

## **Ejercicio 22**

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## Enunciado

Considere el proyecto cuya información se adjunta. 1. Dibuje el diagrama Pert y determine el camino crítico. 2. Reduzca la duración del proyecto dos unidades de tiempo con el menor incremento de coste posible.

| actividad | precedentes | b  | m     | a  | coste | duracion pert | coste | duracion tope | duracion tope |
|-----------|-------------|----|-------|----|-------|---------------|-------|---------------|---------------|
| A         | ---         | 6  | 2.50  | 2  | 1600  |               | 1800  |               | 2             |
| B         | ---         | 6  | 6.00  | 6  | 2800  |               | 2820  |               | 1             |
| C         | ---         | 1  | 1.00  | 1  | 600   |               | 600   |               | 1             |
| D         | ---         | 3  | 3.00  | 3  | 600   |               | 607   |               | 2             |
| E         | A,B         | 12 | 5.00  | 4  | 1600  |               | 2200  |               | 2             |
| F         | A,B         | 12 | 2.50  | 2  | 2000  |               | 2200  |               | 1             |
| G         | B,C         | 6  | 1.25  | 1  | 600   |               | 700   |               | 1             |
| H         | B,C         | 20 | 15.00 | 10 | 3500  |               | 3620  |               | 3             |
| I         | D           | 28 | 18.00 | 8  | 3500  |               | 3503  |               | 17            |
| J         | E,M         | 4  | 4.00  | 4  | 1500  |               | 1500  |               | 2             |
| K         | F           | 7  | 7.00  | 7  | 2000  |               | 2000  |               | 3             |
| L         | J,K,G       | 1  | 1.00  | 1  | 1000  |               | 1000  |               | 1             |
| M         | F           | 3  | 3.00  | 3  | 500   |               | 500   |               | 1             |
| N         | J,K,G       | 1  | 1.00  | 1  | 1000  |               | 1000  |               | 1             |
| P         | D           | 3  | 3.00  | 3  | 1000  |               | 1150  |               | 1             |

# Solución

## Apartado 1

Dibuje el diagrama Pert y determine el camino crítico.

### Matriz de prelación

Empezamos determinando la matriz de prelación. Nos sirve para construir el grafo, si leemos las columnas, y para comprobar que no hemos cometido errores, si leemos las columnas.

