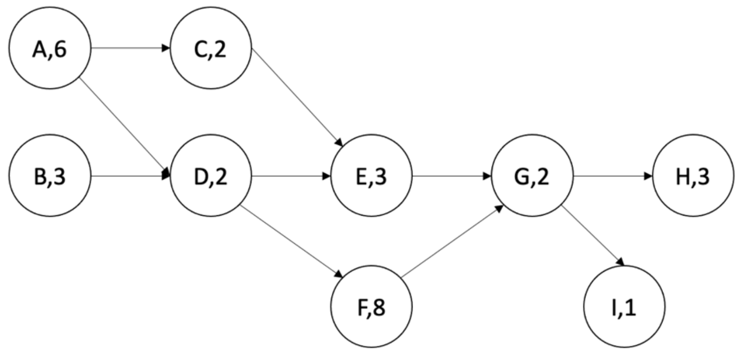
CRIB
Question 1

(a) (i)



(ii) The work content is 30 minutes.
Cycle time = (7.5 hours * 60) / 75 units = 6 minutes / unit
Minimum number of stations = work content/cycle time = 30/6 = 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

Students can also consider that Task D will take 8 minutes, which is 2 minutes more than the cycle time (6 minutes) and this can result in different balancing loss and minimum number of work stations based on the heuristics

(iii) Minimum number of workstations is 5.
Balancing loss $= 1 - \frac{Total\ processing\ time\ per\ item}{Number\ of\ stations * Cycle\ time} = 1 - \frac{30}{5*6} = 0$
Hence the system is optimal and there is no wasted human resource power.

(b) Based on new capacity of 200 units per day, the new cycle time = (7.5 * 60) / 200 units = 2.25 minutes/unit. This would require the company to have a maximum of 12 work stations to meet the renewed demand. At present, task A takes the same duration as the cycle time while task F takes longer than the cycle time. Thus, it would not be possible to operate the line at a faster pace. There could be two potential solutions to the problem: a) single tasks could be further broken down and split across the 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. In comparison, strategy (a) would lend itself best to task A, whereas strategy (b) would lend itself well to task F.

(c) Exponential Smoothing (ES) forecasts contain information on all previous demands, each demand is given a weight that is decreasing exponentially back in time.

Smoothing constant: $0 < \alpha < 1$

$$S_t = \alpha \cdot x_t + (1 - \alpha) \cdot S_{t-1}$$

ES does not cope well with linear trends and seasonality. Therefore, there are adaptations of simple ES to cope with linear trends (double ES) and quadratic trends (triple ES).

Double exponential smoothing:

- Basic idea is to introduce a trend estimate.
- It is similar to single exponential smoothing but we have two equations
- Need to choose two smoothing rates, α and β

Trend adjusted level equation

$$A_t = \alpha x_t + (1-\alpha)(A_{t-1} + \underset{\text{Trend estimate}}{T_{t-1}})$$

Trend equation

$$T_t = \beta(A_t - A_{t-1}) + (1-\beta)T_{t-1}$$

Forecast

$$S_t = A_t + T_t$$

Triple exponential smoothing:

- Basic idea is to introduce a trend estimate and a seasonality estimate
- Similar to double exponential smoothing but we have three equations
- Need to choose three smoothing rates, α, β, and γ

In both methods, trend dominates after a few periods in forecasts so forecasts are only good for a short term.

In addition, in triple ES, we need initial valued for three parameters, which can be difficult to estimate.

- Demand is forecasted to grow and experience shoes that forecasts are reliable.
- The time required to add capacity is sufficiently long that failure to do so will lead to a competitive disadvantage.
- Delivery time is a key order winner.
- The cost of initial investment in capacity is lower compared to the benefit of additional sales.

