2018 MET IIA PAPER 3 A.Parlikad, A. Brintrup

Module 3P4: OPERATIONS MANAGEMENT
(Section A)

Module 3P5: INDUSTRIAL ENGINEERING
(Sections B)

SECTION A

1 (a) (i) A good answer should include the following points:

- There is a minimum amount of inventory in a manufacturing system needed to run the operations without stock-outs. According to Little's Law this inventory is a function of lead time and throughput rate.
- In general this cycle stock found in the production system is half the batch size used. The larger the batch, the less frequent the order is made, the more inventory is needed
- In addition to cycle stock there is also safety stock, to protect against uncertainties. Uncertainties can arise from suppliers (supply uncertainty), the market (demand uncertainty), or the production process (e.g. machine breakdowns, quality problems)
- Extra inventory can be used to smooth / level production in particular in markets with volatile demand, with the notion that the extra cost of inventory is offset by the saving through stable production patterns
- Further points that can be mentioned include taking advantage of economies of scale and price fluctuations

(ii) Little's law states:

WIP = L * T, where WIP is the minimum work in progress inventory, L is the throughput rate in units per time and T is the production lead time.
2 shifts of 7.5 hours give 15 working hours/day. Production rate can be calculated as 14,400 /18,000 (minutes available per month) = 0.8/minute. Production lead time is 130 minutes. Hence WIP = 0.8 units/minute x 130 minutes = 104 units.
Thus the inventory level could be reduced by n=[(180-104)/180]*100=42%

(b) (i) Approaches to include Moving Averages (most basic approach which assumes mean demand is constant), Exponential smoothing (similar to moving average but weight given to each period is a fixed proportion of weight given to succeeding period, can cope with step changes but not with linear trends, choice of alpha can be subjective and needs careful tuning), double Exponential smoothing (adaptation of ES which can cope with linear trends, trend dominates after a few periods so only good for short term forecasting, choice of alpha and beta parameters), triple ES (to cope with quadratic trends, choice of alpha, beta and gamma parameters). MA and ES work well for mdoels with constant mean demand, Double ES works well with linear trends, Triple ES for quadratic trends, which are rare in practice.

Students can further mention qualitative and quantitative (intrinsic / extrinsic) approaches, out of these regression and decomposition methods.

(ii) Exponential smoothing forecasts in principle can be made responsive by using a large smoothing constant Alpha. However, even for large values of Alpha, which would make the forecast very responsive to trend, the forecast would not lock on to such exponential trends.

- One approach for improving the demand forecast might be to use a triple (or quadratic, or Type III) exponential smoothing as neither simple nor double (or linear, or Type II) exponential smoothing models are able to lock on to exponential growth trends

- Another approach might be to extract general patterns from past years to observe how demand climbs in the months leading up to summer, and use that information to predict demand. Fourier analysis and time series can be used.

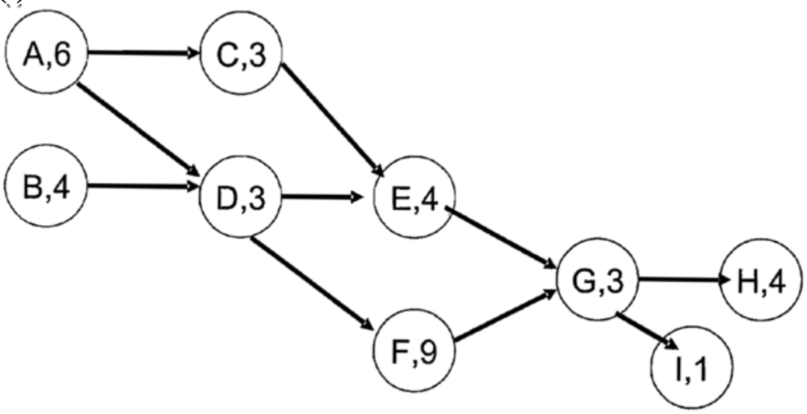
(c) main factors to consider are:

- household disposable income, as this drives purchases on non-essential goods
- interest rates, as this determines to what degree available income has to be used to cover mortgage payments
- consumer confidence indices, as this determines whether consumers are likely to spend disposable income
- demographic profile of UK population, to understand the size of the market
- weather, as this might determine whether consumers will spend time in the garden

Examiner's comments: *This question was aimed at testing the students' understanding of inventory and forecasting. Part (a) asked about the different roles of inventory in a manufacturing system and asked for a calculation of WIP inventory. While almost all students mentioned the role of inventory in smoothing/levelling production and inventory as safety stock, fewer students mentioned the role of cycle stock. Majority of students calculated WIP correctly using Little's law, however almost no student pointed out that the result means that there is excessive inventory and it could be reduced. Part (b) explored students' understanding of how can orders be forecasted, and the strengths and weaknesses of forecasting methods they learned in the lectures. While most students mentioned Moving averages, Exponential Smoothing, and double and triple ES; few students correctly explained how these are suited to different trend types such as step changes, linear or seasonal demands. Those few students then correctly answered the subsequent question of which forecasting method would be suitable for the example given in the question, while others struggled. Part (c) asked about economic factors that should be considered for the development of the fence market. About half of the students identified the economic factors that should be investigated, and some have offered additional considerations such as competition and substitute products, for which they received additional marks.*

2 (a)

(i) The network is:



(ii) The work content is 37 minutes.
Cycle time= (7.5 hours*60) / 50 minutes = 9 minutes / unit
Minimum number of stations = work content / cycle time = 4.11
i.e. 5 stations

The line balancing can be achieved by either the longest chain of followers or largest number of followers heuristics. They will yield the same solution.
Worker 1: A,C
Worker 2: B,D
Worker 3: E,G
Worker 4: F
Worker 5: H,I

(iii) Minimum number of workstations is 5.
Balancing loss= 1-work content/number of workstations * cycle time
= 1-(37/5*9)=17.8%
Hence system is not optimal, there is wasted man power. Company might want to consider overtime / additional roles to some workstations.

(b) Doubling output of the line would mean a new cycle time of 4.5 minutes/unit, meaning a maximum of 9 workstations would be needed. At present, both tasks A and F take longer than cycle time, thus it would not be possible to operate the line at the faster pace. There may be two possible solutions to the problem: a) single tasks could be further broken down and split across work stations to balance them against the faster cycle time, or b) two work stations could be charged with the same task and operate in parallel, which would give them twice the cycle time to complete the task, strategy (a) would lend itself best to task A, whereas strategy (b) would lend itself well to task F.

(c) Consider adding capacity before demand has increased if:

- Demand is forecast to grow and past experience shows forecasts are reliable

- The time required to add capacity is sufficiently long that failure to do so will lead to a competitive disadvantage
- The cost of initial investment in capacity is lower compared to the benefit of additional sales
- Delivery time is a key order winner

Consider waiting to add capacity until after demand has increased if:

- Delivery time is not a key order winner and customers would wait to buy rather than switch (e.g. for products with some degree of monopoly such as luxury goods) Students would need more information on the product and market
- Cost of adding capacity is too great to justify until firm orders are placed (e.g. expensive goods, such as ships or planes)
- Capacity can be added rapidly, so that all risk can be eliminated from the investment decision. This is crucial in young businesses, where cash flow is critical. Production should be designed so that capacity can be increased or decreased rapidly – this is a major driver of outsourcing.

