Version FE/2

EGT2
ENGINEERING TRIPOS PART IIA

Module 3E10

OPERATIONS MANAGEMENT FOR ENGINEERS - CRIB

1 (a) *Indicate whether the following statements are true or false. Provide a brief reason for each answer.*

(i) *The fixed-time period model is preferred over the fixed-order quantity model for more expensive items.* [5%]

ANSWER: FALSE. The fixed-time period model typically requires holding more inventory on average, since it must protect against stockout during the review period and lead time from reordering. Therefore, the fixed-order quantity model is preferred for more expensive items because average inventory is lower.

(ii) *Make-to-stock production outperforms make-to-order production in terms of efficiency and inventory.* [5%]

ANSWER: FALSE. In make-to-stock production goods are made to be placed in stock prior to receiving an order. Therefore, make-to-stock production is indeed efficient, but it faces risk of obsolescence / high stock cost.

(iii) *Forecasting is essential for dependent demand.* [5%]

ANSWER: FALSE. Dependent demand is a known function of independent demand; therefore, no forecasting is required for dependent demand.

(iv) *A process that is under control is also capable.* [5%]

ANSWER: FALSE. A process is capable when it can produce output that meets customer specifications. However, a process is in control when it behaves as expected, that is it exhibits only random variation. Therefore, a process that is under control may not be capable.

(b) *Ada owns and operates a small factory that manufactures plastic bottles which she sells to bottling companies. The annual demand is 1 million bottles spread evenly over the year. The setup cost is £5,000 per batch, the holding cost is £3 per annum for each bottle. The maximum production capacity is 2 million bottles per annum. Currently, bottles are manufactured in 10 equal batches.*

(i) *Calculate the current annual holding cost and setup cost.* [15%]

ANSWER: Current batch size is $Q = 100,000$.

$$\begin{aligned} \text{Annual holding cost} &= \frac{Q}{2} * C_h * (1 - D/P) = \frac{100,000}{2} * 3 * 0.5 = £75,000 \\ \text{Annual setup cost} &= 5,000 * 10 = £50,000 \\ \text{Total cost} &= 75,000 + 50,000 = £125,000. \end{aligned}$$

(ii) *Find the optimal production quantity that Ada should produce to minimise her costs.* [20%]

ANSWER: $D = 1,000,000$, $P = 2,000,000$, $C_s =$ £5000 per batch, $C_h =$ £3 per annum for each bottle,

$$Q^* = \sqrt{\frac{2*D*C_s}{C_h(1-D/P)}} = \sqrt{\frac{2*1,000,000*5,000}{3(1-1,000,000/2,000,000)}} = 81,650$$

(iii) *Calculate Ada's savings relative to the current strategy if she adopts the quantity in part (ii).* [15%]

ANSWER: $Q^* = 81,650$.

$$\begin{aligned} \text{Annual holding cost} &= \text{Annual setup cost} = 5,000*1,000,000/81,650 = £61,237 \\ \text{Total cost} &= 2*61,237 = £122,474. \end{aligned}$$

Therefore, the savings are £2,526.

(c) *Define the customer value equation. Discuss, with examples, how companies can maximise customer value.* [15%]

ANSWER: Value = Performance/Cost, where performance is a function of:

- Quality: doing things right, to a standard
- Speed/Dependability: reliability and speed of delivery
- Flexibility: ability to change (volume, product mix, design)

In order to maximise value, companies may:

(i) Compete on cost: e.g. Aldi, Asda, Ryan Air, etc.

- Offering product at a low price relative to competition
- Typically high volume products
- Often limit product range and offer little customization
- May invest in automation to reduce unit costs
- Can use lower skill labour
- Low cost does not necessarily mean low quality

(ii) Compete on quality: e.g. Wait Rose, Etihad, etc.

- Superior product features
- Excellent customer service
- Consistent delivery
- Process quality; error free delivery

(iii) Compete on speed/dependibility: e.g. Amazon, UPS, etc.

- 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

(iv) Compete on flexibility: e.g. Dell, etc.