Consider adding capacity after demand has increased if:

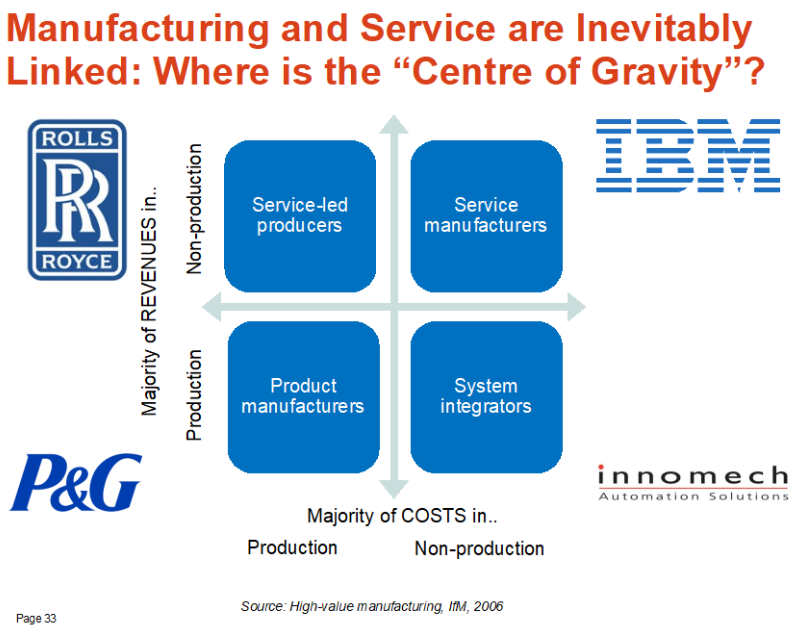
- Delivery time is not a key order winner and customers would wait to buy rather than switch.
- Cost of adding capacity is too great to justify until the company orders are places (e.g. expensive equipment).
- Capacity can be added rapidly, so that all the risk can be eliminated from the investment decision. This is crucial in young businesses, where cash flow is critical. Production should be designed so that capacity can be increased or decreased rapidly, that is a major driver of outsourcing.

Question 2

(a) The nature of manufacturing and services differ considerably:

Pure Goods	Pure Services
• Tangible	• Intangible
• Can be stored	• Cannot be stored
• Production precedes consumption	• Production and consumption are simultaneous
• Low customer contact	• High customer contact → inherent variability
• Can be transported	• Cannot be transported
• Quality is evident	• Quality difficult to judge

However, very few operations are purely good or service. Many operations provide a combination of both (e.g. simple example of a restaurant), but also servitization strategies. That is, service operations and manufacturing operations are inevitably linked:



(b) Here is a brief description of each of these terms:

- **Cycle Stock**: Active component that depletes over time and is replenished cyclically.
- **Safety Stock:** Surplus held to protect against fluctuations of demand, production, and supply.
- **Pipeline Stock:** Stock created by the time spent to move and produce inventory.
- **Anticipation Stock:** Stock held to smooth output rates by stockpiling during the slack season or overbuy before a price increase or capacity shortage.

The discussion on the function of these inventory types:

- Cycle stock:
  - Smoothing or levelling of production
  - Achieving economies of scale and managing fixed costs
- Safety stock:
  - Buffer against uncertainty and disruptions
  - Market demand (seasonality, promotions, etc.)
    - Production throughput (quality, machine breakdown, etc.)
    - Supply of components
- Anticipation stock:
  - Exploitation of price fluctuations: Raw materials: cocoa, coffee, etc.
  - To level production
- Pipeline stock:
  - Exist due to long lead times.

Then, for the last part, students should discuss the main drivers of each component and how that can be decreased. For example, for cycle stock reducing fixed costs through technology.

(c) The key capacity decisions are:

- **Sizing:** How much capacity to invest in?
- **Timing:** When to increase or reduce resources?
- **Type:** What kinds of resources are best?
- **Location:** Where should resources be located?