Examiner's comments: This question was aimed at testing the students' understanding of three different concepts. Part (a) asked about assembly line balancing. Students were expected to use the assembly line balancing heuristic and most of them answered this part successfully. Some students had problems with applying the heuristic correctly in part (ii) and commenting on the minimum number of workstations required in part (iii). Part (b) explored students' understanding of how the capacity of the assembly line in part (a) can be doubled. Once again, students approached this part successfully - the minimum grade for this part was 20, and the maximum 30. There were 2 common issues: - the suggestions were not specific to the assembly line given in Part (a) and - students identified only A or F (but not both) as bottleneck. Part (c) asked about the conditions under which a company such consider adding capacity before and after demand increase. Many students mixed strategic and tactical capacity planning issues in this part, which was problematic. As a result, a common assumption was setting capacity equal to production. Most students captured one aspect, either product or capacity characteristics, but not both.

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SECTION B

3 (a) (i) and (ii)

Principles of motion economy that seem to be violated and corresponding recommendations for improvement include the following:

- **Workholding devices should be designed for the task**; a worker's hand should not be used as a workholder. The worker uses her left hand simply to hold the board. A workholder should be designed for the task.
- **Design the work so that both hands are fully utilized**. Because the left hand is used only as a workholder, it is not fully utilized. The method should be redesigned so that both hands are inserting pegs into the board while the board is being held in a workholder.
- **The work should be designed to emphasize the worker's preferred hand**. Because she reaches for "the top board in the stack with her right hand" even though the board is located "on the left side of the worktable (about 45 inches away from centre), we can infer that the worker is right-handed. Yet the starting boards are located on the left side of the workplace. They should be located on the right side if the right hand is used. If there is some reason why the stack must be located on the left side of the workplace, then she should acquire the top board with her left hand.
- **The worker's two hands should never be idle at the same time**. "Because of delays by the material handling worker, the assembly worker is occasionally forced to stop working and wait for the pallet exchange to occur." The worker is idle and so are both of her hands.
- **The lowest classification of hand and arm motions should be used**. The task description states that the worker "picks up the pegs from a tray about 20 inches away in front of her with her right hand and inserts them into the holes in the board, one peg at a time." The implication is that the forearm and upper arm are used for each peg – reaching for the pegs "one at a time" in a tray that is 20 inches away. The worker should pick up several pegs at a time and insert them all before going back to the tray for more. This would require finger and wrist motions for the insertions. If she could handle 4 pegs at a time in each hand, then all 8 pegs could be retrieved using two simultaneous upper arm trips to the tray rather than 8 trips using one hand to retrieve one peg each trip.
- **Tools and materials should be located close to where they are used.** There are several violations of this principle: (a) The placement of the starting stacks and racks to receive the finished boards, located 45 inches to the left of workplace center, are not optimally positioned in the workplace. A location closer to center would be an improvement. (b) The same comment applies to the location of the tray holding the pegs. It is currently 10 inches away. The time to acquire the pegs could be reduced if the tray were closer. (c) "The rack holding the completed boards has a capacity of six assemblies. When the rack is full, the worker gets up from her worktable, picks up the loaded rack, carries it to a pallet located on the floor three feet away from the workplace, and places it onto the pallet." This is very inefficient. The pallet should be in an elevated location much closer than three feet away so that the worker can move the rack more conveniently.

- **Gravity feed bins should be used to deliver small parts**. Instead of using a tray to hold the pegs, use a gravity feed bin. The capacity of the gravity feed bin would probably be greater than the capacity of a tray.
- **Manual operations should be mechanized or automated wherever economically and technologically feasible.** A conveyorised workstation could be implemented to feed the boards to the worker one at a time, instead of requiring her to reach for the empty boards at the beginning of each cycle and then place the assembled boards in a rack at the end of the cycle. This mechanized method would also avoid requiring the worker to place the filled rack onto a pallet every six boards. An automated storage device could be designed to hold a large supply of starting boards and to feed them to the conveyor system. A similar storage device could be designed to accept the assembled boards as they are completed. Such a system would achieve a much higher production rate because it would avoid (a) the irregular work elements to change racks and load pallets and (b) the forced delays when the material handler does not arrive on time

(b)

(i) With the third machine,

$$SPL_{average} = 10\log_{10}\left[{}^{1}\!/_{8}\sum_{i} T_i(10^{0.1SPL_i})\right]$$