Tabla 2

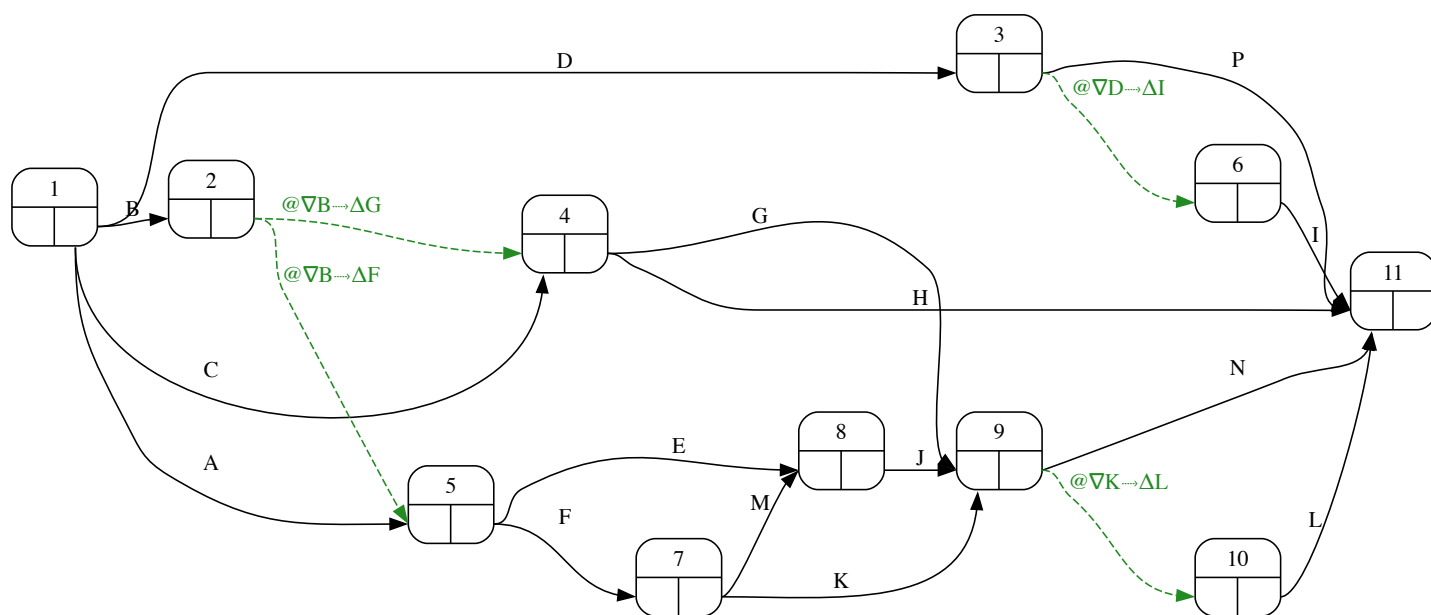
|            | A    | B    | C    | D    | E    | F    | G    | H | I | J    | K    | L | M    | N | P |
|------------|------|------|------|------|------|------|------|---|---|------|------|---|------|---|---|
| activities |      |      |      |      |      |      |      |   |   |      |      |   |      |   |   |
| A          |      |      |      |      |      |      |      |   |   |      |      |   |      |   |   |
| B          |      |      |      |      |      |      |      |   |   |      |      |   |      |   |   |
| C          |      |      |      |      |      |      |      |   |   |      |      |   |      |   |   |
| D          |      |      |      |      |      |      |      |   |   |      |      |   |      |   |   |
| E          | True | True |      |      |      |      |      |   |   |      |      |   |      |   |   |
| F          | True | True |      |      |      |      |      |   |   |      |      |   |      |   |   |
| G          |      | True | True |      |      |      |      |   |   |      |      |   |      |   |   |
| H          |      | True | True |      |      |      |      |   |   |      |      |   |      |   |   |
| I          |      |      |      | True |      |      |      |   |   |      |      |   |      |   |   |
| J          |      |      |      |      | True |      |      |   |   |      |      |   | True |   |   |
| K          |      |      |      |      |      | True |      |   |   |      |      |   |      |   |   |
| L          |      |      |      |      |      |      | True |   |   | True | True |   |      |   |   |
| M          |      |      |      |      |      | True |      |   |   |      |      |   |      |   |   |
| N          |      |      |      |      |      |      | True |   |   | True | True |   |      |   |   |
| P          |      |      |      | True |      |      |      |   |   |      |      |   |      |   |   |

### ### Precálculo de variables de interés

A partir de los datos del enunciado podemos calcular la duración media  $D = \frac{a+4m+b}{6}$ , y el coste unitario de reducción  $\frac{\Delta Coste}{\Delta duracin}$  que utilizaremos para contestar las preguntas realizadas.

