Version FE/3

EGT2
ENGINEERING TRIPOS PART IIA

Module 3E10

OPERATIONS MANAGEMENT FOR ENGINEERS – CRIB

1 (a) Consider a product with a one-month shelf life. The average montly sales for the product is 1,000 units. The fixed cost of ordering is £1,000. The cost per unit is £50. The cost of keeping the product in stock is 40% of its value per year.

(i) Find the optimal order quantity for this product. How frequently must the company place an order? [20%]

ANSWER: D = 1,000*12 = 12,000 per year, C_S = \$ 1,000, and C_H = 50*0.4 = £20 per product per year.

$$EOQ = \sqrt{\frac{2*D*C_S}{C_H}} = \sqrt{\frac{2*12,000*1000}{20}} = 1,095 \text{ units.}$$

However, as the shelf-life of the product is only a month, 95 units would be discarded if this much was ordered. Instead the optimal order quantity is $\min\{1000, 1095\} = 1,000$ units.
That is, the store has to place 12,000/1000 = 12 orders /year

(ii) Write the total cost function. How much does the company spend per year for this product? [15%]

ANSWER:

$$\begin{aligned} TC(Q) &= \frac{Q^*}{2} \times C_H + \frac{D}{Q^*} \times C_S + 50 \times D \\ &= \frac{1,000}{2} \times 20 + \frac{12,000}{1,000} \times 1000 + 50 \times 12,000 \\ &= 10,000 + 12,000 + 600,000 = 622,000. \end{aligned}$$

(iii) The company is considering alternative sourcing options for this product. Discuss key advantages and disadvantages of moving the production in-house rather than outsourcing. [15%]

ANSWER:
Pros of outsourcing:

- Focus on core competencies
- Harness lower labour cost at supplier
- Access to technology
- Stable and predictable financial planning in fee-for-transaction services
- Less investment risk

Cons of outsourcing:

- Loss of control over process
- Limited ability to improve processes
- Risk of opportunistic behaviour of supplier
- Loss of human capital and tacit knowledge

They should consider:

- Cost per unit, including quantity discounts
- Any administrative costs
- Lead time on orders (both mean and variance)
- Order restrictions, e.g., minimum order quantity
- Information sharing, collaboration, communication
- Quality

(b) Using key competitive priorities, explain and discuss how a company's operations can provide a competitive advantage. Provide examples of companies as appropriate. [20%]

ANSWER: Value = Performance/cost

Cost	Quality	Time	Flexibility
Offering product at a low price relative to competition	**Doing things right, to a standard**	**Reliability and speed of delivery**	**Ability to change (volume, product mix, design)**
Typically, high volume products • Often limit product range & offer little customization • May invest in automation to reduce unit costs • Can use lower skill labour	Quality is often subjective Quality is defined differently depending on who is defining it Service quality is meeting and exceeding customer requirements. High quality services companies demonstrate: • Superior product features • Excellent customer service • Consistent delivery • Process quality – error free delivery	Rapid delivery: Focused on shorter time between order placement and delivery, minimal wait times On-time delivery: Deliver product exactly when needed every time Availability: Convenient and readily available when customer requires	Company environment changes rapidly. Company must accommodate change by being flexible Easily customize product/service to meet specific requirements of a customer Ability to ramp capacity up and down to match market demands
E.g., Ryan Air, Aldi	E.g., Rolex, Etihad	E.g., Amazon Prime, UPS	E.g., Zara, Dell

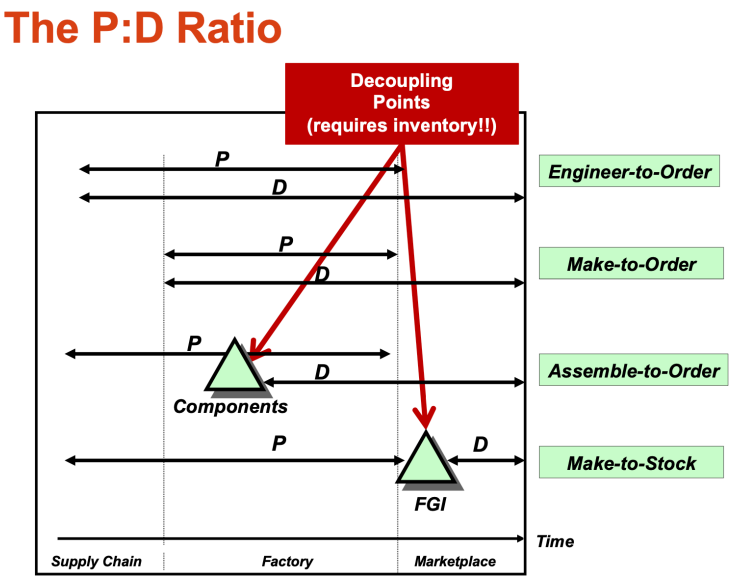
(c) Discuss and explain the following statement: Problems are natural and opportunities to learn, not blame! [10%]