Challenges of capacity planning:

- Capacity is a soft, malleable constraint.
- Capacity depends on everything.
- Capacity frictions: leadtimes, lumpiness, fixed costs.
- Capacity requires large and irreversible investment.
- Capacity decisions can be political.
- Measuring and valuing capacity shortfall is not obvious.
- Capacity investment involves long-run planning under uncertainty, which is arguably the greatest challenge for capacity strategy

(d) **Order Qualifiers**: hygiene factor; minimum requirements a product or service must meet to be considered by a customer in a particular market.

a. Characteristics:
   i. Threshold-based: They have a minimum acceptable level that customers expect. Exceeding the minimum doesn't necessarily provide an advantage.

   ii. Industry-standard: May be common features or expectations across similar products or services.

   iii. Price-driven: Often linked to price sensitivity, where customers compare based on meeting basic needs at the lowest cost.

b. Examples:

   i. Minimum safety standards for a car

   ii. Basic functionality of a smartphone

   iii. On-time delivery for perishable goods

Order Winners: Features or attributes that differentiate a product or service from competitors and influence customers to choose it. They drive competitive advantage and lead to winning orders.

c. Characteristics:

i. Unique or superior: Offer something extra or better than competitors, exceeding basic expectations.

ii. Value-driven: Provide additional benefits or solve specific customer problems, justifying a premium price.

iii. Differentiation: Set the product apart and create a strong competitive edge.

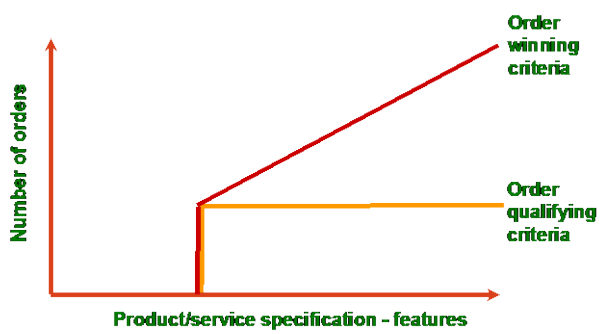
d. Examples:

i. Innovative design features in a phone

ii. Exceptional customer service and support

iii. Faster processing power in a computer

iv. Sustainable and eco-friendly practices



SECTION B

Question 3.

(a)

(i) Proportion of time on the phone

$p\hat{p}1$ = 164/500 = 0.328

Hours on the phone for 4 account executives =

4 (5 days) (7 hr/day) (0.328) = 45.92 hr

(ii) For 97% confidence interval,

Zscore $z_{\alpha/2} = \mathbf{2.17}$

$\hat{\boldsymbol{\sigma}}_{\boldsymbol{p}} = \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$ = 0,021

$\hat{p} - z_{\alpha/2}\hat{\sigma}_p$ = 0.328– 2.17(0.021) = 0.328 – 0.0456 = 0.2824

and $\hat{p} + z_{\alpha/2}\hat{\sigma}_p$ = 0.328+ 2.17(0.021) = 0.328 + 0.0456 = 0.3736

at a confidence level of $1 - \alpha$

(iii) Consider how much time is spent in category 2 by account executives.

$\hat{p}2$ = 150/500 = 0.30

Total hours of 4 account executives in category 2 = 4(7)(0.30) = 8.4 hr/day

The newly hired clerk would spend 7 hr/day performing filing and sorting for the account executives.

Commissions per week = £525,000(0.04) = £21,000/wk

Sales commissions per hour = 21,000/45.92 = £457.32/hr

Increase in commissions for 7 hours = 7(457.32) = £3,201.24

Increase in commissions per week = 5(£3,201.24) = £16,006/wk

The net weekly increase = 16,006 – 750 = £15,256.

With the clerk costing only £750/wk, it is worth recruiting the clerk.

(b)

(i)

Illuminance decreases with distance from the light source:

$E = I/d^2$

Where E = illuminance, l = luminous intensity and d = distance.

Therefore, if one light has a luminous intensity of l

Currently E = 50l/25

if the height is reduced to 3 metres, then E = xl/9

Therefore x = 9 x 50/25 = 18

Lighting requirements

Basic answers. The students will describe and consider different factors by comparing and contrasting the sales offices vs the workshop space.