|           | b  | m     | a  | duracion | cur        |
|-----------|----|-------|----|----------|------------|
| actividad |    |       |    |          |            |
| A         | 6  | 2.50  | 2  | 3.0      | 200.000000 |
| B         | 6  | 6.00  | 6  | 6.0      | 4.000000   |
| C         | 1  | 1.00  | 1  | 1.0      | NaN        |
| D         | 3  | 3.00  | 3  | 3.0      | 7.000000   |
| E         | 12 | 5.00  | 4  | 6.0      | 150.000000 |
| F         | 12 | 2.50  | 2  | 4.0      | 66.666667  |
| G         | 6  | 1.25  | 1  | 2.0      | 100.000000 |
| H         | 20 | 15.00 | 10 | 15.0     | 10.000000  |
| I         | 28 | 18.00 | 8  | 18.0     | 3.000000   |
| J         | 4  | 4.00  | 4  | 4.0      | 0.000000   |
| K         | 7  | 7.00  | 7  | 7.0      | 0.000000   |
| L         | 1  | 1.00  | 1  | 1.0      | NaN        |
| M         | 3  | 3.00  | 3  | 3.0      | 0.000000   |
| N         | 1  | 1.00  | 1  | 1.0      | NaN        |
| P         | 3  | 3.00  | 3  | 3.0      | 75.000000  |

### Grafo PERT con numeración de nodos



El cuadro de prelacones distantes nos permite comparar distintas representaciones gráficas del mismo proyecto.

| Precedentes |                   |
|-------------|-------------------|
| A           |                   |
| B           |                   |
| C           |                   |
| D           |                   |
| E           | A B               |
| F           | A B               |
| G           | B C               |
| H           | B C               |
| I           | D                 |
| J           | A B E F M         |
| K           | A B F             |
| L           | A B C E F G J K M |
| M           | A B F             |
| N           | A B C E F G J K M |
| P           | D                 |

#### Cálculo de tiempos tempranos y tardíos con el método de Zaderenko

|      | 1   | 2   | 3   | 4   | 5   | 6   | 7    | 8    | 9    | 10   | 11   | early |
|------|-----|-----|-----|-----|-----|-----|------|------|------|------|------|-------|
| 1    |     | 6.0 | 3.0 | 1.0 | 3.0 |     |      |      |      |      |      | 0.0   |
| 2    |     |     |     | 0.0 | 0.0 |     |      |      |      |      |      | 6.0   |
| 3    |     |     |     |     |     | 0.0 |      |      |      |      | 3.0  | 3.0   |
| 4    |     |     |     |     |     |     |      |      | 2.0  |      | 15.0 | 6.0   |
| 5    |     |     |     |     |     |     | 4.0  | 6.0  |      |      |      | 6.0   |
| 6    |     |     |     |     |     |     |      |      |      |      | 18.0 | 3.0   |
| 7    |     |     |     |     |     |     |      | 3.0  | 7.0  |      |      | 10.0  |
| 8    |     |     |     |     |     |     |      |      | 4.0  |      |      | 13.0  |
| 9    |     |     |     |     |     |     |      |      |      | 0.0  | 1.0  | 17.0  |
| 10   |     |     |     |     |     |     |      |      |      |      | 1.0  | 17.0  |
| 11   |     |     |     |     |     |     |      |      |      |      |      | 21.0  |
| late | 0.0 | 6.0 | 3.0 | 6.0 | 9.0 | 3.0 | 13.0 | 16.0 | 20.0 | 20.0 | 21.0 |       |

De manera condensada, se muestran los tiempos tempranos y tardíos en la siguiente tabla:

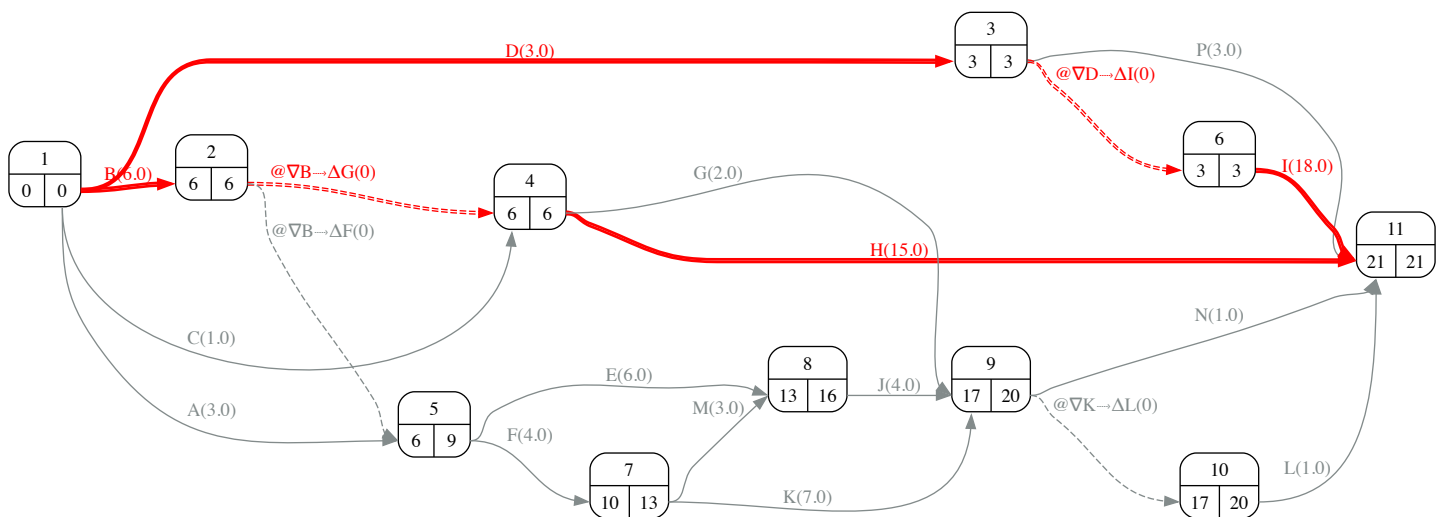
|    | early | late |
|----|-------|------|
| 1  | 0     | 0    |
| 2  | 6     | 6    |
| 3  | 3     | 3    |
| 4  | 6     | 6    |
| 5  | 6     | 9    |
| 6  | 3     | 3    |
| 7  | 10    | 13   |
| 8  | 13    | 16   |
| 9  | 17    | 20   |
| 10 | 17    | 20   |
| 11 | 21    | 21   |

## Holguras

Calculados los tiempos tempranos y tardíos, podemos calcular las holguras totales de las actividades.

|        | H_total |
|--------|---------|
| @ B ΔF | 3       |
| @ B ΔG | 0       |
| @ D ΔI | 0       |
| @ K ΔL | 3       |
| A      | 6       |
| B      | 0       |
| C      | 5       |
| D      | 0       |
| E      | 4       |
| F      | 3       |
| G      | 12      |
| H      | 0       |
| I      | 0       |
| J      | 3       |
| K      | 3       |
| L      | 3       |
| M      | 3       |
| N      | 3       |
| P      | 15      |

## Grafo PERT con indicación de tiempos y camino crítico



Las actividades con holgura total igual a cero constituyen el camino crítico. En este caso el camino crítico está formado por las siguientes rutas:

Route\_15: B, @ B ΔG, H

Route\_19: D, @ D ΔI, I

## Apartado 2.

Reduzca la duración del proyecto dos unidades de tiempo con el menor incremento de coste posible.

Se aborda la solución de este apartado mediante la técnica de reducción de la duración del proyecto con mínimo coste.

Actividades a recortar en iteración 0: ['I', 'B']

Actividades a recortar en iteración 1: ['D', 'B']