ANSWER: Most problems arise from not following standards. Every problem has root cause and counter-measures.

(d) Explain the following order fulfilment strategies: Make-to-Stock, Assemble-to-Order, Make-to-Order, Engineer-to-Order. Provide examples and discuss the P:D ratio for each. [20%]

ANSWER:

- Make-to-Stock (MTS): Customers are not willing to wait for production. Therefore, goods made to be placed in stock prior to receiving an order; typical of commodities and continuous processing, some line production; Efficient production, but risk of obsolescence / high stock cost
- Assemble-to-Order (ATO): Customers value customisation and willing to wait for the assembly. Producers hold components stock to assemble an order as required by the customer; typical of line/ batch production; Responsive for customised products, but still cost of stock
- Make-to-Order (MTO): Customers value customisation are willing to wait even longer for the product. Material ordered and product or service made only after the buyers order is received Âğ Line, batch and job shop production; No FGI cost, but potentially less efficient production
- Engineer-to-Order (ETO): Product designed and built to customer order; typical of projects, some job shop



2 (a) Three refineries with maximum daily capacities of 10, 7, and 10 million gallons of oil supply three Distribution Centres (DCs) with daily demands of 8, 12, and 5 million gallons.

Oil is transported to the three DCs through a network of pipes. The transportation cost is 1 pence per 100 gallons per mile. Refinery I is not connected to DC3. Table 1 shows the mileage among refineries and DCs.

Table 1

	DC1	DC2	DC3	Capacity (in million gallons)
Refinery I	60	95	-	10
Refinery II	150	50	40	7
Refinery III	100	125	60	10
Demand (in million gallons)	8	12	5	

(i) State the basic principles of the North West Corner approach for allocating supply to demand. What are the limitations of the approach? [20%]

ANSWER: Basic Principles:

- Create a matrix of sources and destinations
- Set initial allocation from NW corner
  - Fulfil as much of demand from first destination from the first source as possible
  - If supply from first source > demand from first destination, allocate excess to second destination
  - If supply from first source < demand from first destination, fulfil demand from second source (and so on ...)

Limitations:

- Not necessarily optimal (but “good enough”)
- May not be evident why they work

(ii) Find an initial North West Corner allocation for the configuration in Table 1 and calculate the total distribution cost associated with that allocation. [10%]

ANSWER: This is a necessary condition for solving the problem: the total supply of suppliers should be equal to the total needs of consumers.
Upon checking it

- The total supply of suppliers: 10 + 7 + 10 = 27 units.
- The total needs of consumers: 8 + 12 + 5 = 25 units.

The total supply of suppliers is more than the total needs of consumers. As supply > demand, we will create a dummy distribution point with zero transportation cost to represent surplus supply.

	DC1	DC2	DC3	Surplus	Capacity (in million gallons)
Refinery I	60	95	-	0	10
Refinery II	150	50	40	0	7
Refinery III	100	125	60	0	10
Demand (million gallons)	8	12	5	2	27

Table 1

This is a necessary condition for solving the problem:

- number of used routes = number of suppliers + number of consumers - 1.

Therefore, if we have a situation where it is necessary to exclude a column and a row at the same time, we will exclude one thing.
We will start filling the table from the upper left corner and gradually move to the lower right corner.
From the North-West to South-East:

$$R_1 \text{ to } DC_1 = \min\{10, 8\} = 8$$
$$R_1 \text{ to } DC_2 = \min\{2, 12\} = 2$$
$$R_2 \text{ to } DC_2 = \min\{7, 10\} = 7$$
$$R_3 \text{ to } DC_2 = \min\{10, 3\} = 3$$
$$R_3 \text{ to } DC_3 = \min\{7, 5\} = 5$$
$$R_3 \text{ to } S = \min\{2, 2\} = 2$$

The total distribution cost associated with the above allocation:
= 8*60 + 2*95 + 7*50 + 3*125 + 5*60 = 1,695

(iii) Is the solution in part (a)(ii) optimal? If yes, explain why. If no, find an improved solution. [10%]

ANSWER: This solution is optimal as all the feasible empty cells would have positive opportunity costs.

