ENGINEERING TRIPOS PART IIA

Module 3E10: Operations Management for Engineers

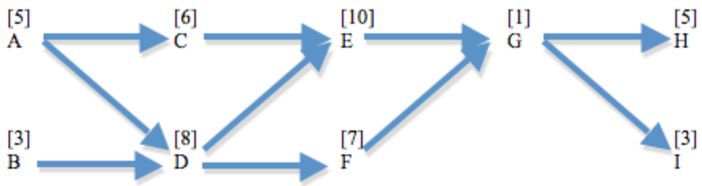
Examples Paper II - CRIB

Question 1: In an assembly line operation there are nine separate tasks, and the table below gives the duration of each task, and the immediate precursors of each task. The line is a traditional, linear line rather than a manufacturing cell horseshoe.

Task	Duration (minutes)	Precursors
A	5	-
B	3	-
C	6	A
D	8	A, B
E	10	C, D
F	7	D
G	1	E, F
H	5	G
I	3	G

Balance this line for a cycle time of 16 minutes. If the cycle time could be decreased by 2 minutes, the company could save £200 per week through volume discounts for the raw material. The wage costs are £150 per week for an assembly line worker. Is it worth attempting to speed the line up?

ANSWER: The network is:



Step 1:

- Work content = $\Sigma\ p_i = 48$
- Minimum number of stations = $\Sigma\ p_i$ / cycle_time = 48/16 = 3.
- The minimum number of stations can be achieved by grouping them as:

  (A,B,D), (C,E), (F,G,H,I)

Step 2:

- If the cycle time could be decreased by 2 minutes, to 14 minutes, then the minimum number of stations = $\Sigma\, p_i$ / cycle_time = 48/14 = 3.4 $\Rightarrow$ 4 stations.
- It is not difficult to show that it is impossible to group the tasks into 4 stations, where each station has a total work content of no more than 14 minutes (not forgetting that we must obey the precedence constraints).
- However, it is possible to achieve a cycle time of 14 minutes with 5 stations. Thus, we will need to hire an additional two workers, for a total cost of £300 per week.
- Since the reduced cycle time results in a savings of £200 per week, the net savings is not a savings at all, but rather a cost increase of £100 per week.
- Conclusion: It is not worth attempting to speed up the line.

Question 2: The demands for a product for weeks 1-20 are as follows:

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Demand	15	18	10	12	20	17	22	16	14	20	15	12	16	20	22	17	15	10	16	20

Suppose that a forecast is to be produced for the following week in each of the weeks 10-19, so that in week 10 the data up to week 10 are available, in week 11 the data up to week 11 are available, etc.

a) Compare the results of using a 10-week moving average with an exponential smoothing approach, using a smoothing constant of $\boldsymbol{\alpha} = 0.1$.
b) What effect would increasing $\boldsymbol{\alpha}$ have on the nature of the forecast?
c) For the forecasts in part (a), calculate MAD, MSE, and MAPE.

ANSWER:

a) Use updating formula for exponential smoothing; $S_t = \alpha\, x_t + (1-\alpha)\, S_{t-1}$. Since the 10-week moving average can only be computer for weeks 11-20, it only makes sense just to compare those last 10 weeks.

   Moving Average for weeks 11-20:
   (16.4, 16.4, 15.8, 16.4, 17.2, 17.4, 17.4, 16.7, 16.1, 16.3).

   Exponential Smoothing for weeks 11-20:
   (16.2, 16.0, 15.6, 15.6, 16.1, 16.7, 16.7, 16.5, 15.9, 15.9).

b) Increasing the coefficient $\boldsymbol{\alpha}$ puts more weight on recent data, thus makes the forecast more responsive (but also potentially "nervous"). It also reduces the average "age" of the data, which is proportional to $1/\boldsymbol{\alpha}$. Thus, one would use a larger $\boldsymbol{\alpha}$ in settings where trends are present and need to be matched (e.g., fashion-related trends in textile), and a smaller $\boldsymbol{\alpha}$ in settings where stability of (i.e., make to forecast production for commodities).

c) For MA: MAD = 2.77; MSE = 12.19; MAPE = 1.92. For ES: MAD = 2.85; MSE = 13.36; MAPE = 1.92.