- 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

(d) *Discuss common methods of adjusting medium term capacity, and describe various trade-offs of these methods.* [15%]

ANSWER: In the medium term, there are four options available to companies for coping with variations in demand:

- Level capacity plan: processing capacity is set at a uniform level throughout the planning period, regardless of the fluctuations in forecast demand. Capacity at uniform level throughout the planning period, thus same number of staff operate the same processes, finished goods transferred to inventory in anticipation of sales at later time. Suitable for non-perishable goods. Advantages: Stable employment patterns, high process utilisation, high productivity with low unit costs Disadvantages: Considerable inventory costs

- Chase demand plan: attempts to match capacity closely to the varying levels of forecast demand. Advantages: Inventory costs are minimal. Disadvantages: Hiring and layoff costs, the system is changing constantly.

- Optimal capacity plan: balances the costs of levelling and varying the capacity

- Demand management: change demand to suit capacity; may work effectively if capacity costs are high

2 (a) *The table below shows the distribution matrix for a transportation problem..*

	L	M	N	Supply
P	3	5	8	22
Q	4	3	7	18
R	6	4	8	11
S	8	2	5	9
Demand	15	17	20	

(i) *Explain the concept of degeneracy in a solution given by the northwest corner method.* [15%]

ANSWER: Northwest corner method may not be able to find solution (i) if there are less than $m+n-1$ assignments and (ii) when shifting assignments, to achieve improvement, more than one assignment goes to 0.

Degeneracy can be solved by regarding one of the unallocated squares as having an extremely small ε allocation. Such a small amount does not affect rim totals and it is treated exactly the same as other allocations, but makes it possible to meet $m+n-1$ condition.

(ii) *Write down the initial solution given by the northwest corner method and calculate the total distribution cost associated with that allocation.* [15%]

ANSWER: In this problem, supply > demand. Then, we need to create dummy distribution points with zero transportation cost to represent surplus supply.

	L	M	N	Dummy	Supply
P	3	5	8	0	22
Q	4	3	7	0	18
R	6	4	8	0	11
S	8	2	5	0	9
Demand	15	17	20	8	

We can then apply the method to find the initial solution as follows:

	L	M	N	Dummy	Supply
P	15	7			22
Q		10	8		18
R			11		11
S			1	8	9
Demand	15	17	20	8	

Total cost is = 3 * 15 + 5 * 7 + 3 * 10 + 7 * 8 + 8 * 11 + 5 * 1 + 0 * 8 = 259

(iii) *Show that this initial solution is not optimal by providing an alternative solution with a lower cost.* [20%]

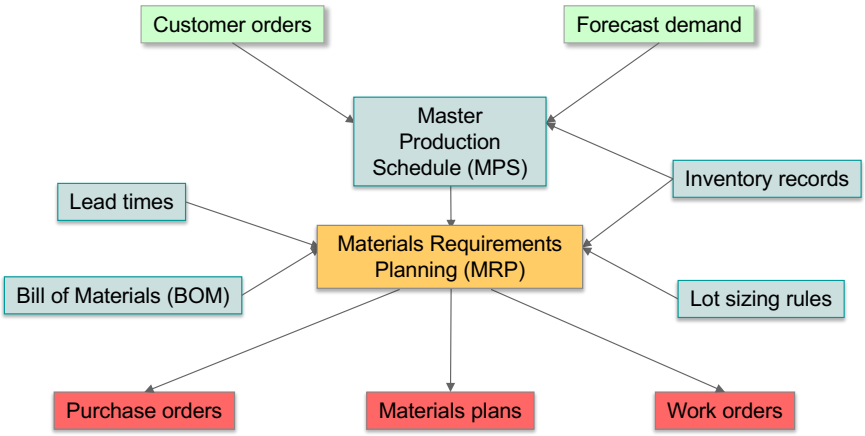
ANSWER:

	L	M	N	Dummy	Supply
P	15		7		22
Q		17	1		18
R			11		11
S			1	8	9
Demand	15	17	20	8	