	DC1	DC2	DC3	Surplus
R1	8 60	2 95	-	30 0
R2	135 150	7 50	55 40	75 0
R3	10 100	3 125	5 60	2 0

(b) Explain the following terms: cycle stock, safety stock, pipeline stock, and anticipation stock. Discuss the function of each of these inventory types. How can a company decrease them? [20%]

ANSWER: 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.

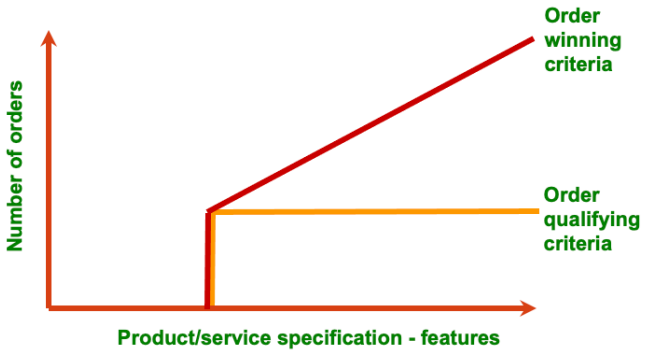
Then, for the last part, students should discuss the main drivers of each component and how that can be decreased. For example, for cycle stock reducing fixed costs through technology.

(c) All operations management decisions are trade-offs. Discuss the need of trade-offs in short- and long-term. [20%]

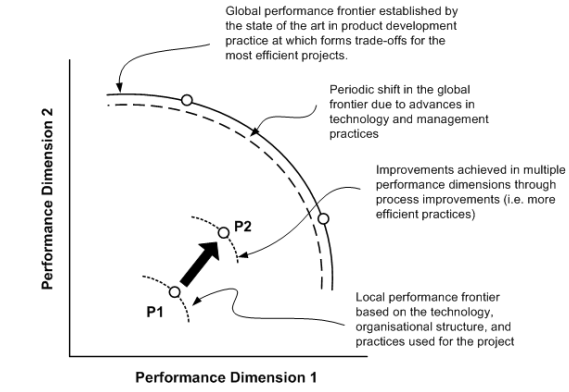
ANSWER: Decisions about competitive capabilities must emphasise performance objectives that support business strategy. World-class companies no longer view cost, quality, speed/time of delivery, and even flexibility as trade-offs. They have become order qualifiers.

Order Qualifiers: hygiene factor, needed to be considered by customer

Order Winners: distinguishing factors that drive customer choice



Performance Frontiers



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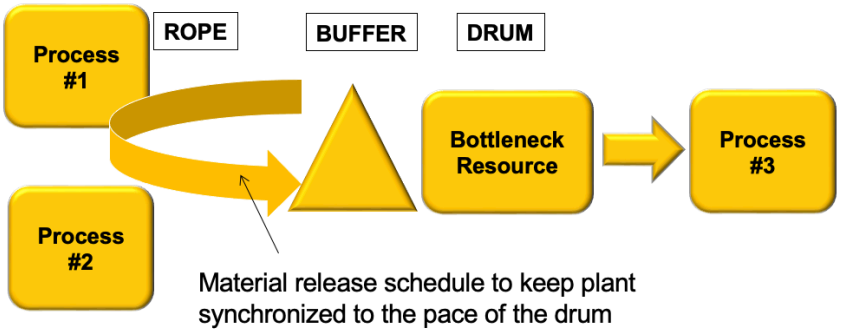
(d) According to Goldratt, "An hour lost at a bottleneck is an hour lost to the system." Based on this statement, discuss how a company following the priciples of theory of constraints can manage its operations. [20%]

ANSWER: Theory of constraints (TOC) focuses on the improvement on the bottlenecks.The method allows the bottleneck to control the activity of the system.

How to schedule operations to maximise throughput?