Question 3: Consider the problem of minimising average tardiness on one machine with the following processing times and due dates:

Job	1	2	3	4
p_j	7	6	8	4
d_j	8	9	10	14

Find a production sequence using the MDD rule. Is this solution optimal?

ANSWER: Recall that the MDD Rule is a good *heuristic* for minimising average tardiness, although it is not guaranteed to be optimal. Since we are asked to find the *optimal* sequence, and the problem is small, one approach is to started with the given sequence and try to improve via pair wise interchanges. There is one optimal sequence: 1, 2, 4, 3, where the total tardiness is $\sum T_j = 0 + 4 + 3 + 15 = 22$, so the average tardiness is 22/4 = 5.5.

Question 4: Joe's Auto Seat Cover and Paint Shop is bidding on a contract to do all the custom work for Ed's used car dealership. One of the main requirements in obtaining this contract is rapid delivery time, because Ed wants the cars facelifted and back on his lot in a hurry. Ed says that if Joe can refit and repaint five cars that Ed has just received in 24 hours or less, the contract will be his. Following is the time (in hours) required in the refitting shop and the paint shop for each of the five cars. Assuming that cars go through the refitting operations before they are repainted, can Joe meet the time requirements and get the contact?

CAR	Refitting Time (hours)	Repainting Time (hours)
A	6	3
B	0	4
C	5	2
D	8	6
E	2	1

ANSWER: The problem can be viewed as a two-machine flow shop and easily solved using Johnson's rule. The final schedule is B – D – A – C – E, with 22 hours flowtime. Contract can be fulfilled.

Manually, the problem is solved as:

CAR	Order of Selection	Position in Sequence
A	4	3
B	1	1
C	3	4
D	5	2
E	2	5

<u>Question 5</u>: A manufacturer has sixty hours to complete the processing of ten jobs. Each job requires the same machine for the first operation which consists of Raw Processing. The technology is such that two jobs cannot be processed together. The Finishing Operation takes longer, for which as many additional workers as required can be brought in, with the proviso that only one worker can work a single job at a time, although - if necessary - jobs can be subcontracted. The cost of subcontracting a job is the same for each job. If the sixty hour deadline is to be met and we are to minimise the total cost of subcontracting jobs, provide the optimal schedule and indicate which jobs have to be subcontracted.

	Time (hours)	
Job	Raw	Finishing
A	7	6
B	7	12
C	12	0
D	10	18
E	4	9
F	14	25
G	10	14
H	11	7
I	5	13
J	4	10

ANSWER: [First note that Johnson's Rule is obviously inappropriate here, since we are not attempting to minimise makespan.] We have that jobs may overlap in their second operation, but all jobs must meet the sixty-hour deadline. This implies a deadline for the first operation, by subtracting from 60, as follows:

Job	A	B	C	D	E	F	G	H	I	J
Due	54	48	60	42	51	35	46	53	47	50

Moore's algorithm can now be applied.

Sort the jobs according to earliest due dates (EDD):

Job	F	D	G	I	B	J	E	H	A	C
Raw	14	10	10	5	7	4	4	11	7	12
Due	35	42	46	47	48	50	51	53	54	60

Start with a schedule based on EDD:

$F_{14}\ D_{24}\ G_{34}\ I_{39}\ B_{46}\ J_{50}\ E_{54}$

So job E is late; drop the longest job allocated (F) and start again:

$D_{10}\ G_{20}\ I_{25}\ B_{32}\ J_{36}\ E_{40}\ H_{51}\ A_{58}$

So job A is late; drop the longest job allocated (H) and start again:

D_{10} G_{20} I_{25} B_{32} J_{36} E_{40} A_{47} C_{59}

Hence we subcontract jobs F and H.