Total cost is = 3 * 15 + 8 * 7 + 3 * 17 + 7 * 1 + 8 * 11 + 5 * 1 + 0 * 8 = 252

(b) *Describe the MRP concept, including inputs to MRP, components of an MRP record, and the outputs of MRP.* [40%]

ANSWER: MRP calculates what you need to get and do from what you expect to sell



INPUTS: MRP requires five types of information:

- Master Production Schedule: a complete list of the volume and due dates of all expected product sales
- Bill of material file: design information relating products to components; usually expressed in hierarchical form
- Inventory record file: a record of current stocks
- Lead times: prediction of how long it will take to complete each task
- Lot sizing rules: to determine the size of batch to be ordered

 (cont.

COMPONENTS of an MRP record:

- Gross Requirements: Total independent and dependent demand, before netting on-hand inventory and scheduled receipts
- Scheduled Receipts: Production orders and purchase orders that have already been released . On their due date, they will be added to the projected available balance. Scheduled receipts are not altered automatically by the MRP system, and are not exploded into requirements for components
- Projected Available Balance: on-hand inventory, projected into the future
- Planned Order Release: a suggested order quantity, release date and due date created by the MRP system. Planned orders at one level of the bill of material will be exploded into gross requirements for components at the next lower level.

OUTPUTS: From these, MRP packages calculate

- Gross and New material requirements plans
- Also Purchase Orders and Work Orders are generated

(c) *Describe the Collaborative Planning Forecasting and Replenishment (CPFR) framework. Discuss the potential advantages and disadvantages of this framework.* [10%]

ANSWER: CPFR combines the intelligence of multiple partners across the supply chain in the planning and fulfilment of customer demand. The core elements of CPFR are information sharing, coordinated production planning, joint demand forecasting, coordinated shipments, and risk sharing, e.g. on promotions.

Advantages of collaboration: Greater efficiency; Reduced variability; Reduced contract costs; Mutual learning; Greater stability for supplier; Greater visibility of supplier for customer

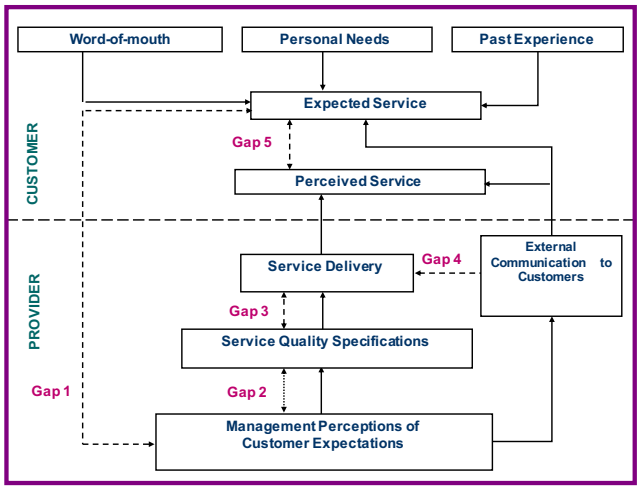
Disadvantages of collaboration: Cost of communication; Risk of opportunism; Reduced flexibility in supplier selection; Information leakages

3 (a) *Define service quality. Explain the challenges of delivering service quality and discuss how the gap model can help overcoming these challenges.* [25%]

ANSWER: Quality of Service = Perceived Performance - Expectation.

Service quality is the relationship between what is expected and what is actually delivered and it is relative. It is determined by customer, not by provider and thus it varies from one customer to another. Service quality is enhanced by meeting or exceeding expectations and by controlling customer expectations.

Gap analysis identifies the differences between desired and actual performance by defining this gap as a combination of multiple, more easily managable gaps.



(b) *Describe the Exponential Smoothing (ES) forecasting method and explain its advantages and disadvantages. Discuss how ES can be modified to overcome its disadvantages.* [20%]

ANSWER: Exponential smoothing forecasts contain information on all previous demands, each demand is given a weight that is decreasing exponentially back in time. It uses a smoothing constant: $0 < \alpha < 1$. The general formula for exponential smoothing is:

$$S_t = \alpha x_t + \alpha(1-\alpha)x_{t-1} + \alpha(1-\alpha)^2 x_{t-2} + \alpha(1-\alpha)^3 x_{t-3} + \cdots$$

where S_t is based on all (available) data up to period t to forecast x_{t+1}.