Tabla 8

|          | A     | B   | C   | D   | E     | F    | G     | H    | I   | J   | K   | L   | M   | N   | P    | 0    | 1    | 2    |
|----------|-------|-----|-----|-----|-------|------|-------|------|-----|-----|-----|-----|-----|-----|------|------|------|------|
| Route_1  | 200.0 |     |     |     | 150.0 |      |       |      |     | 0.0 |     |     |     |     |      | 14.0 | 14.0 | 14.0 |
| Route_2  | 200.0 |     |     |     | 150.0 |      |       |      |     | 0.0 |     |     |     |     |      | 14.0 | 14.0 | 14.0 |
| Route_3  | 200.0 |     |     |     |       | 66.7 |       |      |     |     | 0.0 |     |     |     |      | 15.0 | 15.0 | 15.0 |
| Route_4  | 200.0 |     |     |     |       | 66.7 |       |      |     |     | 0.0 |     |     |     |      | 15.0 | 15.0 | 15.0 |
| Route_5  | 200.0 |     |     |     |       | 66.7 |       |      |     | 0.0 |     |     | 0.0 |     |      | 15.0 | 15.0 | 15.0 |
| Route_6  | 200.0 |     |     |     |       | 66.7 |       |      |     | 0.0 |     |     | 0.0 |     |      | 15.0 | 15.0 | 15.0 |
| Route_7  |       | 4.0 |     |     | 150.0 |      |       |      |     | 0.0 |     |     |     |     |      | 17.0 | 16.0 | 15.0 |
| Route_8  |       | 4.0 |     |     | 150.0 |      |       |      |     | 0.0 |     |     |     |     |      | 17.0 | 16.0 | 15.0 |
| Route_9  |       | 4.0 |     |     |       | 66.7 |       |      |     |     | 0.0 |     |     |     |      | 18.0 | 17.0 | 16.0 |
| Route_10 |       | 4.0 |     |     |       | 66.7 |       |      |     |     | 0.0 |     |     |     |      | 18.0 | 17.0 | 16.0 |
| Route_11 |       | 4.0 |     |     |       | 66.7 |       |      |     | 0.0 |     |     | 0.0 |     |      | 18.0 | 17.0 | 16.0 |
| Route_12 |       | 4.0 |     |     |       | 66.7 |       |      |     | 0.0 |     |     | 0.0 |     |      | 18.0 | 17.0 | 16.0 |
| Route_13 |       | 4.0 |     |     |       |      | 100.0 |      |     |     |     |     |     |     |      | 9.0  | 8.0  | 7.0  |
| Route_14 |       | 4.0 |     |     |       |      | 100.0 |      |     |     |     |     |     |     |      | 9.0  | 8.0  | 7.0  |
| Route_15 |       | 4.0 |     |     |       |      |       | 10.0 |     |     |     |     |     |     |      | 21.0 | 20.0 | 19.0 |
| Route_16 |       |     |     |     |       |      | 100.0 |      |     |     |     |     |     |     |      | 4.0  | 4.0  | 4.0  |
| Route_17 |       |     |     |     |       |      | 100.0 |      |     |     |     |     |     |     |      | 4.0  | 4.0  | 4.0  |
| Route_18 |       |     |     |     |       |      |       | 10.0 |     |     |     |     |     |     |      | 16.0 | 16.0 | 16.0 |
| Route_19 |       |     |     | 7.0 |       |      |       |      | 3.0 |     |     |     |     |     |      | 21.0 | 20.0 | 19.0 |
| Route_20 |       |     |     | 7.0 |       |      |       |      |     |     |     |     |     |     | 75.0 | 6.0  | 6.0  | 5.0  |
| 0        | 1.0   | 5.0 | 0.0 | 1.0 | 4.0   | 3.0  | 1.0   | 12.0 | 1.0 | 2.0 | 4.0 | 0.0 | 2.0 | 0.0 | 2.0  |      |      |      |
| 1        | 1.0   | 4.0 | 0.0 | 1.0 | 4.0   | 3.0  | 1.0   | 12.0 | 0.0 | 2.0 | 4.0 | 0.0 | 2.0 | 0.0 | 2.0  |      |      |      |
| 2        | 1.0   | 3.0 | 0.0 | 0.0 | 4.0   | 3.0  | 1.0   | 12.0 | 0.0 | 2.0 | 4.0 | 0.0 | 2.0 | 0.0 | 2.0  |      |      |      |

La suma del sobre coste de la primera y segunda iteración es de 18.

## Proyecto con la duración reducida