Stronger answers will discuss the tasks for the sales executives such as include reading and research, which might require a different lighting condition than working on a machine tool. In the machine tool workshop, the students will discuss better lighting requirements for critical operations and inspection bays.
Best answers will discuss some of the lighting and the ergonomics of the lighting requirements and the use of direct light as opposed to indirect focal lights. They might illustrate with an specific examples seen in Domino Printing case explain during class.

Question 4.
(a)
(i)
Basic time: $T_b = T_{obs} \times PR$

$T_b = 0.50(0.80) + 0.25(1.0) + 0.58(0.95) + 0.72(1.0) + 0.85(1.0)/6 + 1.01(0.95)/4$

$\boldsymbol{T_b = 2.30}$ **min**

Standard time: T_{std} = Basic Time + Allowances

$T_{std} = 2.30(1 + 0.17)$

$\boldsymbol{T_{std} = 2.69}$ **min**

(ii)
Basic time: $T_b = T_{obs} \times PR$

$T_b = 0.50(0.80) + 0.25(1.0) + 0.58(0.95) + 0.72(1.0) + 1.01(0.95)/4 + 0.62/6(0.95)$

$\boldsymbol{T_b = 2.2590}$ **min for the 2024 production**

Standard time: T_{std} = Basic Time + Allowances

$T_{std} = 2.2590(1 + 0.17)$

$\boldsymbol{T_{std} = 2.6430}$ **min for the 2024 production**

(b)
OEE = Availability* EEP*Quality (expressed as %)
Availability =75-3-7.5/75 = 86%
EEP = 10*4.5/60 =75%
Quality = 96%
OEE = (0.86*0.75*0.97)*100%
OEE = **62.56%**

(c)
Process also called functional layout
Process also called functional layout consists of departments containing operations with the same function. Products move around the factory, from department to department, having operations performed in sequence.
In the process layout, equipment is arranged according to function. The Group Technology (GT) is combined by the functions of that the technologies performed. For example, department of drilling, milling, etc. Different parts or products are processed through different operations in batches.

- Each batch of products follows its own routing

- Different machine tools are in different departments
- Examples: Satellites

Cellular also called cell layout
A cellular or cell layout co-locates all the operations required to manufacture a group of products. Layout in which work units flow between stations, as in a production line, but each station can cope with a variety of part styles without the need for time-consuming changeovers.

- Combination of product and process layouts. It tries to combine efficiency of product layout with versatility of process layout.
- Neither objective is achieved perfectly, but it is more efficient than a process layout and more versatile than a product layout.
- Based on principles of group technology (group different types of products), e.g. by customer, size or shape or range of products.

In the cellular layout, the group technology method groups together components having similar design characteristics or manufacturing processing requirements. When Group Technology is combined with cellular production, products are manufactured completely in one cell.

Basic answers will describe the basic definitions of the process layout and cellular layouts and their individual advantages and disadvantages.

Process layout
Advantages include high mix and product flexibility, relatively robust in the case of disruptions, relatively easy supervision of transforming resource
Disadvantages include low facilities utilization, very high work-in-progress or customer queuing and complex flow can be difficult to control.
Cellular layout
Advantages include a compromise between cost and flexibility for relatively high-variety operations, fast throughput, potential good staff motivation.
Disadvantages include could be costly to rearrange existing layout, require more equipment, lower equipment utilization.
Stronger answers will discuss the above plus the differences between the two layouts by using the two key production layout factors: (a) quality and (b) variety/volume.
The typical advantages of a cellular layout compared to a process layout, include:

- Shorter throughput times – overlapping operations and reduction of queues
- Reduced inventory
- Simplified planning and control at factory level

Whereas the advantages of process layout over cellular are

- Suited to low and medium production quantities and medium to high product variety.
- High variety of sequences of operations

Best answers will discuss the above plus provide more descriptive examples drawing from manufacturers such as Zara and Domino Printing production processes, etc.

END OF PAPER