ES is a simple method that copes OK with step changes in demand. It does not cope well with linear trends. However, an adaptation of simple ES can cope with linear trends: double ES (sometimes known as Type 2 ES). Triple ES is needed for quadratic trends.

(c) *You have received an order from a customer to process six jobs for delivery on the following due dates:*

Job	**A**	**B**	**C**	**D**	**E**	**F**
Processing time (days)	2	4	2	1	2	4
Due date (from current day)	6	8	7	4	10	9

Assign the order of jobs to minimise the number of tardy jobs and explain the rationale for your answer. Calculate the mean flow time and the average tardiness. [15%]

ANSWER: Use Moore's Algorithm, which minimises the number of tardy jobs.

Job	**D**	**A**	**C**	**B**	**F**	**E**
Processing time (days)	1	2	2	4		
Completion time (days)	1	3	5	9		
Due date (from current day)	4	6	7	8		

Job B is the first tardy job. Of the jobs up to B, the longest is B, so remove job B and start again

Job	**D**	**A**	**C**	**F**	**E**	**B**
Processing time (days)	1	2	2	4	2	4
Completion time (days)	1	3	5	9	11	
Due date (from current day)	4	6	7	9	10	

Job E is the second tardy job. Of the jobs up to E, the longest is F, so remove job F and start again

Job	**D**	**A**	**C**	**E**	**B**	**F**
Processing time (days)	1	2	2	2	4	4
Completion time (days)	1	3	5	7	11	15
Due date (from current day)	4	6	7	10	8	9

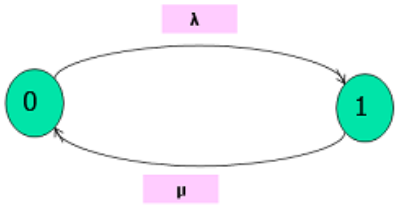
Average flow time: 15/6 = 2.5

Average lateness: 9/6 = 1.5

(d) *Consider a queuing model with a single server, where only one customer is allowed in the system. Customers who arrive and find the system busy never return. Assume that the arrival distribution is Poisson with mean λ and the service time is exponentially distributed with mean service rate μ.*

(i) *Set up the transition diagram, and determine the balance equations.* [10%]

ANSWER: For this M/M/1 queue with a capacity, there are two states 0 and 1. The arrival rate at state 0 is λ and the arrival rate at state 1 is 0 because customers never wait for service. The outgoing rate at state 1 is μ which is equal to the service rate and the outgoing rate at state 0 is 0 because there is no customer in the system. The queue diagram is shown below.



The balance equations at both states are the same and are the following

$$\lambda P_0 = \mu P_1,$$

where (P_0, P_1) are the steady-state probability distribution.

(ii) *Determine the steady-state probabilities.* [15%]

ANSWER: Note that $P_0 + P_1 = 1$. The above balance equation and the total probability equation give the solution:

$$P_0 = \frac{\mu}{\lambda + \mu} \quad \text{and } P_1 = \frac{\lambda}{\lambda+\mu}.$$

(iii) *Determine the average number of customers in the system, the average queue length, the average waiting time in the system, the average waiting time in the queue, and the arrival rate for the customers who are served in the system.* [15%]

ANSWER: The average number of customers in the system is given by $L = P_1$. Clearly, $L_q = 0$ and $W_q = 0$ because no customer is willing to wait for service. Furthermore, we have

$$W \quad = \quad W_q + \frac{1}{\mu} = \frac{1}{\mu}.$$

By Little's law we have that the effective arrival rate in the system is

$$\frac{L}{W} = \frac{\frac{\lambda}{\lambda+\mu}}{\frac{1}{\mu}} = \frac{\lambda\mu}{\lambda+\mu},$$

which is the same as $P_0\lambda + P_1 0 = P_0\lambda$.

END OF PAPER