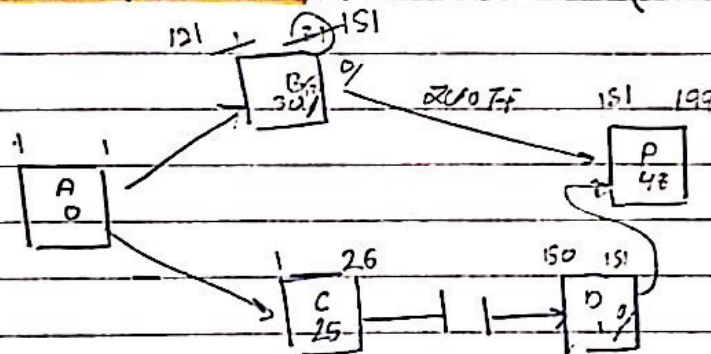
$$ES_k = 45$$

$$ES_k \text{ (calculated)} = 47$$

Mandatory do not allow float to pass them

- Zero TF , Zero FF :

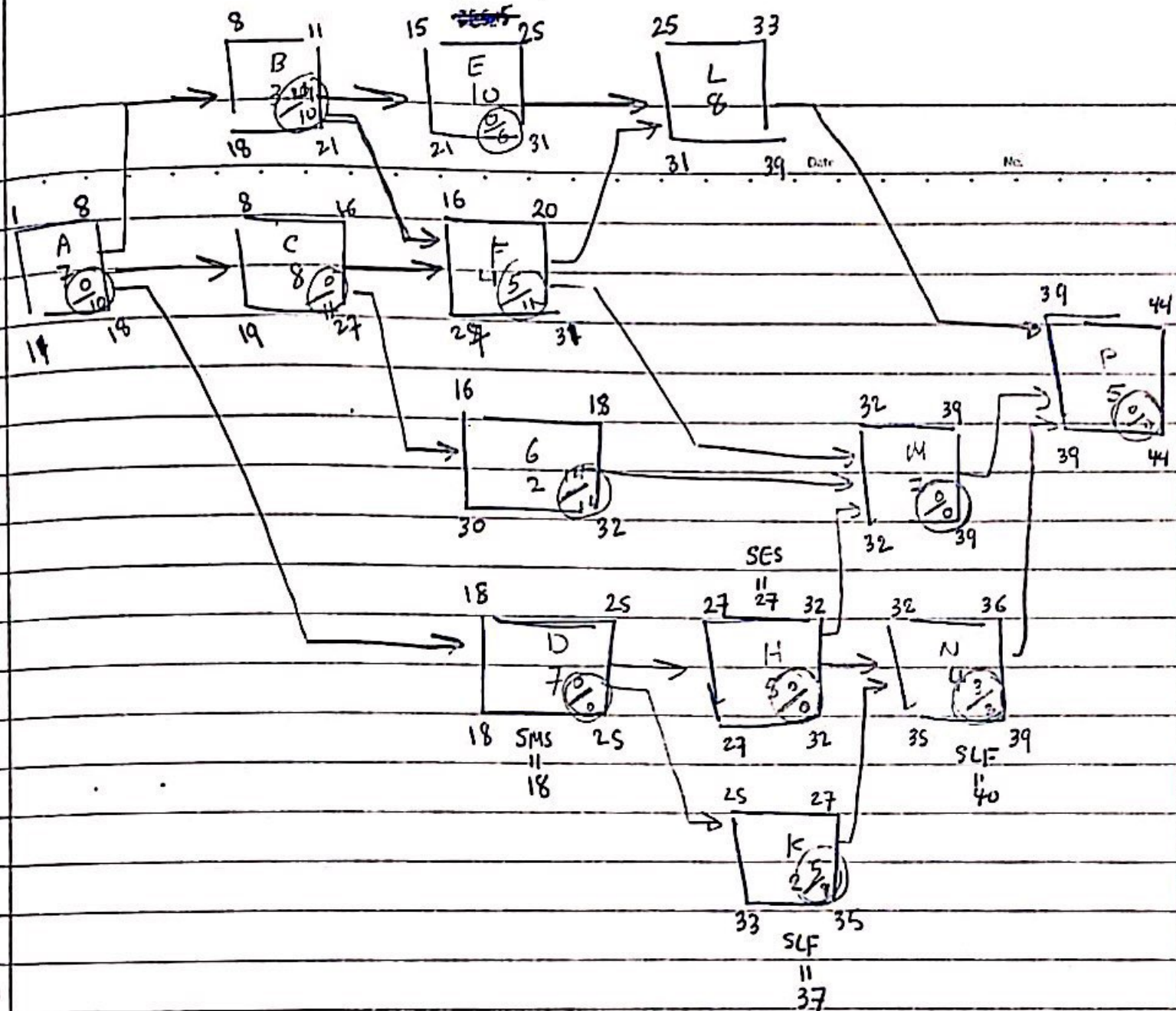
(Zero FF)