$SPL_{avg} = 10 \log_{10}(10^{8.3} + 10^{8.6})$
$SPL_{avg} = 10 \log_{10}(199{,}526{,}232 + 398{,}107{,}171) = 87.76$ dbA

(ii) To be acceptable to noise regulations, the third machine must have a reduced noise level. Let x = the acceptable noise level of the third machine.
$SPL_{avg} = 10 \log_{10}(10^{8.3} + 10^{8.6} + 10^{x/10}) = 90$
$SPL_{avg} = 10 \log_{10}(199{,}526{,}232 + 398{,}107{,}171 + 10^{x/10}) = 90$
$SPL_{avg} = 10 \log_{10}(597{,}633{,}402 + 10^{x/10}) = 90$
$597{,}633{,}402 + 10^{x/10} = 10^{90/10} = 10^{9} = 1{,}000{,}000{,}000$
$10^{x/10} = 1{,}000{,}000{,}000 - 597{,}633{,}402 = 402{,}366{,}598$
$x/10 = \log_{10}(402{,}366{,}598) = 8.605$
$x = 86.05$ dBA

(iii) Steps to reduce the noise exposure level include (1) reduce the time of exposure to 5.0 hours, (2) wear ear plugs, (3) enclose the noise source with sound proofing to isolate the noise, (4) install sound absorbing walls in the facility, and (5) use a quieter machine.

Examiner's comments: This question explored the candidates' understanding of basic industrial engineering concepts – the principles of motion economy and ergonomics. Part (a) which required candidates spot the deficiencies in a manual operation was a differentiator, with the best candidates identifying all the issues and coming up with meaningful recommendations for improvement. The best candidates had explained the issues very clearly and even used pictures to describe potential changes to the operations. Part (b) was well answered by most candidates –

some of the poorer responses exhibited lack of understanding of combining multiple sound sources.

4 (a) A process layout is a layout in which the equipment is arranged according to function. A product layout is a layout in which the equipment and workers are arranged along the line of flow of the work units. In a cellular layout, the work units flow between workstations, roughly as in a production line, but each workstation is equipped to deal with a variety of part or product styles without the need for time-consuming changeovers. The cellular layout attempts to combine the efficiency of a product layout with the versatility of a process layout.

Advantages of a process layout include (1) versatility to cope with product variety, (2) general purpose equipment, (3) higher-skilled labour, and (4) less risk of equipment obsolescence. The disadvantages of a process layout include (1) Low facilities utilization, (2) Can have very high work-in-progress or customer queuing, and (3) Complex flow can be difficult to control.
Advantages of a product layout include (1) higher efficiency, (2) higher production rates, (3) lower-cost labour, and (4) lower work-in-process. The disadvantages include (1) can have low mix flexibility; (2) not very robust if there is disruption, (3) Work can be very repetitive.
A process layout is suited to low and medium production quantities where product variety is medium or high. A product layout is suited to high production and low product variety. In addition, it must be possible to divide the total work content of the product into much smaller work elements that can be assigned to workstations along the line of flow.

The advantages of a cell layout are (1) it gives a compromise between cost and flexibility for relatively high-variety operations, (2) Fast throughput, (3) Potential good staff motivation. On the other hand, the disadvantages are (1) Can be costly to rearrange existing layout, (2) Can require more equipment, and (3) Can give lower equipment utilization.

Good candidates will be expected to discuss this in greater detail and provide examples of situations/product types that are suited for each type of layout.