- Protect throughput at bottleneck with buffer
- Bottleneck becomes pacemaker for entire process
- Every minute that is not used at the constraint is a minute lost to the whole process



3 (a) Consider a company that estimates the following demand for its products over the next three months:

Month	July	August	September
Demand Forecast	2,000	1,600	2,000

There are currently 10 workers working at the company and it is estimated that one worker can produce 5 products per day. It can be assumed that each month has 20 working days. Hiring cost is £1,000 and lay-off cost is £2,000 per worker. Inventory cost is £10 per product per month.

The company will have 450 products in inventory at the end of June, and would like to have at least 600 products in inventory at the end of September. Assuming that stock-outs or backorders are not allowed:

(i) Determine the minimum constant workforce plan and the cost of that plan. [20%]

ANSWER:

Month	Cumulative Net Demand (A)	Cumulative # of Units Produced per Worker (B)	Ratio of A/B (round up)
July	1550	100	16
August	3150	200	16
September	5750	300	20

Month	# Units Produced per Worker (A)	Monthly Production (B= A*20)	Cum. Production (C)	Cum. Net Demand (D)	Ending Inventory (E=C-D)
July	100	2000	2000	1550	450
August	100	2000	4000	3150	850
September	100	2000	6000	5750	250
					1550

	Number of Units	Unit Cost	(Number of Units) x (Unit Cost)
Hiring Cost	10	1000	10000
Layoff Cost	0	2000	0
Inventory Cost	1550	10	15500
Adjusted Cost	600	10	6000
TOTAL			31500

(ii) Determine the zero-inventory plan (chase strategy) and the cost of that plan. [20%]

ANSWER:

(cont.

Month	Net Demand	# Units Produced per Worker	Number of Workers Required
July	1550	100	16
August	1600	100	16
September	2600	100	26

Month	Number of Workers Required	Hires/Layoffs	Number of Units Produced	Cumulative Production	Cumulative Demand	Ending Inventory
July	16	6	1600	1600	1550	50
August	16	0	1600	3200	3150	50
September	26	10	2600	5800	5750	50
						150

	Number of Units	Unit Cost	(Number of Units) x (Unit Cost)
Hiring Cost	16	1000	16000
Layoff Cost	0	2000	0
Inventory Cost	150	10	1500
Adjusted Cost	600	10	6000
TOTAL			23500

(iii) Assume that estimates for the following 2 months became available and the company also wants to capture those months in the plan.

Month	October	November
Demand Forecast	400	1,200

Now assume that you do not need to have any inventory on hand at the end of September but you still have 450 products in inventory at the beginning of July and no ending inventory is needed at the end of November. Now the company is allowed to hire/layoff workers once at the beginning of July and second at the end of September (beginning of October). Suggest the mixed plan possible in this situation where no backorders or stock-outs are allowed. Determine the total holding and hiring/layoff cost in this mixed case. [20%]

ANSWER:

Month	Cumulative Net Demand (A)	Cumulative # of Units Produced per Worker (B)	Ratio of A/B (round up)
July	1550	100	16
August	3150	200	16
September	5150	300	18

Month	# Units Produced per Worker (A)	Monthly Production (B= A*18)	Cum. Production (C)	Cum. Net Demand (D)	Ending Inventory (E=C-D)
July	100	1800	1800	1550	250
August	100	1800	3600	3150	450
September	100	1800	5400	5150	250
		(B=A*7)			
October	100	700	6100	5550	550
November	100	700	6800	6750	50
					1550

Month	Cumulative Net Demand (A)	Cumulative # of Units	Ratio of A/B (round up)
October	150	100	2
November	1350	200	7

	Number of Units	Unit Cost	(Number of Units) x (Unit Cost)
Hiring Cost	8	1000	8000
Layoff Cost	11	2000	22000
Inventory Cost	1550	10	15500
Adjusted Cost	0	10	0
TOTAL			45500

(b) Many manufacturing companies include 'set-up time reduction' activities in their production improvement programmes. Explain how reducing set-up times in manufacturing can benefit an organisation, and what can be done for implementing shorter set-ups. [20%]

ANSWER: A good answer would discuss the impact of set-up time reduction on batch sizes, inventory, quality problems.

(c) Discuss the impact of recent capacity problems/closures of Suez and Panama canals on supply chains and customers. [20%]

ANSWER: A good answer would discuss increase in lead times, uncertainty, costs, inventory fluctuations, factory closures, etc.

END OF PAPER