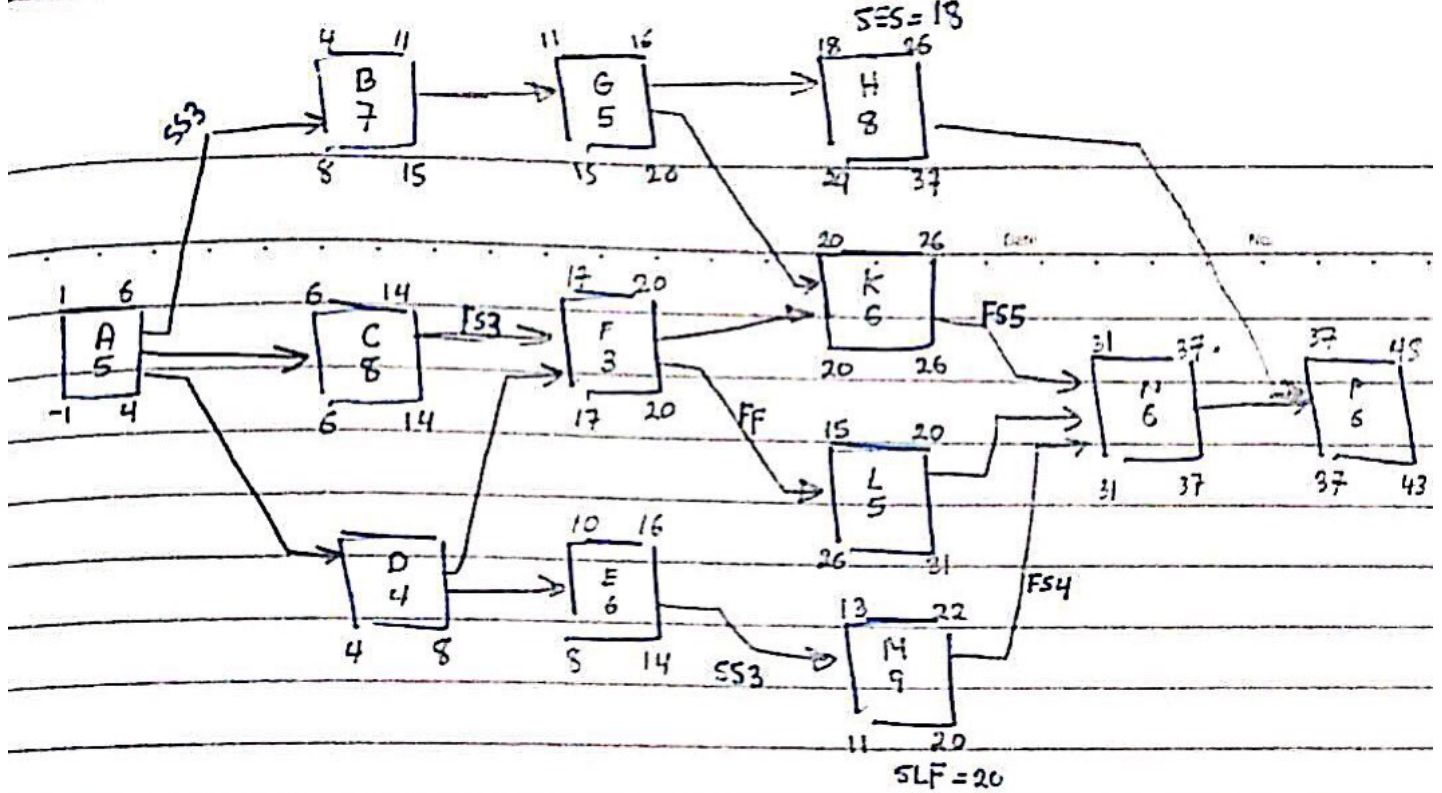


بناوب B قبل P 30 يوم
عندئذ افء FF=0 بين
B , P

(Zero FF) يعني اني (activity) لنزلا ← (critical)

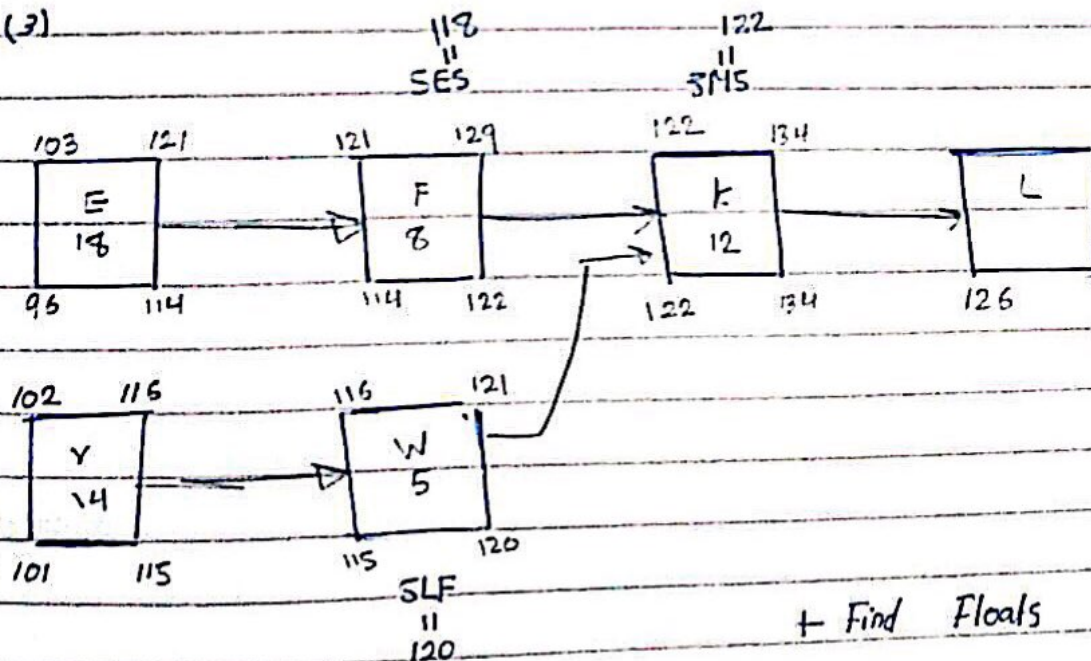
SES = 15





	P (0%)	N (0%)	H (1/11)	G (1/4)	A (0/2)
FF	K (0%)	L (1/11)	M (5/2)	F (0%)	
	E (0/2)	B (0/4)	L (0%)	D (0/2)	

EX (3)



+ Find Floats