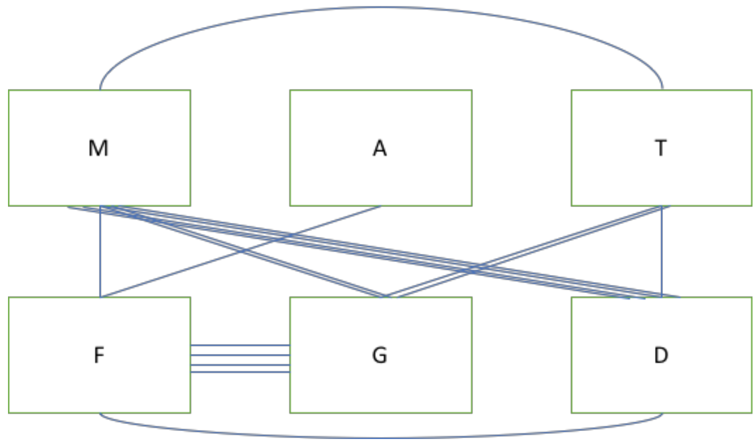
(b) (i)

The From-To chart and the corresponding activity relationship chart based on the data given is shown below:

From\To	M	D	T	G	F	A
M	-	110	10	70	30	
D	70	-	20		60	
T	30		-	60		
G				-	180	
F					-	130
A						-

	M	D	T	G	F	A
M	-	A	O	I	O	U
D		-	O	U	I	U
T			-	I	U	U
G				-	A	U
F					-	E
A						-

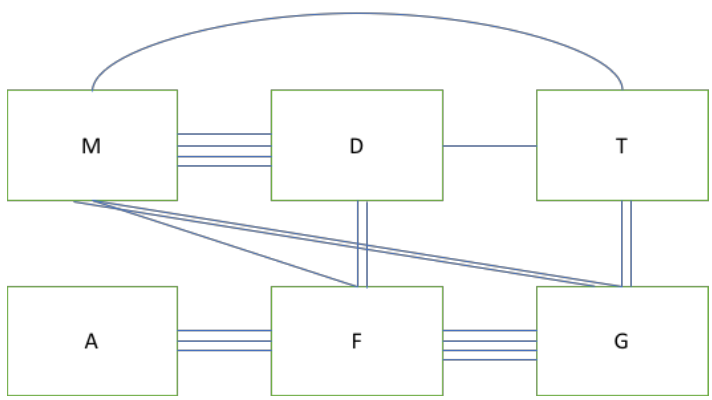
The activity relationship diagram for the proposed layout is shown below:



Using the following points for the closeness ratings – A=4; E=3; I=2; O=1; U=0, based on the activity relationship chart, the adjacency score is given by:

$CR_{FG}+CR_{MF}+CR_{TD} = 4+1+1 = 6$
Maximum adjacency score = 20
Hence, Layout Efficiency Rating = 0.3

(ii) Based on the activity relationship chart, an improved activity relationship diagram is shown below:



And the corresponding layout is shown below:

M	D	T
A	F	G

The Layout Efficiency Rating of this Layout = 16/20 = 0.8.

(iii) There are a number of missing elements to this analysis that the candidates are expected to discuss:

- Need to consider the space required in each department considering the number of machines required, which in turn is based on the predicted demand.
- Various adjustments and allowances will need to be added to the space calculation, which includes:
  - Personnel requirements - rest rooms, locker rooms, food services, plant entrances and exits
  - Material handling methods - may affect floor space and building height
  - Storage facilities - treat as separate department or add allowance
  - Aisle space - add a percentage allowance
  - Offices - for individual departments
  - Building features - walls, column locations
- Further, additional considerations include:
  - Budget - construction costs may impose limitation on building size
  - Building codes - may affect location of building on property as well as structural and utility details
  - Safety requirements - some included in building codes
  - Since this is an existing building, its shape and size of building is a limitation on plant layout design

Examiner's comments: This question focused on production layout design. Responses to part (a) was variable – the best responses explained the differences in great detail, picking up the volume-variety graph as a means to explain the layouts. Interestingly, some candidates really had not understood the different layouts, making fundamental mistakes and even confusing the definitions. Part (b), which required the candidates to evaluate a given layout and suggest an improved layout also brought out wide variation in understanding. The calculations for LER were not done correctly by many candidates. Most candidates suggested an improved layout, however did not explain the methodology clearly.

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